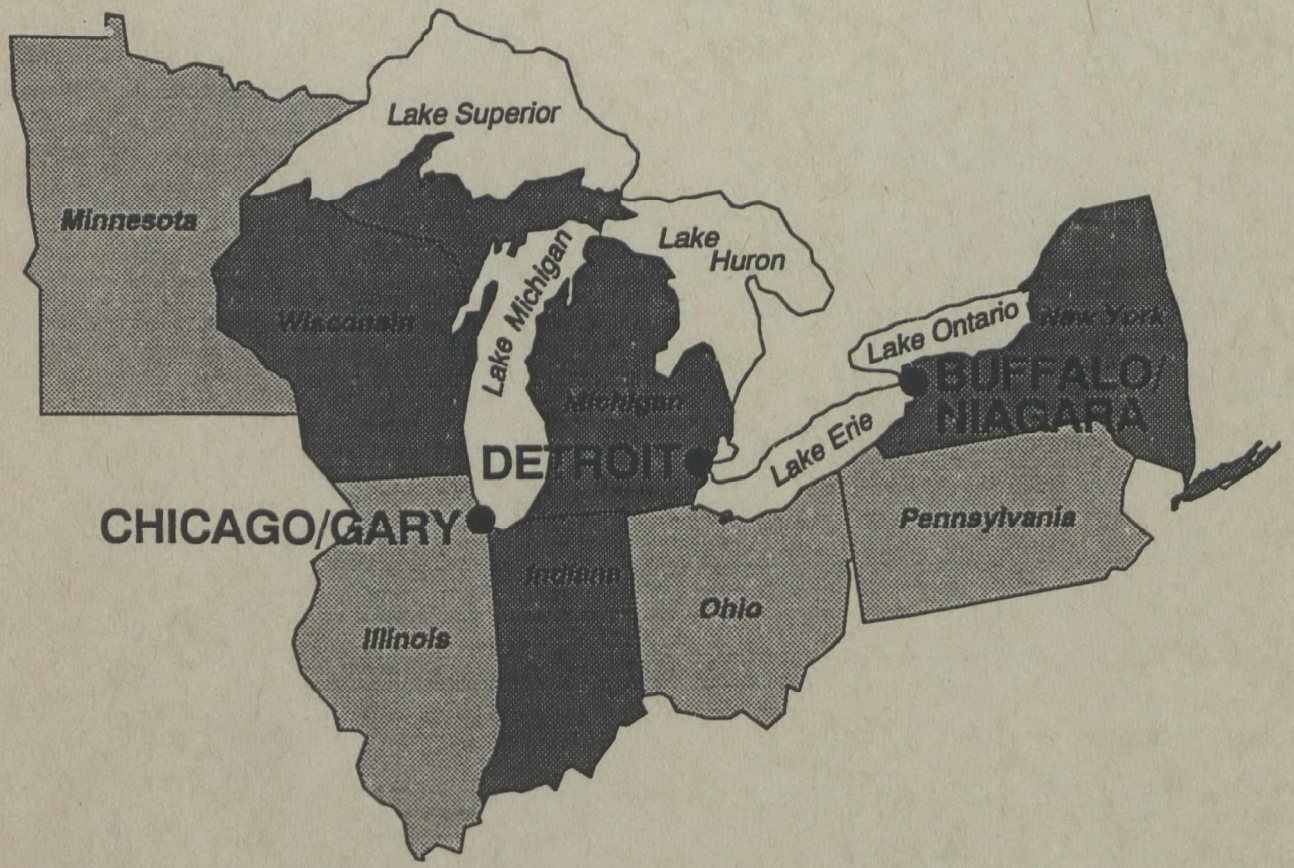
GREAT LAKES BASIN RISK CHARACTERIZATION STUDY



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A. INTRODUCTION

1. EXECUTIVE SUMMARY

PURPOSE OF THE STUDY

The Great Lakes, the largest freshwater ecosystem in the world, has received a variety of chemical and physical impacts from human activities, particularly those involving industry, agriculture and urbanization. The eight states which cover the Great Lake watershed (Minnesota, Wisconsin, Illinois, Michigan, Indiana, Ohio, Pennsylvania and New York) contain diverse ecosystems including inland lakes, sand dunes, wetlands, old growth and second growth forests, agricultural lands and urban areas. Approximately 30 million people live and work in the Great Lakes Basin. While progress has been made to reduce chemical contamination in the Great Lakes, the ecosystem and its inhabitants still face significant environmental risks. This study is the first attempt to apply the methodology of EPA's comparative risk process to assess and rank such risks in the United States portion of the Great Lakes Basin.

The study provides EPA Regions 2, 3, and 5 and the Great Lakes States with a risk-based approach which can assist in protecting and restoring this vast yet sensitive ecosystem and reducing risks to its human cohabitants. The Great Lakes National Program Office (GLNPO) and the three EPA Regions will use the results of this study to better target their activities. Study results are integrated into the Great Lakes Five Year Strategic Plan.

The study will also be used in conjunction with restoration efforts, such as implementing Remedial Action Plans for Great Lakes Areas of Concern and Lakewide Management Plans, to help evaluate the relative environmental risks being addressed by these and other activities.

PROBLEM AREA DESCRIPTIONS

The study is organized into twenty-three separate topics (problem areas). These problem areas generally reflect EPA programmatic priorities and therefore represent mixed sources, receptors, media and regulatory obligations. However, three problem areas reflect issues of particular importance to the Great Lakes: Introduction of Exotic Species; Toxic Sediments; and Changing Lake Levels. Data is sketchy for some of these problem areas (e.g., Underground Storage Tanks). Further information could cause the evaluations of problem areas to change.

The study groups problem areas into four categories:

- **Emerging Basin-wide Issues** are potentially catastrophic risks to human and ecological populations:
    - Physical Degradation of Water and Wetland Habitats,
    - Physical Degradation of Terrestrial Ecosystems,
    - Introduction of Exotic Species,
    - Spills and Other Accidental Releases,
    - Global Climate Change, and
    - Changing Lake Levels.
- **Primary Water Problem Areas** are sources of pollutant loadings which pose significant risks to aquatic ecosystems and to human health through fish consumption: Industrial Point Source Discharges, Municipal Point Source Discharges, Nonpoint Source Loadings, Atmospheric Loadings, Toxic Sediments, and Pesticides Discharges. Due to the difficulty in apportioning the exact share of effects to specific types of

sources, human health and environmental risks from these sources are discussed in the aggregate. An informed, but speculative apportionment of risks among types sources has been attempted to estimate their relative contributions.

- **Primary Air and Waste Problem Areas** are sources which are also considered to pose potentially significant risks: Hazardous/Toxic Air Pollutants, Abandoned Hazardous Waste Facilities, Sulfur and Nitrogen Oxide Emissions, Active RCRA Hazardous Waste Management Facilities, Municipal Solid Waste Facilities, and Industrial Solid Waste Facilities.

- **Secondary Problem Areas** are believed to present lower risks: Aggregated Drinking Water, Aggregated Ground Water, Ozone and Carbon Monoxide, Particulate Emissions, Underground Storage Tanks, Pesticides (Applications and Food Residues).

METHODOLOGY, DATA GAPS AND UNCERTAINTY

The general methodology used in EPA's 1987 risk project, Unfinished Business, and in Regional comparative risk studies was used to characterize risks found in the Basin. The study uses data on a county-wide basis within the watershed of the Great Lakes system. Each problem area analyzes the magnitude of the problem, toxicity of contaminants (where applicable), and exposure levels. Three general categories of impacts are considered: cancer human health risks, non-cancer human health risks, and ecological risks. In some cases, welfare impacts (i.e., economic damages) were also considered. Risks are those that are believed to be in effect today, after the implementation of remedial programs.

Risk estimates are made in a semi-quantitative manner whenever possible. However, there are numerous uncertainties and gaps in available data, leaving significant uncertainties in the risk characterization and underscoring the need for further environmental data and integration of data. Data gaps are addressed in Appendix A.

Problems associated with Indoor Air, Indoor Radon, and Stratospheric Ozone were not addressed because this study focuses on environmental issues specific to the Great Lakes. Discussion of these issues are available in the Regional analyses.

RESULTS

Not surprisingly, both human health and ecological risks were found to be most significant where human populations are greatest. Large urban and industrial areas such as Chicago/Gary, Cleveland, Detroit and Buffalo/Niagara Falls have multiple significant sources of environmental contaminants. A spatial relationship between high ecological risks and risks to human health was also found. High ecological risks should be viewed as sentinels of potential adverse human health effects.

It is clear that the Great Lakes, because of their unique properties, are particularly vulnerable to the effects of toxic substances, regardless of the pollution source. When persistent toxic chemicals, such as PCBs and mercury, enter the Great Lakes, they are not readily removed. Unlike rivers or coastal areas, where pollutants are borne off to do damage elsewhere, the retention time of the lakes vary from 3 years (Erie) to 200 years (Superior).

The most significant ecological and human health risks in the Great Lakes were identified by following the approaches used in the Region 5 Comparative Risk Project. Significant risks which are directly associated with the Great Lakes are summarized below. Other risks, which are significant in the Basin, but not directly limited to the Great Lakes, are also briefly described.

A. ECOLOGICAL RISKS

Significant ecological risks directly associated with the Great Lakes themselves were found to be:

- Persistent toxic contaminants, from all sources, bioaccumulate in fish and wildlife causing birth deformities, tumors, and reproductive problems for species in a number of areas in the Great Lakes Basin.
- Nonpoint source loadings to surface waters are currently a significant source of ecological risk to the Basin.
- Toxic sediments are a significant reservoir of past contamination that contributes to poisoning the Great Lakes food web.
- Industrial and Municipal water discharges in many cases cause substantial impacts to aquatic ecosystems.
- Spills and other accidental releases could cause devastating and widespread damage to aquatic and terrestrial ecosystems.
- Exotic species, especially the zebra mussel, could impose catastrophic effects on the great Lakes food web.

Other significant ecological risks include:

- Agricultural, residential and other development activities, destroy wildlife habitats (e.g. fish spawning areas, wetlands, prairies, and old-growth forests) at disturbing rates.
- Global climate change presents potentially significant impacts in the Great Lakes Basin on fish and wildlife, forestry and agriculture, although estimates of impacts are highly uncertain.
- Atmospheric sources of sulfur and nitrogen oxides, and mercury were found to affect a large number of inland lakes within the watershed.

B. HUMAN HEALTH RISKS

Significant human health risks directly associated with the Great Lakes are:

- Risks from consumption of sport fish were linked to industrial and municipal point source discharges, nonpoint sources, atmospheric deposition and toxic sediments. The majority of the risk is presented by exposure to PCBs. Other contaminants of high concern include chlordane, mercury, dioxins, mirex and DDT.
- Potential spills and other accidental releases present risks to human health.

Other significant risks to human health in the watershed include:

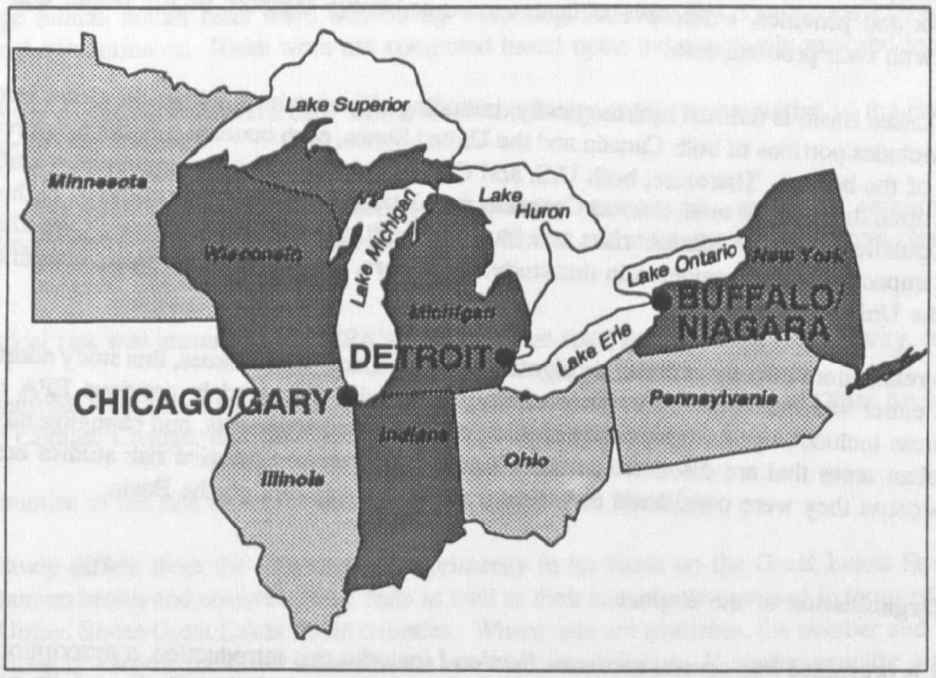
- Risks from exposure to hazardous/toxic air pollutants and to sulfur and nitrogen oxides.
- Risks from consumption of sport fish from inland lakes due to mercury contamination.

RECOMMENDATIONS

The importance of several measures which are now being pursued by EPA and States are supported by this study. This study recommends that EPA:

- Institute a Lakewide Management Process that identifies environmental objectives for each Lake and load reductions necessary to achieve those objectives. Management priorities should be based upon risk reduction, including prioritization of Areas of Concern for remediation.

- Give priority to reducing chemical releases from locations where human and ecological risks are high such as Chicago/Gary, Detroit, Cleveland and Buffalo/Niagara Falls (see figure).



- Focus future risk analyses on a geographical basis (e.g., through Remedial Action Plans) to characterize the type and magnitude of risks and to help decision-making.

- Increase integration of efforts to reduce ecological risks, within EPA and among other agencies to provide for maximum protection of wetlands, spawning areas, and other wildlife habitats.

- Increase coordination of efforts to reduce human health risks, including the development of risk-based fish advisories which are consistent across the lakes.

- Develop environmental indicators to judge the health of the environment and to monitor the efficacy of programs. Indicators would be chemical and biological, including: achievement of water quality standards, the restoration of beneficial uses, reduction in fish consumption advisories, reduction in toxic chemical loadings/emissions, and measurements of contaminant concentrations in toxicological and environmental endpoints, and achievement of stable populations of species that are indicators of ecosystem health such as bald eagles and lake trout.

These recommendations are consistent with the ten recommendations of the SAB's 1990 report, Reducing Risk: Setting Priorities and Strategies for Environmental Protection.

2. Purpose of the Study

This study is designed to support ongoing Great Lakes protection and planning efforts conducted by EPA Regions 2, 3, and 5 and the Great Lakes National Program Office (GLNPO). Such efforts include, but are not limited to, identifying Great Lakes Areas of Concern (AOCs), preparing and implementing Remedial Action Plans to restore beneficial uses to AOCs, developing and implementing Lakewide Management Plans to eliminate effects of key pollutants, and designing and implementing strategic plans for the Great Lakes National Program Office. This study characterizes the relative environmental risks to be addressed by these and other ongoing activities.

The study attempts to characterize, quantitatively where possible, the nature and extent of current health and environmental risks within the United States portion of the Great Lakes Basin. It follows the same general approach developed for previous comparative risk studies by EPA Headquarters and the Regions. This report describes the current risks and provides, where available, a semi-quantitative measure of the health and environmental risks associated with each problem area.

The Great Lakes Basin is defined hydrologically, including all watersheds within the Great Lakes system. Because the Basin includes portions of both Canada and the United States, each country is home to sources of risk that impact both sides of the border. Therefore, both U.S. and Canadian populations face potentially similar risks. However, depending upon the problem area, risks to Canadian populations and ecosystems could be higher or lower than those to U.S. populations. While similar risks are found in both portions of the Basin, Canadian human health and ecological impacts are not considered in this study. Therefore, references to the Basin contained in this report refer solely to the United States portion.

In order to relate more directly to currently significant Great Lakes Basin issues, this study addresses several problem areas that either were not considered or were only minimally discussed in previous EPA risk analyses. These problem areas include impacts from exotic species, contaminated sediments, and changing lake levels. In addition, some problem areas that are discussed in other Agency or State comparative risk studies are not included in this analysis because they were considered to have only a minimal impact on the Basin.

3. Organization of the Report

The study is organized into several sections. Section I includes this introduction, a description of the approach used and data issues that arose in the study, an overview of the Great Lakes Basin and its population, and a brief characterization of the current health of Great Lakes and its ecosystems. Risk characterizations, the primary emphasis of the study, are found in Section II, Emerging Basin-wide Issues, Section III, Primary Water Problem Areas, Section IV, Primary Air and Waste Problem Areas, and Section V, Secondary Problem Areas. The problem areas examined are presented in a preliminary order to reflect risks which are believed to be most significant and requiring the particular attention of Great Lakes planners.

B. GREAT LAKES BASIN PROBLEM AREAS: APPROACH AND DATA ISSUES

1. Overview of the Study Approach

This study is intended to build upon the comparative risk studies that have been completed in Regions 2, 3, and 5. Many of the analytical and risk assessment approaches described in those studies were adopted as guidelines for this analysis. In particular, the following guidelines were followed:

- When available, health risks were derived from environmental data and measurements of exposed populations rather than on modeled estimations.
- Average human health risks were derived by weighting the risks for populations exposed to ranges in chemical contaminants. Risks were not computed based upon the maximally exposed individual.
- Chemicals or case studies were used which were considered most representative of the risks posed by the problem areas.
- A risk assessment procedure consisting of toxicity assessment, exposure assessment, and risk characterization was applied. EPA cancer potency factors and reference doses for non-cancer effects were used.
- Ecological risk was assessed using EPA's approach that analyzes area affected, severity, and reversibility.
- Risk analyses were based solely on current risks with the exception of Spills and Other Accidental Releases, Global Climate Change, and Introduction of Exotic Species.
- Uncertainties in the risk analyses, including data gaps, were identified.

However, this study differs from the previous work primarily in its focus on the Great Lakes Basin. This focus means that the human health and environmental risks as well as their sources are assessed in terms of the populations residing in the United States Great Lakes Basin counties. Where data are available, the number and type of problem sources or activities in each of the Great Lakes Basin counties are depicted. If county-specific information is not available, Basin-wide estimates are noted for each problem area. This reflects a new attempt to quantify the actual level of potential or residual human health and environmental risk found within the United States portion of the Great Lakes Basin.

While the Great Lakes Basin is defined by watershed, most Basin data was collected at the county level. Therefore, data was collected on all counties which fall within or contain a portion of the Basin watershed. The population of the Great Lakes Basin as presented in this study was determined by summing the populations of the counties within the Great Lakes' watershed. This yields a United States Great Lakes Basin population of approximately 30,050,000 people in 1988. This figure is used as the "Basin population" in the problem area risk assessments.

Most of the problem areas used in this were defined by EPA Headquarters. They correspond generally with existing environmental programs, statutes, or budget categories, such as RCRA hazardous waste management facilities, industrial point source discharges regulated under the Clean Water Act, and toxic air emissions regulated under the Clean Air Act. These programs are reducing substantial risks. However, the problem areas included here characterize current, or residual risks, or those environmental and health risks that remain beyond those presently controlled by those environmental programs or statutes.

Because of the correspondence with EPA programs or activities, some problem areas have been defined as sources of contaminants, while other as pathways or receptors of those contaminants. This leads to some inconsistencies in

methodology. For example, portions of some problem areas may overlap with several others, as is the case with a problem area such as pesticides, which enters the Basin through several pathways, including atmospheric deposition, sediments, and nonpoint source discharges to surface waters. Sources may contribute to environmental or human health risks more than pathways. Future risk characterizations will benefit greatly from a redefinition of problem areas by endpoints for more consistency in the risk analysis.

The problem area discussions separate human health and ecological risks among the various sources of environmental contamination and, where possible, attempt to avoid double counting of risks. For example, risks in the Great Lakes Basin surface waters are divided by contaminant source including industrial point sources, municipal point sources, nonpoint sources, and atmospheric deposition. Furthermore, toxic sediments and contaminated ground-water discharge are also recognized as sources of contamination. However, their relative contribution to health and ecological risks from surface water was difficult to quantify. As a result, these problem areas are addressed separately. Where possible, the difficulties inherent in differentiating among human health and ecological risk across the problem areas are also discussed.

Under the problem areas, four different types of risk are considered, including cancer and non-cancer human health risk, ecological impacts, and welfare effects. These risks are expressed in terms of potential cancer cases that are estimated to be caused by the problem area. In several of the problem areas, human health or environmental risks are described as possible impacts rather than as documented current risks.

Sections II through V characterize the magnitude of risks posed by twenty-three problem areas relative to the Great Lakes Basin. Under each section, the activities addressed by the problem area, the relative magnitude of the problem area sources or activities, and estimates of human health, environmental, and welfare impacts are outlined in each subsection A through X.

Indoor Air, Indoor Radon, Radiation and Stratospheric Ozone problem areas were addressed by the risk analyses conducted Regions 2, 3 and 5. Discussions of these problem areas are available in the Regional risk project reports, and consequently, are not addressed in this report.

Other risks to the Great Lakes Basin and its populations have not been addressed due to time constraints. These risks include:

- Risks from stratospheric ozone to plankton and other links within the Great Lakes food web;
- Risks associated with consumption of wild rice, cranberries, and other foods gathered by Native Americans in the Great Lakes Basin;
- Risks stemming from mobile sources of toxic air emissions within the Basin.

2. Problem Area Organization

Problem areas in Section II, Emerging Basin-wide Issues, are very important to Great Lakes Basin human health, ecological populations, and economic welfare: forms of habitat destruction and their causes, exotic species, and other problem areas that reflect potentially catastrophic risks.

Sections III and IV, Primary Problem Areas, present water, waste and air problem areas that represent primary sources of risks to the Basin and its populations. The diverse and complex nature of atmospheric loadings, toxic sediments, and other nonpoint sources, their effects, and probable remediation methods within the Great Lakes Basin have justified separate discussions. It is very difficult at this time to accurately apportion risks from contaminants found in surface waters to specific sources or to industrial and municipal point source discharges to surface water. A rough estimate has been attempted to show possible proportions. However, due the difficulties in accurately attributing health, ecological and welfare effects to specific sources, this study groups the three nonpoint source and two point source problem areas together as primary water concerns, and discusses the effects only once, in the first

of the five, Industrial Point Source Discharges to Surface Water.

Section V, Secondary Problem Areas, presents water, air and waste problem areas which are believed to be of secondary concern to the Basin. This belief is partly predicated on professional judgment, but was influenced by the lack of data. With more information, some of these risks may actually shift in priority for the Basin.

3. Data Uncertainties

Until this study, no generalized attempt has been made to use EPA's comparative risk approach to quantitatively characterize all the major human health, ecological, and welfare risks in the Great Lakes Basin. The ground-breaking nature of this work has, however, meant several uncertainties and data gaps were inevitable. The risks which are derived for several of these problem areas are subject to considerable uncertainty.

Treatment of many risks in the study was restricted to qualitative discussions. Often the data needed to conduct an ideal quantitative risk analysis simply does not exist. In addition, the data which does exist was generally created for other purposes, and is often ill-suited for risk analysis. These factors create significant levels of uncertainty in many of the preliminary results shown here. To help clarify these data issues, the databases used, their weaknesses, and major data gaps that exist are discussed in Appendix A.

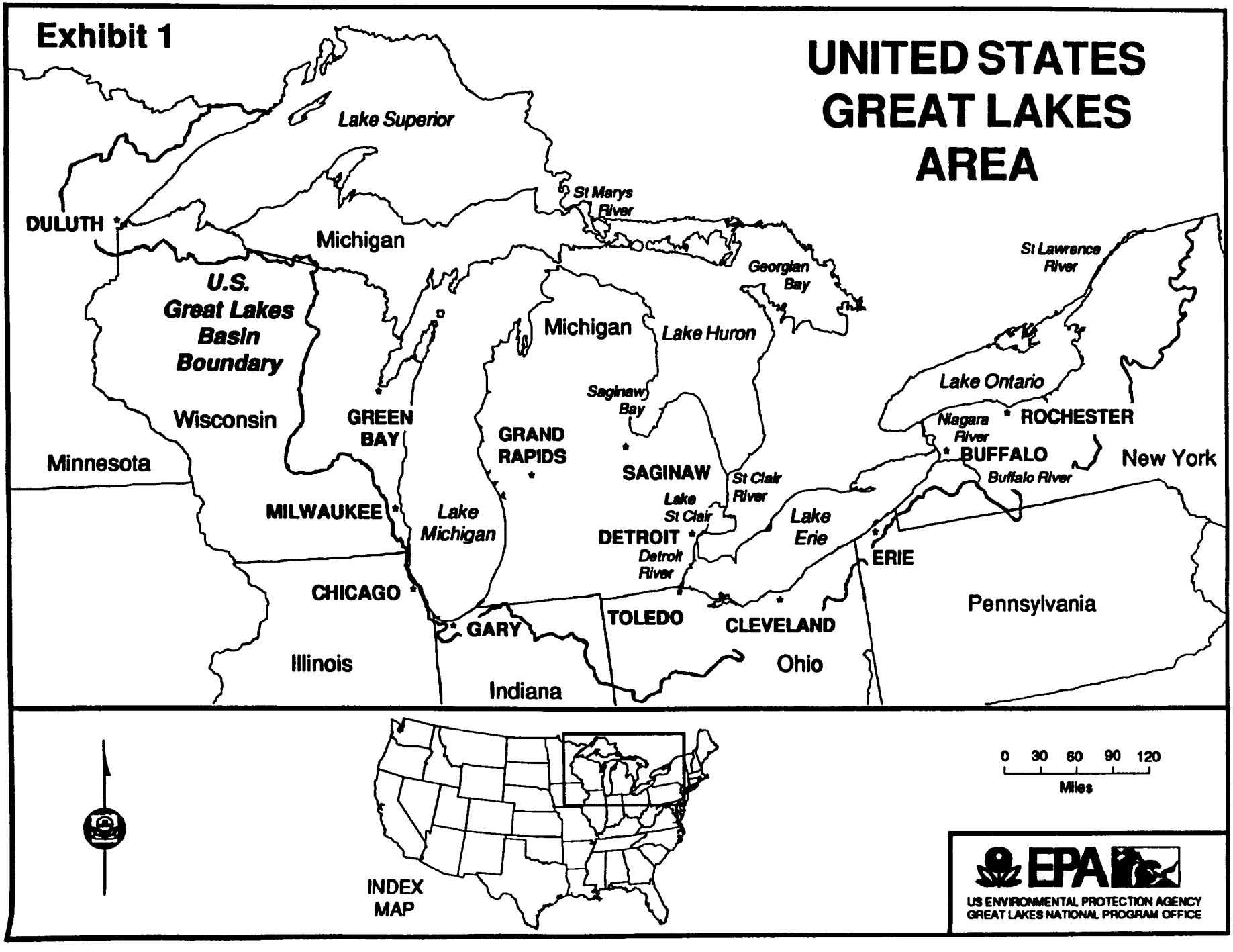


Exhibit 1
UNITED STATES
GREAT LAKES
AREA
Lake Superior
St Marys
River
DULUTH
Michigan
U.S.
Great Lakes
Basin
Boundary
Georgian
Bay
St Lawrence
River
Michigan
Lake Huron
Lake Ontario
Saginaw
Bay
Wisconsin
GREEN
BAY
GRAND
RAPIDS
Niagara
River
ROCHESTER
BUFFALO
New York
Minnesota
SAGINAW
St Clair
River
Buffalo River
Lake
St Clair
MILWAUKEE
Lake
Michigan
Lake
Erie
DETROIT
Detroit
River
ERIE
CHICAGO
Pennsylvania
GARY
TOLEDO
CLEVELAND
Illinois
Ohio
Indiana
INDEX
MAP
0 30 60 90 120
Miles
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C. GREAT LAKES BASIN AND POPULATION

1. A Description of The Great Lakes Basin[1]

The Great Lakes Basin encompasses all or parts of eight states: Michigan, Minnesota, Wisconsin, Illinois, Indiana, Ohio, Pennsylvania, and New York (see Exhibit 1). The Lakes have a total shore line of over 4,000 miles within the United States and cover an area of 94,250 square miles. This makes the Great Lakes the largest freshwater system in the world, with about 18 percent of the world's supply of fresh surface water.

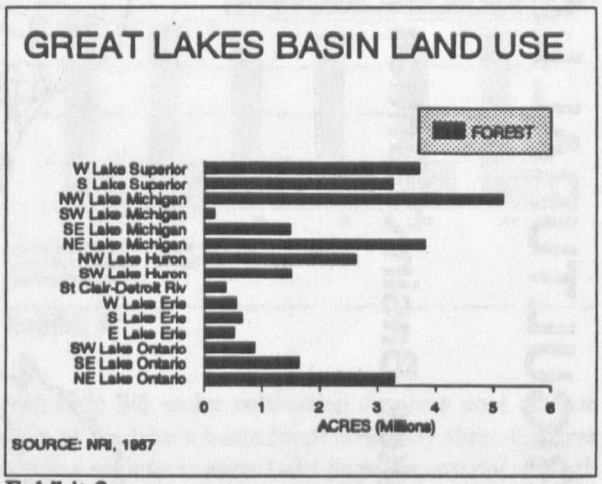


Exhibit 2

In addition to expansive urban areas, the Great Lakes Basin is home to numerous ecosystems including lakes, wetlands, dunes, old growth and second growth forests, prairies, and agricultural lands. Much of the Basin is covered with glacial-remnant freshwater lakes. There are four general types of wetlands in the Basin: fens, marshes, bogs, and swamps. Fens and bogs both develop in shallow stagnant water. Fens are characterized by grasses and shrubs while bogs are generally mossy. Fens and bogs usually occur in the cooler areas of the Basin. Swamps and marshes contain trees and shrubs which are rooted in the sediment below the water. Marshes often occur in ponds or bays. Swamps and marshes occur in the warmer areas and are seen mostly in the southern and eastern sections of the Basin.

Boreal, mixed and deciduous forests cover much of the northern half of the Basin. Exhibit 2 shows the relative amounts of forest acreage by sections of each Great Lake watershed. However, much of the original forests in the Basin have been clear-cut for logging, agricultural and residential purposes, and this decline in forest land is continuing today.

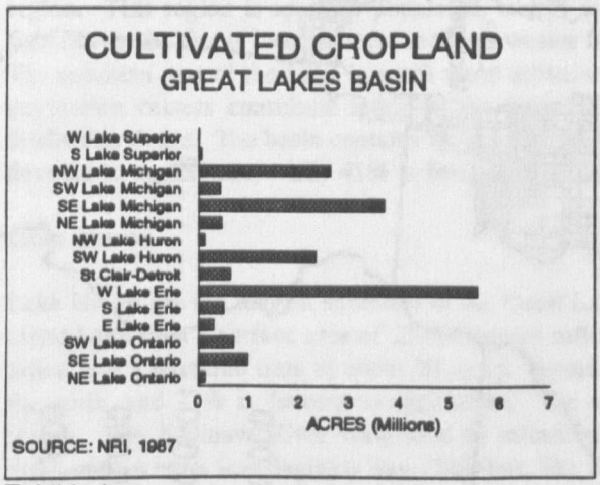


Exhibit 4

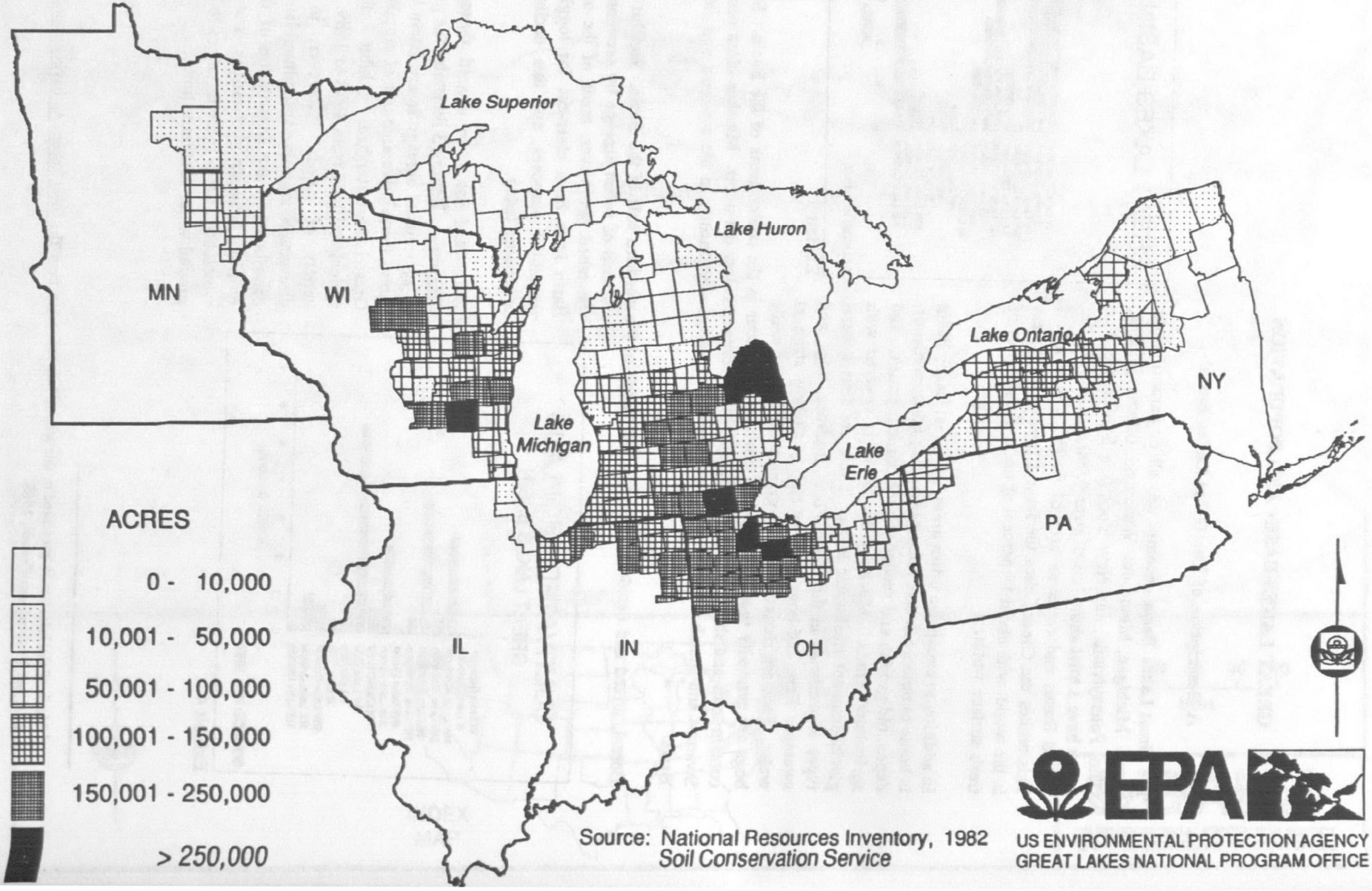
Much land has been cleared throughout the Basin for agriculture. Exhibit 3 illustrates the geographic distribution of agricultural acreage in the Basin by county. Exhibit 4 shows the relative amounts of cropland by section of each Great Lake watershed. Exhibit 5 depicts trends in Basin agricultural land from 1984 to 1989. Basin soils support a variety of crops. However, in addition to habitat destruction, intensive agricultural land use has been a major contributor to the degradation of the Basin through soil erosion, fertilizer applications, and the use of pesticides which has lead in some instances to both surface water and ground water contamination.

[1] Much of the information presented in this section has been taken from The Great Lakes: An Environmental Atlas and Resource Book, U.S. EPA and Environment Canada, 1988.

Exhibit 3

TOTAL AGRICULTURAL LAND

Great Lakes Basin Counties



Source: National Resources Inventory, 1982
Soil Conservation Service

EPA

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The urban ecosystem is perhaps the most evident setting in the Basin. Urban areas are prevalent throughout the southern end of Lake Michigan, Lake St. Clair, and surround Lakes Erie and Ontario. The urban ecosystem also contributes greatly to the degradation of the Basin through manufacturing and industrial pollution, urban runoff, and municipal wastewater discharge.

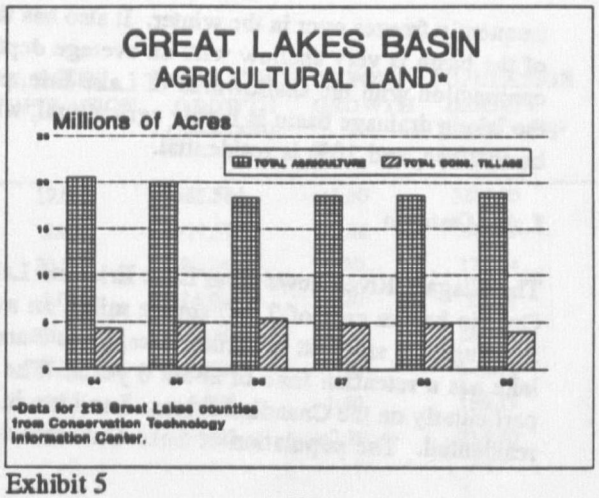

Exhibit 5

2. The Five Great Lakes

Lake Superior

The largest Great Lake in both surface area and volume is Lake Superior. Lake Superior has an area of 31,700 square miles, an average depth of 483 feet, and a volume of 2,900 cubic miles. Superior has a long retention time of about 190 years. About 90% of Lake Superior's basin is forested with only 3% under cultivation due to a cool climate and poor soils. The surrounding forests and the sparse population of the lake's basin (approximately three-quarters of a million people in the United States) help insure that relatively few pollutants enter Lake Superior, except through significant atmospheric loading. Lake Superior flows into Lake Huron by way of the St. Mary's River. The population of the Lake Superior basin is economically dependent on its rich natural resources, including mineral extraction, and forests. The area also receives a significant amount of its income from recreation and tourism.

Lake Michigan

Lake Michigan is the second largest of the Great Lakes by volume with 1,180 cubic miles, and is the only Great Lake that does not share a shore with Canada. It has an area of 22,300 square miles, an average depth of 280 feet, and a retention time of about 100 years. The northern part of the lake is in the less developed upper Great Lakes region. This region is sparsely populated, except for Green Bay. While the Bay has one of the most productive fisheries in the Great Lakes, it also receives wastes from the world's largest concentration of pulp and paper mills. The southern part of the Lake is much more urbanized, with cities such as Chicago, Milwaukee, and Gary. These population centers contribute much to the pollution of the Lake. Lake Michigan also has the world's largest freshwater dunes. The basin contains the most farmland of all the Great Lakes Basin, with 44% of its drainage basin devoted to agriculture, while 41% is forested and 9% is residential.

Lake Huron

Lake Huron has the longest shoreline of the Great Lakes and includes thousands of islands. It is the second largest Great Lake with a surface area of 23,000 square miles. It has an average depth of 195 feet, a volume of 850 cubic miles, and a retention time of about 20 years. Approximately 68% of Lake Huron's basin is forested, especially in the north, and 27% is devoted to agriculture. The southern portion of the Lake leads to Detroit via the St. Clair River. The Saginaw River watershed is intensively farmed and flows through Flint, Saginaw and Bay City metropolitan areas into Saginaw Bay. This bay, like Green Bay, contains a very productive fishery. The Lake Huron basin has the second smallest population in the Great Lakes, 2.4 million people.

Lake Erie

Lake Erie has the smallest volume of the Great Lakes with 116 cubic miles. It has an area of about 9,900 square miles, and an average depth of only 62 feet. Almost all of Lake Erie's water comes from the Northern Lakes via the Detroit River. Seventeen metropolitan areas of over 50,000 people are located within Erie's basin, with a total of 11 million people. It is the shallowest Great Lakes and therefore warms rapidly in the spring and summer and

frequently freezes over in the winter. It also has the shortest retention time of the lakes, 2.6 years. The western fifth of the basin is very shallow with an average depth of only 24 feet. Nonpoint source and municipal discharges, in conjunction with the shallowness of Lake Erie, put the lake in the greatest danger of eutrophication. Land use in the lake's drainage basin is highly agricultural, with 67% of it used for farming. Foresting accounts for 21% of the basin's use, and 10% is residential.

Lake Ontario

The Niagara River flows from Lake Erie into Lake Ontario, which then empties into the St. Lawrence River. Lake Ontario has an area of 7,340 square miles, an average depth of 283 feet, and a volume of about 390 cubic miles. Although the smallest in surface area, Lake Ontario contains more than three times the water volume of Erie. The lake has a retention time of about 6 years. The Lake Ontario basin is largely rural, with a few large urban areas, particularly on the Canadian shores. Land use in the drainage basin includes 49% forestry, 39% agriculture, and 7% residential. The population of Lake Ontario's drainage basin is approximately 7.3 million people.

3. Basin Populations

Population declined in a number of the Great Lakes Basin Counties from 1980 to 1986. Overall Basin county population declined by about 37,000 during that period. Exhibit 6 depicts the population changes of the Great Lakes Basin counties by state. Much of this decline can be attributed to industrial relocation. However, not all Basin states have had population declines. Counties in Illinois and Wisconsin have shown growth. This may be attributed to the increased manufacturing and service industries in the Kenosha, Milwaukee and Green Bay metropolitan areas. Population characteristics of the Great Lakes Basin States are further summarized in Exhibit 6. The geographic distribution of the 1988 Basin population is depicted in Exhibit 7. Population density patterns, in terms of population per square mile, mirror the general distribution of population by county as shown in Exhibit 8. The percent change in county population in the Basin is depicted in Exhibit 9.

There are several Indian Tribes currently located upon the United States shoreline of Great Lakes: Grand Portage, MN, Bad River, WI, Red Cliff, WI, Keweenaw Bay, MI, Bay Mills, MI, and Sault Ste. Marie, MI are located on Lake Superior; The Grand Traverse Band of Ottawa and Chippewa and the Oneida Tribe near Green Bay, WI, are located on Lake Michigan; The St. Regis Mohawk Tribe is located on the St. Lawrence River, NY; the Seneca Tribe near Irving, NY, is located on Cattaragus Creek, which flows into Lake Erie, and the Seneca and Tuscarora Tribes are located within the Great Lakes watershed, near Buffalo, NY.

Heavy industry and manufacturing are not the only prominent industries in the Basin. Agricultural activities are the mainstay in much of the Basin. Because many agricultural practices rely heavily on pesticide use to control insects, weeds, and fungi, contamination of ground and surface waters from pesticides is a growing concern in the Basin. This problem is particularly noticeable on the Southern end of Lake Huron and in the Lake Erie basin.

In addition to agricultural activities, the lakes are commercially fished for whitefish and smelt. Historically, the fisheries of the Great Lakes have held enormous significance for the Basin economies. In the 1960s and 1970s, commercial fishing declined due to over-fishing and the bioaccumulation of unacceptable levels of pesticides, PCBs and other contaminants in the fish. Since then, commercial fishing activity has failed to regain its former share of the Basin economy.

EXHIBIT 6

STATE	NO. COUNTIES IN BASIN	SHORELINE IN MILES	POPULATION IN BASIN COUNTIES (millions)	% BASIN POPULATION	POPULATION GROWTH (1980-1986)	% POP GROWTH	POPULATION DENSITY PEOPLE/MI² (1986)
ILLINOIS	2	71	5.78	19.0	+85,584	+1.50	3293.95
INDIANA	14	31	1.70	5.6	+14,570	+0.86	245.49
MICHIGAN	78	2552	9.24	30.5	-22,244	-0.30	173.34
MINNESOTA	7	175	0.32	1.0	-24,944	-7.20	16.30
NEW YORK	32	561	4.38	14.5	-63,038	-1.50	180.74
OHIO	34	294	5.23	17.3	-88,925	-1.70	346.72
PENNSYLVANIA	3	46	0.38	1.3	-5,375	-1.40	150.17
WISCONSIN	37	768	3.21	10.6	+67,482	+2.10	218.40

One of the most significant industries in the Basin is the recreation and sports industry. The Great Lakes Fishery Commission estimates that sport fishermen spent about $2 billion in 1985 on sport fishing in the Great Lakes for perch, trout, bass, coho and chinook salmon.[2] However, it has been limited because of fish contamination and fish consumption advisories within the Basin. Michigan, Minnesota and Wisconsin maintain large recreation areas. Additionally, there are many national parks, recreation areas, and underwater preserves scattered throughout the Basin.

[2] Great Lakes: Great Legacy?, The Conservation Foundation, 1990, page 150.

Exhibit 7

GREAT LAKES BASIN COUNTIES 1988 POPULATION[1]

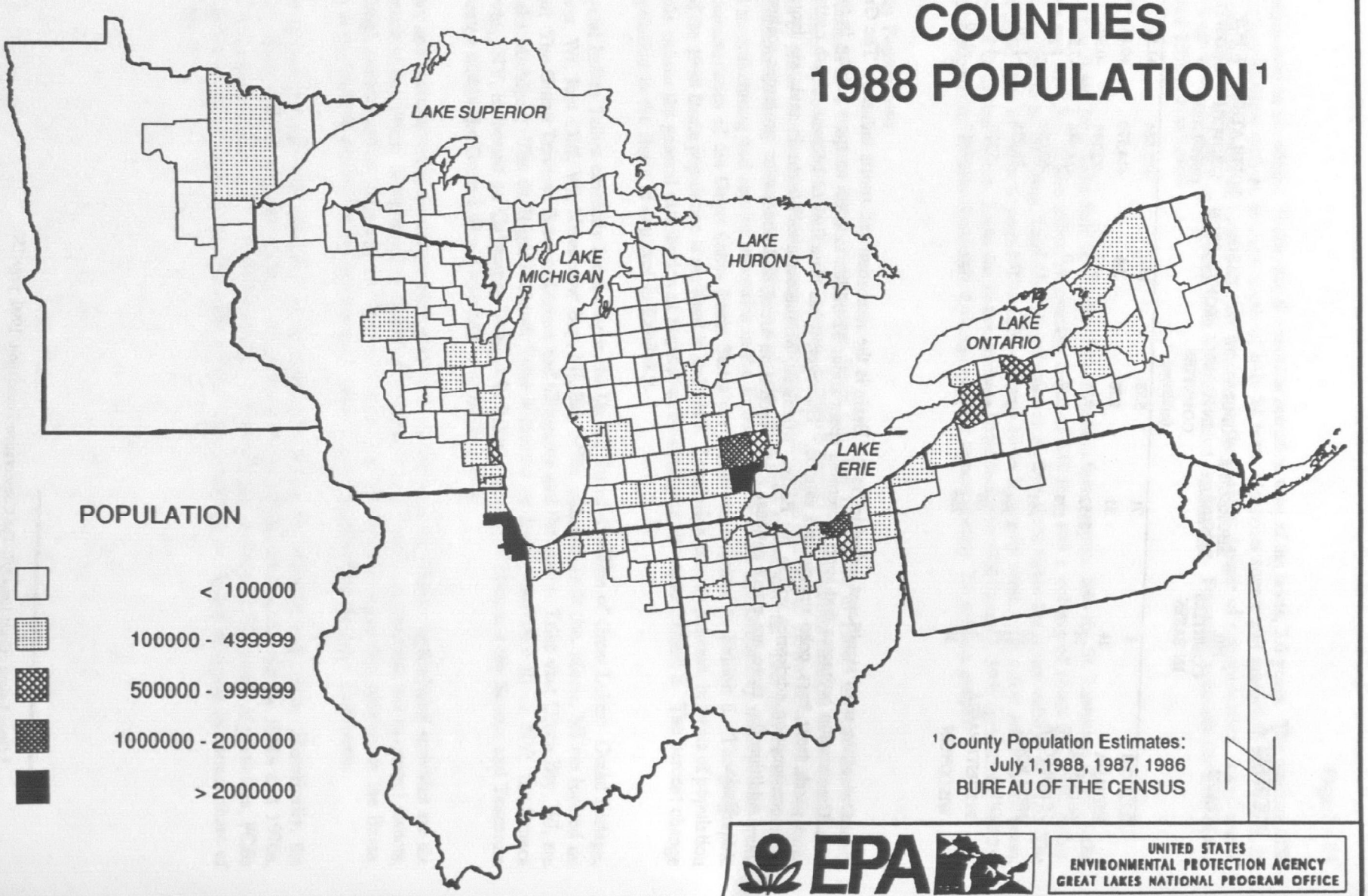

Exhibit 8

1986 POPULATION DENSITY

Great Lakes Basin Counties

Source: Bureau of the Census
County Population Estimates
July 1, 1988, 1987, 1986

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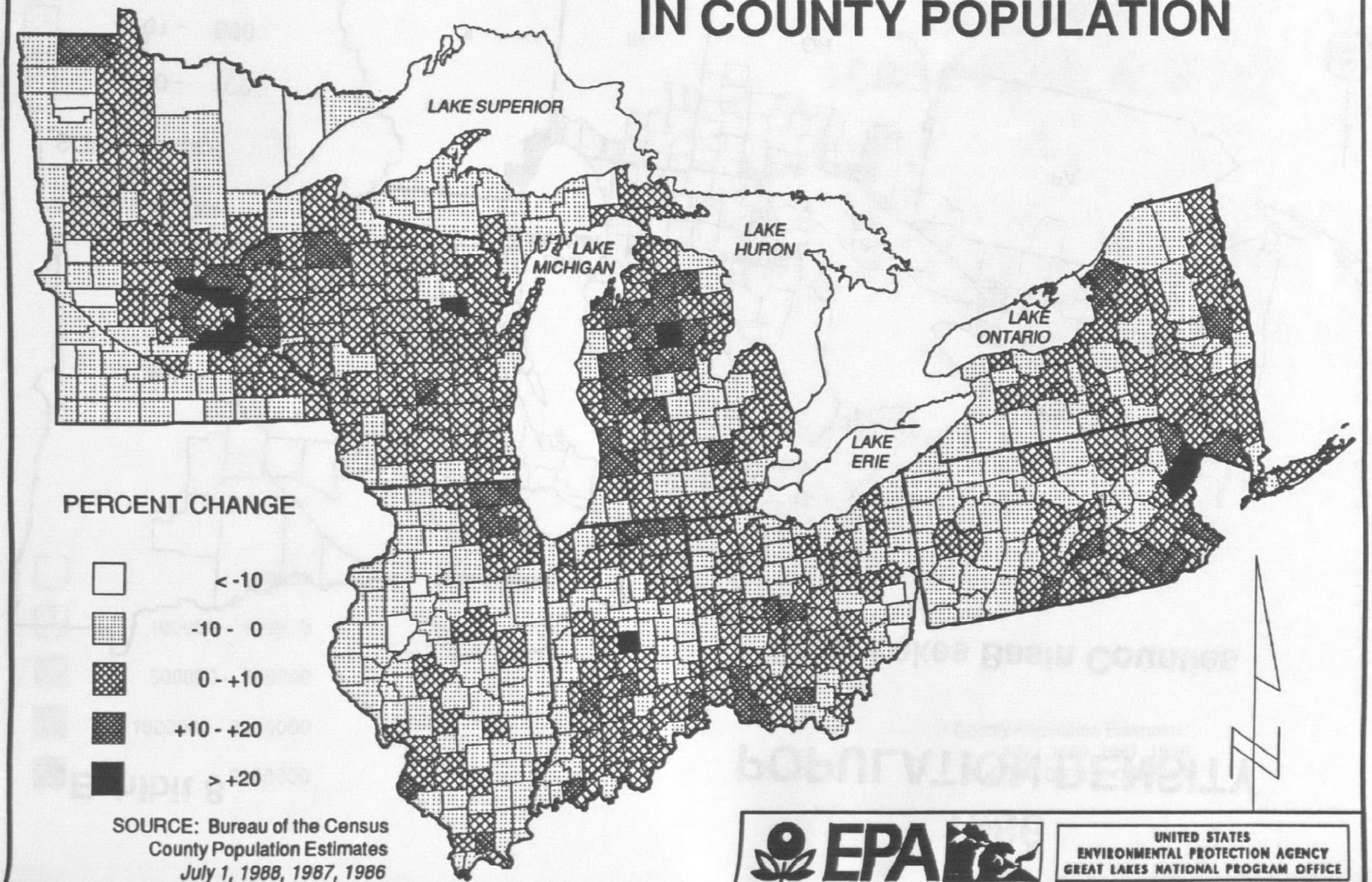
Exhibit 9

GREAT LAKES STATES
1980 - 1988 PERCENT CHANGE IN COUNTY POPULATION



SOURCE: Bureau of the Census
County Population Estimates
July 1, 1988, 1987, 1986

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UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
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4. Future Trends

Future trends for many factors will likely influence the risks addressed in this study. Factors such as changes in population distributions, land use patterns, industrial activity, and recreational patterns serve as indicators of where future environmental impacts are likely to be felt.

The Basin's population distribution influences many human health risks because of exposure to the problem areas. For example, air emission of a toxic contaminant in Detroit is likely to be a greater threat to human health in terms of the total number of potentially impacted persons than a similar emission in Saginaw, Michigan; while the risk to an individual may be similar in the two areas, the differences in population density signify a greater danger in terms of numbers exposed. As discussed above, population trends throughout the Basin indicate an overall decrease in Basin inhabitants. While the total human population which may be exposed to problem areas sources and activities is declining, areas of localized growth and new activities could witness increased residual risks.

Land use patterns also impact residual risks in the Basin. For example, changes in agricultural land use will affect those areas where pesticides are intensively applied. From 1949 to 1987 agricultural acreage declined over one-third in the United States portion of the Basin. This is depicted in Exhibit 10. In spite of less acreage, however, dramatic increases in crop production have occurred. This was accomplished with the use of great quantities of both pesticides and fertilizers.

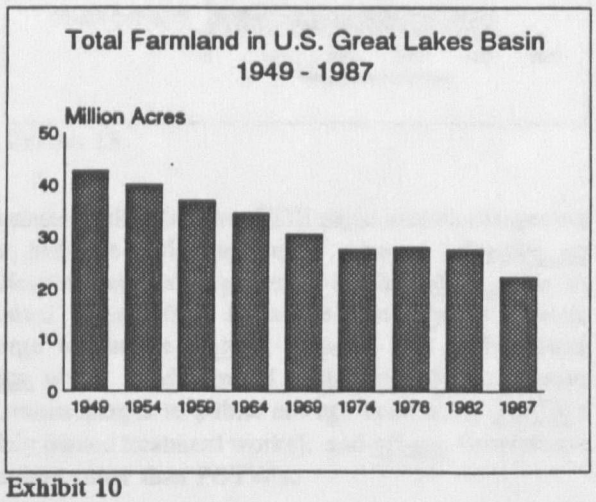

Exhibit 10

Presently Basin land use can be generally divided among agricultural, residential, industrial, commercial, recreational and forest areas. These uses are changing. Industry along the Lakes' shores is being replaced by recreational and leisure-based development. According to a mid-1980s study by Francies Demoy of Rochester Institute of Technology's Center of Management Study, "...the next 20 years will see the growth of a water-based recreation economy, steeped in sport-fishing, supported by private investment... and played against the backdrop of improved water quality."[3]

This trend of recreational development is also occurring along Lake Michigan shores. The increase of certain stressors on the ecosystems in these areas result in increased habitat destruction. Areas such as Traverse Bay have seen increased condominium and resort development, and are witnessing a high degree of permit applications to fill in wetlands.

The extent of industrial activity in the Basin has a direct impact on the intensity of industrial water discharges, air emission, and land disposal of wastes. Long term decline in worker-intensive industry in the Basin is evident in the forecasts for manufacturing employment. The Erie County Pennsylvania Task Force on Economic Adjustment reported in 1989 that, "Despite the high concentration of manufacturing employment in Erie, the sector is forecast to decline from 35,200 in 1989 to 33,800 by 1992."[4] Where such changes represent a decrease in industrial activity, they could result in a lowered importance in industrial point wastewater discharges and toxic air emissions, although it may indicate a potential increase in other risks, such as abandoned waste sites.

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[3] 1985-86 Annual Report, Monroe County Water Quality Management Agency, page 19.

[4] Economic Adjustment Strategy for Erie County, Pennsylvania, August, 1989, The Economic Development Corporation of Erie County, Pennsylvania Task Force on Economic Adjustment.

Finally, changes in environmental statutes may also affect many of the risks described under the problem areas. For example, pending amendments to the Clean Air Act will reduce risks from sulfur and nitrogen oxides, hazardous and toxic air emissions.

D. THE HEALTH OF THE GREAT LAKES ECOSYSTEMS

1. Stressors

As the problem area discussions indicate, anthropogenic releases of contaminants to the Great Lakes Basin occur through all media, and from a myriad of sources. The following exhibits provide a flavor of these stressors and some of their sources.

Exhibit 11 depicts the geographic distribution of estimated total releases for all media in Great Lakes Basin counties in pounds per year. Exhibit 12 shows releases of known, probable and suspected human carcinogens to the Basin. The information for these exhibits was taken from 1988 Toxic Chemical Release Inventory (TRI) which estimates releases for a limited number of chemicals (slightly higher than 300) from the heavy manufacturing sector in the Basin. Therefore, this TRI data represents only a portion of the many chemicals released to the Basin. Exhibits 13 and 14 show the proportions by media for these emissions, and Exhibit 15 shows the distribution of facilities monitored in TRI. Exhibit 16 depicts the distribution of total air releases to all media for the Basin counties.

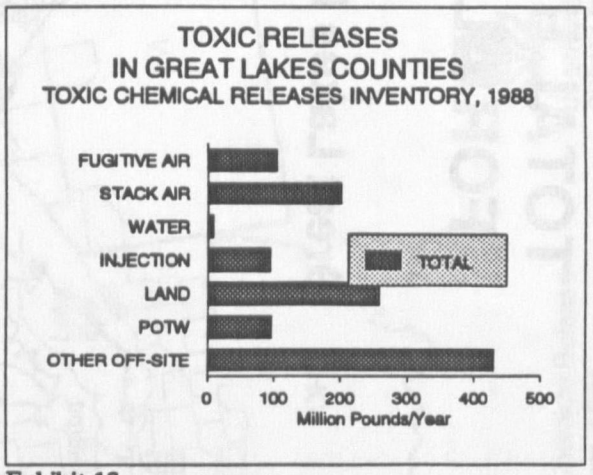


Exhibit 13

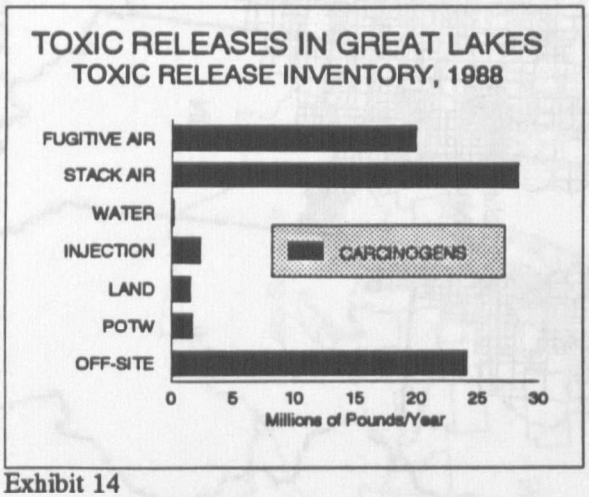


Exhibit 14

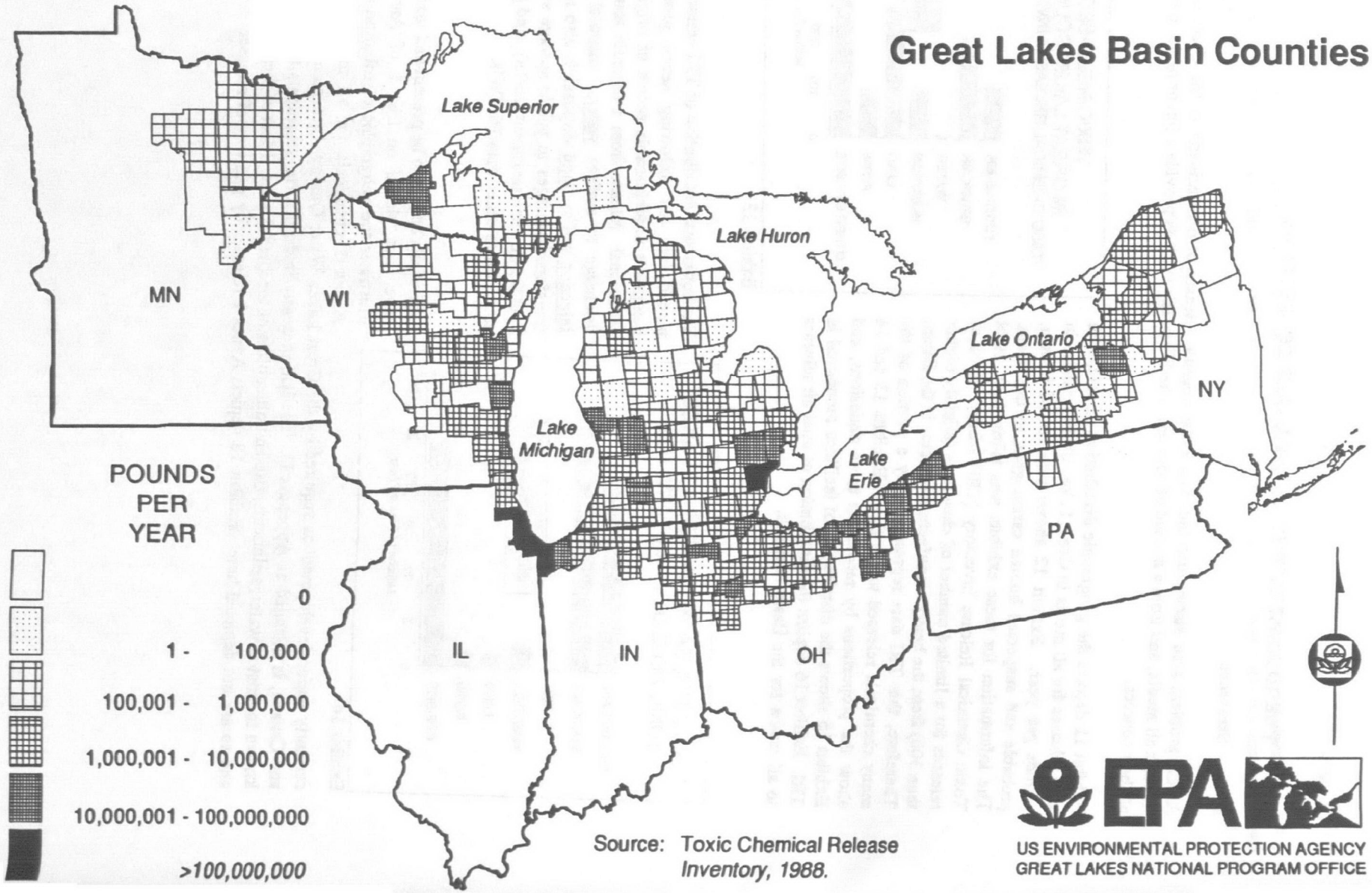
Environmental distribution of TRI emissions/discharges are placed into the following seven groups: fugitive air comprises unidentifiable points of origin; stack air is an intentional release from a discrete source (point source); discharge to surface water; disposal into underground injection wells; land disposal is also regarded as on-site; transfers/discharges to public sewage systems or POTW's (publicly owned treatment works); and off-site transfers are to locations other than POTW's.

Chemicals known to be present and toxic in the Great Lakes have been placed on List 1 of Annex 1. Exhibit 17 illustrates the geographic distribution of releases for these Annex 1 chemicals for all media. This list, which is currently under development as required by the Great Lakes Water Quality Agreement between the United States and Canada, is included as Appendix D. The list, presently in draft form, represents the toxic substances that are known to exist in water, sediments, fish and other biota of the Great Lakes. Most of these substances are not in TRI, and so are not depicted here. Exhibit 18 depicts Annex I releases by pathway of release.

Exhibit 11

TOTAL RELEASES FOR ALL MEDIA

Great Lakes Basin Counties



Source: Toxic Chemical Release Inventory, 1988.

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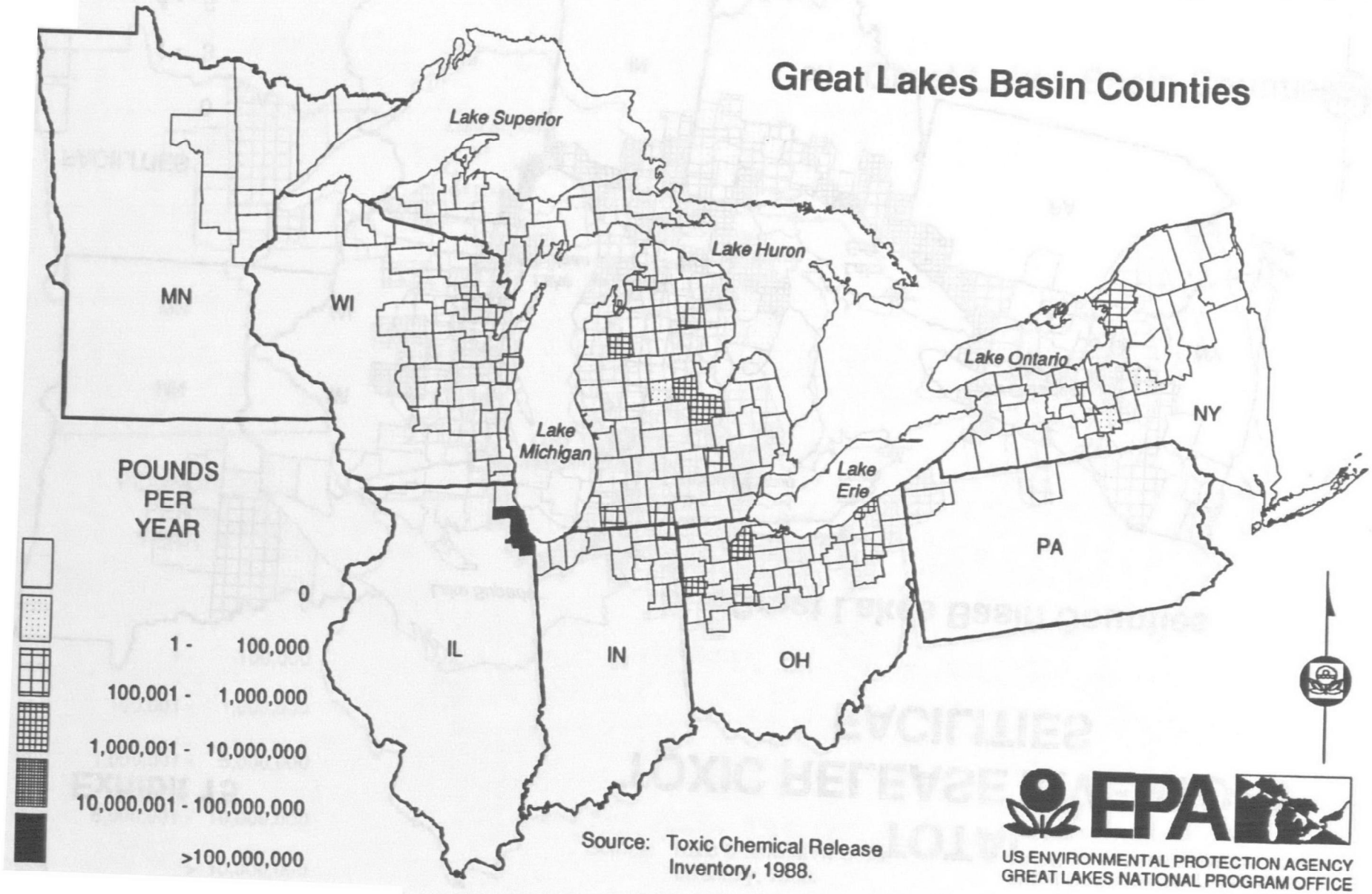
Exhibit 12

RELEASES OF CARCINOGENS FOR ALL MEDIA

Great Lakes Basin Counties



Source: Toxic Chemical Release Inventory, 1988.

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Exhibit 15

TOTAL TOXIC RELEASE INVENTORY FACILITIES

Exhibit 16

TOTAL AIR RELEASES FOR ALL MEDIA

Great Lakes Basin Counties

Source: Toxic Chemical Release Inventory, 1988.

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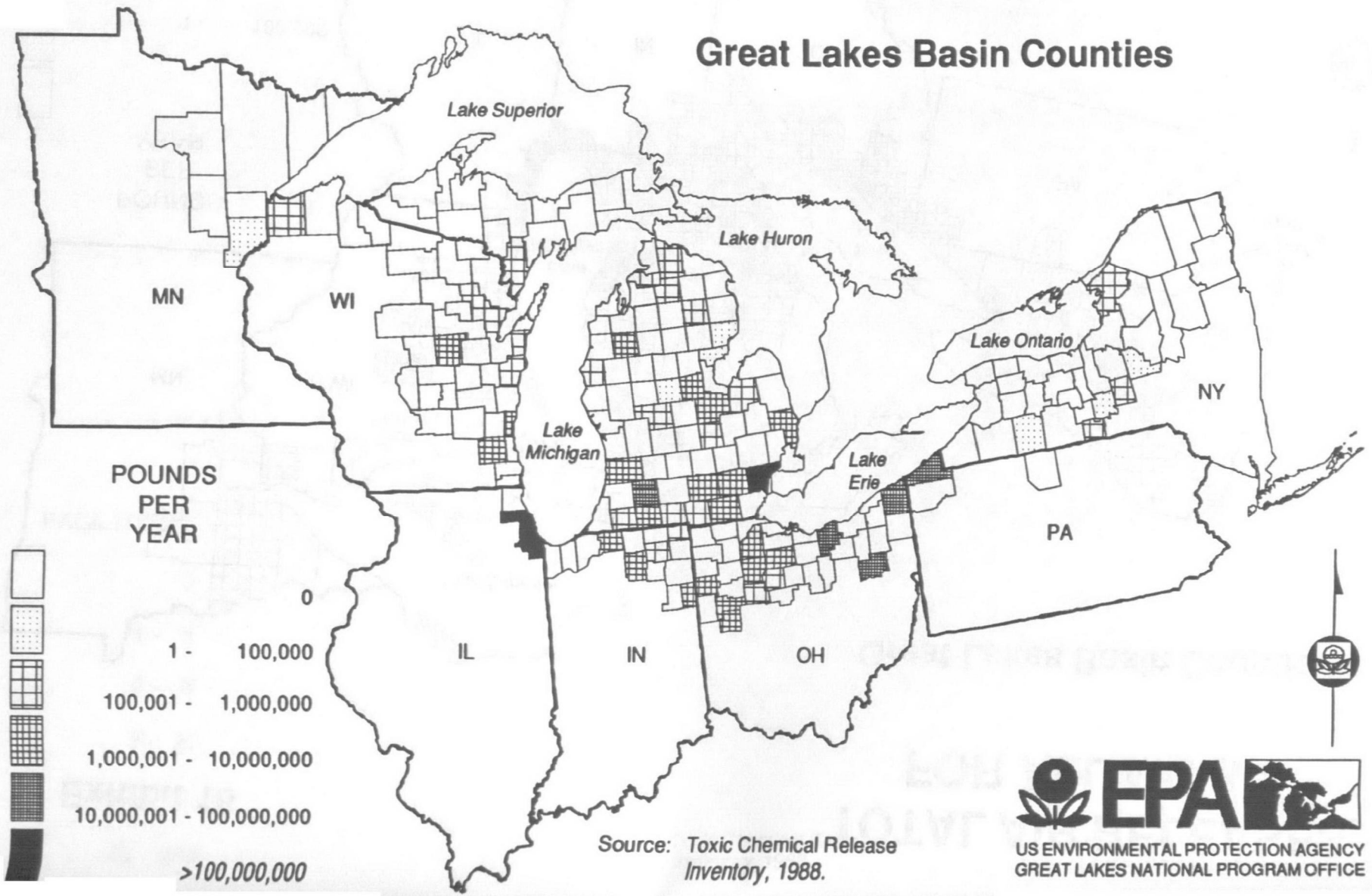
Exhibit 17

RELEASES OF ANNEX 1 CHEMICALS FOR ALL MEDIA



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Exhibits 19[5] through 24 provide information on the type of industrial processes, major companies, and facilities that are included in TRI and that release Annex 1 and carcinogenic substances.

A significant amount of toxic contaminants in the Great Lakes Basin may be emitted from mobile sources. For example, Exhibit 25 shows the relative contribution of mobile, point, and other sources to emissions of benzene, lead, and trichloroethylene in the Detroit/Windsor area.[6] Mobile sources were also shown to be a significant source of cancer risk from air pollution in southeast Chicago.[7] Gasoline vapors are primarily released from mobile sources as well. While mobile sources may have potentially significant impacts on the Lakes, especially through atmospheric loadings, time constraints have prevented these sources from being fully analyzed here.

Exhibit 26 shows the distribution and magnitude of TRI PCB releases in the Great Lakes Basin. PCBs have been shown to be a major source of risk to wildlife and to human health through fish consumption. In addition to industrial releases, they enter the water and the food chain through the resuspension of toxic sediments.

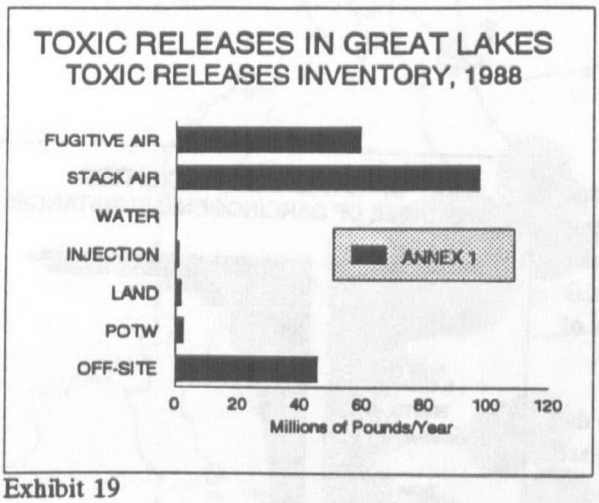


Exhibit 19

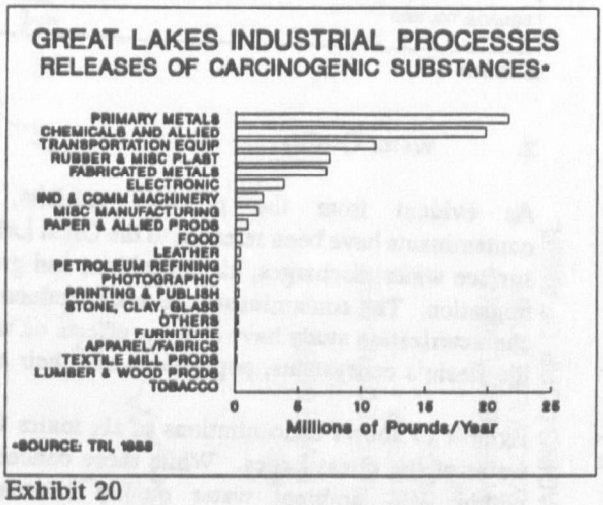


Exhibit 20

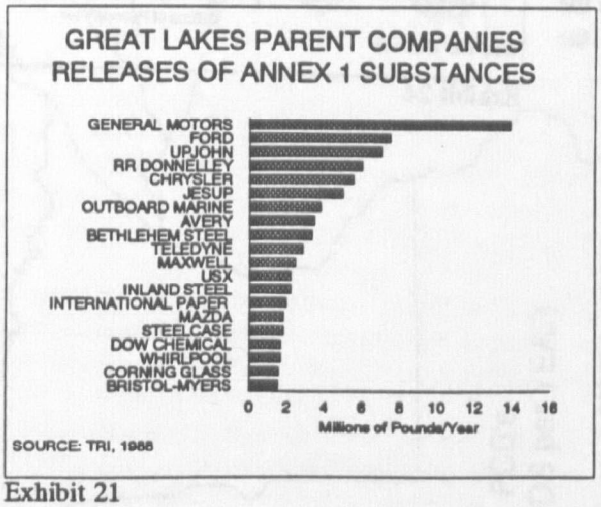


Exhibit 21

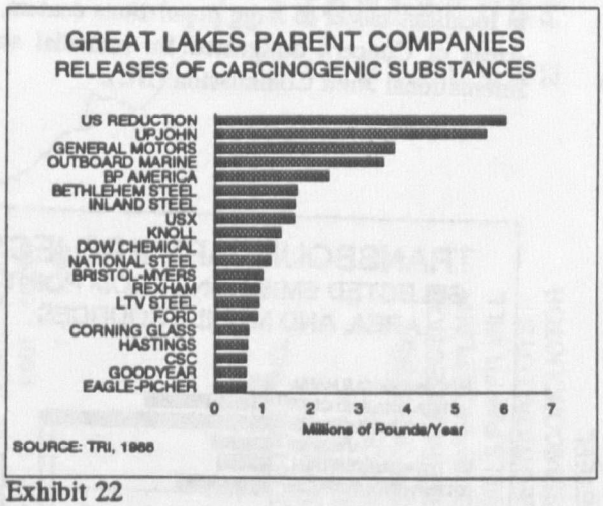


Exhibit 22

[5] Exhibit 18 has been deleted.

[6] Preliminary information from Draft U.S. EPA Transboundary Air Emissions Project, 1990.

[7] U.S. EPA. "Estimation of Cancer Risks Attributed to Air Pollution in Southeast Chicago." Region 5, Air and Radiation Division, September, 1989.

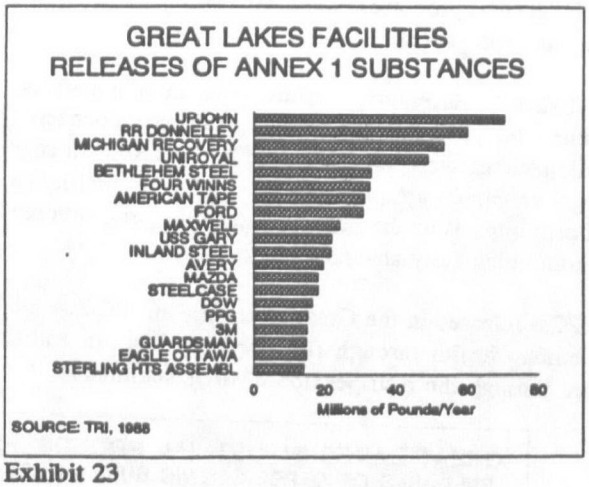


Exhibit 23

2. Water Quality

As evident from the previous exhibits, numerous contaminants have been released to the Great Lakes through surface water discharges, air deposition, and ground water migration. The contaminants that are examined in this risk characterization study have striking effects on the health of the Basin's ecosystems, populations and their activities.

Exhibit 27 shows concentrations of six toxics found in the water of the Great Lakes. While these concentrations are within EPA ambient water quality criteria, they are lakewide averages. Concentrations are likely to be higher in locations closer to large populations centers, such as the Areas of Concern designated for remedial action by the International Joint Commission (IJC).

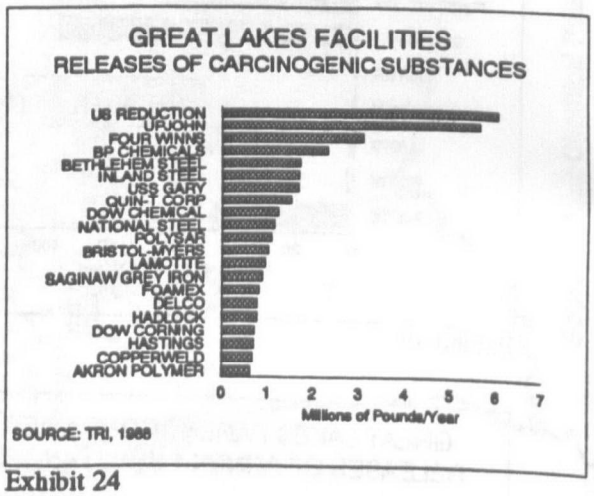


Exhibit 24

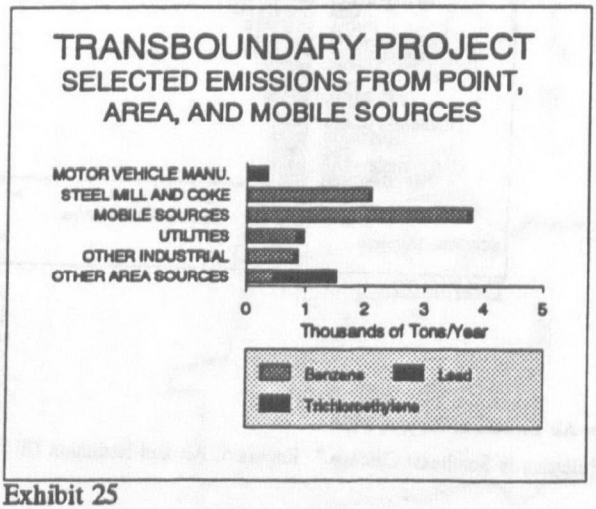
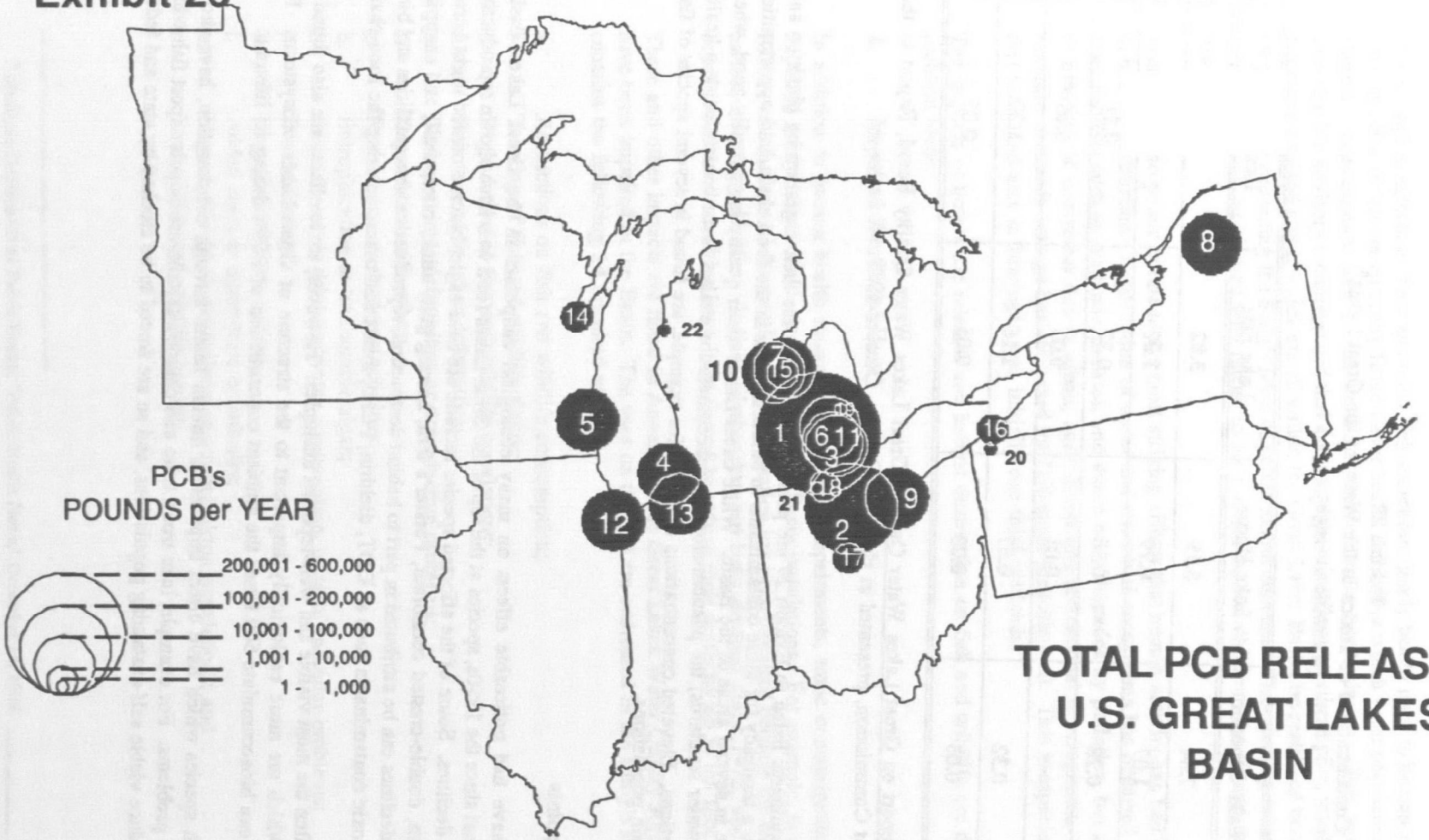


Exhibit 25

Exhibit 26



TOTAL PCB RELEASES U.S. GREAT LAKES BASIN

1 DYNEX INDUSTRIES INC.
2 WHIRLPOOL CORP.
3 ROUGE STEEL CO.
4 WHIRLPOOL CORP.
5 G. E. MEDICAL SYSTEMS
6 TRANSFORMER INSPECTION
7 SAGINAW GREY IRON PLANT
8 NEWTON FALLS PAPER MILL
9 MANOIR ELECTROALLOYS
10 HEMLOCK SEMICONDUCTOR
11 NATIONAL STEEL
12 CHICAGO HEIGHTS STEEL
13 RACO INC.
14 JAMES RIVER CORP.
15 GMC
16 GENERAL ELECTRIC-ERIE
17 EATON CORP.
18 BP OIL CO.
19 TRW INC.
20 TELEDYNE PENN-UNION
21 GERITY SCHULTZ CORP
22 PACKAGING CORP. OF AMER.

Source : Toxic Release Inventory, 1988.

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Exhibit 27
Concentrations of Toxics in the Water of the Great Lakes[8]
(lakewide averages, ng/L)

Contaminant	Lake Superior	Lake Huron	Lake Erie	Lake Ontario
alpha-BHC	7.84	5.19	3.82	3.95
Lindane	1.07	0.79	1.02	1.25
Dieldrin	0.28	0.36	0.37	0.31
pp-DDE	--	0.01	0.03	0.05
PCBs	0.32	0.57	1.16	1.20
HCB	0.03	0.03	0.05	0.05

Source: 1989 Report on Great Lakes Water Quality, Great Lakes Water Quality Board, Report to the International Joint Commission, presented at Hamilton Ontario, October 1989.

Furthermore, the six contaminants listed in Exhibit 27 are persistent, allowing for their ingestion by plankton and other species. This creates a tendency for these contaminants to bioaccumulate in the food chain, and opportunities to impact fish and wildlife in several areas of the Basin. While Great Lakes water quality is generally good, when judged by EPA drinking water standards, the phenomenon of bioaccumulation makes these contaminants a health concern for human populations. Elevated concentrations of PCBs, for example, are found in several species of fish that are consumed by Basin populations.

3. Ecological Endpoints

Anthropogenic stresses have had noticeable effects on many ecological endpoints in the Great Lakes Basin. Researchers have found that since the 1950s, species at the top of the Great Lakes food web have shown reproductive problems and population declines. Some of the affected species include the bald eagle, black crowned night heron, caspian tern, common tern, double-crested cormorant, Forster's tern, herring gull, mink, otter, wolf, and snapping turtle. While population declines can be attributed in part to habitat destruction, reproductive abnormalities and birth defects are the result of toxic contaminants such as DDT, dieldrin, PCBs, mirex and others entering the food chain.

Effects on wildlife are often the most visible and well-reported examples. However, toxic effects are also found in more common species which are more ecologically important to the structure of Great Lakes ecosystems. For example, a zooplankton can bioaccumulate 500 times the ambient concentration of PCBs during its lifetime.

Furthermore, several fish species which have direct impacts on human health through consumption, have shown tumors and reproductive problems. For example, lake trout, coho and chinook salmon are popular sport fish which have been unable to produce viable self-sustaining populations, and so are forced to be stocked by state and federal agencies.

[8] Data were not available for Lake Michigan.

The ecological effects in these and other fish sometimes imply health risks to human populations as well. These and other species of fish are currently listed under health advisories which warn populations to reduce or, in some cases, eliminate consumption due to the accumulation of toxic contaminants. For example, Michigan's 1989 fish consumption advisory recommended that consumption of walleye, northern pike, muskie, and several other fish from Michigan's inland lakes, which are all within the Great Lakes Basin, be restricted because of tests finding some fish with mercury exceeding the State's level of public health concern.[9] The advisory recommends that pregnant women, nursing mothers, or women who intend to have children, and children age 15 and under avoid eating any of these fish.

This study also points to one of the most striking effects that human activity has had on the Great Lakes Basin, that of habitat destruction. Degradation of water and terrestrial ecosystems has occurred at an alarming rate. Not only have habitats such as wetlands, prairies, and dunes been degraded by pollution, but more striking, is the wholesale elimination of ecosystem due to urban, agricultural and recreational development. In the State of Michigan, for example, wetlands acreage has decreased by 71% since presettlement. This is especially sobering when considering that total land area in Michigan was initially one-third wetlands.[10]

The impacts of both toxic releases and habitat destruction on fish and wildlife are discussed in more detail in the problem areas.

4. Impaired Beneficial Uses

In addition to human health impacts and wildlife impairments, toxic contaminants and habitat destruction have impaired many other uses deemed beneficial to Basin populations. For example, in some harbors, such as Indiana Harbor and the lower Maumee River, transportation has been impaired because the existence of toxic sediments has halted dredging activities. Indiana Harbor has not been dredged since 1972, and as a result of the sediments deposited since then, ships have been forced to reduce their drafts by up to ten feet.

These and other impacts are listed in Annex I of the Great Lakes Water Quality Agreement as beneficial uses that have been impaired in the Basin. The uses on this list are addressed in the study's risk characterizations. The list contains the following 14 impaired uses:

a. Restrictions on fish and wildlife consumption;
b. Tainting of fish and wildlife flavor;
c. Degradation of fish and wildlife populations;
d. Fish tumors or other deformities;
e. Bird or animal deformities or reproductive problems;
f. Degradation of benthos;
g. Restrictions on dredging activities;
h. Eutrophication or undesirable algae;
i. Restrictions on drinking water consumption, or taste and odor problems;
j. Beach closings;
k. Degradation of aesthetics;
l. Added costs to agriculture or industry;
m. Degradation of phytoplankton and zooplankton populations; and
n. Loss of fish and wildlife habitat.

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[9] Michigan Department of Public Health, "Public Health News," December 14, 1988.

[10] Great Lakes: Great Legacy?, pp. 143-144.

5. Ecosystem Approach

The problems mentioned above stem from human activities in the Basin that have taken place over a long period of time. While a pristine natural setting cannot be restored, many of the ecostressors can be corrected thereby reducing human health and ecological risks.

The contaminants that have caused damage come through several pathways and from many sources. Furthermore, the Great Lakes Basin is a unique and complex collection of ecosystems encompassing many interactions. These two facts signify that the problems presented here cannot be treated in isolation from each other. For example, as the problem area discussions show, numerous pesticides have many sources, both rural and urban. They enter the Basin by using several pathways: urban and rural runoff, ground water, atmospheric loading, and through resuspension of contaminated sediments. Many pesticides can directly impact the health of human applicators. And many have persisted in the environment thereby indirectly affecting the health of all organisms through biomagnification in the food chain.

Such complexity is best addressed by using a holistic, ecosystem approach that targets specific risks and geographic areas for action. An ecosystem approach to risk reduction involves a comprehensive analysis of the interrelated activities that affect human health and ecological risks in the Great Lakes Basin, aspects which include: the physical, chemical, and biological health of the Great Lakes; geographic aspects of air, water, and land use problems; and the social, economic, technical, and political variables which must also be considered.

This report points to several problems which create the highest risks for human populations and ecosystems in the Basin. The issues which demand more attention than others are exotic species, habitat destruction, toxic sediments, spills, toxic loadings and their bioaccumulative impact in the food chain. On many issues, important action has already been taken. Two of the most important initiatives in the Great Lakes Basin are the development of Lakewide Management Plans for each Great Lake, and Remedial Action Plans to remediate degraded locations known as Great Lakes Areas of Concern. Through these efforts, binational, federal, State, Tribal, local governments and the public have the mechanism to address the worst problems and locations in the Great Lakes Basin.

6. Great Lakes Lakewide Management Plans[11]

Annex 2 of the Great Lakes Water Quality Agreement, as amended in 1987, and the Great Lakes Critical Programs Act of 1990, direct the United States and Canada to develop Lakewide Management Plans (LaMPs) for each of the Great Lakes. LaMPs are meant to reduce loadings of Critical Pollutants in order to restore the beneficial uses of open lake waters, as defined by the Agreement, and to move toward the goal of "virtual elimination of persistent toxic substances and toward restoring and maintaining the chemical, physical and biological integrity of the Great Lakes Basin Ecosystem."[12]

The first LaMP being developed is the Lake Michigan LaMP, for which the United States has sole responsibility. EPA is preparing a draft Baseline Report for the Lake Michigan LaMP which is meant to describe current knowledge of Lake Michigan as a basis for the further development of a comprehensive plan. LaMPs will be submitted as they satisfy four stages as laid out by the IJC: 1) when a definition of the problem has been completed; 2) when the schedule of load reductions is determined; 3) when remedial measures are selected; and 4) when monitoring indicates that the contribution of the Critical Pollutants to impairments of identified beneficial uses has been eliminated.

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[11] Much of this section is summarized from EPA's draft "Baseline Report: Lake Michigan Lakewide Management Plan," October, 1990.

[12] Annex 2, Subsection 2(b), Great Lakes Water Quality Agreement of 1978, as amended by Protocol signed November 18, 1987.

The draft Lake Michigan LaMP baseline report describes current knowledge regarding:

1. Lakewide beneficial use impairments and the Critical Pollutants associated with those impairments, including identification of the highest priority candidate Critical Pollutants for immediate action and a process for updating the priority list;

2. The sources of the highest priority candidate Critical Pollutants and, where possible, load estimates from these sources;

3. An inventory of ongoing pollution control activities being conducted by Federal, State, local and private organizations;

4. Recommendations for specific "fast track" actions to be undertaken to maximize current authorities in order to reduce, and where possible, eliminate pollutant loads in order to move towards the environmental objectives described earlier.

A LaMP is currently under development for Lake Ontario as well. This LaMP will build upon the work done to develop a Lake Ontario Toxics Management Plan. The Toxics Management Plan (TMP) was developed in 1989 and is to be periodically updated to reflect new developments. A 1990 update is scheduled for distribution and discussion by the TMP's coordinating committee and the public in December, 1990. While the TMP will form the bulk of the LaMP, the LaMP will cover two additional issues not addressed by the TMP: 1) the development of a committee to ensure public participation, and 2) attention to habitat losses.

EPA does not believe that the LaMP process should overshadow other efforts underway to address issues such as habitat destruction, exotic species introduction, and other human activities which impair beneficial uses of the Lakes. The emphasis on Critical Pollutants for open waters is meant to focus the efforts of the LaMPs to achieve clear results in each Lake. LaMPs will also address contaminant problems that occur in near shore areas, and where possible, will work in concert with Remedial Action Plans for the Areas of Concern described below.

LaMPs can also take full advantage of current and future risk characterizations when targeting specific chemicals and remedial actions. Risk analysis is a necessary tool for LaMP success.

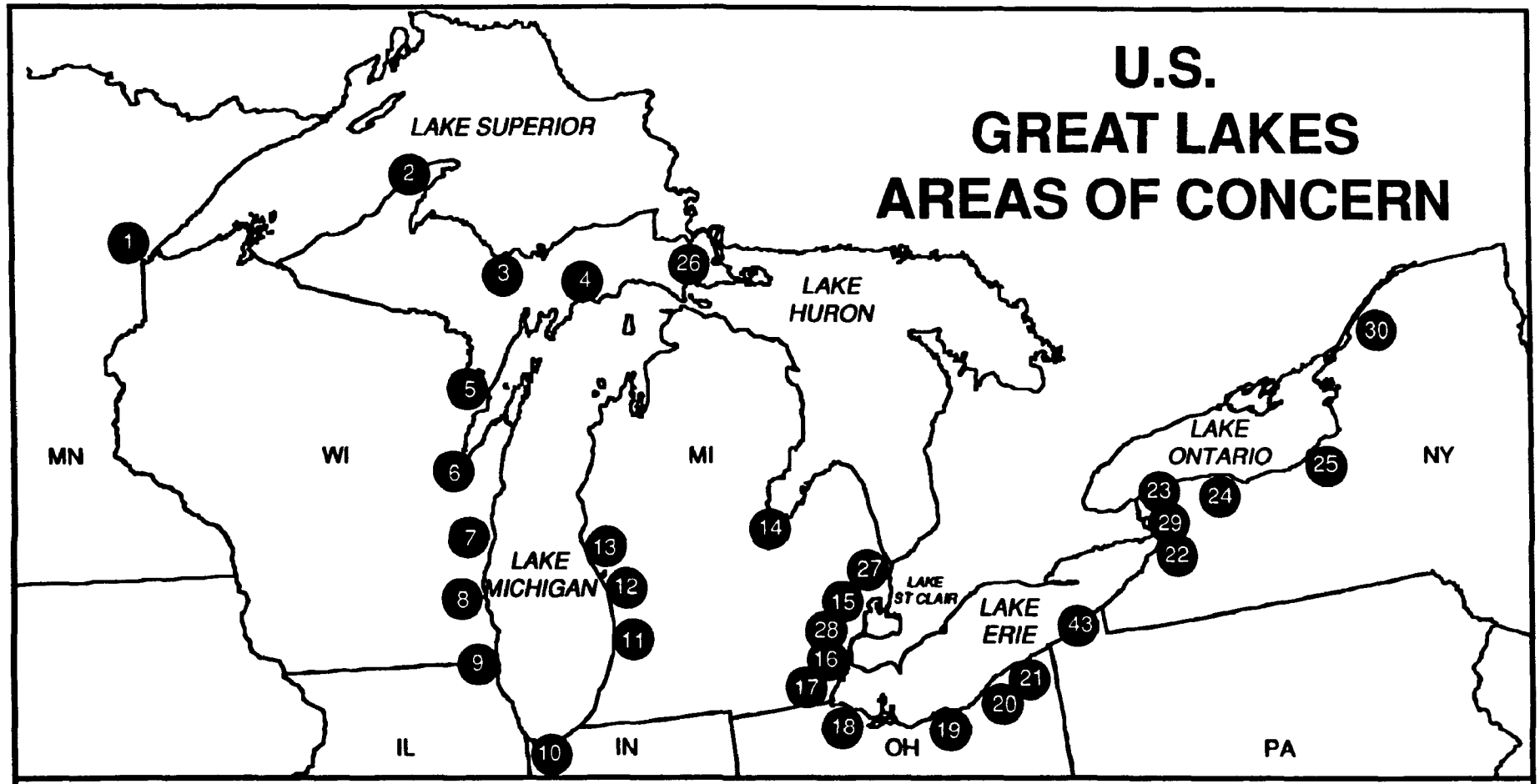
7. Great Lakes Areas of Concern

The Great Lakes Areas of Concern (AOCs) are depicted in Exhibit 28. Brief descriptions of the AOCs in the United States along with their problem contaminants are provided in Appendix E.[13]

a. Definition and History

For more than twenty years, the Water Quality Board of the IJC has identified specific polluted areas in the Great Lakes. Over time, as more environmental data have become available, environmental conditions have changed, and as a result, the number of areas has fluctuated. In 1985, the IJC identified forty-two AOCs and the United States designated the forty-third AOC in 1990. These are areas where water use is impaired and objectives of the Great Lakes Water Quality Agreement or local environmental standards are not being achieved. Of the forty-three AOCs, twenty-six of them are in the United States alone, and five are shared with Canada. The most significant issue for

[13] For detailed descriptions of the AOCs, see Appendix A, 1989 Report on Great Lakes Water Quality, Water Quality Board, IJC.



LAKE SUPERIOR
(1) St Louis River
(2) Torch Lake
(3) Deer Lake-Carp Creek -Carp River

LAKE MICHIGAN
(4) Manistique River
(5) Menominee River
(6) Fox River/Southern Green Bay
(7) Sheboygan
(8) Milwaukee Estuary
(9) Waukegan Harbor
(10) Grand Calumet River /Indiana Harbor Canal
(11) Kalamazoo River
(12) Muskegon River
(13) White Lake

LAKE HURON
(14) Saginaw River /Saginaw Bay

LAKE ERIE
(15) Clinton River
(16) Rouge River
(17) Raisin River
(18) Maumee River
(19) Black River
(20) Cuyahoga River
(21) Ashtabula River
(22) Buffalo River
(43) Presque Isle Bay

LAKE ONTARIO
(23) Eighteen Mile Creek
(24) Rochester Embayment
(25) Oswego River

CONNECTING CHANNELS
(26) St Mary's River
(27) St Clair River
(28) Detroit River
(29) Niagara River
(30) St Lawrence River

0 50 100 150 200
KILOMETERS

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the vast majority of the AOCs is the presence of chemical toxic contamination, with hundreds of toxic substances identified in the Lakes. Many AOCs are so saturated with contaminants that the areas themselves have become a major source of pollutant loadings to the Lakes.

b. Remedial Action Plans

The IJC identified the AOCs to encourage jurisdictions to rehabilitate these areas. The federal, State, Tribal and provincial governments around the Great Lakes have agreed to cooperate with local governments to clean up AOCs through the development of Remedial Action Plans (RAPs). RAPs are being developed by federal, State, Tribal, local, and provincial governments around the Great Lakes, with the respective States functioning as lead coordinators for AOCs within their borders. A RAP is being developed for each AOC. They will identify the degree of contamination at each area, and the level to which the area must be restored in order to make the area safe for fishing, swimming, drinking, and other beneficial uses. They will also recommend which remedial measures are appropriate for each problem, and a time table for their execution.

An important objective in developing the RAPs is to use an ecosystem approach to remediation. Another important aspect of developing the RAPs is public involvement. The public, particularly the communities adjacent to the AOCs, must be involved with RAP planning and implementation. The insights and priorities of local residents is vital to the success of each RAP, and ongoing public involvement and support will be important to sustain the lengthy process.

As part of the Great Lakes Water Quality Agreement, each RAP will be submitted to the IJC for review at three different stages of the RAP's development. The first stage is the definition of the contamination problems in the AOC; the second stage comes after appropriate plans for addressing the contamination problems have been developed; and the third stage is after monitoring activities have been conducted and the monitoring data indicates that beneficial uses have been restored.

By the end of the fiscal year 1990, 14 United States RAPs had been submitted to the IJC for Stage 1, the identification of problems, sources, and impaired beneficial uses, and 9 of those for Stage 2, the selection and implementation of remedial options. However, initial submission of RAPs is not a completion of the plan. Rather, RAPs are an iterative procedure where sections of some Stages will be refined and resubmitted, based on new information or advice from the IJC. The Great Lakes Critical Programs Act of 1990 requires that all U.S. RAPs be submitted to the IJC by January 1, 1992.

8. Relationship Between AOCs and the Risk Characterization Problem Areas

The AOC approach to remediation has been a vital beginning to remediation of the Great Lakes. But while the worst cases of pollution must be cleaned up in order to achieve clear progress, a risk-based approach which deals with the whole ecosystem is also necessary in order to ensure overall reductions in toxics. AOCs often represent remediation. This must also be accompanied by source reductions guided by risk assessments. A risk-based approach focusing on aggregate risks as a means to prioritize AOCs for action and to identify other areas or sites for special attention should also be used. The broadened approach would draw in new sites for attention based upon terrestrial and other human health risks not considered in the general AOC approach to environmental problems.

Many of the environmental problems addressed in this report exist within the AOCs. While discharges or releases to surface water predominate, waste management and air emission problem areas are present at many. Several of the environmental problems, such as toxic sediments and point source discharges to surface waters, are found in virtually all of the AOCs. Nonpoint source loadings are also common problems. Nonetheless, the number of environmental problem areas associated with an AOC does not necessarily provide an adequate measure of the relative level of residual risk at that site. The current risk at each AOC can only be measured by assessing the level of overall environmental contamination, constituents involved, likely exposure routes, and environmental receptors

at the site.

As apparent, each AOC may not encompass all sources of environmental risk described in this study. Many risks are not addressed by each RAP, such as those associated with atmospheric loading, climate change, and introduction of exotic species. But many of the risks which are addressed by RAPs are in fact problems outside the AOCs as well. Risks from environmental problems such as sediments, active and abandoned hazardous waste sites, point and nonpoint source discharges to surface water could be just as significant outside AOC boundaries.

The apparent inconsistency between what problems are addressed by this study and what is addressed by RAPs is due, in part, to the definitions of an Area of Concern, a Remedial Action Plan, and the risk analysis problem areas. The AOC approach inherently focuses on impairments to specific beneficial uses at a particular location. The problem areas, which were defined by EPA Headquarters, are not always compatible with the RAP approach for specific actions directed at risk reduction. For example, the air problem areas focus on risks associated with inhalation of constituents within the air emissions, an exposure pathway not considered in the RAPs.

Risk-based analyses and actions should not replace the important work of the RAP process. In fact, in-depth risk characterization studies can complement the work being achieved in AOCs. For example, they can fit into this process by helping prioritize the tasks to be done, as well as by giving a general indication of which AOCs may need more immediate attention. This approach can help to point out other locations with risk that are not part of the formal AOC process. It may also help to guide the overall direction of AOC clean-up from an ecosystem approach. The interrelationships between the AOCs, their surrounding communities, and sources of degradation should be tied together. Such connections between AOCs and broader risks can be addressed largely with LAMP development.

9. Where to Go

1. Future Study and Refinement of Risk Analysis in the Great Lakes

Reassessment of problem area definitions. To better assess risks, environmental endpoints, appropriate indicators, and stressors must be characterized. Problem areas should be redefined to reflect this approach, rather than programmatic divisions or budget categories in EPA. Future emphasis will be on areas of risk which reflect the uniqueness and interaction of the Great Lakes.

Characterization of risks on a lake-by-lake basis. Average concentration data may underestimate real risks for humans and ecosystems in nearshore areas. Therefore, the use of Great Lakes-wide contaminant data is not necessarily the best approach for targeting risk-based activities. A better approach would be to assess risk on a lake-by-lake basis, and eventually even a segment-by-segment basis. Contamination of water and fish varies significantly from one place to another, and there are a number of geographic areas, particularly in the Connecting Channels and embayments, that have toxic chemical gradients. The development of LaMPs and RAPs provides the opportunity to develop such refined characterizations of risk.

Mass Balance data for each Lake. In general, this report assumed that concentrations in the lakes, sediment and fish are in equilibrium with loads. For sodium equilibrium, concentrations may well be too low. For others, they may be too high. The way to determine this and the materials balance in the ecosystem for all contaminants of concern is to develop mathematical mass balance models and measures with a good degree of confidence in the loadings. EPA's Large Lakes Research Station has begun modeling contaminants using this approach in Green Bay. A mass balance input-output approach is a necessary component of an ecosystem approach to define contamination of each Great Lake, or of the Basin as a whole. LaMPs provide the institutional structure to conduct such Mass Balance analysis.

Data development, coordination, and improved access. Because EPA Programs generally do not collect information on the success of the problems they address in the environment, there is a need for more data collection. In addition,

data which does exist in other federal or state agencies could contribute much to understanding contamination in the Great Lakes. The development of new data sets, coordination and improved access to these databases need to become priorities in future risk characterizations.

2. Future Action to Clean Up and Manage the Great Lakes

Environmental Indicators. Future actions must include a focus on environmental indicators to judge the success of new and continuing efforts. Measurements of success, such as good monitoring data on loadings, emissions, fish advisories, designated uses, and measurements of contaminant concentrations in endpoints, can all help determine if actions are having an effect. In addition to successes measured in this way, successes in the prevention of new problems must also be measured.

Ecological Risks. Ecological risks need to receive more attention than they have in the past. New inter-agency approaches and activities must address the destruction of wetlands, spawning areas, and other wildlife habitats.

Pollution Prevention and Source Reduction. In addition to conventional forms of dealing with pollution in the Great Lakes, this study encourages several new approaches to clean up and manage the Great Lakes. The complex interrelationships between problem areas, for both sources and pathways of pollutants, encourage further refinement of ecosystem approaches. These strategies stress the importance of reducing contaminants at their sources. LaMPs and the clean-up in Remedial Action Plans must be complemented with pollution prevention activities.

Risk-based Planning and Strategies. Future actions should be based on targeting the most critical problems first from a risk perspective, while remaining aware of financial and institutional feasibility. Public education must also occur to help direct the attention of States, EPA Regions, other federal agencies and general populations to those issues that have high residual risks. In addition, enforcement and prevention priorities should be set for geographically targeted areas where the suspected estimated human and ecological risks presented here are thought to be high, such as, Chicago/Gary, Detroit, Cleveland and Buffalo/Niagara Falls (see Exhibit 29).

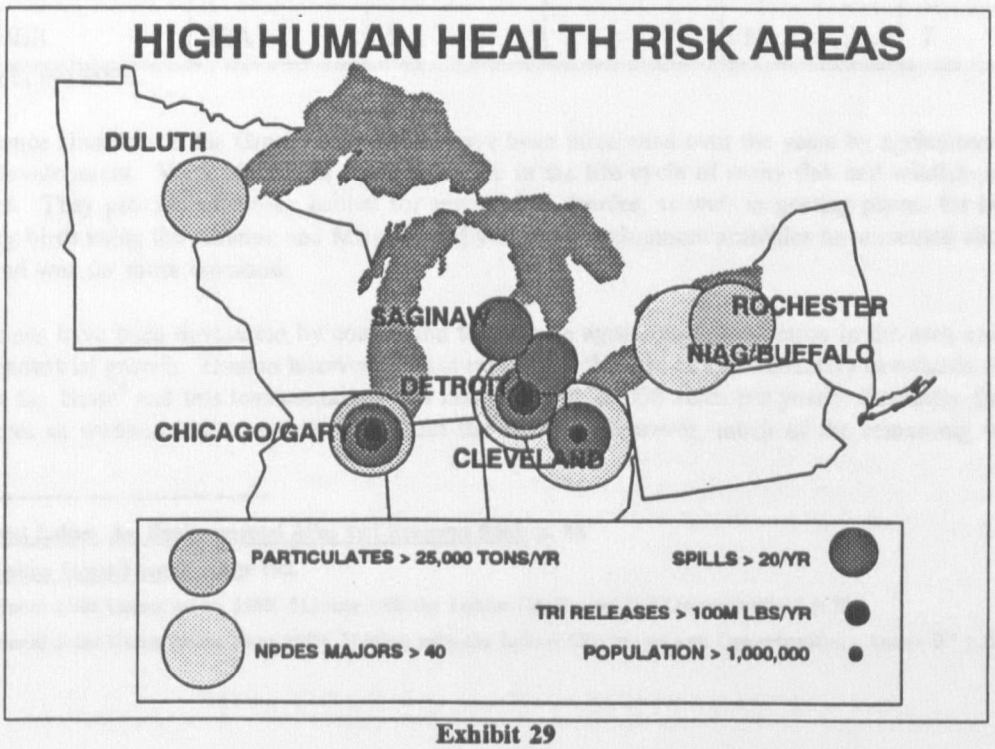

Exhibit 29

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II. EMERGING BASIN-WIDE ISSUES

A. PHYSICAL DEGRADATION OF OPEN WATER AND WETLANDS HABITAT

Problem Area Description

This section presents information on the physical degradation of aquatic habitats and wetlands in the Great Lakes Basin. Chemical effects from toxic contaminants and degraded water quality are discussed in Primary Water Problem Areas. Over many decades, development along the shores of the Great Lakes has significantly affected aquatic habitats, including wetlands. Habitat for many species has become impaired by shoreline development and water quality degradation in open water areas and tributaries.

In the United States, there are about 4400 miles of Great Lakes shoreline permanent loss. Much of it has undergone significant urban and agricultural development. Depletion of shoreline along the Great Lakes threatens the many species that spend part or all of their lifecycles along the Great Lakes shores. The following table summarizes 1985 shoreline use by lake[1]:

SHORELINE USE	SUPERIOR %	MICHIGAN %	HURON %	ERIE %	ONTARIO %
RESIDENTIAL	N/A*	39	42	45	40
RECREATIONAL	N/A	24	4	13	12
AGRICULTURAL	N/A	20	15	14	33
COMMERCIAL	N/A	12	32	12	8
OTHER	N/A	5	7	16	7

* not available.

Wetlands, once abundant in the Great Lakes Basin, have been threatened over the years by agricultural, urban, and industrial development. Wetlands play a significant role in the life cycle of many fish and wildlife species in the Great Lakes. They provide spawning habitat for several fish species, as well as nesting places for large numbers of migratory birds using the Atlantic and Mississippi flyways. Development activities have created shoreline where once wetland was far more common.

Basin wetlands have been devastated by conversion to increase agricultural production in the area and to facilitate urban and industrial growth. Human intervention has resulted in the loss of approximately two-thirds of the original wetlands in the Basin[2] and this loss continues at a rate of about 20,000 acres per year[3]. Currently there are about 500,000 acres of wetland left scattered throughout the Basin[4]. However, much of the remaining wetland areas

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[1] The Great Lakes: An Environmental Atlas and Resource Book, p. 18.

[2] Great Lakes: Great Legacy?, page 190.

[3] International Joint Commission. 1989. "Living with the Lakes: Challenges and Opportunities" p.28.

[4] International Joint Commission. June 1989. "Living with the Lakes: Challenges and Opportunities - Annex B" p.B-90.

functions and values are further reduced due to changes in shoreline, proximity of human intervention, and reduced size or access of the lakes. Nevertheless, the remaining wetlands are of extreme value to the system.

Ecological Impacts

The ecological impacts of the physical degradation of aquatic habitats and wetlands are severe. Wetlands are often used as places to deposit sediment dredged from navigation channels in lakes or rivers, which increases in times of low water levels. Dredging can disrupt wetland ecosystems and may contaminate them with pollutants in the sediment. Deposition of contaminants may also impact wetland fish and wildlife habitat and thus increase the likelihood of contaminant uptake in the food chain (See ecological effects addressed in Primary Water Problem Areas).

The effect of dredging sediments on aquatic habitats is a concern in the Great Lakes Basin due to the large amount of dredging the U.S. Army Corps of Engineers initiates annually to support the Great Lakes shipping industry. Throughout the Great Lakes, there are 26 confined disposal facilities that are used to store sediments dredged from Great Lakes ports. Their locations are depicted in Exhibit A-1[5]. Although no data exists regarding the effect of dredging sediments on aquatic habitat, the amount of dredging can be put into perspective by looking at the capacity of the combined disposal facilities. According to a USEPA report, 48 million cubic yards of sediments have been dredged and stored in confined disposal facilities in the Great Lakes since 1960. According to the same report, the remaining capacity of the facilities in the Great Lakes is about 30 million cubic yards[6].

Section 404 of the Clean Water Act regulates dredge and fill activities. Exhibit A-2 depicts the number of dredge and fill permit applications for 1989 by the Basin county. This information suggests that areas such as Traverse Bay and the St. Clair River, which contain ecologically significant wetlands, are witnessing serious dredge and fill activities.

Destruction of wetlands in the Great Lakes Basin has had severe ecological impacts. It is estimated that one-third of the land area of Michigan was once wetland. Wetlands also covered about 60% of southwestern Ontario. At the west end of Lake Erie, the Black Swamp covered about 1,500 square miles from Sandusky Bay to the Indiana border. Once wetlands are developed or drained, they cannot be restored to their natural state. Further, there are several different types of wetlands that serve different functions. Swamps, marshes, bogs, and fens all provide different habitats for different plant and animal species that depend on these wetlands for their survival.

The Natural Heritage Program data base has identified the most biologically significant wetlands in the Great Lakes Basin, and while there are several occurrences of high ranking wetlands, the occurrences are only a handful compared to the number of wetlands in the region. The data base identifies the last remaining wetlands that are considered biologically significant and a priority for protection. Biological significance, according to The Nature Conservancy, is the contribution a locality or site makes to sustain biological diversity. Biological diversity is the variety and process of life, comprised of species and communities of species, their interactions, and the functioning ecosystems they make up. Sites are biologically significant if they: first, represent ecosystem remnants that are little affected by European-American development compared to the regional landscape, or second, harbor concentrations of imperiled species under threat throughout the region. The following table indicates the types of biologically significant occurrences of wetlands remaining in the Great Lakes Basin. The sites described were selected on the basis of the presence of exemplary plant communities and/or rare and endangered species. They are located throughout the Basin.

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[5] U.S. Environmental Protection Agency, 1989. Report on Great Lakes Confined Disposal Facilities, p.13.

[6] U.S. Environmental Protection Agency. 1989. Report on Great Lakes Confined Disposal Facilities, Table 3.

EXHIBIT A-1

LOCATIONS OF CONFINED DISPOSAL FACILITIES
U.S. GREAT LAKES

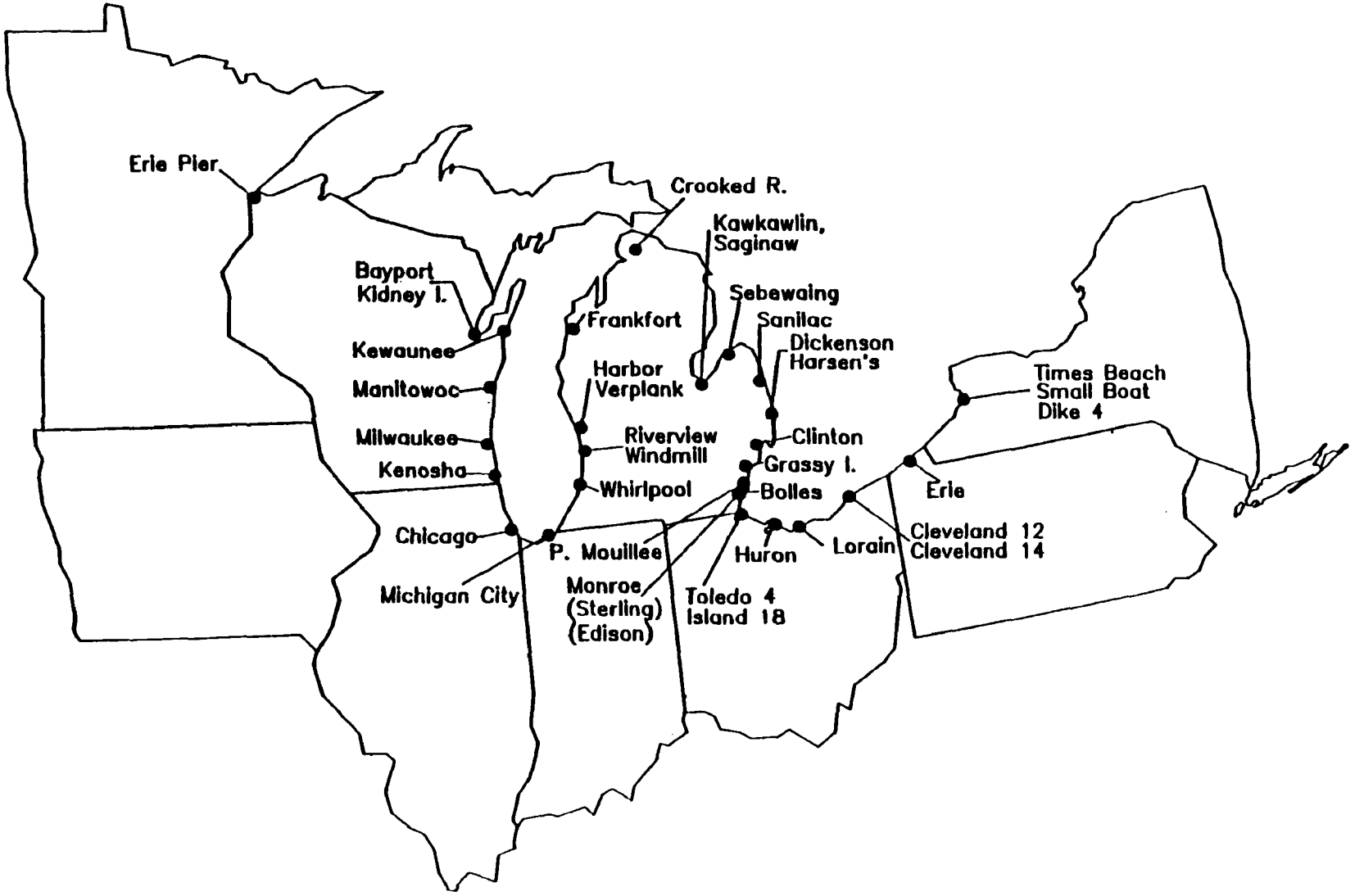
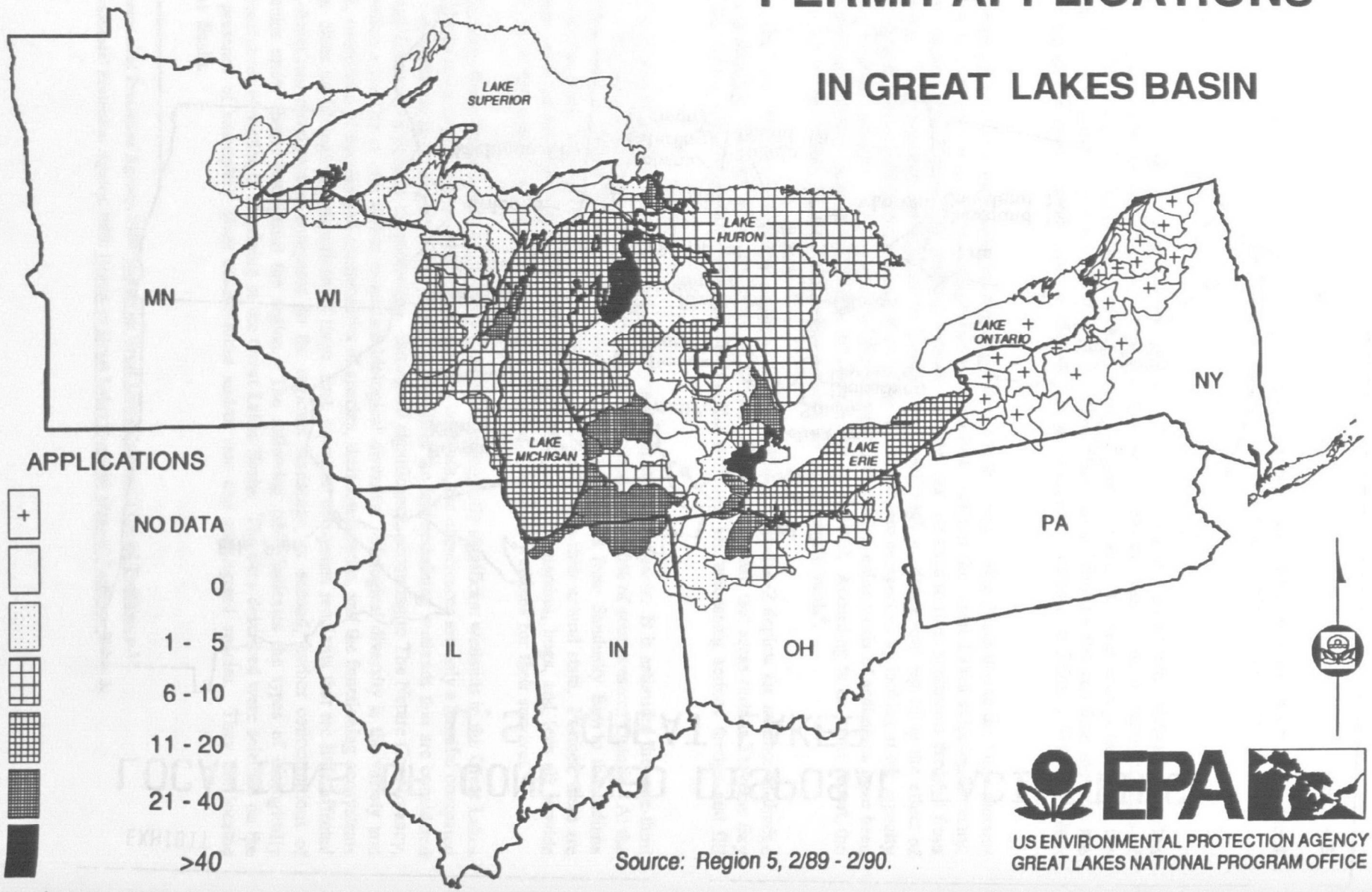


Exhibit A-2

REGION 5
DREDGE & FILL
PERMIT APPLICATIONS

IN GREAT LAKES BASIN



Source: Region 5, 2/89 - 2/90.

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Biologically Significant Wetlands Remaining in the Great Lakes Basin[7]

State	Type
Wisconsin	open bog, calcareous fen, coastal plain marsh, interdunal wetland, southern hardwood swamp, slough, bog relict.
Ohio	leatherleaf bog, tall shrub bog, mixed swamp, submergent marsh, cinquefoil sedge fen, sphagnum bog, tamarack fen, tall shrub bog, tamarack-hardwood bog, mixed swamp, mixed emergent marsh, mixed shrub swamp, maple-ash swamp.
New York	rich hemlock-hard wood peat swamp, rich sloping fen, red maple-tamarack peat swamp, rich graminoid fen, northern white cedar swamp, marl fen, perched white oak swamp, rich shrub fen, black spruce-tamarack bog, patterned peatland, dwarf shrub bog, inland poor bog, rich shrub fen, marl pond shore, inland salt marsh, deep emergent marsh, spruce-dir swamp, rich sloping fen, sinkhole wetland, northern white cedar swamp.
Minnesota	shrub swamp
Michigan	rich conifer swamp, Great Lakes marsh, bog, southern swamp, hardwood-conifer swamp, poor conifer swamp, muskeg, relict conifer swamp, prairie fen, patterned fen, coastal plain mars, northern fen, emergent marsh, southern wet swamp, interdunal wetland, rich conifer swamp, southern swamp, relict conifer swamp, inland salt marsh, emergent mars, intermittent wetland.
Indiana	beach marl, bog, forested fen, fen, flat muck, mars, panne, meadow sedge, swamp shrub, bog, acid bog circumneutral, flat sand

Welfare Impacts

The environmental costs of physical degradation of aquatic habitats and wetlands can be illustrated by the number of wetlands acres lost. The following table summarizes the amount of wetlands lost in the Great Lakes region since presettlement times.

Wetlands Losses in the Great Lakes Region [8]

Location/Area	Wetland Assessment
Lake St. Clair wetlands	85% loss since presettlement
Minnesota	76% loss since 1953
Wisconsin	50% loss since presettlement
Illinois	90% loss since presettlement
Indiana	86% loss in areas studied
	71% loss in northern Indiana
Michigan	71% loss since presettlement
Ohio	loss of almost the entire 1,500 square miles of the Black Swamp

[7]The Nature Conservancy. 1990. Report to EPA on Significant Biological Areas of the Great Lakes Watershed.

[8]The Conservation Foundation and the Institute for Research on Public Policy. 1990. Great Lakes Great Legacy?. p.144. The source cited did not present an overall assessment for Pennsylvania or New York.

Material and Property Damage

It is difficult to assign a value to the material and property damage resulting from physical degradation of aquatic habitat and wetlands. Studies have been conducted to quantify the economic value of wetlands. A study conducted by the Region 2 office of the Environmental Protection Agency concludes that the economic benefit generated per acre of coastal wetland ranges from $9,000 to $17,000 using a discount rate of 3%, or from $2,400 to $6,400 using a discount rate of 8%. The report also looked at the costs associated with replacement of wetlands and the functions that they provide. The analysis did not look at Great Lakes wetlands[9].

It is important to understand the various functions that wetlands play, not only in providing spawning areas for fish and habitat for a variety of other species, but as an influence on water quality and ground water conditions. For example, wetland losses may have a devastating effect on the multi-billion dollar Great Lakes sport fisheries.

[9]U.S. Environmental Protection Agency. 1990. Region 2 Comparative Risk Project Problem Area Analysis, Estimating Wetland Values, p.5.

B. PHYSICAL DEGRADATION OF TERRESTRIAL ECOSYSTEMS

Problem Area Description

This section describes the stressors on terrestrial ecosystems in the Great Lakes Basin and presents information on the biologically significant[10] occurrences that remain in the Basin. The primary data sources used in this section include reports from the Natural Heritage Inventory Program and the Region 5 report on physical degradation of terrestrial ecosystems.[11]

The fact that so few Basin terrestrial ecosystems can be found in a diverse, self-sustaining, and natural state indicates that degradation of these ecosystems has been significant since European settlement. The reversibility of terrestrial ecosystem damage due to destruction of habitat is very limited. Some work is being done in the area of natural area restoration, but the work generally focuses on restoring degraded natural areas still in existence, not on the establishment of new habitat.

Within the Great Lakes Basin the main types of native terrestrial ecosystems include old and second growth forests, wetlands, prairies and other grasslands, and dune communities. Two types of Basin ecosystems, prairies and dunes, are especially rare. Prairies are complex natural grassland communities whose habitat structure is vulnerable to changes in wildlife and plant populations as well as changes in the proportions in which they exist.

Dunes result from wind and water deposits of lake bottom sand over a sustained period. The dune ecosystem consists of a natural succession of plant life and accompanying wildlife. Tracts of dune land occur, in varying widths, intermittently along the Lake Michigan shoreline from northern Wisconsin, around the southern tip of the Lake, and up the Michigan shoreline to the northernmost area of the lower peninsula. Michigan dune lands are by far the largest tracts in the Basin.

Stressors

The conversion of natural terrestrial habitat to agricultural and urban environments has had a considerable impact on numerous plant and animal species in the Basin. The remaining habitat continues to be threatened by a variety of stressors, including agricultural practices, urbanization, silviculture, mining, road construction, and a variety of recreational activities. Today, land in the Great Lakes Basin is used for several purposes, all of which have impacts on terrestrial ecosystems. Exhibit B-1 depicts the percentages of agricultural, residential, forest and other land uses for each Lake's basin.[12]

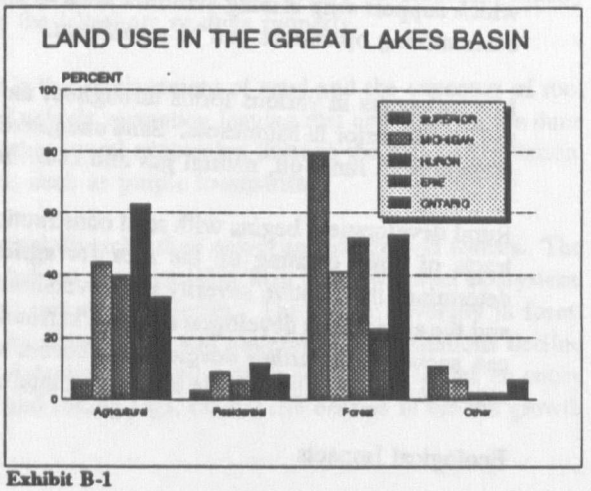

Exhibit B-1

The impacts associated with agriculture in some circumstances can be reversible, but the cessation of farming activities is not likely. Over several hundred years,

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[10] Biological significance is defined in the Physical Degradation of Water Habitats and Wetlands.

[11] One of the most apparent human health impacts from the destruction of natural terrestrial ecosystems is the increase in noise associated with the anthropogenic changes and their resultant activities. As noise pollution is not peculiar to the Great Lakes Basin, it is not discussed here. The reader is referred to the Regional comparative risk projects for more information.

[12] Environment Canada, Brock University, Northwestern University, United States Environmental Protection Agency. 1988. The Great Lakes, An Environmental Atlas and Resource Book. p. 18.

clearing woodlands, plowing under prairies, and draining of wetlands to accommodate farming practices has served to degrade all these terrestrial ecosystems. In addition, through farming activities, food and cover for wildlife is reduced, soil fertility is decreasing, and soil is more susceptible to erosion by wind or runoff. Soil is currently eroding at a rate that is exceeding the top soil creation process. This results from a variety of farming practices. For example:

- Planting patterns that do not match the natural contour of the land;
- Reducing hedge rows to accommodate larger equipment or to increase acreage;
- Plowing harvested fields;
- Plowing stream banks or roadsides for weed control;
- Planting fewer crop strains, leading to monocultural agriculture which increases the chance of diseases and requires more intensive use of pesticides and fertilizers.

The major influences on the region's forests include forestry practices (silviculture), farming, mining, recreation, and urbanization. While selective cutting and replanting activities do occur, many forested ecosystems cannot withstand the effects of silviculture due to the lack of contiguous habitat needed to sustain them. Only a small fraction of original old growth forests remain in the Basin. The majority of the forests are second-growth and are less biologically diverse than the original old growth forests.

Stresses that result from silviculture have very long term effects. Degrading practices include:

- Short rotation management and monotypic reforestation for future timber supplies;
- Clear cutting forests to harvest timber;
- Logging support activities, including construction of maintenance roads, camps and storage areas.

Mining activities can have a devastating effect on both water and terrestrial ecosystems, and the localized impacts can be seen throughout the Basin. The space needed to support mining activities is significant, especially in areas which support strip mining activities such as northeastern Minnesota, and the noise and vibration from blasting and other mining operations can be significant.

Mining occurs in various forms throughout the Basin. Iron ore mining has been extensive and still exists adjacent to Lake Superior in Minnesota. Sand and gravel pits exist throughout the Basin. Other resources mined in the Basin include peat, lime, oil, natural gas and coal. Impacts from mining activities are often irreversible.

Rural development begins with road construction which provides access to previously undisturbed or less developed tracts of land, opening up the area for agriculture, housing, business, or recreation. The siting of new roads determines the relative severity and reversibility of the habitat impacts caused by both the road construction itself and the subsequent development of the surrounding area. The new land uses that are spawned by road development can snowball as further development occurs to support them, resulting in urbanization. In addition, increases in roadside litter create hazards to many animal species.

Ecological Impacts

Impacts of the stressors described above on terrestrial ecosystems are numerous. For example:

- Loss of soil fertility;
- soil erosion or compaction;
- ground or surface water contamination from tailings;
- Loss of biodiversity;

- Reduction in species populations;
- Increase in noise pollution;
- Loss of vegetation with the capacity to convert urban pollutants such as carbon dioxide;
- Long-term or permanent loss of habitat.

The most obvious ecological impact of terrestrial ecosystem degradation is the loss of habitat which directly affects species populations. Many species in the Great Lakes Basin are witnessing population declines. Some of these species include the bald eagle, black crowned night heron, caspian tern, common tern, double-crested cormorant, Forster's tern, herring gull, mink, otter, wolf, and snapping turtle. The number of plant species that have become threatened is another sign of the physical degradation of terrestrial ecosystems.[13]

Prairies provide a good example of how ecosystems are impacted by stressors such as agriculture and development. In addition to the primary destruction that results from these stressors, the unintentional introduction of exotic species of plants and animals upset the delicate habitat structure. Opportunistic weeds are hardier than many prairie plant species and compete effectively for nutrients and soil space. Likewise, exotic animal species upset the food web by altering the predator/prey balance.

The shrinking geographic scope of prairies exacerbates declining habitat quality as the community becomes too small to buffer non-prairie species and as reproduction opportunities decrease due to reduced population size. The shrinking range of continuous prairies becomes insufficient to enable the long-term survival of species such as prairie chicken, marbled godwit, badger and bison.

Dune lands are likewise fragile and therefore face possible extinction in their natural form due to the human encroachments described above. In particular, construction and recreation are significant stressors to the dune ecosystem. These lands are often stabilized for development purposes, thereby altering the natural evolution of the terrain. Unnatural stabilization is accomplished through the introduction of exotic plant species, and by primary physical alterations including driving beams into the ground and constructing wind breakers to enable development of homes and industry. The impact is potentially reversible, but unlikely because the nearby development usually occurs specifically for the aesthetic amenities associated with the lakeshore or dune property.

A major impact from recreational stressors such as trampling is the displacement of sand and the exposure of root systems. Recently, severe impacts have resulted from off-road vehicle recreation leaving ruts and scars on the dune tracts. The unnatural destabilization of the plant cover delays the natural succession through the loss of vegetation, as well as increasing the area's vulnerability to noxious weeds such as purple loosestrife.

Remaining old growth forests in the Basin have greater biological diversity than newer second growth forests. The fragile wildlife-rich ecosystem is more severely impacted by habitat fragmentation than the new forest ecosystem. Clearing results in localized and peripheral reductions of plant and animal species. The loss of diversity in forest ecosystems causes alterations in native animal populations. As pioneer tree and undergrowth populations decline through the reduction of old growth forest, the local gene pool declines as well, which potentially leaves an entire species in a localized area more vulnerable to disease. Snags and rotting logs, crucial life bearers in the old growth ecosystem, are notably absent in young forests.

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[13] The Conservancy Foundation, The Institute for Research on Public Policy. 1990. Great Lakes Great Legacy? p. 131.

Biologically Significant Sites in the Great Lakes Basin

The Natural Heritage Inventory Program was established to identify the biologically significant[14] areas across the country in an effort to set priorities for the protection of biotic diversity by private or government organizations. In a report compiled by The Nature Conservancy of Natural Heritage Inventory data, biologically significant sites within the Great Lakes watershed are identified. The sites described in the report were selected on the basis of the presence of exemplary plant communities and/or rare and endangered species. The following table summarizes the significant sites found in the Great Lakes Basin.[15]

Biologically Significant Sites in the Great Lakes States[16]

State	No. of Sites	Type	
Wisconsin	130	Grassland:	northern sedge meadow, southern sedge meadow, bracken grassland, acid bedrock glade
		Pond:	spring pond, ephemeral pond
		Forest:	northern mesic forest, pine barrens, boreal, southern dry-mesic forest, northern dry-mesic forest
		Prairie:	wet mesic prairie
		Sand:	beach, lake dune, cobble beach
		Other:	shaded cliff, shrub carr, open cliff
Ohio	66	Forest:	Maple-ash, hemlock-white pine hardwood, beech-sugar maple, beach-oak-red maple, hemlock-white pine hardwood, mixed mesophytic, oak hickory, flood plain forest, mixed mesophytic forest
		Sand:	beach dune community, sand barren
		Prairie:	little blue stem, slough grass-bluejoint
		Grassland:	sedge grass meadow
New York	62	Forest:	spruce-northern hardwood, oak openings, beech maple-mesic forest, limestone woodland, beach sample mesic, calcareous talus slope woodland, hemlock-northern hardwood forest
		Pond:	inland salt pond, pine barrens
		Grassland:	alvar grassland
		Sand:	Great Lakes dunes
		Other:	calcareous pavement barrens, sandstone pavement barrens, pitch-heath barrens

[14] The term "biologically significant" is defined in Problem Area A.

[15] The relative sizes of these sites can indicate much about the amount of risk that they face. However, the data presented currently shows no indication of locational size.

[16] The Nature Conservancy. 1990. Report on the Significant Biological Areas of the Great Lakes Watershed. The names and locations of the sites are presented in exhibits B-2 through B-9.

Minnesota	27	Forest:	hardwoods, Great Lakes pine forest, norther hardwood conifer forest, upland white cedar forest
Michigan	140	Sand:	open dunes, Great Lakes barrens, bedrock beach, wooded dune and swale complex, cobble beach
		Forest:	Oak barrens, mesic northern forest, dry-mesic northern forest, dry northern forest, mesic southern, dry-mesic southern, boreal, southern plain
		Prairie:	wet, lake plain wet-mesic, dry sand, hillside
		Other:	Moist non-acid cliff, bedrock glade, southern wet meadow, dry non-acid cliff, northern bald
Indiana	56	Forest:	Flatwoods boreal, upland dry-mesic, flood plain wet, flood plain mesic, upland dry, sand dry, flood plain wet mesic
		Prairie:	sand wet mesic, sand dry, sand dry-mesic, dry-mesic, mesic,
		Savanna:	dry mesic, sand dry-mesic
Illinois	6	Prairie:	mesic, wet-mesic, sand
		Savanna:	dry savanna
Pennsylv.:	7	Not Available	

Welfare Impacts

There are very few significant examples of natural terrestrial ecosystems left in the Great Lakes region. Continued loss of habitat resulting from increased development, agriculture, and silviculture, results in the further degradation of terrestrial ecosystems.

The material and property damage impacts of the loss of terrestrial ecosystems is difficult to assess. Healthy terrestrial ecosystems assure biotic diversity. The protection of biotic diversity may be vital for the future of agriculture or medicine.

Uncertainties in the Analytical Approach

There is no hard data that can be used to accurately quantify the physical degradation of terrestrial ecosystems. Data provided by the Nature Conservancy only identifies the examples of natural areas that are biotically diverse, sensitive, or that hold a rare or endangered plant or animal species. No substantive data exists that could be used to calculate the risks posed to terrestrial ecosystems.

The locations of the following biologically significant sites as registered in the Heritage Data Base are shown in Exhibits B-2 through B-9.

ILLINOIS

1. Burnham Prairie
2. Calumet City Prairie
3. Dolton Avenue Prairie
4. Illinois Beach Nature Preserve
5. Illinois Dunes North
6. Powderhorn Lake and Prairie

INDIANA

1. Barker Woods Nature Preserve
2. Basin Lake
3. Beaver Dam Lake
4. Beechwood Nature Preserve
5. Bell Lake
6. Bender (Lloyd W.) Nature Preserve
7. Big Swamp
8. Binkley Bog
9. Boot Lake
10. Brunswick Center Savanna
11. Clark and Pine Dune and Swale
12. Clarke Junction Prairie
13. Cline Lake Fen
14. Croteau Till Hill Prairie
15. Douglas Woods
16. Dutch Street Bog
17. East Lake
18. Elkhart River Floodplain
19. Engle Lake Marsh
20. Fawn River Fen
21. Fish Creek Fen Nature Preserve
22. Gary Dune Forest (Lakewood)
23. Gibson Woods Nature Preserve
24. Grider's Woods Nature Preserve
25. Hildebrand Lake
26. Hoosier Prairie Nature Preserve
27. Howard Lake
28. Indiana Dunes National Lakeshore
    - IDNL - Cowles Bog
    - IDNL - Dune Acres Unit
    - IDNL - Heron Rookery Unit
    - IDNL - Miller Unit
    - IDNL - Pinhook Bog Unit
    - IDNL - Tamarack Unit
    - IDNL - Tolleston Unit
    - IDNL - West Beach Unit
29. Indiana Dunes State Park
30. Ivanhoe Dune and Swale
31. Lime Lake
32. Long Swamp Woods
33. Loon Lake
34. Lost Forty
35. Malaxis Bog
36. Marsh Lake Wetland Conservation Area
37. Merry Lea Nature Preserve / Environmental Center
38. Mongoquinong Nature Preserve
39. Moraine Nature Preserve
40. Mudd Lake
41. North Chain Lake Woods
42. Olin Lake Nature Preserve
43. Paul Thomas Memorial Bog
44. Pipewort Pond Nature Preserve
45. Plato Oak Opening
46. Pottawatomie Lake
47. Rodenbeck (Albert D.) Nature Preserve
48. Ropchan Wildlife Refuge Nature Preserve
49. Springfield Fen Nature Preserve
50. Spurgeon (Edna W.) Nature Preserve
51. Suman Fen
52. Tamarack Bog Nature Preserve
53 Tolleston Ridges Nature Preserve
54. Umbrella Sedge Bog
55. Walters Lake Wetlands
56. Wood Lake Dune Savanna

MICHIGAN

1. Agate Harbor
2. Allegan Oak Barrens
3. Arquilla Creek
4. Baie De Wasai
5. Bakertown Fen
6. Barfield Lakes
7. Bates Tower
8. Bay Park
9. Bear Creek (Kalamazoo)
10. Bear Swamp
11. Beavertown Lakes
12. Big Sable Point
13. Boardwalk
14. Brandy Creek Wetlands
15. Bridge Valley
16. Cadillac Bog
17. Captain Jenks Homestead
18. Carr Lake
19. Cathead Bay
20. Cedar Island (Schoolcraft)
21. Charles
22. Cheboygan Point

Michigan (cont.)

23. Chilson Fen
24. Clinton River Headwaters
25. Creighton Marsh
26. Crooked Lake
27. Crow River Mouth
28. Dan's Point
29. Dayton Wet Prairie
30. Detroit River
31. Devil's Washtub
32. Dukes RNA
33. Elizabeth Lake
34. Empire Bluffs
35. Escanaba River Gorge
36. Essexville Prairie
37. Estivant Pines
38. Fairchild Lake
39. Finger Prairie
40. Gogomain River
41. Good Harbor Bay Dunes
42. Grand Beach
43. Grand Sable Dunes
44. Grass Bay
45. Hagerman Swamp (Oakland)
46. Harlow Lake (Marquette)
47. Harris Cedar Swamp
48. Hartwick Pines
49. Harwood Lake
50. Haven Hill
51. High Rollway Prairie
52. Highland Cemetery
53. Hog Island
54. Horseshoe Bay
55. Horseshoe Harbor
56. Huron Mountain
57. Huron Mountains
58. Indian Bowl
59. Indian Mound Savanna
60. Inland Harbor
61. Isle Royale National Park
62. Ives Road Fen
63. Jack-Pine Swamp
64. Jenney Woods
65. Kates Lake
66. Lake Gogebic State Park
67. Lakeville Swamp
68. Laughing Whitefish Falls
69. Liberty Fen
70. Loon Lake (Gogebic)
71. Lost Lake Bog
72. Maple River Salt Marsh
73. Marsh Creek
74. Maxton Plains
75. McCormick Tract
76. McMahon Lake
77. Monette Street
78. Moss Lake (Oakland)
79. Mt. Lookout
80. Mud Lake Swamp (Oakland)
81. Mulligan Creek
82. Munuscong/Little Munuscong Rivers
83. Muskegon State Park
84. Noble Lake
85. Nordhouse Dunes
86. Northern Hardwoods
87. Northshore RNA
88. Norway Oak Barrens
89. Ogontz Lakeplain
90. Pennefield Bog
91. Pickford Point
92. Pine Hill
93. Pine Island Lake (Kalamazoo)
94. Pine Lake (Van Buren)
95. Pine River - Frith Road
96. Pine River - Gratiot Road
97. Platte Bay
98. Platte River Point
99. Pointe Aux Chenes
100. Porcupine Mountains
101. Pottawattomie Bayou
102. Presser Bog
103. Radrick Fen
104. Rattalee Lake Fen
105. Roach Point
106. Roscommon Red Pines
107. Ross Property
108. Rush Pond
109. Russ Forest
110. Sand Island
111. Sand Portage Falls
112. Saugatuck Dunes
113. Sebewaing Bay South
114. Sebewaing Railroad
115. Section 27 Bowl Prairie
116. Shakey Lakes
117. Sharkey Lake
118. Sheldon Forest
119. Shingle Bay
120. Silver Creek Hemlocks
121. Silver Lake Dunes
122. Skeel Creek Prairie
123. Sleeping Bear Dunes
124. Smith's Woods
125. Snake Island (Mackinac)
126. South Fox Island
127. South Manitou Island
128. St. Clair Woods
129. St. John's Marsh
130. Sturgeon Bay
131. Summerby Fen
132. Sylvania
133. Thompson Road Prairie
134. Thompsons Harbor
135. Union Lake
136. Walt Creek
137. Warren Woods
138. Waugoshance Point

MICHIGAN (cont.)

139. Wells State Park
140. Wildfowl Bay Prairie

MINNESOTA

1. Bogus Lake Hardwoods
2. Cascade River SP
3. Cathedral Grove
4. Cherry Portage
5. Clearwater Lake
6. Cloquet Turtle Preserve
7. Cross River Hardwoods
8. Daniels Lake
9. Fourmile Creek White Cedar
10. Gaskin Lake
11. Gooseberry Falls SP
12. Hovland Woods
13. Jay Cooke SP
14. Lake Agnes Hardwoods NHR
15. Marble Lake Lookout Tower
16. Mineral Center Maple Ridge
17. Moose Mountain SNA
18. Mt. Leveaux
19. Palisade Head
20. Pigeon Point
21. Royal River
22. Schroeder RNA
23. Split Rock Lighthouse SP
24. Spring Beauty Hardwoods SNA
25. Susie Islands
26. Tettegouche SP
27. Yellow Birch Natural Area

NEW YORK

1. Bear Swamp Sempronius
2. Beaver Brook Fen Cortlandville
3. Beaver Brook Springs
4. Bergen Swamp
5. Blueberry Patch Swamp
6. Bonaparte Swamp
7. Boreal Heritage Macrosite
8. Brandy Brook Swamp
9. Brennan Beach Fen
10. Brewers Corners Bog
11. Burnt Rock Barrens
12. Caledonia Swamp
13. Carncross Salt Pond
14. Chaumont Barrens
15. Chippewa Bay
16. Chittenango Falls
17. Clarence Escarpment
18. Colton Ponds
19. Dansville Fen
20. Dead Creek Flow
21. East Malloryville Tamarack Swamp
22. El Dorado Beach
23. Five Ponds Old-Growth
24. Fox Ridge Salt Marsh
25. Gadway Road Flatrock
26. Goat Island
27. Great Gully
28. Groton City Fen
29. Johnny Cake Road Sinkhole Wetlands
30. Junius Ponds
31. Letchworth SP Big Bend
    Letchworth SP Highbanks Entrance Site
    Letchworth SP Highbanks Recreation Area Site
    Letchworth SP Kisil Point
    Letchworth SP Kisil Point East Bank
    Letchworth SP Lower Falls
    Letchworth SP Mt Morris Road Site
32. Limerick Cedars
33. Limerick Game Farm Road Site
34. Little Gallop Island
35. Lucky Star Alvar
36. Malloryville Fen
37. Malloryville Swamp
38. Massawepie Mire Macrosite
39. McLean Fen
40. McLean Marl Meadows
41. Mendon Ponds
42. Middaugh Road Woods
43. Mud Creek Swamp
44. Mud Pond Fen
45. Nelson Swamp
46. Oatka Creek Gulf
47. Rainbow Shores Wetlands
48. Rome Sand Plains
49. Route 222 Fen
50. Rush Oak Opening
51. Sam Adams Road Woods
52. Smith Woods
53. South Hill Swamp
54. Star School Road Barrens
55. Three Mile Creek Road Barrens
56. Tonawanda Creek Millersport
57. Tonaqwanda Creek Rapids
58. Twomile Creek
59. Upper and Lower Lakes
60. White Lake Swamp
61. Wyckoff Swamp
62. Zurich Bog

OHIO

1. Barnacle Bog Wetlands
2. Bird Bog
3. Black Swamp Woods
4. Bradley Woods Reservation

OHIO (cont.)

5. Camp Calvary
6. Camp Timaberlane
7. Cedar Point National Wildlife Refuge
8. Cemetery Lane
9. Central Marblehead Quarry
10. Crane Creek State Park
11. Crystal Lake
12. Cuyahoga River Aconitum Site
13. Cuyahoga Wetlands-Fried's Bog
14. Dupont Marsh State Nature Preserve
15. East Marblehead Quarry
16. Erie Sand Barrens State Nature Preserve
17. Evans R. Beck Memorial Nature Preserve
18. Fish Creek
19. Fish Ridge
20. Flatiron Lake Bog
21. Fowler Woods Nature Preserve
22. Frame Lake Fen-Herrick Nature Preserve
23. Freedom Twp. Sand Pit
24. Girdham Road Openings
25. Goll Woods Nature Preserve
26. Gott State Nature Preserve
27. Grand River Terraces
28. Headlands Dunes State Nature Preserve
29. Irwin Prairie Nature Preserve
30. Kenestrick Woods
31. Kent Bog Addition (DNAP)
32. Killdeer Plains Wildlife Area
33. Kitty Todd Preserve
34. Lakeside Daisy Prairie
35. Little Mountain & Crile-s Knob
36. Louis W. Campbell Nature Preserve
37. Mantua Swamp
38. Marie Delarme Creek
39. Maumee State Forest
40. Monclova Woods and Dunes
41. Morgan Swamp
42. Morgan Woods
43. Mud Lake Nature Preserve
44. Oak Openings Metropolitan Park
45. Old State Line Road Dune
46. Ottokee Cemetery
47. Padanaram Swamp
48. Pennline Bog
49. Perry Nuclear Plant Woods
50. Pickerel Creek State Wildlife Area
51. Reed Road Dunes
52. Resthaven Wildlife Area
53. Rocky River Reservation
54. Russell Park
55. Sandy Point
56. Schwamberger Prairie
57. Sheldon's Marsh
58. South Beach
59. Stebbins Gulch
60. Temky Bog
61. Tontogany Prairie South
62. Triangle Lake Bog
63. Walnut Beach
64. West Marblehead Quarry
65. White Pine Bog Forest
66. Yondota Road Orchid Site

PENNSYLVANIA

1. Eight Mile Creek Gorge
2. Lake Erie Bioreserve
3. Little Elk Creek Slumps
4. Northeast Slump
5. Pennline Swamp
6. Presque Isle Macrosite
7. Wintergreen Gorge

WISCONSIN

1. Alvin Creek Headwaters
2. Argonne Esker
3. Bark Bay Slough
4. Bass Lake Fen
5. Bastile Lake
6. Bear Island Hemlocks
7. Belden Swamp
8. Berlin Fen
9. Bibon Marsh
10. Bibon Swamp
11. Big Bay Sand Spit and Bog
12. Black Lake Bog
13. Bloch Tract
14. Bose Lake Hemlock Hardwoods
15. Brooks Bluff Prairie
16. Brule River Cliffs
17. Budsin Mudflats
18. Burney Lake
19. Camp Two Creek Swamp
20. Cheemon Maskik
21. Cherry-Maple Ridge
22. Chiwaukee Prairie
23. Coleman Lake Meadows
24. Comstock Bog-Meadow
25. Crooked Lake Shrub-Carr
26. Crowell Lake
27. Dalles Creek Maskik
28. Deadman Kapo
29. Devil's Island
30. Dunbar Barrens
31. Dunn Lake Pines
32. Fox River Crane Marsh
33. French Creek Fen
34. Giant White Pine Grove
35. Glocke Lake
36. Goodman Wild Lakes
37. Grandma Lake Wetlands
38. Green Bay West Shore
39. Hemlock Lake
40. Highway 70 Virgin Maple Woods

WISCONSIN (cont.)

41. Hortonville Bog
42. Island Lake State Trust Land
43. Jackson Harbor Ridges
44. Jackson Marsh Swamp
45. Johnson Springs
46. Jones Swamp
47. Kakagon Sloughs
48. Kettle Moraine Red Oaks
49. Kewaskum Woods
50. Kohler Park Dunes
51. Lauterman Lake (South)
52. Lawrence Creek
53. Lewiston Sedge Meadow
54. Long Island - Chequamegon Point
55. Lost Creek Embayment
56. Lower Bass Lake
57. Lower Hiwanka Lake
58. Lunch Creek Wetlands
59. Manger Boreal Forest
60. Marinette County Beech Forest
61. Marshall's Point
62. Match Cedar Swamp
63. McCall Lakes
64. McDougal Springs and Cedars
65. McPhillips Mud Lake
66. Menominee Creek Muskik
67. Millhome Dry-Mesic Forest
68. Mink River Slough
69. Miscauno Cedar Swamp
70. Moquah Barrens
71. Mud Lake
72. Mud Lake - Springwater
73. Mud Lake Wildlife Area
74. Mullet Lake
75. Murphy Lake
76. Myklebust Lake
77. New Hope Pines
78. Newport State Park
79. North Twin Island
80. Oak Island
81. Oak Lake
82. Ordway Pines
83. Osamiwaeket Island
84. Otter Island Cliffs
85. Outer Island Hemlocks
86. Outer Island Sand Spit
87. Peshtigo Harbor Wildlife Area
88. Piel Creek
89. Pine Bluff
90. Pine Lake
91. Point Beach Ridges
92. Pope Lake
93. Popple Lakes
94. Port Wing Boreal Forest
95. Puchyan Prairie
96. Quartz Lake
97. Raspberry Bay
98. Raspberry Island
99. Rat Lake
100. Renak-Polak Maple-Beech Woods
101. Rhine Center Bog
102. Ridges Sanctuary
103. Riley Lake and Conifer Swamp
104. Riveredge Creek
105. Rush Lake
106. Rushes Lake Cedar Swamp
107. Sadjak Springs
108. Sand Island
109. Scout Lake
110. Seidel Lake
111. Shivering Sands Wetland Complex
112. Shoe Lake
113. Silver Lake - Shields
114. Skunk-Foster Lake
115. Snow Falls Creek
116. Spider Lake Black Ash Swamp
117. Spread Eagle Barrens
118. Springvale Wet Prairie
119. Stockton Island Tombolo
120. Summerton Bog
121. Swader Tamarack Swamp
122. Thompson Hill Muskik
123. Three Springs Creek
124. Toft Point
125. Van Zile Cedars
126. West Alaska Lake
127. Westphal Woods
128. White River Marsh
129. Whitefish Dunes
130. Wisconsin Point

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County Outline

ILLINOIS

AMC

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EXHIBIT B-3

MI
IL
OH
KY
ST. JOSEPH
ELKHART
LAGRANGE
STEUBEN
DE KALB
NOBLE
KOSCIUSKO
MARSHALL
STARKE
PORTER
LAPORTE
JASPER
NEWTON
PULASKI
FULTON
WHITLEY
ALLEN
WABASH
MIAMI
HUNTINGTON
WELLS
ADAMS
WHITE
CASS
BENTON
CARROLL
GRANT
TIPPECANOE
HOWARD
BLACKFORD
JAY
WARREN
CLINTON
TIPTON
MADISON
DELAWARE
RANDOLPH
FOUNTAIN
MONTGOMERY
BOONE
HAMILTON
HENRY
WAYNE
PARKE
VERMILLION
HENDRICKS
MARION
HANCOCK
PUTNAM
RUSH
FAYETTE
UNION
SHELBY
VIGO
MORGAN
JOHNSON
FRANKLIN
CLAY
OWEN
DECATUR
MONROE
BROWN
BARTHOLOMEW
DEARBORN
SULLIVAN
RIPLEY
GREENE
JENNINGS
JACKSON
LAWRENCE
OHIO
SWITZERLAND
KNOX
MARTIN
JEFFERSON
DAVIESS
WASHINGTON
SCOTT
ORANGE
CLARK
PIKE
DUBOIS
GIBSON
CRAWFORD
FLOYD
HARRISON
POSEY
VANDERBURGH
WARRICK
SPENCER
PERRY
0 10 20 30 40 50 Miles
0 10 20 30 40 50 60 70 80 Kilometers
Cleartype
County Outline
INDIANA
AMC
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County Outline

MICHIGAN

AMC

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0 20 40 60 80 Miles
0 20 40 60 80 100 Kilometers
Cleartype
County Outline
MINNESOTA
AMC
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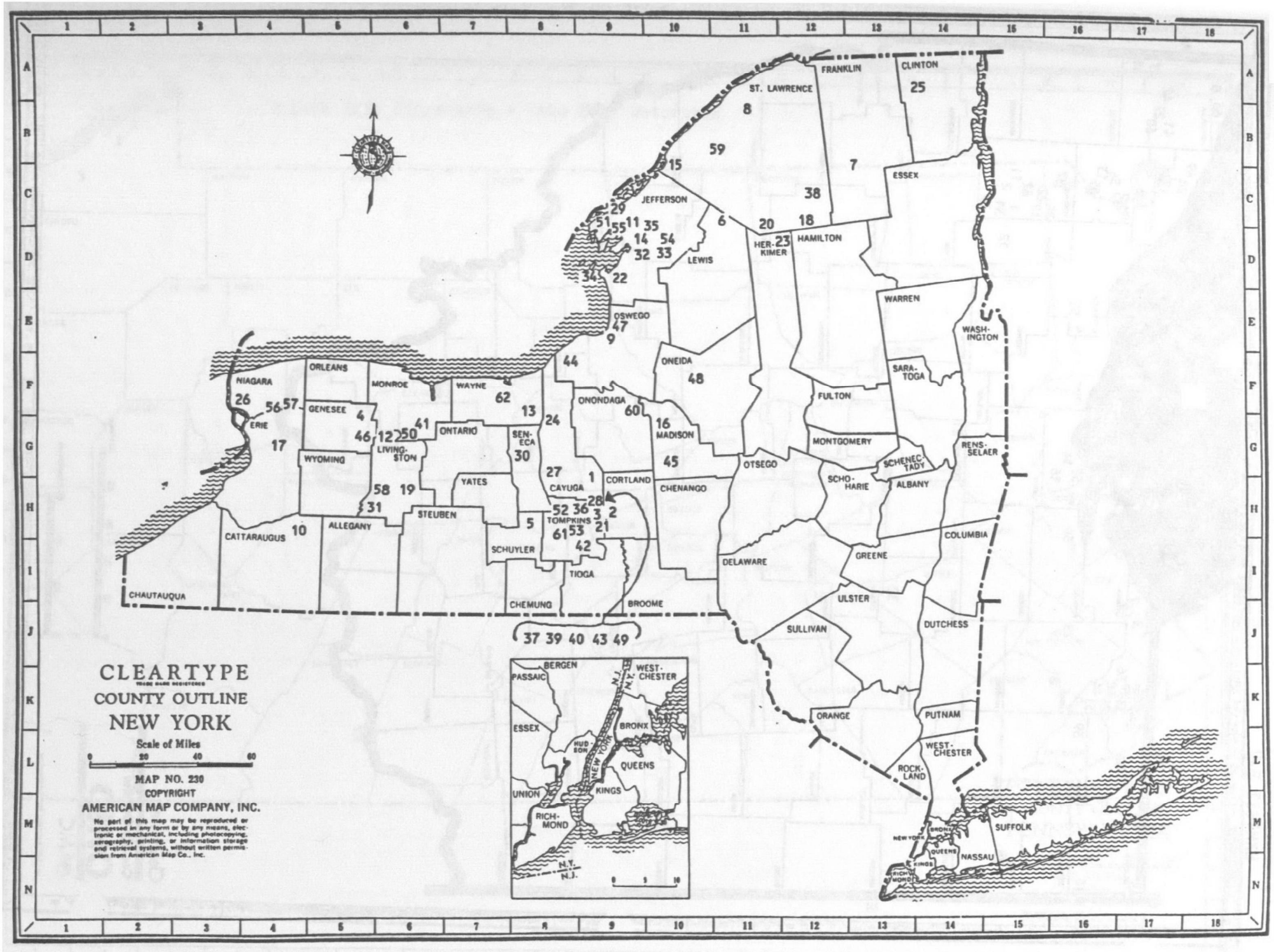
KITTSON
ROSEAU
LAKE OF THE WOODS
CANADA
MARSHALL
KOOCHICHING
BELTRAMI
ST. LOUIS
POLK
PENNINGTON
CLEAR WATER
RED LAKE
ITASCA
LAKE
COOK
NORMAN
MAHNOMEN
HUBBARD
CASS
ND
CLAY
BECKER
AITKIN
WADENA
CROW WING
CARLTON
OTTER TAIL
WILKIN
TODD
PINE
MILLE LACS
KANABEC
GRANT
DOUGLAS
MORRISON
STEVENS
POPE
STEARNS
BENTON
ISANTI
CHI-SAGO
TRAVERSE
BIG STONE
SHERBURNE
SWIFT
KANDIYOHI
ANOKA
WRIGHT
MEEKER
WASH-INGTON
CHIPPEWA
LAC QUI PARLE
HENNEPIN
RAMSEY
McLEOD
CARVER
YELLOW MEDICINE
RENVILLE
DAKOTA
SD
LINCOLN
LYON
SIBLEY
SCOTT
RED WOOD
GOODHUE
WI
NICOLLET
LE SUEUR
RICE
WABASHA
BROWN
PIPE-STONE
MURRAY
COTTON-WOOD
WATONWAN
BLUE EARTH
WASECA
STEELE
DODGE
OLMSTED
WINONA
ROCK
NOBLE
JACKSON
MARTIN
FARIBAULT
FREEBORN
MOWER
FILLMORE
HOUSTON
IA


CLEARTYPE
TRADE MARK REGISTERED
COUNTY OUTLINE
NEW YORK
Scale of Miles
0 20 40 60
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FRANKLIN
CLINTON
ESSEX
JEFFERSON
LEWIS
HERKIMER
HAMILTON
WARREN
WASHINGTON
OSWEGO
ONEIDA
SARATOGA
FULTON
NIAGARA
ORLEANS
MONROE
WAYNE
ONONDAGA
MONTGOMERY
RENSSELAER
ERIE
GENESEE
LIVINGSTON
ONTARIO
SENECA
MADISON
SCHENECTADY
SCHOHARIE
ALBANY
OTSEGO
WYOMING
YATES
CAYUGA
CORTLAND
CHENANGO
STEUBEN
TOMPKINS
COLUMBIA
GREENE
DELAWARE
CATTARAUGUS
ALLEGANY
SCHUYLER
TIOGA
ULSTER
DUTCHESS
SULLIVAN
CHAUTAUQUA
CHEMUNG
BROOME
ORANGE
PUTNAM
WESTCHESTER
ROCKLAND
SUFFOLK
NASSAU
BERGEN
PASSAIC
ESSEX
HUDSON
BRONX
QUEENS
KINGS
UNION
RICHMOND
NEW YORK
N.J.
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EXHIBIT B-6

EXHIBIT B-7

OHIO
CANADA
MI
PA
IN
WV
KY
WILLIAMS
FULTON
HENRY
DEFIANCE
PAULDING
PUTNAM
HANCOCK
WOOD
OTTAWA
SANDUSKY
SENECA
WYANDOT
CRAWFORD
ERIE
HURON
LORAIN
CUYAHOGA
LAKE
GEAUGA
ASHTABULA
TRUMBULL
PORTAGE
SUMMIT
MEDINA
ASHLAND
WAYNE
MAHONING
STARK
COLUMBIANA
VAN WERT
ALLEN
HARDIN
MARION
MORROW
KNOX
HOLMES
TUSCARAWAS
CARROLL
JEFFERSON
HARRISON
BELMONT
MONROE
NOBLE
GUERNSEY
MUSKINGUM
COSHOCTON
LICKING
DELAWARE
UNION
LOGAN
SHELBY
AUGLAIZE
MERCER
DARKE
MIAMI
CHAMPAIGN
CLARK
MADISON
FRANKLIN
PREBLE
MONTGOMERY
GREENE
FAYETTE
PICKAWAY
FAIRFIELD
PERRY
MORGAN
WASHINGTON
BUTLER
WARREN
CLINTON
ROSS
HOCKING
ATHENS
MEIGS
VINTON
HAMILTON
CLERMONT
HIGHLAND
PIKE
JACKSON
BROWN
ADAMS
SCIOTO
GALLIA
LAWRENCE
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County Outline
OHIO
AMC
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0 10 20 30 40 50 Miles
0 20 40 60 Kilometers
Map No. 233

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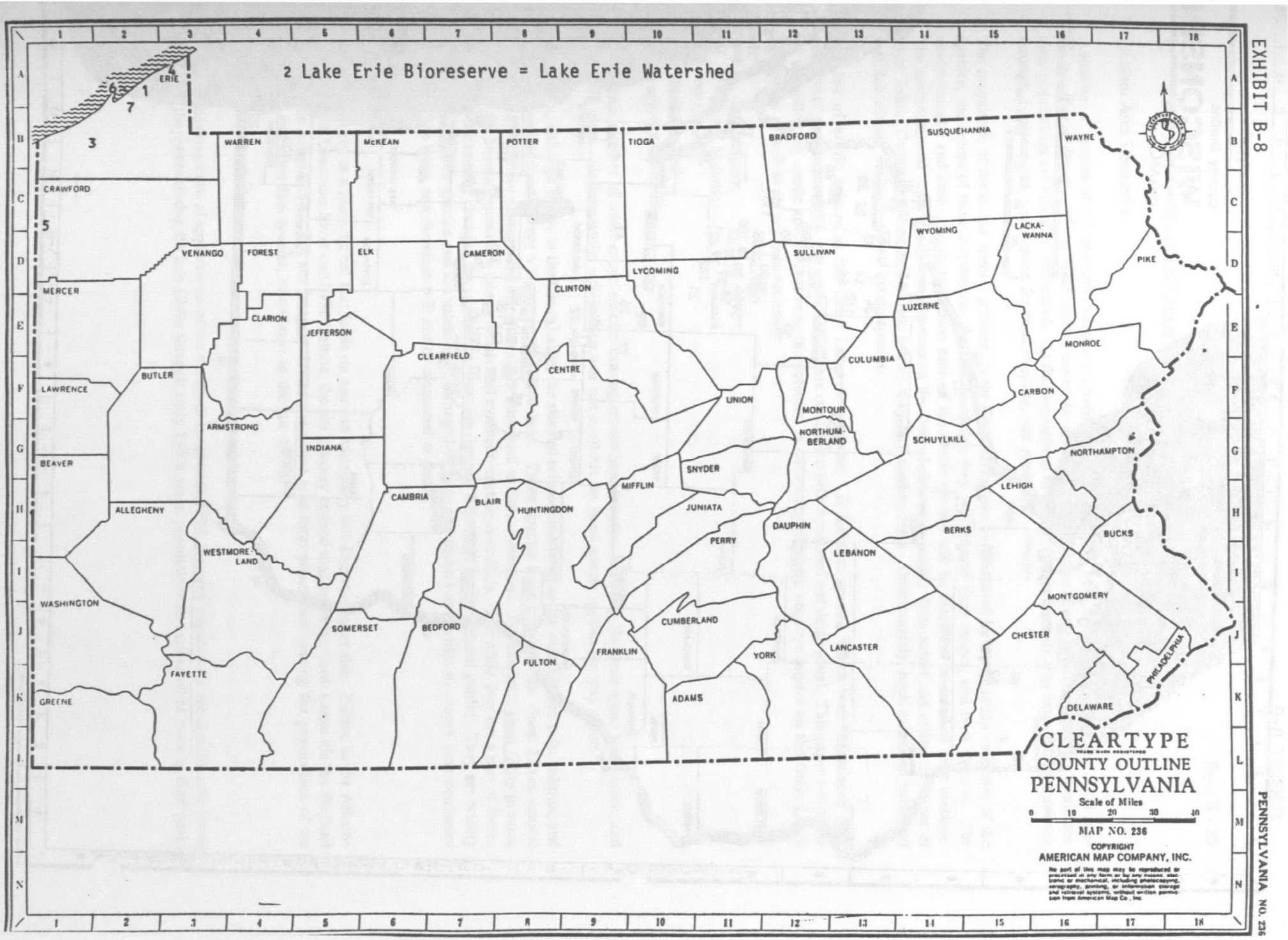

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C. EXOTIC SPECIES INTRODUCTION TO THE GREAT LAKES

Problem Area Description

A number of species of fish and invertebrates not native to the Great Lakes have been introduced to the Lakes over the last several decades. Since these species are exotic and therefore do not have any naturally occurring predators, their populations are virtually unchecked. As the populations of exotic species increase they impact native species through displacement, competition for food supplies, and predation.

The magnitude of the exotic species problem in the Great Lakes can be measured by a population estimates of the species, the extent of their distribution, the likelihood that they will expand their ranges, and their impacts. The environmental and economic impacts from each of the exotic species will be discussed in detail in later sections. The environmental costs of the exotic species in the Great Lakes stem largely from actual and estimated losses of sport fishes. Commercial and subsistence fishing may face similar costs. Unfortunately, even estimated values of lost fish are not available for all exotic species.

The list of exotic species in the Great Lakes is extensive. It includes species which were introduced both accidentally or purposefully, and species which are considered both beneficial and detrimental. This paper will focus on the following exotic species that have the potential to have a significantly negative impact on the Great Lakes ecosystem as well as its regional economy:

- Sea lamprey;
- Zebra Mussel;
- Alewife;
- Ruffe; and
- Spiny Water Flea.

There are a number of other exotic species causing researchers concern, including the three spine stickleback, and the Asian clam. Unfortunately, information was not available on these exotic species for this report.

In addition, although exotic to the Great Lakes, the stocked salmonoids, such as the chinook and coho salmon, and other non-native sport fishes, will not be discussed here. These species have impacted the Great Lakes aquatic ecosystem in a variety of ways that are often either unnoticed or little understood. For example, sport fishes provide a pathway for human exposure to heavy metals and synthetic organic chemicals. Yet, while they are a part of forces that have permanently changed the ecosystem, they are deemed beneficial by the general public. They are widely considered desirable species and are intensively managed by state and federal authorities to ensure their continued survival in the lakes and therefore will not be discussed in detail.

Sea Lamprey

The sea lamprey is a parasitic eel that feeds on and can ultimately kill desirable sport fish. Native to the Atlantic Ocean, the St. Lawrence River and Lake Ontario, the sea lamprey entered the remaining Great Lakes via the Welland Canal in the early 1930s. The sea lamprey devastated native lake trout population causing the populations of the sport fish, and other fish species, to collapse in the late 1950s.

Magnitude of the Problem

Due to widespread use of applications of the chemical lampricide TFM, lamprey populations are significantly lower now than they were during the late 1940s through early 1960s when populations in various lakes were at their peak.

One 1987 study estimates the number of adult lamprey in the most heavily populated areas of the upper Great Lakes at approximately 390,000 individuals.[17] By contrast, in 1949 lamprey populations in Lake Huron were at their peak as measured by the approximately 25,000 lamprey counted at one sampling weir. Lamprey numbers reached their peak in Lake Superior in 1961.[18]

Today, the sea lamprey population is distributed widely over the three upper Great Lakes of Superior, Michigan, and Huron and their tributaries where the lamprey spawns. The largest populations are concentrated in the northern section of Lake Huron, northern Lake Michigan, and various sections of Lake Superior. The single largest population in is the northern section of Lake Huron near the St. Marys River. The large size and swift currents of the St. Marys River have severely limited the success of lampricide applications in the river. As a result a relatively large population of lamprey survive in the river and nearby portions of Lake Huron.[19]

Ironically, improvements in water quality are believed to have allowed the sea lamprey to repopulate some lake tributaries that were effectively treated with lampricides in the past. The high costs of lampricides and the need for periodic applications in lamprey preferred tributaries will likely allow sea lamprey to at least maintain their present geographic distribution in the upper Great Lakes.

Ecological Impacts: Severity

To survive, the sea lamprey must feed on the bodily fluids of fish. Upon arriving to the Great Lakes, the lamprey found a large supply of food in a number of native fish species, particularly the lake trout. The ecological impacts of the infestation of the sea lamprey were particularly devastating during the late 1930s through the 1960s. At that time lake trout production in each of the upper Lakes fell by as much as 97 per cent over 15 years, eventually collapsing completely in Lake Huron in 1959.[20] Lamprey then turned to other native fish species such as the turbot, lake whitefish, walleye, and rainbow trout.

The ecological impact of the lamprey's rapid depletion of predator species was obvious soon afterwards. Populations of smaller baitfish, namely the cisco and the exotic alewife, were unchecked and exploded. The lamprey turned their attention to the larger of these baitfish as the populations of their preferred hosts fell. Two of the largest cisco species were hit first and were reduced to near extinction in the early 1960s.[21] The flourishing alewife population also forced serious reductions in a number of native species such as the lake herring, yellow perch, and the emerald shiner.

The application of lampricides and intensively fish stocking programs allowed lake trout populations to rebound. However, the remaining lamprey population is still impacting game fish in the lakes. In 1981 and 1985, 60 per cent of the chinook salmon sampled in the St. Marys River were wounded by lamprey with a wound rate of 130 wounds per 100 fish.[22]

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[17]Water Quality Board, International Joint Commission. 1987. "1987 Report on Great Lakes Water Quality," p. 2.3 - 65.

[18]Smith, B. R., and J. J. Tibbles. 1980. "Sea Lamprey in Lakes Huron, Michigan and Superior: history of invasion and control, 1936-78," in Canadian Journal of Fisheries and Aquatic Sciences 37: pp. 1780-1801.

[19]Water Quality Board, International Joint Commission. 1987. "1987 Report on Great Lakes Water Quality," p. 2.3 - 65.

[20]Smith, B. R., and J. J. Tibbles. 1980. "Sea Lamprey in Lakes Huron, Michigan and Superior: history of invasion and control, 1936-78," in Canadian Journal of Fisheries and Aquatic Sciences 37: pp. 1780-1801.

[21]Smith, B. R., and J. J. Tibbles. 1980. "Sea Lamprey in Lakes Huron, Michigan and Superior: history of invasion and control, 1936-78," in Canadian Journal of Fisheries and Aquatic Sciences 37: pp. 1780-1801.

[22]Water Quality Board, International Joint Commission. 1987. "1987 Report on Great Lakes Water Quality," p. 2.3 - 65.

The invasion of the sea lamprey in the Great Lakes, and more specifically, the resulting lamprey control program has caused secondary ecological impacts in the Great Lakes' ecosystem. The use of lampricides, applied in tributaries to kill larval lamprey, has killed numerous non-target species. Total numbers of non-target species killed by TFM are not known but several incidents are noted. In approximately 12 separate incidents, lampricide applications killed over:

- 75,000 white and longnose suckers;
- 12,500 northern pike;
- 6000 walleye;
- 5000 carp; and
- 2000 brown trout.[23]

Given the thousands of applications of lampricides since the lamprey control program began, these fish kills likely account for only a small percentage of species impacted by the control program. Lampricides are also known to adversely affect aquatic invertebrates, especially mayfly nymphs. Lamprey barriers have also caused non-target fish kills by trapping fish.

Ecological Impacts: Reversibility

The reversibility of the present populations of sea lamprey in the Great Lakes and their impacts on the ecosystem appears to be low. The lamprey control efforts during the past few decades have reduced sea lamprey populations in the Lakes but the rates of decrease have slowed significantly in the past few years suggesting that sea lamprey populations may be stabilizing at current levels. The lamprey population in the St. Marys River is very difficult to control given the limited effects of lampricide treatments due to the size and swift currents in the river. The rising costs of the lampricides and limited budgets will also likely result in less intensive control treatments in the future making it more difficult to reduce present lamprey populations.

Welfare Impacts: Environmental Costs

The sea lamprey caused enormous losses to the commercial and sport fish industries during the late 1940s through the early 1960s when lamprey populations were at their peak in various lakes. The sea lamprey devastated populations of many important sport fishes, especially the lake trout, during these years as well as afterwards. By 1950 the lake trout almost disappeared with populations at only 10 percent of their average during the previous decade. Lamprey also preyed heavily on lake whitefish, another important commercial fish species.

There is little information on the value of lost fish harvests due to lamprey predation. In 1985 the Great Lakes Fishery Commission (GLFC), however, estimated the annual gross economic value (consumer expenditures plus willingness to pay) of the U.S. Great Lakes fishery at $3.3 billion.[24] The GLFC further estimated the economic value of total losses in U.S. fishing opportunity without a sea lamprey control program at approximately $260 million in 1985. This estimate was made at a time when the sea lamprey population was lower than previously as a result of an extensive lamprey control program over the last few decades. The annual economic loss from lamprey predation during the years of heaviest impact on sport fisheries was likely to be much greater than the estimate.

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[23]Dahl, F. H., and R. B. McDonald. 1980. "Effects of Control of the Sea Lamprey on Migratory and Resident Fish Populations," in Canadian Journal of Fisheries and Aquatic Sciences 37: pp. 1886-1894.

[24]Great Lakes Fishery Commission. 1989. "The Report of the Evaluation of the Great Lakes Fishery Commission by the Bi-National Evaluation Team: an analysis of the economic contribution of the Great Lakes sea lamprey program," p. 6.

Welfare Impacts: Material and Property Damage

Part of the social cost of the sea lamprey introduction into the Great Lakes is the cost of controlling this parasite. The GLFC estimated that the sea lamprey control program in the U.S. cost taxpayers nearly $6.6 million in 1988.[25] Since this estimate covers only one year, it does not include the hundreds of millions of dollars likely spent in the past on such items as researching various lamprey control strategies, the expenditures for previous applications of expensive lampricides especially during the peak years of infestations, the construction and maintenance of lamprey barriers, and other lamprey control expenditures. No figures were available on the total costs of the lamprey control program to date.

Zebra Mussel

The zebra mussel is small (1-2 inches long) freshwater shellfish native to areas of the Black and Caspian seas in the southern region of the Soviet Union. Zebra mussels were apparently introduced in the Great Lakes in 1985 or 1986 when one or more transoceanic ships discharged ballast water into Lake St. Clair. Zebra mussels are extremely prolific with females capable of producing 30,000 to 40,000 eggs each year. With few predators, zebra mussels are spreading quickly and causing various environmental and economic damages in the Great Lakes.

Magnitude of the Problem

Zebra mussels, which first appeared in Lake St. Clair in 1985 or 1986, are now found in each of the Great Lakes. Exhibit C-1 shows the extent of the mussel's geographic distribution as of July, 1990. Since then, its range has continued to expand, and has now gone beyond the Great Lakes Basin. This rapid spread is due in part to their prolific reproduction rates. Females can produce between 30,000 and 40,000 eggs each year. Water temperatures in the lakes are also very conducive to the mussels reproductive cycles. Researchers believe that water temperatures allow females to produce eggs from late April to October, a few months longer than in the mussels' own native habitat.[26,27] Once eggs hatch, lake currents spread the free-swimming larvae far and wide.

The increase in concentrations of zebra mussels is as astounding as the speed with which the mollusk has spread across the Lakes. The zebra mussel, which clusters in colonies and must attach to a firm surface or die, have increased in concentrations from 50 per square meter to over 700,000 per square meter in one year in Lake Erie near Monroe, Michigan.[28] In addition to the fertile females and the relatively long reproductive season, the wide availability of plankton in the lakes, especially Lake Erie, allows the zebra mussel to thrive. Compounding the problem, the zebra mussel population is virtually unchecked by currently available natural controls such as predators. Diving ducks such as bluegills and the lesser scalp appear to feed on zebra mussels but researchers do not feel they will significantly reduce zebra mussel populations due to their migration periods and limited numbers.[29,30]

Most authorities are virtually certain that the zebra mussel will spread quickly to inland lakes and rivers across North

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[25]Great Lakes Fishery Commission. 1989. "The Report of the Evaluation of the Great Lakes Fishery Commission by the Bi-National Evaluation Team: an analysis of the economic contribution of the Great Lakes sea lamprey program," p. 14.

[26]Snyder, F. L., Ohio Sea Grant College Program. 1990. "Zebra Mussels in the Great Lakes: The invasion and its implications," p. 1.

[27]Mackie, G. L., W. N. Gibbons, R. W. Muncaster, and I. M. Gray, Environment Ontario. 1989. "The Zebra Mussel, Dreissena Polymorpha: A Synthesis of European Experiences and a Preview for North America," pp. 6-7.

[28]Green, Larry, Los Angeles Times. January 15, 1990. "Invasion of Zebra Mussels Threatens U.S. Waterways."

[29]Wisse, John, The Vindicator. December 24, 1989. "'Trash' Fish, Ducks Could Save Lake Erie."

[30]EPA Region V. 1989. "Zebra Mussels Fact Sheet," p. 1.

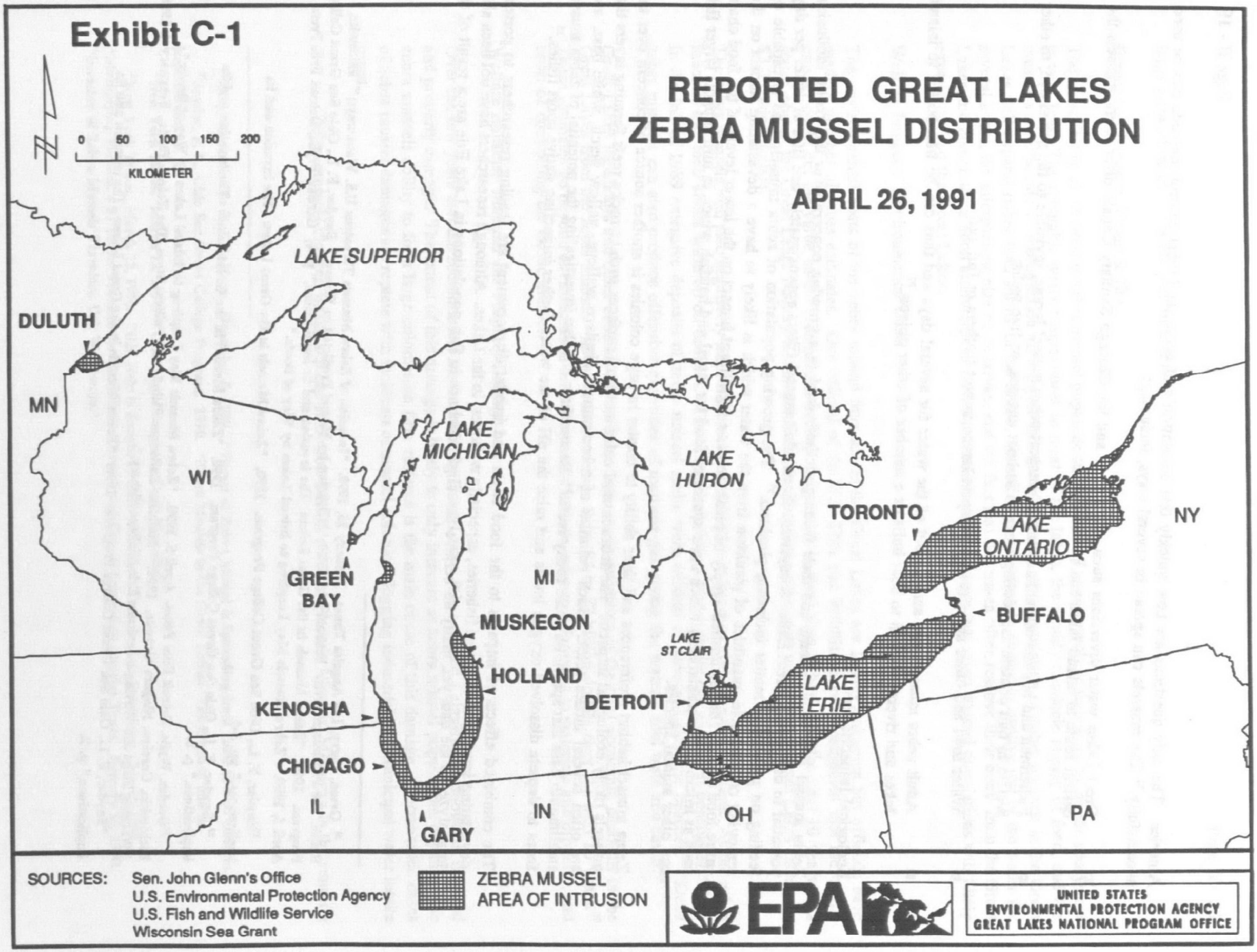
Exhibit C-1
REPORTED GREAT LAKES
ZEBRA MUSSEL DISTRIBUTION
APRIL 26, 1991
0 50 100 150 200
KILOMETER
LAKE SUPERIOR
DULUTH
MN
WI
LAKE MICHIGAN
LAKE HURON
TORONTO
LAKE ONTARIO
NY
GREEN BAY
MI
MUSKEGON
LAKE ST CLAIR
BUFFALO
HOLLAND
DETROIT
LAKE ERIE
KENOSHA
CHICAGO
IL
IN
GARY
OH
PA
SOURCES:
Sen. John Glenn's Office
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
Wisconsin Sea Grant
ZEBRA MUSSEL
AREA OF INTRUSION
EPA
UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

America. The only questions are how quickly this infestation will occur, and what control methods can be used successfully.[31] The mussels can spread in several ways, including:

- Great Lakes water diversions such as the Erie and the Chicago Sanitary Canals offer zebra mussels the easiest route to inland lakes and river systems;
- Fishermen and boaters can unknowingly transport zebra mussel larvae, invisible to the naked eye, to other waters in bait containers, cooling systems in boat engines, or live wells;
- Water fowl and other animals can transport larvae in wet feathers or fur; and
- Adult zebra mussels can survive out of the water for several days and thus can be transported to inland lakes and rivers attached to boat hulls or a number of other objects.[32]

Ecological Impacts: Severity

Zebra mussel food requirements and their feeding methods lead to a growing concern over the exotic mollusk's potential to disrupt the Great Lakes ecosystem. Each adult mussel filters approximately one liter of water per day feeding on particulate matter including plankton.[33] The growing population of zebra mussels thus is capable of removing considerable quantities of plankton from the water which is likely to have a devastating impact on the entire food chain. The diminished supply of plankton has a significant impact on the lower levels of the food chain such as microscopic crustaceans which are a source of food for larval and baitfish which in turn support larger fish and other animal species.

Zebra mussel habitat preferences and their ability to cluster in large colonies is another source of concern over the mussels likely ecological impacts. The zebra mussel colonizes hard surfaces such as rocky reefs forming layers that are often several inches thick. Such colonies of zebra mussel displace walleye, yellow perch, white bass, and smallmouth bass that spawn on these rocky reefs.[34] Researchers are also investigating the potential of zebra mussel feces to deplete dissolved oxygen levels and raise the pH of the water further impacting native sport fishes.[35]

The combined effects of impacts to the food chain and habitat displacement are leading researchers to portend devastating impacts to the sport fisheries, especially walleyes, in the Lakes. Although researchers have not been able to analyze all the data yet, many do believe that slight declines in fish populations in Lake Erie are a result of the

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[31] Green, Larry, Los Angeles Times. January 15, 1990. "Invasion of Zebra Mussels Threatens U.S. Waterways;" Haurwitz, Ralph, The Pittsburgh Press. February 26, 1990. "Clogging by Mussel Predicted in Rivers;" Snyder, F. L., Ohio Sea Grant College Program. 1990. "Zebra Mussels in the Great Lakes: The invasion and its implications," p. 4; Gerdes, Wylie, Detroit Free Press. April 5, 1990. "Zebra Mussels May Leapfrog to Inland Lakes by Way of Boats."

[32] Snyder, F. L., Ohio Sea Grant College Program. 1990. "Zebra Mussels in the Great Lakes: The invasion and its implications," pp. 3-4.

[33] Snyder, F. L., Ohio Sea Grant College Program. 1990. "Zebra Mussels in the Great Lakes: The invasion and its implications," p. 3.

[34] Gerdes, Wylie, Detroit Free Press. April 5, 1990. "Zebra Mussels May Leapfrog to Inland Lakes by Way of Boats;" McMeekin, Carolyn, Niagara Gazette. 1990. "Mollusks Endanger Fish;" and Pollick, Steve, The Toledo Blade. February 4, 1990. "Warning Flags are Waving over Lake Erie Walleye Fishery."

[35] Snyder, F. L., Ohio Sea Grant College Program. 1990. "Zebra Mussels in the Great Lakes: The invasion and its implications," p. 2.

large population of zebra mussels in that lake.[36]

Ecological Impacts: Reversibility

The reversibility of the present zebra mussel population in the Great Lakes as well as their impacts on the ecosystem is very low. The favorable water temperatures in most of the lakes, the readily available supply of food, and the mussel's prolific rate of reproduction all suggest that the distribution and population of zebra mussels in the Great Lakes will expand rather than shrink in the future. In addition, the mussels ability to survive out of the water for several hours, the microscopic size of its larvae, and the fact that fishermen often remove their boats from the Great Lakes and launch them soon afterwards in inland lakes and rivers suggests that zebra mussel populations will likely expand beyond the Great Lakes.

Welfare Impacts: Environmental Costs

The environmental costs of the zebra mussel invasion in the Great Lakes are largely unknown but officials have made a number of gross estimates. One official of the U.S. Fish and Wildlife Service estimated that the exotic mussel could cut the value of the commercial and sport fisheries in the Lakes in half over the next 10 years. As stated above, the Great Lakes Fishery Commission has estimated the economic value of the Great Lakes fishery at $3.3 billion dollars.

The zebra mussels will also negatively impact recreational activities at beaches along the Great Lakes. As the zebra mussels die, their shells wash up on beaches. The razor-sharp edges of the shells can easily cut beachgoers' feet. In the fall of 1989 extensive deposits of zebra mussel shells were evident on several Lake Erie beaches.[37] Dead zebra mussels can also produce offensive quantities of methane gas giving the water a foul taste and smell.[38]

Great Lakes legislators and other officials in the Basin have made estimates of the total economic damages in the Great Lakes from the zebra mussel. These estimates range from $4 to $7 billion dollars over the next 10 years.[39] These estimates go beyond environmental costs alone, and include estimated damages to materials and property, and costs of controlling the exotic mussel.

Welfare Impacts: Material and Property Damage

Over the few years that the zebra mussel has invaded the Great Lakes, it has caused a significant amount of material and property damage. The extent of this damage is likely to only increase as zebra mussel populations expand. The zebra mussels ability to form large colonies on firm surfaces is the main cause of this damage. Documented cases of zebra mussel damages are replete with incidents of mussel colonies clogging industrial and municipal water intake pipes.

- Zebra mussels clogged intake screens at Detroit Edison's Power Plant in Monroe, Michigan in the summer

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[36]Levy, Michael, The Buffalo News. December 5, 1989. "Threat of Zebra Mussel is Spreading from Lake Erie to Ontario."

[37]Snyder, F. L., Ohio Sea Grant College Program. 1990. "Zebra Mussels in the Great Lakes: The invasion and its implications," p. 3.

[38]New York Times. March 12, 1990. "U.S. Help is Sought to Curb Mussels."

[39]New York Times. March 12, 1990. "U.S. Help is Sought to Curb Mussels;" Croman, Jan, Soundings. March 1990. "Multiplying Mollusk a $7 Billion Problem for Great Lakes Area;" and Green, Larry, Los Angeles Times. January 15, 1990. "Invasion of Zebra Mussels Threatens U.S. Waterways."

of 1989. Remedial activities were estimated to cost $100,000.[40]

- A water intake pipe at the Monroe Water Treatment Plant in Monroe, Michigan was clogged by zebra mussel colonies on two separate occasions in January and December 1989. The plant operator estimated it would cost about $100,000 to mechanically clean the intake. The reduced flows caused a number of bars, restaurants, and manufacturing plants to close for a day or longer. One restauranteur estimated he lost $5,000 in business. A manager at one steel plant that shut down operations for one day estimated that lost production cost the plant as much as $40,000.[41]

Several hundred other manufacturing plants located on the shores of the Great Lakes have water intake pipes that are at risk of being clogged by zebra mussels.

Control of zebra mussel populations can be expensive. For example, in October, 1990, Bethlehem Steel and Inland Steel spent $41,000 and $49,000 respectively on molluscicides to control zebra mussels at their water intakes in Southern Lake Michigan. The use of molluscicides show not only a direct economic damage from zebra mussels, but a potential for further deterioration of water quality and new toxic threats from the techniques chosen to fight this exotic species. The consequences of the introduction of such chemicals should be weighed carefully against those other forms of treatment. EPA Region 5 is presently encouraging industries to control zebra mussel infestations with CO_2 and chemicals of raw toxics by.

In addition to water intake problems, zebra mussels are likely to cause significant economic losses to materials and property. Examples of such impacts include damages to:

- boats and ships where zebra mussels clog engines and attach to hulls;[42]

- buoys and floating docks that can be colonized by zebra mussels to the point of submergence;[43]

Unfortunately dollar estimates of these damages are not available.

As in the case of the sea lamprey, the total cost of the zebra mussel infestation of the Great Lakes must include expenditures on control policies. Members of Congress from the Great Lakes States proposed spending $40 million dollars to research and apply measures to control the zebra mussel.[44] At an EPA workshop on zebra mussels in September, 1990, several current and potential control measures were discussed.[45] Alternatives would have economic and environmental costs. Methods include:

- Chemical actions: oxidizing chemicals such as hydrogen peroxide, and non-oxidizing chemicals such as carbon dioxide or molluscicides;

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[40]Wozniak, Mary, Niagara Gazette. 1990. "Mussel-bound Plants Seek Safe Way to Oust Invaders."

[41]Wozniak, Mary, Niagara Gazette. 1990. "Mussel Menace has Already Hit Other Water Plant."

[42]Mackie, G. L., W. N. Gibbons, B. W. Muncaster, and I. M. Gray, Environment Ontario. 1989. "The Zebra Mussel, Dreissena Polymorpha: A Synthesis of European Experiences and a Preview for North America," p. 22; and Johnson, Ann, Erie Daily Times. March 28, 1990. "Zebra Mussels Expected to Plague Boaters."

[43]EPA Region V. 1989. "Zebra Mussels Fact Sheet," p. 3.

[44]Turner, Douglas, Buffalo News. March 8, 1990. "$40 Million Sought to Fight Zebra Mussel."

[45]The final report for this workshop is due in mid-November, 1990.

- Mechanical actions: removal by scraping or other means, and engineering/design such as deep water intakes or larger pipes;

- Physical actions: the use of screens or filters such as infiltration beds, strainers or biofilters, and other physical actions such as heat, acoustics, magnetic fields, irradiation, and others;

- Biological actions: such as the use of parasites, natural or bioengineered disease, human or wildlife predation.

Potential economic benefits from the harvesting of zebra mussels for commercial, industrial, or other uses should also be examined. Such uses of the exotic species, if found, may provide further economic incentives to control their numbers.

Alewife

The alewife is a small baitfish that was introduced into the Great Lakes in the late 1800s. Alewife populations frequently surge and then crash creating massive die-offs that foul beaches, reduce supplies of dissolved oxygen in the lakes, and lead to obnoxious odor problems.

Magnitude of the Problem

Alewives were first identified in the Great Lakes in 1873 when an established colony was found in Lake Ontario.[46] Researchers, however, are unsure whether they migrated themselves through the Erie barge canal system or were inadvertently introduced during stocking efforts of the American Shad. Regardless of their origin, alewife populations are seen as both a curse and a blessing. Massive die-offs foul beaches, but the small baitfish is also a critical source of forage for the native Lake Trout as well as stocked salmon populations in the Great Lakes.[47]

Due to the favorable habitat in the Great Lakes, alewives quickly expanded their range in some lakes as well as spread to other lakes. They circumnavigated the Niagara Falls through the Welland Canal and were first reported in Lake Erie in 1931. From there, however, their expansion to the other lakes was much more rapid.

The size of the alewife population in the Great Lakes has fluctuated widely over the years. Alewife numbers rose dramatically, especially in Lake Michigan, after the precipitous decline in native Lake Trout population in the late 1950s and early 1960s due to predation by the sea lamprey. Estimates of biomass of alewives in Lake Michigan during the late 1960s through the late 1970s showed less radical change but still fluctuated. Alewife biomass in Lake Michigan rose gradually from 46,000 metric tons in 1967 to 114,000 in 1973, then declined to 45,000 in 1977 only to rise again to 77,000 metric tons in 1978.[48]

Alewife biomass surveys in Lake Huron revealed lower total alewife biomass in that lake, although numbers still fluctuated. Alewife biomass estimates in Lake Huron increased sharply from 15,000 metric tons in the spring of 1973 to 71,000 in 1975, then dropped as sharply to 14,000 metric tons one year later. Alewife biomass estimates

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[46]Emery, Lee, U.S. Fish and Wildlife Service. 1985. "Review of Fish Species Introduced into the Great Lakes, 1819-1974," p. 4.

[47]Argyle, R. L., U.S. Fish and Wildlife Service. 1982. "Alewives and Rainbow Smelt in Lake Huron: Midwater and Bottom Aggregations and Estimates of Standing Stocks" in Transactions of the American Fisheries Society 111:, p. 267.

[48]Hatch, R. W., Haack, P. M., and Brown, Jr., E. H. "Estimation of Alewife Biomass in Lake Michigan, 1967-1978" in Transactions of the American Fisheries Society, 110:, p. 575.

climbed back to 41,000 metric tons in 1978, dropping again to 28,000 in 1980.[49]

Ecological Impacts: Severity

Increases in alewife populations over the years have severely impacted populations of several fish species native to the Great Lakes including the bloater, lake herring, emerald shiner, yellow perch, and deepwater sculpin. The populations of these species in Lake Michigan all declined when alewife populations were high.[50] The lake herring and emerald shiner were particularly affected as their numbers did not rebound when alewife populations declined.

Researchers believe that alewives impact native species in a number of ways. First, it is believed that alewives adversely affect other species through the competition for food. Zooplankton populations in Lake Michigan were subjected to severe changes between 1954 and 1966 which corresponded to periods of a tremendous abundance of alewives in the lake.[51] Other researchers have found evidence that alewives impact other fish species by preying on their larvae or eggs.[52]

Rainbow Smelt and Alewife[53]

The ecological impacts of the rainbow smelt and the alewife in the Great Lakes are similar. The rainbow smelt and the alewife serve as both prey and predator. As prey, these exotic fish to the Great Lakes, have become an important source of food for the native lake trout and the introduced coho and chinook salmon. This new food source has not, however, been a clear benefit for these sport fishes. Several researchers have found that the accumulation of mercury in the lake trout accelerates with increases in the consumption of rainbow smelt.

It is as a predator, however, that the rainbow smelt and alewife have perhaps their greatest ecological impact in the Great Lakes. Together the rainbow smelt and alewife have adversely impacted a number of native species of fish. The rainbow smelt is known to feed on lake trout eggs and larvae, but researchers feel this predation is of little consequence. It is also believed that the rainbow smelt has impacted recruitment of the bloater chub, but researchers have not confirmed this. Smelt and alewives, however, are known to have had widespread impacts on those fish species that have diets similar to theirs. After the establishment of the rainbow smelt and alewife in Lake Michigan, the abundance of a number of species that have diets similar to these exotic species' diets, such as emerald shiners, lake herring, and deepwater ciscoes, declined.

Perhaps the greatest impact of the rainbow smelt, however, is on lake herring populations. Researchers speculate that rainbow smelt predation on young lake herring adversely affects this native species more than any adverse impact this exotic species has on lake herring through competition. Interestingly, the rainbow smelt and alewife also adversely affect each other as well as native fish species. However, the full impact of this interaction is not clear.

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[49]Argyle, R. L., U.S. Fish and Wildlife Service. 1982. "Alewives and Rainbow Smelt in Lake Huron: Midwater and Bottom Aggregations and Estimates of Standing Stocks" in Transactions of the American Fisheries Society 111:, p. 267.

[50]Eck, G. W. and Wells, L. 1987. "Recent Changes in Lake Michigan's Fish Community and Their Probable Causes, with Emphasis on the Role of the Alewife" in Canadian Journal of Fisheries and Aquatic Sciences 44:, p. 53.

[51]Colby, P. J. 1971. "Alewife Dieoffs: Why do they occur?" in Limnos 4:, p. 26.

[52]Eck, G. W. and Wells, L. 1987. "Recent Changes in Lake Michigan's Fish Community and Their Probable Causes, with Emphasis on the Role of the Alewife" in Canadian Journal of Fisheries and Aquatic Sciences 44:, p. 53.

[53] Information for the rainbow smelt and alewife from Evans, David O. and Loftus, David H. 1987. "Colonization of Inland Lakes in the Great Lakes Region by Rainbow Smelt, Osmerus mordax: Their Freshwater Niche and Effects on Indigenous Fishes," Canadian Journal of Fisheries and Aquatic Sciences 44: pp. 249-266. At the time of this writing, at least one other report on the rainbow smelt and alewife, which may yield further information, has not been received.

Some researchers have reported that smelt adversely affect recruitment of the alewife while other researchers have found that the abundance of rainbow smelt have declined during periods of alewife population increases.

Ecological Impacts: Reversibility

Due to its presence in the Great Lakes for over 100 years and its importance to maintaining native Lake Trout and stocked salmon populations, the likely reversibility of the alewife population is very low.

Welfare Impacts: Environmental Costs

No information was available at the time of this report.

Welfare Impacts: Material and Property Damage

The alewife has caused a variety of material and property damages principally as a result of massive die-offs in specific lakes. Decaying alewife carcasses from large scale die-offs foul recreational beaches creating obnoxious odor problems, clog municipal and industrial water intakes, and deplete dissolved oxygen levels in the lakes.

The most infamous alewife die-off occurred in Lake Michigan in 1967. This nationally publicized incident involved an alewife die-off of astounding proportions, with one estimate placing the amount of dead alewives at several hundred millions pounds. Tremendous numbers of dead alewives washed up on beaches in Chicago. The resulting odor problems from the decaying fish forced city officials to bulldoze beaches to bury the dead fish. Large mats of floating, dead alewives covered harbors in Chicago, and drinking water intakes collapsed from the weight of alewives, requiring officials to temporarily shut down the plant for repairs. One researcher estimated the costs and economic losses to industry, municipalities, and recreational interests from this alewife die-off to be in excess of $100 million. A similar die-off in the southern end of Lake Huron and in St. Clair River resulted in an estimated 200 million dead alewives.[34]

Die-offs similar to these have occurred sporadically since the late 1890s when the alewife was introduced in the Great Lakes. Researchers believe that the die-offs occur as a result large alewife population coupled with severe stress from low water temperatures during cold winters. A predicted large alewife die-off during the winter of 1989-1990 and, although it did not materialize, fear that one may occur in the near future.[35]

Ruffe

The ruffe is a small fish related to the indigenous yellow perch. It is native to Europe and is believed to have been introduced in the Great Lakes sometime between 1986 and 1987 via the discharge of ballast water. Officials are concerned that the ruffe will impact native fish populations. The ruffe has already been found to eat whitefish eggs.

Magnitude of the Problem

The Ruffe, like the zebra mussel is very prolific with females capable of producing up to 100,000 eggs per year. As such, the Ruffe population is growing larger each year. Introduced in 1986 or 1987 from the ballast water in grain ships, the 1989 spring spawning population expanded at a dramatic rate to a total of 300,000 individuals. One

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[34]Colby, P. J. 1971. "Alewife Dieoffs: Why do they occur?" in Limnos 4:, p. 18.

[35]Per conversation with Dave Walsh, Assistant Director, U.S. Fish and Wildlife Service. August 27, 1990.

year later, the population was estimated to be at 500,000 to 700,000.[56]

The Ruffe's range in the Great Lakes, however, is currently confined to the St. Louis River estuary and Duluth harbor in western Lake Superior. Although the Ruffe has not expanded beyond this portion of Lake Superior at this time, researchers do not feel that the temperature, food supply, or other natural features of Lake Superior will act as a barrier to the spread of this exotic specie. In fact conditions found in the near shore areas of Lake Superior are consistent with the Ruffe's preferred habitats. Researchers believe the Ruffe will eventually find its way to the other lakes, but feel this expansion will not take place rapidly.[57]

U.S. Fish and Wildlife Service (USFWS) researchers in Duluth, Minnesota have been intensively studying the population of exotic Ruffe in the Great Lakes. To date, however, these researchers do not have any citable data on the ecological impacts of the Ruffe. What they do know is that (1) through 1990, the abundance of Ruffe has continued to increase dramatically although it has not expanded its range, and (2) from 1989 through 1990, every other prey-type species (e.g., the several species of shiners and minnows) has declined in abundance. As a result of the increase in the Ruffe population and the decline in other prey-type species, the Ruffe is the second most abundant prey-type species in its range.[58]

Ecological Impacts: Severity

Although there is little hard data, researchers widely believe that the Ruffe will seriously impact some native fish populations. As a member of the perch family, the Ruffe is known to be an aggressive competitor of the native yellow perch. Scientists studying exotic populations of Ruffe in Europe found that yellow perch and whitefish suffer due to competitive displacement by the more prolific Ruffe.[59]

What USFWS researchers do not yet know is how, if at all, the Ruffe affects these or other species. It is possible that efforts by the States of Wisconsin and Michigan to increase the populations of certain predator species may be responsible for the decrease in the populations of shiners and minnows rather than the Ruffe. For the last two years, these two States have undertaken a massive program to increase the density of walleye, northern pike, and muskellunge in an attempt to control the abundance of Ruffe through predation.

Since the population of Ruffe has continued to increase despite efforts to control it through changes in the management of predator species, USFWS researchers say they have started to examine the possible use of other methods of control such as the release of sterile male Ruffe and chemical controls. Researchers said it was too early to assess potential ecological impacts from these alternative control measures.

Researchers at USFWS say they do not yet know if the decrease in native prey species is a result of greater predation from the increase in the density of predator sport fishes, or due to competition from the Ruffe. More generally, researchers say they are several years away from knowing basic information regarding how the Ruffe affects other species and the ecology of the Lakes. The USFWS researchers guaranteed that no other researchers can speak of the ecological impacts of the Ruffe in the Great Lakes either. Additionally, the USFWS researchers said they would be the first to know of any impacts of the Ruffe since they are the only researchers in North America undertaking

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[56] Per conversation with Jim Selgeby, U.S. Fish and Wildlife Service. August 27, 1990.

[57] Ibid.

[58] Information per conversations with Dr. Jim Selgeby, U.S. Fish and Wildlife Service, and Dr. Tom Simon, U.S. Environmental Sciences Division, Region 5, on March 28, 1991.

[59] Per conversation with Jim Selgeby, U.S. Fish and Wildlife Service. August 27, 1990.

a comprehensive study of the Ruffe population in the Great Lakes.[60]

Spiny Water Flea[61]

The spiny water flea (*Bythotrephes Cederstroemii*) is an exotic aquatic animal, or zooplankter, that was first reported in the Great Lakes in late 1984. The spiny water flea gets its name from its very long spiny tail. The spiny water flea is very large for a zooplankter. It is about three-eighths to one-half inch long including its tail, and is easily seen with the naked eye. It is not known exactly how the spiny water flea found its way to the Great Lakes, but researchers suspect it was transported from its native territories in Europe and western Soviet Union via ballast water from ships. The spiny water flea was first found in the Great Lakes in southern Lake Huron in December, 1984. It spread quickly to the other Great Lakes, moving east to Lakes Erie and Ontario in 1985, west into Lake Michigan in the late summer of 1986, and northwest into Lake Superior in 1987.

The information on the ecological impacts of the spiny water flea in the Great Lakes comes primarily from over four years of research on the effects of this exotic species on the food web of Lake Michigan. Researchers have found that the spiny water has caused changes at different levels in the food web. In Lake Michigan, the spiny water has selectively fed on a few species of Daphnia, the dominant herbivorous plankton in the system. Populations of certain species of Daphnia have been severely reduced since the invasion of the spiny water flea.
The spiny water flea's impacts on Daphnia may also be having serious consequences for the bloater chub, an important prey species for the Lakes' salmon populations. The young-of-the-year bloater chubs also feed on Daphnia, but it appears that the spiny water flea is out-competing the bloater for this food source. The decline in the abundance of Daphnia has also caused an apparent increase in the algae that Daphnia feed on. These effects of the spiny water flea are not limited to the Great Lakes. The spiny water flea has also been found in an inland lake north of Duluth, Minnesota.[62] Officials are not certain how the spiny water flea made the trip to inland waters, but like the zebra mussel, the spiny water flea can travel inland via minnow buckets, and bilge and live wells from recreational boats.

Researchers theorize that the combined effects of the spiny water flea may ultimately affect sport fishes at the top of the food web in the Great Lakes as well as inland lakes in the Basin. Researchers have written, "All these changes [caused by the spiny water flea] may be influencing the flux of carbon and energy through the food web in such a manner that the future may require fundamental changes in fisheries management practices and a reevaluation of realistic sport fishing expectations. An assessment of the economic impact of the [spiny water flea] must wait until a clear fisheries response to the fundamental and complex food web alterations of the last few years can be ascertained."[63]

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[60] Information per conversations with Dr. Jim Selgeby, U.S. Fish and Wildlife Service, and Dr. Tom Simon, U.S. EPA Great Lakes National Program Office, on March 28, 1991.

[61] Information on the Spiny Water Flea primarily from Sandgren, Craig D. and John T. Lehman. September 1990. "Ecology of the Cladoceran Bythotrephes Cederstroemii (Spiny Water Flea or "BC") in the Laurentian Great Lakes", submitted for the Introduced Species Workshop. At the time of this writing, at least one other report which may yield further information on the Spiny Water Flea has not been received.

[62] The Seiche. Fall 1990. "B.C. Jump to Inland Lake".

[63] Sandgren and Lehman.

D. SPILLS AND OTHER ACCIDENTAL RELEASES

Problem Area Description

This section presents information about hazardous materials that are transported or spilled in the Great Lakes Basin. Data from a spills report by the Canadian Coast Guard and U.S. Coast Guard data are used in this section. Information on accidental releases to all media in the Great Lakes Basin is also presented here. For an assessment of accidental nuclear releases in the Basin, see Appendix G.

Magnitude of the Problem

Exhibits D-1 through D-4 portray the geographic distributions of spills through water, air, land and ground water by Basin county. This information was obtained from EPA's 1990 Emergency Response Network System (ERNS) for accidental chemical releases.

Spills and accidental releases of oil, or other hazardous substances to the Great Lakes and its tributaries, are a common occurrence in the Basin. For example, reports to ERNS for 1989 indicate that 298 spills to surface waters occurred in Michigan counties alone. Furthermore, research done by the International Joint Commission indicates that the spills recorded in various data bases underestimates the actual number of spill occurrences. The data also suggest that the toxic loading from spills greatly exceeds the amount of toxics released through regulated pathways.[64]

Data compiled by the United States Coast Guard regarding spills in the Great Lakes and connecting channels indicates that from January 1, 1980 through September 30, 1989 approximately 5,000 spills of oil and toxic materials occurred. Eighty percent of those spills came from land-based facilities such as storage tanks and pipelines. For example, one facility located on the shores of the Great Lakes stores over 1.5 million gallons of the canceled pesticide dinoseb. Given this relatively large quantity of a canceled pesticide stored in one area, the severity of an accidental release could be devastating to the Great Lakes ecosystem in that area.

Only twenty percent of the spills in the Coast Guard data came from vessels. However, given the amount of hazardous bulk material that is transported by vessel through the Great Lakes, there is a potential for significant spills.

Most spills on the Great Lakes occur in port areas. This tendency can be beneficial because of proximity to on-shore facilities that can help to prevent the spread of the spill. However, it could be detrimental if these spills tended to occur near drinking water intakes of the many large centers of population around the Lakes. Because port areas are population centers, spills to these areas not only threaten the local drinking water, they can be a source of airborne toxics if the chemical spilled is volatile. In fact, most of the volume of hazardous chemicals shipped on the Great Lakes

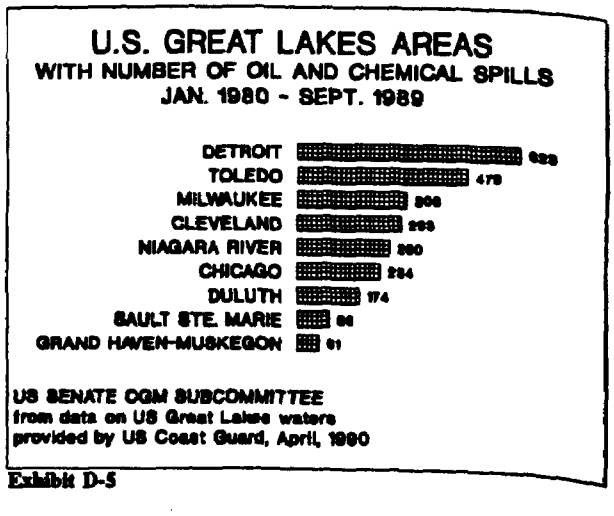


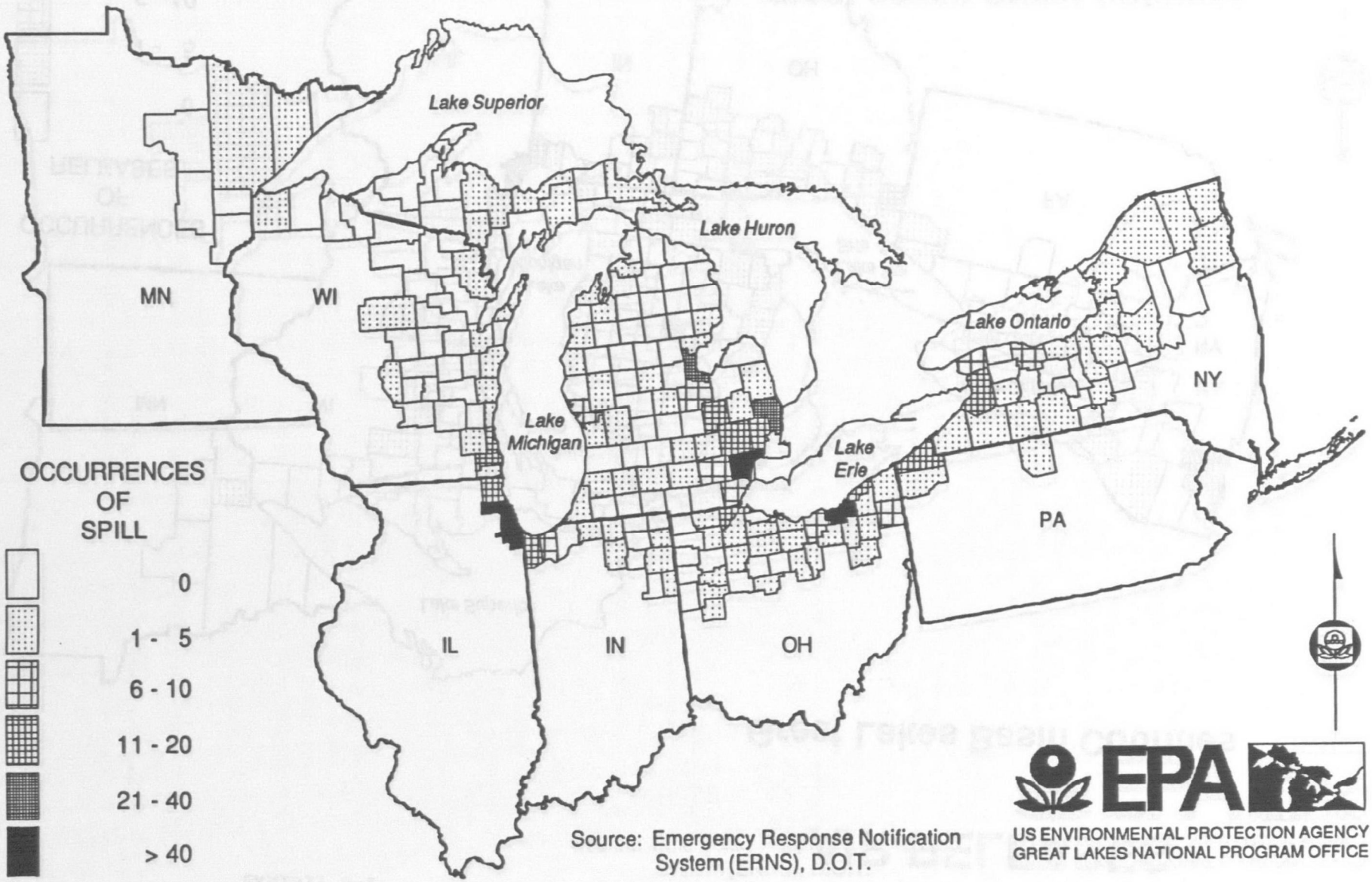
Exhibit D-5

[64] International Joint Commission. June 1988. "Spills: the Human-Machine Interface".

EXHIBIT D-1

SURFACE WATER SPILLS

Great Lakes Basin Counties



Source: Emergency Response Notification System (ERNS), D.O.T.

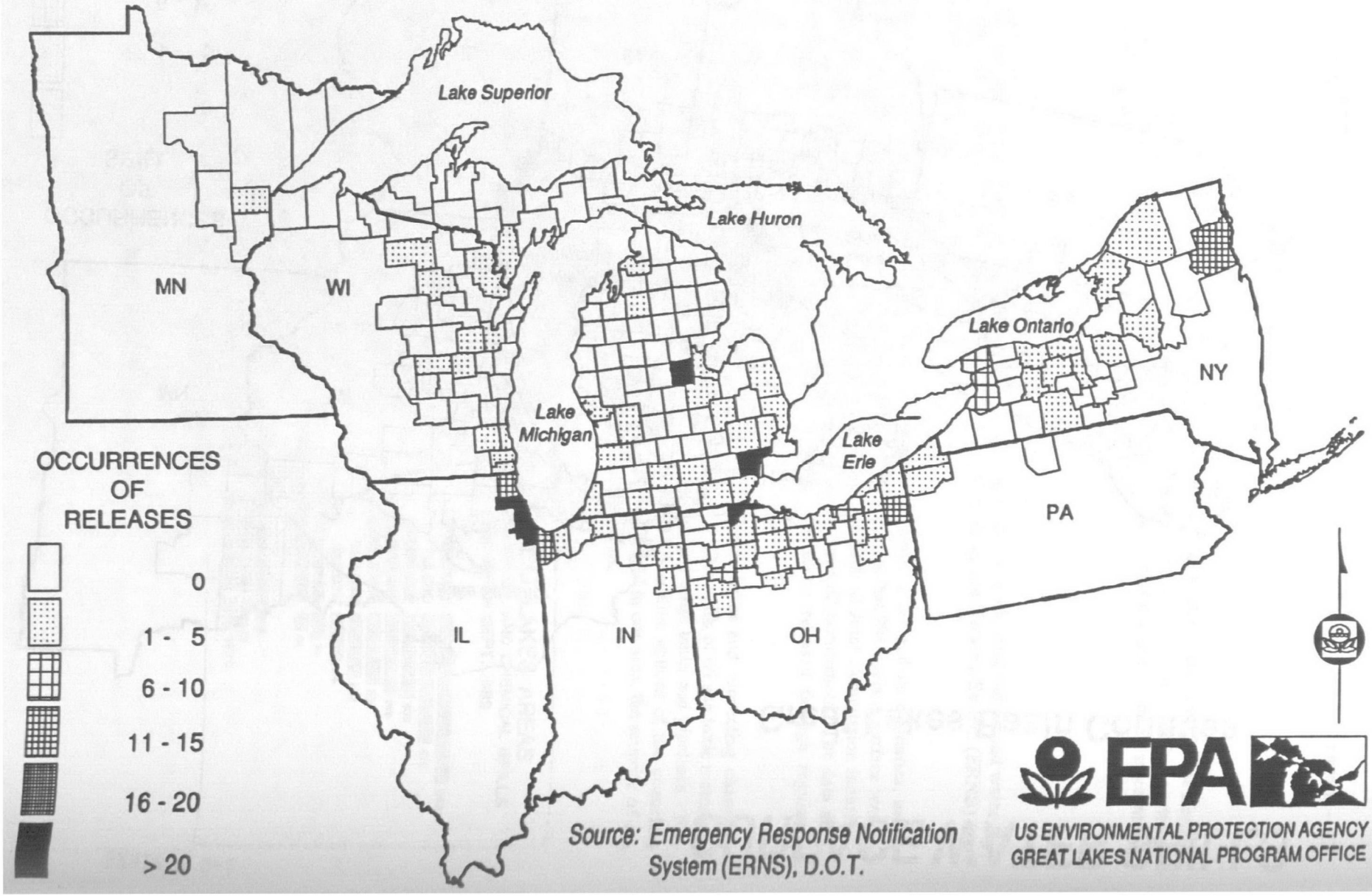
EPA

US ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

EXHIBIT D-2

AIR RELEASES

Great Lakes Basin Counties



Source: Emergency Response Notification System (ERNS), D.O.T.

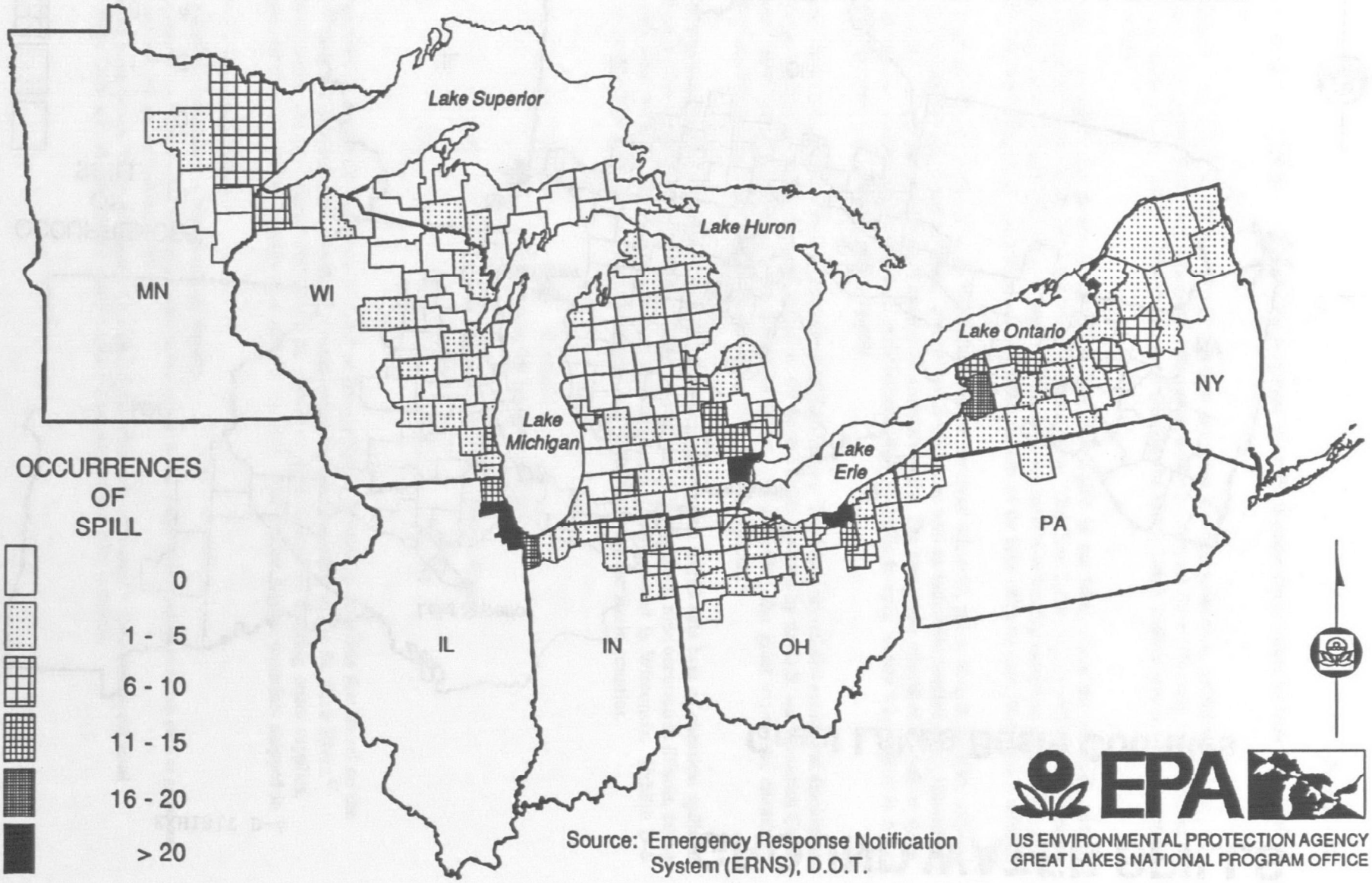
EPA

US ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

EXHIBIT D-3

LAND SPILLS

Great Lakes Basin Counties



Source: Emergency Response Notification System (ERNS), D.O.T.

EPA

US ENVIRONMENTAL PROTECTION AGENCY
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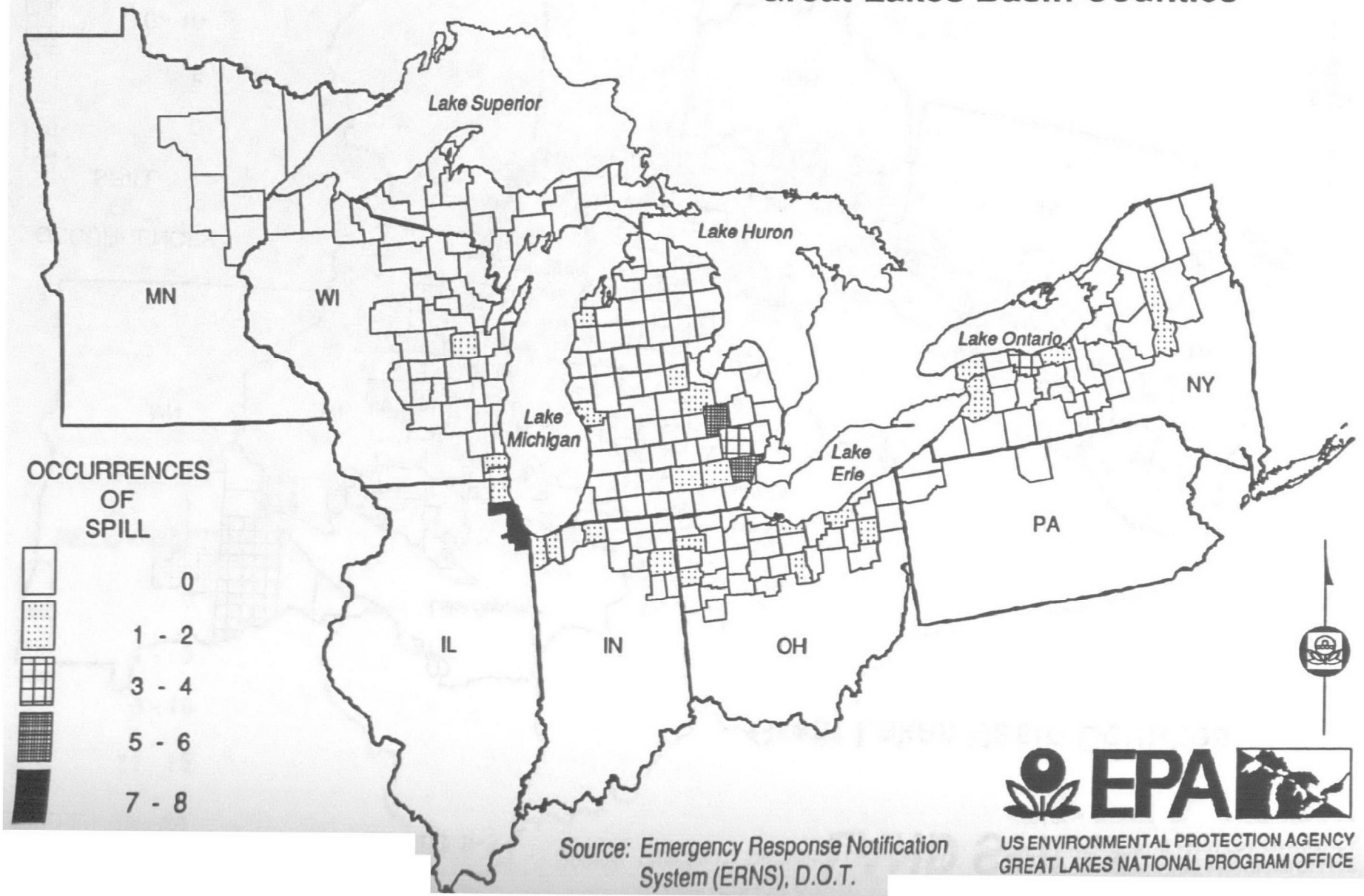
EXHIBIT D-4

GROUND WATER SPILLS

Great Lakes Basin Counties



Source: Emergency Response Notification System (ERNS), D.O.T.

EPA

US ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

are volatile to some extent. Exhibit D-5 shows the frequency of spills in some Great Lakes harbors from 1980 to 1989.

Maritime Traffic on the Lakes presents a serious potential for spills through grounding, collision, leakage, and unregulated emissions. Vessels carrying hazardous substances, however, account for a relatively small amount of the overall cargo traffic on the Lakes. Other sources of spills to the Great Lakes include sewer systems, power plants, and industry.

Severe environmental and health problems can result from such spills in the lake, where the relatively closed freshwater ecosystem is fragile and highly sensitive to contamination. The Great Lakes supply millions of residents with drinking water, and hundreds of drinking water supply intakes are located in heavily navigated areas. Fisheries and freshwater wetland bordering industrialized and trafficked regions of the lake risk exposure from spill incidents.

Some of the reported oil and chemical spills into the lake have involved oil, acid, paint, phenol, styrene, sodium hydroxide, vinyl chloride, xylene, and benzene. Near-shore facilities, as well as industries located along tributaries in the Basin contribute to the potential treat of hazardous materials spills. The composite effects of near-shore spills have a larger impact on the lake and longer-term ramifications, than do spills to open waters where there is more opportunity for dispersion and cleansing of the system.

Transformer oil was also released, presenting a source of PCB pollution. Total industry-related accidental discharges and spills may represent up over 30 percent of all spills. Of the 492 spills reported by the U.S. and Canadian Coast Guards in 1987, 85% were oil spills, and the remainder toxics. In particular, the great variety of chemicals manufactured in the Basin pose a threat of spills and make containment difficult.[65]

In 1989, 51 chemical spills that impacted ground water were reported in the ERNS data base of chemical spills in counties within the Great Lakes Basin. Twenty of these spills occurred in Michigan, nine occurred in Illinois, seven occurred in both New York and Ohio, five occurred in Indiana, and three occurred in Wisconsin. Exhibit D-6 presents the occurrences of spills in the Basin to different media, summed for the Basin counties.

Exhibit D-6
Occurrences for Medium of Spill

	Air	Land	Water	Ground Water
Basin Totals	358	741	677	51

Exhibit D-7 presents tons of bulk shipments of some of the potentially hazardous materials that travel on the Great Lakes.[66] This list represents the tonnage for materials transported annually on the St. Clair River.[67] Each of these materials can have significant effects on various ecosystems and on drinking water supplies, depending upon where and in what quantity they may be released. The exhibit depicts materials shipped in

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[65]Region 2 summary of problem area impacts on Lake Ontario.

[66]These materials are included because of their potential impact on the Lakes. Major nonhazardous materials such as grains and soybeans, coal and iron ore, are not included in this list.

[67]The Canadian Coast Guard, "Counter Measures for Marine Spills of Hazardous Materials." Total commercial vessel movements on the St. Clair, not including car and railcar ferries, are annually between 4,500 and 5,000.

quantities of greater than 1000 tons per year. Other hazardous materials shipped on the St. Clair River, but under 1000 tons per year, include: Acetate Monomer, Ammonium Sulfate, Calcium, Calcium Fluoride, Calcium Sulfonate, Carbon Tetrachloride, Caustic Potash, Chloroform, Dichloromethane, Dowfax, Dowtherm, Dowvanol EPH, Ethylene, Ethylhexanol, Formic Acid, Genklene A, Hexane, Isodecanol, Methacrylate Monomer, Methyl Methacrylate, MMM (HQ 60), MMM (PMP 50), Monopropylene Glycol, Multanol-7249, Nonanol, Palm Oleine, Perchloroethylene, Perklone A, Propionic Acid, Triklone NFS, Vinyl Acetate, and Zinc Bromide.

Exhibit D-7

Hazardous Material Movement on the Great Lakes: St. Clair River

Material	Tons/Yr. (thousands)	Number of Vessels
Benzene	25-40	4-6
Brine	30-40	4-5
BTX Mix	20-30	4-6
C9-200	0-5	1-2
Calcium Chloride	60-80	8-12
Caustic Soda	150-200	20-25
Distillate	30-40	6-8
Ethyl Benzene	5-10	2-3
Gasoline	500-700	80-110
Isopropyl Alcohol	30-40	6-8
Jet Fuel	150-200	30-40
Light Oil		
10% Benzene	25-35	7-9
Mixed Xylene	10-20	2-4
Naphtha	15-25	3-6
Nitrogenous Chemical Fertilizers	30-40	4-5
Nonene	5-10	2-3
Ortho Xylene	10-20	2-4
Pentane	10-20	2-4
Phosphate Rock	20-30	2-3
Potash	900-1100	50-60
Propylene Tetramer	5-10	2-3
Rock Salt	700-900	40-50
Shell Sol 16	5-10	2-3
Shell Sol 2	0-5	1-2
Shell Sol 7	5-10	2-3
Styrene Monomer	80-100	8-14
Tolulene	70-90	10-13
Tolulene-Xylene Mix	20-30	4-6
Urea	50-75	5-7
Xylene	80-100	40-60
Other Chemicals	80-100	40-60
Totals	3120-4115	360-497

The Canadian Report determined the annual probability of a spill of hazardous material per vessel shipment by assessing the number of vessels carrying hazardous cargo in the Great Lakes for the years 1985 and 1986, the frequency with which these vessels are involved in "incidents" that can breach containment, and the relative ability of different vessel types to inhibit cargo releases. Based on these factors, the report determined the relative annual probability in each of eleven areas in the Canadian Great Lakes. The aggregate probability that any one vessel shipment in the Canadian Great Lakes will result in a hazardous material spill is slightly more than 1 out of 10,000. If one assumes that similar characteristics apply to U.S. shipping on the Great Lakes, then this spill probability may be applied to all Great Lakes shipping. The probabilities are:

LOCATION	PROBABILITY	EST. MOVEMENTS PER YEAR	FREQUENCY PER YEAR
Thunder Bay	8/100,000	2500	0.2
N. Shore Lake Superior	47/100,000	90	<0.1
St. Marys River	3/100,000	3750	0.1
L. Huron North Channel	13/100,000	700	0.1
L. Huron East Coast	163/100,000	250	0.4
St. Clair River	1/10,000	5000	0.5
Detroit River	4/100,000	7500	0.3
N. Shore Lake Erie	5/100,000	5000	0.3
Welland Canal	44/100,000	4500	2.0
N. Shore L. Ontario	17/100,000	3250	0.6
St. Lawrence - L. Ontario	42/100,000	3500	1.5

Ecological Impacts

Many of the hazardous chemicals that are shipped on the Great Lakes are light and volatile, a combination posing special threats to the Great Lakes ecosystem. These chemicals include carbon tetrachloride, toluene, and gasoline. Once spilled, these toxic chemicals are likely to spread rapidly because of fast lake currents and changing winds. While many of these chemicals evaporate quickly thereby lessening impact to the water column, they may also be highly combustible. Furthermore, hazardous chemical spills which occur during the winter months may slide underneath shore ice and make remediation more difficult. Because these chemicals may tend to spread more rapidly than oil and are, therefore, more difficult to contain, cleanup costs are often higher for hazardous chemicals as compared to oil cleanups.

Nonetheless, most reported releases in the Great Lakes have involved oil. For example, 218 verified pollution incidents in the Great Lakes were reported to the U.S. Coast Guard in 1989, and all but nine of those incidents involved releases of oil. Although oil spills have occurred on the Lakes, very little is known about the cumulative ecological impacts of these spills. Even less is understood about the consequences of chemicals or oil that enter the aquatic environment in smaller amounts from ship sources other than tanker accidents. It is very likely that more oil and chemicals enter the Lakes from non-spill shipping incidents than from actual spill events.

According to an official with the U.S. National Oceanic and Atmospheric Administration[68], the greatest potential for a disastrous spill, is along the connecting channels. The heavy flow of vessel traffic and extremely fast currents in these channels (e.g., the St. Lawrence River, St. Clair-Detroit river system, and St. Mary's River) will further complicate any cleanup efforts in these areas.

Most information on potential ecological impacts in the Great Lakes and connecting channels is derived from observations of past spill incidents. One of the best documented of these incidents occurred in 1976 in the St. Lawrence River. During the evening of June 23, the Tank Barge NEPCO spilled an estimated 1,167,000 liters of oil into the St. Lawrence River after grounding on Wellesley Island in the American Narrows Region.[69]

Following the spill a two-year study of environmental impacts in the River and Lake Ontario was conducted under the sponsorship of the U.S. Environmental Protection Agency. The immediate impact of the spill was found to be extensive on fish and wildlife, with some species such as the great blue heron becoming endangered and many other species becoming threatened. Although the spill occurred after the reproductive season for most species, the collection of the spill in bays and marshes impeded several species' ability to raise their young. In addition, human activities associated with the cleanup process also disturbed habitat in the marshes and bays. Overall, however, the high flow rate of the lake and river at the time of the spill may have increased flushing of the oil and mitigated some of the potential adverse impacts in the bay and marsh habitats.[70]

Long-term effects on resident species was difficult to quantify due to a lack of baseline data. Nonetheless, the available data did suggest that losses went beyond the initial direct mortality of individuals, and that reproduction and survival was reduced for some species. For example, the number of golden and spottail shiners remained low two years after the spill, while the yellow perch population increased. This may indicate a higher degree of tolerance to the oil for the perch. The number of fish species remained the same in the study area, with the pumpkin seed being the dominant species.

Waterfowl populations may also have been affected, with a decline in the success of breeding pairs to produce broods in the heavily oiled areas. Pairs outside the impacted areas experienced an increase in breeding success, although this pattern may also have been influenced by high water levels during the study period. Finally, the study found no relationship between the abundance of oil and populations of muskrats, songbirds, or reptiles.

Overall, the study concluded as follows:

> It is not known how long the oil residuals will remain in the marshes and influence fish and wildlife populations. An oil spill catastrophe compares in its ecological effects with those of

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[68] Reported in the "Great Lakes Reporter," January/February 1991, Vol. 8, Number 1. Center for the Great Lakes, Chicago.

[69] U.S. EPA. 1979. "Damage Assessment Studies following the NEPCO 140 Oil Spill on the St. Lawrence River. EPA-600/7-79-256.

[70] Ibid, p. 8.

> natural catastrophes such as fire and flood. In each, the losses are great and the recovery is slow. However, fish and wildlife can overcome these adversities. The question becomes one of evaluating the loss of a resource to the using public and the local economy for a period of one to several years.[71]

As apparent, the environmental, social and economic consequences of spills to a relatively enclosed fresh water body can be devastating. Oil or chemical spills can destroy the microscopic organisms that anchor the food chain, causing extensive damage to aquatic ecosystems. Spills can seriously reduce fish stocks, either directly or by damaging spawning areas. Waterfowl are frequent casualties of spills, and are especially vulnerable to direct contamination as well as to habitat/food source losses. In some cases on the Great Lakes entire populations of a species could be put at risk by either the spill itself, or the subsequent cleanup operation. Spills affecting wetlands and ecologically sensitive areas can have severe long-term impacts. Tourism, and therefore local economies, is known to be severely impacted by contaminated shorelines and drinking water supplies or by reduced fish and waterfowl stocks. Major spills can therefore jeopardize the environmental health of all members of the ecological community, in addition to threatening the health of all human residents in the Basin.

Preparedness

The need for well-planned emergency response preparedness in the Great Lakes has emerged as an area of concern following the Exxon Valdez accident and other recent releases to U.S. coastal waters. In 1989, a special review board convened by the Canadian federal Cabinet, concluded that "the capability to respond effectively to a spill of any significant magnitude does not presently exist anywhere in Canada."[72] In addition, the Great Lakes Water Quality Board of the International Joint Commission concluded that unplanned and illicit releases from vessels and from onshore and offshore facilities constitute a significant source of contamination to the Great Lakes. Furthermore, the Water Quality Board encouraged the thorough training of personnel who operate complex spill cleanup machinery.[73]

Despite these concerns, the United States has several mechanisms in place to respond to releases in the Great Lakes Basin. On June 24, 1974, a joint U.S./Canada Marine Pollution Contingency plan was adopted. This agreement resulted in regular updates of the plan to ensure that a coordinated and integrated response to spills in the Great Lakes would involve U.S. Federal, Canadian, State, and local agencies.

Continued preparedness of U.S. agencies is led by the U.S. Coast Guard, which has developed contingency plans for addressing spills within the jurisdictions of each of its Great Lakes Marine Safety Offices. These contingency plans inventory the facilities or other sources from which spills can occur, specify the names and numbers of available cleanup contractors, and identify the locations of equipment needed to contain and cleanup accidental releases. The ability to implement these contingency plans is further tested through joint spill response exercises conducted in cooperation with the Canadian government. Although the Coast Guard acknowledges that impacts will occur as a result of future releases, they believe that they are adequately prepared to respond to spills and thereby lessen the potential environmental damage.[74]

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[71] Ibid, p.9.

[72] Ibid.

[73] Water Quality Board, International Joint Commission. 1989. "1989 Report on Great Lakes Water Quality," pp. 39-41.

[74] Personal communication, Commander P. Chubb, U.S. Coast Guard.

In addition to the above activities, the United States is continuing to develop new spill response capabilities. For example, a spill response law was passed in August, 1990. Among other things, the law will phase in mandatory double-hull requirements by the year 2015; establish special pilotage requirements for operation in U.S. waters; and provide the Great Lakes region with Federal emergency response centers during the next few years. The Canadian government is examining similar plans. State and local agencies and private organizations are also working to increase response capabilities.

Prevention activities are also being initiated. The Council of Great Lakes Governors is studying several preventive strategies. Additionally, the Coast Guard and EPA are increasing inspection activities, especially at industrial sites in the Basin, in an effort to reduce the number of spills and accidental releases. Testimony before a U.S. Senate subcommittee in 1990 indicated that as inspections increase, spills decrease.[75]

[75]Ibid.

E. GLOBAL CLIMATE CHANGE

Problem Area Definition

Gases in the atmosphere allow sunlight to pass through the air and heat the Earth's surface. The Earth's surface absorbs the sunlight and emits thermal radiation back to the atmosphere. Several gases in the atmosphere, often referred to as greenhouse gases, absorb some of the outgoing thermal radiation and heat the atmosphere. The atmosphere emits thermal radiation, both upward to outerspace and downward to the Earth's surface, further warming the surface. This is known as the "greenhouse effect."

Since the beginning of the Industrial Revolution, human activities have led to increased concentrations of greenhouse gases in the atmosphere. Scientists have concluded that the increase in greenhouse gases will eventually change global climate. In 1979, the National Academy of Sciences estimated that doubling carbon dioxide concentrations over preindustrial levels would lead to an increase of 1.5 to 4.5 degrees Celsius (2 to 8 degrees Fahrenheit) in global air temperatures. In 1985, the World Meteorological Organization, the United Nations Environment Programme, and the International Council of Scientific Unions reaffirmed these estimates.

Magnitude of the Problem

While the global climate is continuously changing as a result of natural processes, current greenhouse warming is different from past climate changes. Not only will temperatures be higher than they have been in the last 125,000 years, but the rate of temperature change will be unprecedented. Past climate changes of comparable magnitude have generally occurred over tens of thousands of years. The change in temperature resulting from the greenhouse effect, however, is estimated to take less than a century.

Carbon dioxide, the most abundant greenhouse gas, is responsible for approximately half of the total anthropogenically caused greenhouse effect. Since the industrial revolution, the concentration of carbon dioxide in the atmosphere has increased 25 percent and continues to increase at a rate of .4 percent each year. Fossil-fuel combustion and deforestation are the primary sources of this increase in atmospheric carbon dioxide.

Methane in the atmosphere has more than doubled in the past 300 years and is currently responsible for about 18 percent of anthropogenically caused greenhouse effect. Currently, total methane emissions are increasing at a rate of 1 percent per year. Agricultural sources, particularly rice cultivation and livestock, seem to be the most significant contributors to recent increases in methane concentrations. Other important sources of methane emissions include landfills, coal seams, melting permafrost, natural gas exploration and pipeline leakage, and biomass burning associated with deforestation.

Chlorofluorocarbons (CFCs) currently account for about 14 percent of the anthropogenically caused greenhouse effect. CFCs are used in refrigerants, aerosol propellants, foam-blowing agents, and solvents. In the "Montreal Protocol" of 1987, international cooperation resulted in commitments by many nations to phase out their use of CFCs. While efforts like these will probably result in a reduction of CFCs in the future, the total impact of CFCs on the greenhouse effect will most likely increase for some time because of the long lifetime of these gases.

Nitrous oxide has increased in concentration by 5 to 10 percent in the past 200 years and is currently increasing at a rate of 0.25 percent per year. The cause of this increase is uncertain, but nitrogen-based fertilizers, land clearing, biomass burning, and fossil fuel combustion are all contributors. Oceans are a significant natural source

of nitrous oxide. Including both natural and anthropogenic sources, nitrous oxide contributes about 6 percent to the enhanced greenhouse effect.

The contribution of ozone to global warming was not estimated. However, it should be noted that both ozone increases in the troposphere and lower stratosphere and ozone decreases in the upper stratosphere tend to warm the Earth's surface.

It should also be noted that water vapor is an important natural greenhouse gas. When the climate warms, more water will evaporate into the atmosphere from the warmed surface and thus enhance the greenhouse effect. This, in turn, will result in the production of still more water vapor through evaporation.

Human Health Risk

Human illness and mortality are linked to weather patterns. A variety of human illnesses show sensitivity to changes in temperature or humidity which accompany changes in season. Stroke and heart attacks, for example, increase with very cold or very warm weather and allergic disease such as asthma and hay fever increase in spring and summer when pollens are released. Mortality rates, particularly for the elderly and very ill, are influenced by the frequency and severity of extreme temperatures.

Indirectly, the incidence or severity of respiratory disease such as emphysema and asthma are likely to increase due to increases in air pollution which are frequently associated with climate change. Increases in ozone concentrations, in the lower atmosphere in particular, are associated with increasing temperature. Higher temperatures will speed reaction rates among chemicals in the atmosphere, causing higher concentrations of ozone. Also, longer summers will result in longer ozone seasons and thus a greater potential for ozone problems.

Ecological Risk Assessment

Toxicity Assessment

If current trends continue, the rate of climate change could be much quicker than rates of natural migration and adaptation. Climate zones may shift hundreds of miles northward, and animals and especially plants, may have difficulty migrating northward. The presence of urban areas, agricultural lands, and roads would restrict habitats and block migratory pathways. Inhabited ranges and populations of many species are likely to decrease, and in many cases species may become extinct. The effects could last for centuries and would be virtually irreversible.

Climate change may significantly alter forest composition and reduce the land area of healthy forests. Higher temperatures may lead to drier soils in many parts of the United States. Consequently, trees that need wetter soils may die. Studies of the potential effects of climate change on forests predict northward shifts in ranges and significant changes in composition, although specific results vary depending on sites and scenarios used.

Higher temperatures may lead to more aquatic growth, such as algal blooms, and decreased mixing of lakes. This would deplete oxygen levels in shallow areas of the Great Lakes and make them less habitable for fish. Fish in small lakes and streams may be unable to escape temperatures beyond their tolerances, or their habitats may simply disappear.

In many regions of the Basin, climate change alone could reduce dryland yields of corn, wheat, and soybeans with site-to-site losses ranging from negligible amounts to 80 percent. These decreases would be primarily the

result of higher temperatures, which would shorten a crop's life cycle. Even under the more extreme climate change scenarios, the production capacity of U.S. agriculture was estimated to meet domestic needs. However, a decline in crop production of this magnitude would reduce exports, which could significantly impact food-importing nations.

Higher temperatures will speed reaction rates among chemicals in the atmosphere, causing higher concentrations of ozone in many urban areas. In addition, the length of the summer season would be increased, which implies an increase in the ozone season. Although the impact of higher temperatures on acid rain have not been analyzed, it is likely that sulfur and nitrogen would oxidize more rapidly under higher temperatures.

Exposure Assessment

Due to the nature of global warming, the entire Basin may be affected by climate change, with the agricultural areas in the southern portion of the Basin experiencing crop yield declines and the urban areas experiencing increased ozone production.

Ecological Risk Characterization

In "The Potential Effects of Global Climate Change on the United States," the effects of global warming on various regions of the country were studied. In the Basin, impacts on three ecosystems were studied: lakes and aquatic ecosystems, forests and agricultural areas. All scenarios show dramatic increases in temperature for the Basin. The combination of significant increases in temperature and relatively small increases in precipitation make the Geophysical Fluid Dynamics Laboratory model the most severe scenario of the three.

Lakes and Aquatic Ecosystems

Global climate change could affect the Great Lakes by lowering lake levels, reducing ice cover, and degrading water quality in rivers and shallow areas of the lakes. It is estimated that higher temperatures may cause lake levels to fall by 0.5 to 2.5 meters, a decrease within the normal range of long-term fluctuations. Even if precipitation increases, lake levels would continue to fall because higher temperatures would reduce the snowpack and accelerate evaporation. It should be noted that estimates of lake level drop are sensitive to assumptions about evaporation and that under certain limited conditions, lake levels could rise.

Warmer winters are expected to reduce ice cover on the Great Lakes, with ice formation generally limited to near shore and shallow areas. In addition, the duration of ice cover on the lakes would be reduced by 1 to 3 months. While less ice could extend the Basin's shipping season, this reduction in ice cover could have negative impacts because the ice protects some aquatic life, such as whitefish, and protects shorelines against the erosive impact of high-energy waves.

Higher temperatures may lead to more aquatic growth, such as algal blooms, and increase stratification. The increased turnover time of lake waters could disrupt mixing of oxygen and nutrients, possibly affecting the abundance of life in the lower and upper layers of the lakes. In addition, fish in small lakes and streams may be unable to escape temperatures beyond their tolerances, or their habitats may simply disappear. Shifts in community structures toward warm water fisheries would occur and be accompanied by a decrease in diversity.

Forests

The composition and abundance of forests could change significantly. Higher temperatures and lower soil moisture could reduce forest biomass in dry sites in central Michigan by about 80 to 100 percent. These mixed hardwood and oak forest could become oak savannas or grasslands. In northern areas like Minnesota, boreal and cedar bog forests could become treeless bogs and mixed northern hardwoods. It is anticipated that productivity may decrease on dry sites and bogland sites, but may increase on some well-drained wet sites. Softwood species may be eliminated and replaced by hardwoods, such as oak and maple. It is uncertain whether forests in the southern part of the Basin will die back leaving grasslands or whether new species will be able to migrate. Such forest could also be transplanted in these areas. In addition, the rate of forest migration, where it is still possible, is likely to be slower than the climate change. Many tracts of forest are cut off by geography or by human development. Consequently, the total range of many species would be reduced.

Agriculture

Studies indicate that temperature and precipitation changes could reduce crop yields throughout the Basin, with the exception of the northernmost latitudes where yields could increase depending on rainfall availability. The reduction in yields in the southern portion of the Basin would primarily result from the shortened growing season caused by extreme summer heat. Production in the north would increase largely due to a longer frost-free season which would result in increased yields.

Corn yields throughout most of the Basin could decrease from 3 to 60 percent depending on climate and water regime (dryland or irrigated). It should be noted that yields in areas near Duluth, for example, may increase as much as 49 to 86 percent. While current corn yields are lower in this northern area than in more southern sites, increases in yield of this magnitude could result in a dryland yield equal to other sites and an irrigated yield exceeding other locations.

Dryland soybean yields are expected to decrease by 3 to 65 percent throughout all but the northernmost part of the Basin. Irrigated yields in the north are estimated to increase by about 100 to 140 percent. Even with percent increases in yield of this magnitude for northern areas, northern lands may still have yields lower than in areas to the south.

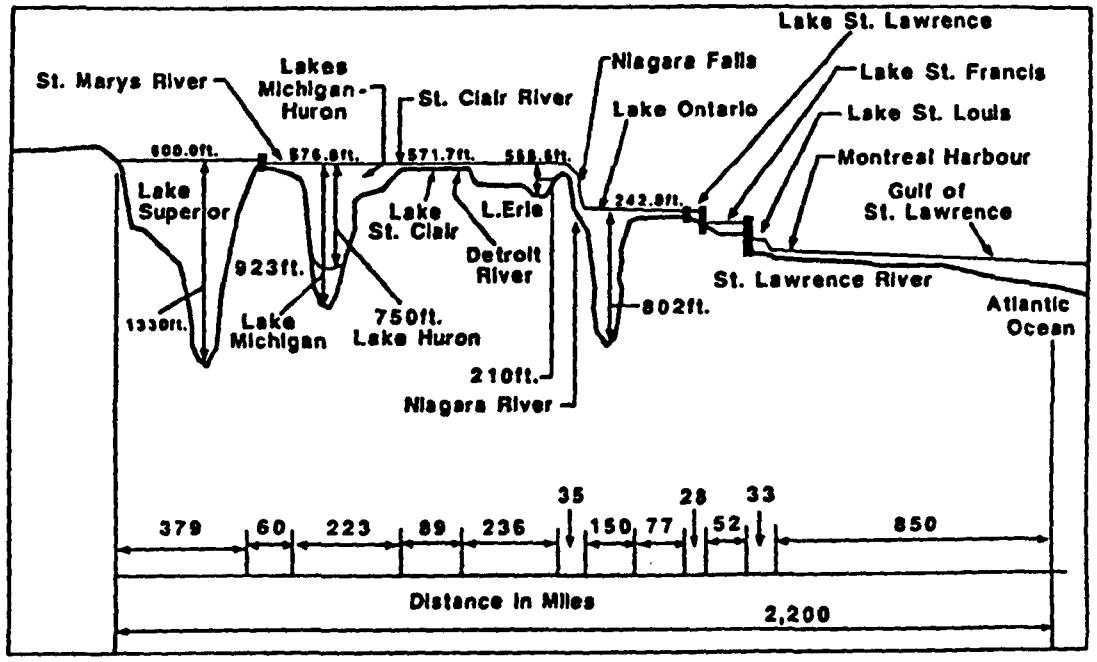
F. CHANGING LAKE LEVELS

Problem Area Description

The changing lake levels problem area addresses the risks to humans and the environment from fluctuations in lake water levels of the Great Lakes Basin. The Great Lakes Basin consists of an area approximately of 297,000 square miles[76]. A profile of the Basin is shown in Exhibit F-1.[77] An estimated 5,400 cubic miles of water held in the system[78]. Maximum water depths range from 21 feet in Lake St. Clair to over 1,300 feet in Lake Superior[79].

Fluctuations in water levels are considered a natural occurrence; they have occurred since the Basin's formation, and will continue. It is difficult to generalize about the magnitude of the problem lake level fluctuations present because the Basin covers such a large area. Also, what affects one lake may be of an entirely different scale from the effect on another lake. In addition, what may be considered an adverse effect for some shoreline interests, may not be considered a problem for others (i.e. hydroelectric facilities prefer high water levels and beach front property owners often prefer lower levels). However, it is typically the extreme events of record high and low lakes levels (i.e. flooding and drought) that generate the most concern. These extreme events are particularly difficult to deal with because they usually take people by surprise.

EXHIBIT F-1



PROFILE OF THE GREAT LAKES - ST. LAWRENCE RIVER SYSTEM

[76] International Joint Commission. 1989. "Living with the Lakes: Challenges and Opportunities" p.14.

[77] Exhibits F-1 through F-5 are taken from "Living with the Lakes." op. cit.

[78] Ibid.

[79] Ibid.

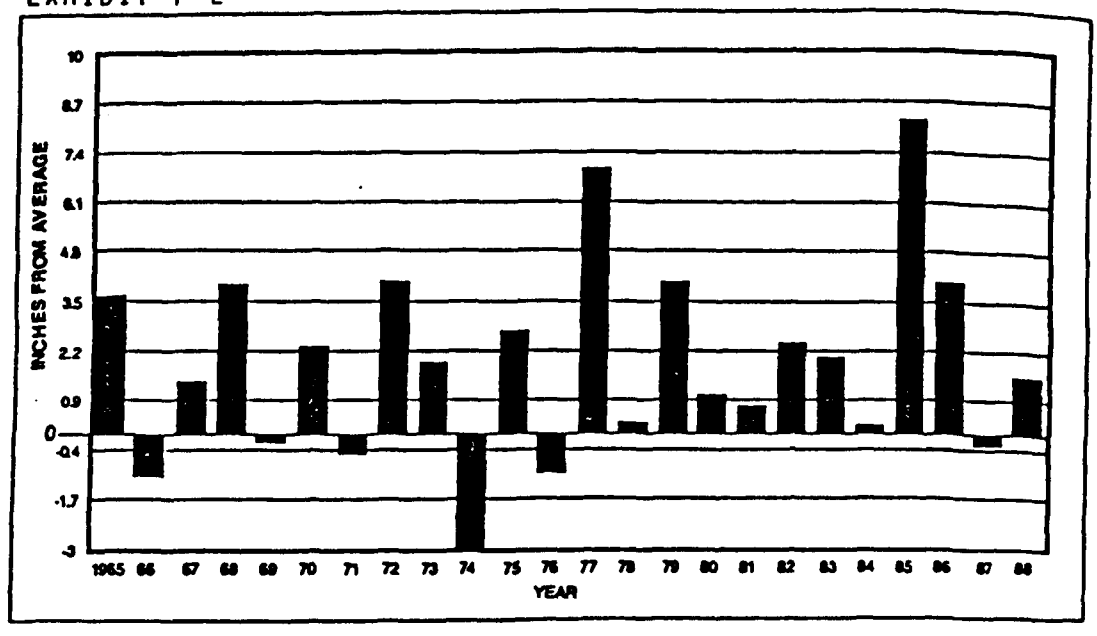
The Great Lakes are of such large size and their individual outlets so limited, that when extremely high or low lake levels occur, they will persist for a considerable length of time, even after those factors which caused the extremes have changed. However, predicting future water levels is extremely difficult because lake level measurements began only in 1860. The intervening 130 years is considered too short a period of record from a hydrologic and geologic standpoint. Accurate information would be required for many of the factors that affect lake levels.

Factors influencing lake levels

A variety of natural factors affect Great Lakes water levels including precipitation, runoff, temperature, evapotranspiration, meteorological events, crustal movement, and flooding and erosion[80]. Although all these factors have some significance in terms of lake level changes, precipitation is the main cause of long-term water level fluctuations on the Great Lakes.

The average annual precipitation for the Great Lakes Basin ranges from approximately 25 inches in northern Minnesota, to about 50 inches in New York.[81] Over the course of the century two distinct precipitation patterns have been determined for the region. From 1900-1939 the Great Lakes experienced below average precipitation. However, during the period of 1940-1984 the Great Lakes received above average precipitation. On average, the Basin received 2 additional inches of precipitation per year representing a 6% increase overall. Exhibit F-2 indicates the degree of variation in precipitation for the Great Lakes Basin as a whole. Precipitation usually leads lake levels by about one year.[82]

EXHIBIT F-2



GREAT LAKES BASIN ANNUAL PRECIPITATION
(1965 - 1988)

[80]Ibid., p.2-4.

[81] The Great Lakes: An Environmental Atlas, op. cit.

[82]Ibid.

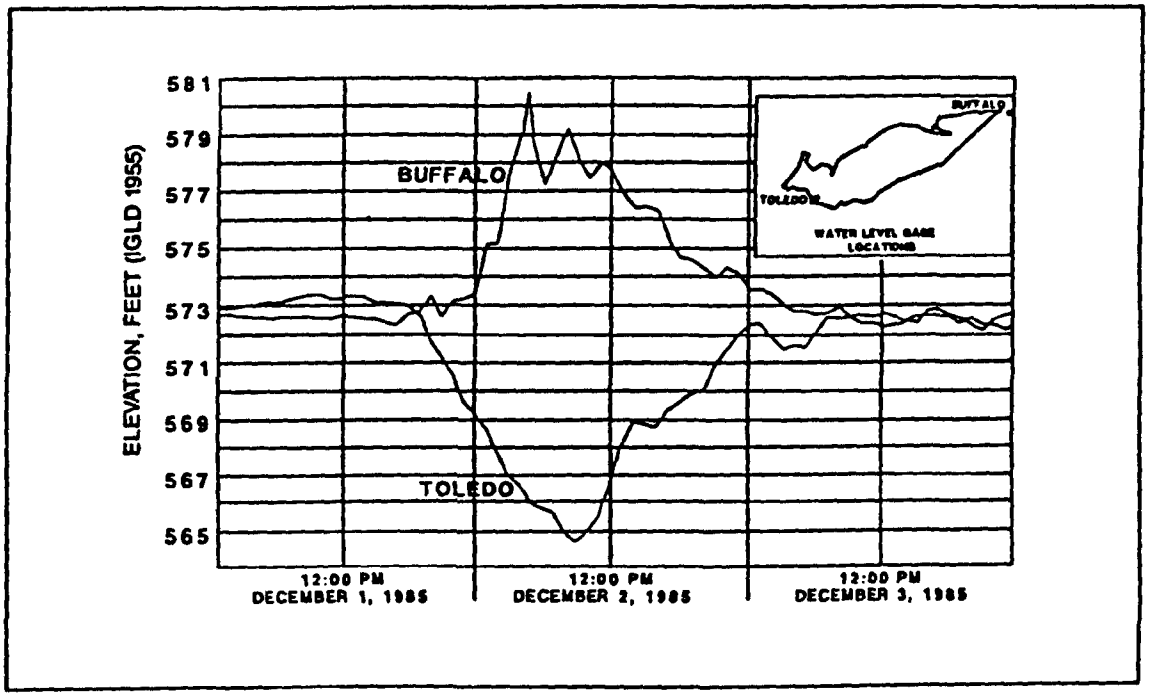
Other factors that influence lake levels include dredging for navigation improvements, regulation, and control structures. In addition, the actual amount of water withdrawn for consumptive uses and diversions from the Basin impact water levels. Water withdrawn for consumptive use is that amount assumed to be lost or otherwise not returned to the Great Lakes Basin due to evaporation, incorporation into products or other processes. Inter-basin diversions refer to the amount of water transferred from the Great Lakes Basin into another watershed. Artificial modifications that attempt to regulate water levels do so only to a small degree. It is the natural factors, particularly climatic changes, that influence lake levels the most.

Lake level fluctuations

Water levels in each of the lakes will rise or fall according to the amount of water entering or leaving the lake. Great Lakes lake levels fluctuate on a very short-term basis due to strong winds and storms. On a seasonal basis and on a longer-term year-to-year basis, lake level alterations are due to changes in the balance between precipitation, inflow, and runoff, on one hand, and evaporation and drainage, on the other.

Short-term changes can be dramatic and can cause considerable amounts of damage along exposed shoreline areas. An example would be the storm of December 2, 1985 that caused a 16 foot difference in water levels on Lake Erie between Toledo (eight feet lower) and Buffalo (eight feet higher) (Exhibit F-3). Although this is an extreme example, all the lakes are affected by harsh weather, the severity of which is dependent on the size and depth of the lake, and the orientation and shape of the lake as well as the magnitude of the storm[83].

EXHIBIT F-3



WIND TIDE AND SEICHE EFFECT ON LAKE ERIE
DURING STORM OF DECEMBER 2, 1985

[83]International Joint Commission. 1989. "Living with the Lakes: Challenges and Opportunities" p.20.

Seasonal fluctuations occur over the course of a year and account for average changes of about 12 to 18 inches with lows normally occurring in January or February and highs in June through September[84] (Exhibit F-4). Long-term fluctuations in lake levels as shown in Exhibit F-5 during the period of 1950 - 1988, are on the order of five to six feet from record lows to highs. Significant changes in lake levels will only occur as a result of significant climatic changes, such as a period of higher than normal precipitation. For example, Great Lakes water level records indicate that the record high lake levels set in 1985 and 1986 were the result of a 5-year period of higher than normal precipitation[85].

It is the short-term changes, similar to those found in agricultural runoff, that cause the most damage because of their severity and usually unanticipated occurrence. The seasonal and long-term fluctuations do impact certain interests within the Great Lakes Basin, however, these impacts are not as severe and are usually expected. For the most part, higher water levels (i.e. levels above the average normal, up to the point of flooding) are preferred over low water levels.

Ecological Impacts

Changes in Great Lakes water levels have a variety of ecological impacts, including impacts associated with wetlands and other water resources, which in turn affect aquatic plant and animal life, terrestrial plant and animal life and humans.

Wetlands of the Great Lakes are exposed to variations in water levels caused by long-term climatic cycles, short-term climatic occurrences, and annual distribution of water, and wave actions. The extent and quality of wetlands found along the shores of the Great Lakes during any time period, are essentially the product of seasonal and long-term environmental conditions. Wetland communities react to the pattern and magnitude of water-level variations according to the tolerance of the biotic community to them. Also, it has been determined that the highest quality wetlands are those that experience water level fluctuations.

Wetland vegetation is dependent on the ground water table that is on or close to the surface. During periods of reduced lake levels, the ground-water table may be lowered, thus changing the wetland. Some wetland vegetation will change their growth form to accommodate drier conditions, but the overall vegetation will usually change dramatically as species intolerant of drying die and are replaced by species emerging from reserves of buried seed[86].

The optimal wetland wildlife habitat has been described as a semi-marsh, i.e. 50 percent open water and 50 percent wetland vegetation[87]. High water conditions (i.e., levels above the historical long-term mean) produce habitat approaching the semi-marsh which benefit wildlife such as waterfowl, muskrats, black terns and herons[88]. These conditions increase wildlife species diversity. High water may facilitate the interchange between the lake and wetland, and thus permit fish spawning (i.e., northern pike). Low water conditions (i.e., water levels below the historical long-term mean) encourage the predominance of the sedge-meadow and dense emergent zones. During extended low water years, wildlife species diversity decreases with habitat conditions

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[84]Great Lakes Commission. 1990. "A Guidebook to Drought Planning, Management and Water Level Changes in the Great Lakes" p.49.

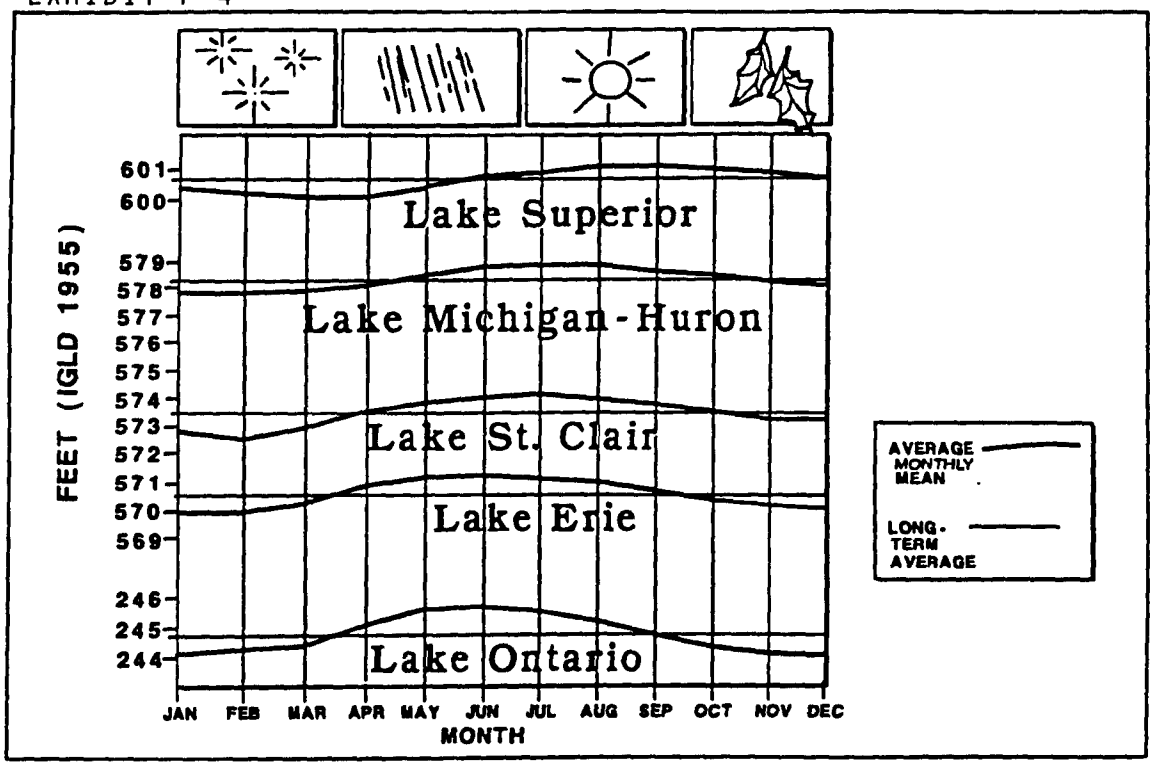
[85]Ibid.

[86]Ibid.

[87]Ibid., p.B-95.

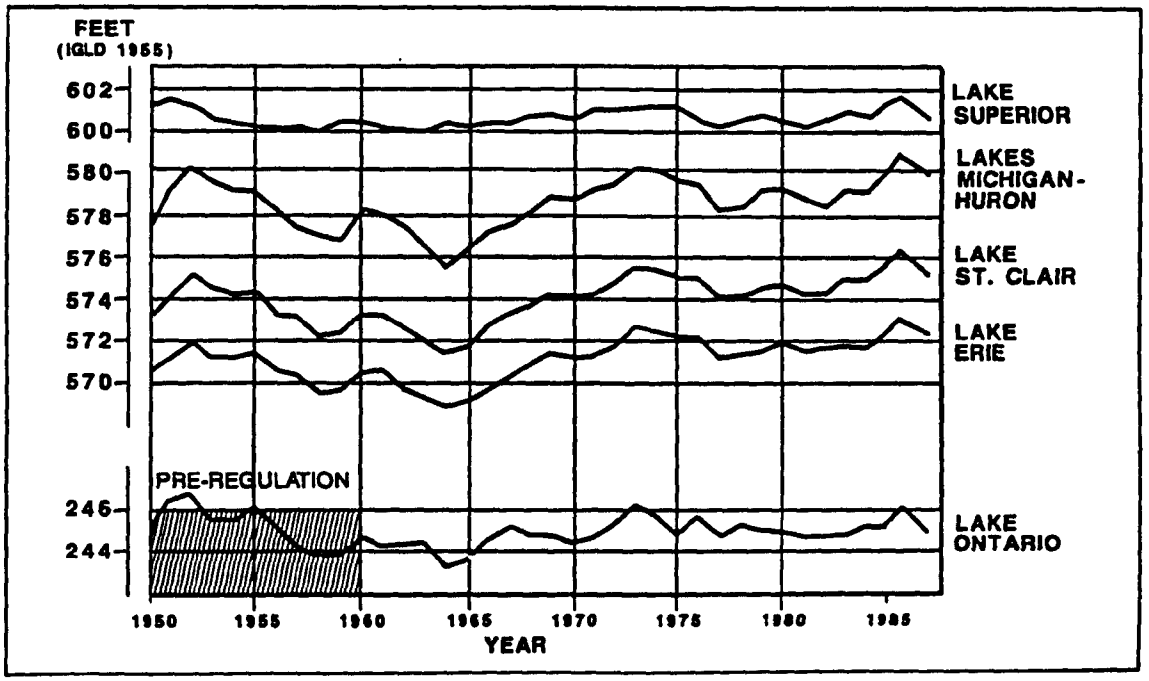
[88]Ibid.

EXHIBIT F-4



SEASONAL FLUCTUATIONS
GREAT LAKES WATER LEVELS
(1900-1988)

EXHIBIT F-5



ANNUAL AVERAGE GREAT LAKES WATER LEVELS
(1950-1988)

favoring red-winged blackbirds, short-billed marsh wrens, rails, white-tailed deer, cottontail rabbits and small rodents[16]. When a wetland area is reduced, many important functions and values, such as ground-water discharge and recharge; absorption of toxic pollutants and nutrients entering the lakes; habitat for fish, waterfowl, and other wildlife; and recreation such as hunting, fishing, and canoeing, are reduced also.

The aquatic environment of the lakes is less influenced by fluctuating lake levels than are wetlands and shorelines. A rich variety of aquatic life is found in the waters of the Great Lakes. Water temperature, levels of oxygen, the quantity of nutrients available for food, the amount of sunlight penetrating the shallower depths, and the amount of contaminants in the water or sediments determine the species present and their relative abundance[89].

High lake levels tend to be beneficial to aquatic habitat and water quality because low levels result in raised water temperatures, reduced dissolved oxygen, increased concentrations of pollutants, particularly sewage effluent, and increased need for dredging of contaminated sediments. Nevertheless, water quality degradation can result from flooding of septic systems,reduced treatment plant efficiency and submergence of shoreline vegetation and nutrient-rich soil[90]. However, the impacts of extreme levels on the resuspension of pollutants and on the volume of discharge from sewage treatment plants and septic systems will require future study in order to better establish the relationship between water quantity and water quality[91].

Low lake levels also reduce the amount of "edge" habitat for fish, particularly fish spawning areas, and other aquatic organisms. High flows, however, move larval fish and other small organisms more rapidly through the system, improving prospects for growth and survival.

Reductions in lake water levels affect other water resources within the Basin such as rivers, smaller lakes, reservoirs, and ground water by decreasing the availability of these resources for use. The most limited of these resources are affected first by increased demand for water, and decreased runoff into streams and lakes that in turn recharge ground-water supplies. Continued low water levels commonly result in water use conflicts. Well interference complaints typically arise when a user withdraws large quantities of water from a high-capacity well and thereby restricts the withdrawal capability of a domestic user's smaller well.

Welfare Impacts

Changes in lake levels can have major implications for a variety of interests. Typically, it is the extreme events of flooding and drought that cause the most severe problems, and it is these extreme events that tend to persist overtime due to the size of the lakes and their limited individual outlets. This section will address the impacts of low and high lake levels on humans and the environment.

Environmental costs

The environmental costs associated with changing lake levels include the economic losses due to the loss of wetlands (see Physical Degradation of Wetlands and Aquatic Ecosystems). Other associated environmental costs due to changing lake levels include the economic losses of fish, wildlife, recreation, and other aesthetic values, and the costs to developed areas of maintaining drainage and erosion control.

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[89]Ibid.

[90]International Joint Commission. 1989. "Living with the Lakes: Challenges and Opportunities" p.29.

[91]Ibid.,p.30.

Materials and property damage

Navigation on the Great Lakes and in particular its harbors and connecting channels, is significantly affected during periods of extended low water levels and flows. During low water periods, cargo volume is reduced and trip frequency is adjusted. These changes compromise efficiency by increasing transportation costs and decreasing revenue[92]. Also, recreational harbors pose navigation problems during low water periods, with the impacts of drought compounded by substantial sediment loads from nearby shorelands and rivers.

Channel and harbor dredging may be needed during low water periods. However, dredging of commercial harbors, canals, and navigation channels can remove a large volume of polluted sediments, though a small percentage may be resuspended. Disposal of this material can be difficult and expensive if it does not meet state and provincial environmental requirements for open water disposal. On-land or in-water confined disposal areas/facilities are difficult to establish and access (particularly under emergency conditions) and pose their own set of environmental concerns.

Hydroelectric facilities are the greatest users of Great Lakes water and represent more than 94% of the total amount of water used per day. Hydroelectric withdrawals are, however, considered an in-stream use, not a withdrawal in the sense that water is lost. A major concern of power companies during periods of low water levels is meeting environmental standards for the discharge of cooling water from thermal generating facilities into rivers or lakes. Water temperatures tend to rise during low water levels, reducing dissolved oxygen levels which can be hazardous to fish and other aquatic animals. Power company discharges are typically limited during drought conditions, resulting in the power company having to reduce its energy production, thereby limiting revenues and possibly disrupting electricity supply. Also, hydroelectric power generation may be reduced due to decreased streamflows. Usually, the costs incurred on the utilities of having to purchase higher priced electricity from other suppliers are passed onto the consumer.

Commercial and industrial water users are also impacted by changing lake levels. Major industries located along the shores of the Great Lakes use the lakes for both water supply and waste disposal. As with all structures and facilities along the shores, periodic property damage occurs due to storms and flooding. However, in general higher water levels are preferable, up to the point of flooding, for water supply, greater dilution of waste discharges, access to water for boats, and clearances for commercial navigation deliveries to industrial users. Persisting low water levels can result in difficult access to high quality water if near-shore water quality is reduced due to lower lake levels. In addition, changes in water temperatures due to low levels may affect industrial cooling processes. Emergency or alternative water supplies may be needed to accommodate declining lake levels, reduced streamflows, or lowered ground water levels. Most commercial and industrial businesses accept the fluctuating water levels as a part of the cost of doing business and consider location on the shore to be a greater advantage than the disadvantage of changing water levels.

Many public water utilities obtain their water directly from the lakes. Even though intake systems are generally located in deep water, low lake levels can be an issue for public water suppliers who may be forced to do additional treatment if the concentration of pollutants has increased due to reductions in water levels. In addition, when an extended period of reduced precipitation occurs, lake levels are reduced, as well as surface water flows, ground-water flows, and reservoir levels. Those public water suppliers who are not using Great Lakes water as their primary source, may need emergency or alternative water supplies which can be obtained by deepening existing wells, drilling new wells, building temporary dams, changing supply from groundwater to

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[92]Ibid.

surface water, or extending pipelines to deeper water or to different sources. Conflicts between competing users (particularly domestic users and irrigators) are frequent.

The degree of risk to shoreline property depends on the location. The most serious impacts on riparian property are due to erosion and flooding which occur during severe storms. The impacts could result in loss of land and trees, and damages to shore protection structures and buildings and their contents[93]. Economic impacts include the cost of alternate accommodations, costs of maintaining septic systems and costs of repairing or replacing damaged property. At this time there is no data available which indicates costs incurred by property owners due to damages from high lake levels. However, a large census and survey is underway in order to gain a better understanding of the magnitude of these impacts on shoreline properties[94]. In general, shoreline property will benefit from lower lake levels. Shore erosion is reduced and low lake levels may expose enough beach to enable on-shore winds to form dunes which can protect shoreline property during storms. Finally, beaches on the lakes will become wider, accommodating recreationists.

Relatively little of the Basin's extensive agricultural land is on the shore of the lakes. However, persistent low water levels do impact those areas as well. Low soil moisture may result in loss of arable land and reduced crop productivity, causing farm revenues to drop. In addition, if feed crop productivity is affected, feed shortages can result in problems for dairy farmers, cattle ranchers, and other livestock operations. Furthermore, shallow wells, ponds, and wetlands may dry up forcing farmers and rural residents to drill new wells, deepen old wells, or transport water from other sources. Many farmers must increase their irrigation activities during these times, thereby reducing stream flows, reservoirs and ground water levels. Conflicts between irrigators and domestic water users are common. In addition, as topsoil loses moisture, it becomes more susceptible to wind erosion. Topsoil erosion can reduce agricultural productivity by as much as 30% - 40%[95]. There are some farmers, however, who benefit from low water levels in the Great Lakes Basin, particularly those in less affected regions. They may experience substantial increases in total income due to higher unit prices. For those agricultural areas located close to the water, particularly on former floodplain or wetland areas, high lake levels make those lands vulnerable to flooding and erosion.

Many of the impacts already discussed contribute to the overall impact of changing lake levels on residents in general. During periods of low lake levels homeowners may experience reductions in available water supplies, high costs for electrical power, high food prices due to reduced crop yields, and damage to landscaping. During periods of high lake levels, particularly flooding, property damage is a major concern.

In sum, water level changes can affect a variety of interests including property owners, water-use industries, recreational and commercial users of the lakes, those whose source of drinking water is the lakes or ground water fed sources, and agriculturalists. Changes in the lake levels also affect non-human populations including terrestrial, shoreline, and aquatic plants and animals, particularly those associated with wetlands.

The issue of changing lake levels is a low priority for those potentially affected. Because these changes are natural and have been occurring since the Great lakes were formed, people are accustomed to them, expect them, and have adjusted accordingly. In addition, plant and animal life have adapted as well. For many, changing lake levels are more an inconvenience than a risk. However, the extreme events of flooding and drought are a major concern throughout the Basin and have the greatest potential catastrophic impact.

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[93]Great Lakes Commission. 1990. "A Guidebook to Drought Planning, Management and Water Level Changes in the Great Lakes" p.15.

[94]International Joint Commission. 1989. "*Living with the Lakes: Challenges and Opportunities*" p.42.

[95]Ibid.,p.43.

III. PRIMARY WATER PROBLEM AREAS

The water quality of the Great Lakes and their connecting channels and tributaries are of great importance to the health of the Basin. In Section III, we discuss a number of primary water problem areas (generally defined by pollutant source) related to the Basin's water quality. The following problem areas are discussed in this section:

- Industrial point source sicharges to surface waters;
- Municipal point source discharges to surface waters;
- Nonpoint surface loadings to surface waters;
- Atmospheric loadings to surface waters;
- Toxic sediments; and
- Pesticide discharges.

These problem areas all contribute to the load of pollutants that degrade water quality and increase the body burden of contaminants in fish and other aquatic organisms.

G. INDUSTRIAL POINT SOURCE DISCHARGES TO SURFACE WATER

Problem Area Description

This problem area addresses contaminant load and surface water quality impairment resulting from industrial point source discharges. This problem area does not include point source discharges from publicly and privately owned municipal wastewater discharges. Typical sources of industrial point source discharge permitted under the National Pollutant Discharge Elimination System (NPDES) include electric utilities, metal finishing, pulp and paper processing, and iron and steel production. Within the Great Lakes Basin, there are 40 utilities classified as major dischargers. While electric utility cooling water discharges principally contribute to thermal load in receiving waters, other pollutants discharged by industrial sources include total suspended solids, biochemical oxygen demand (BOD), toxic organics such as pesticides and phenols, and toxic inorganics such as heavy metals.

Most health and ecological risks that result from surface water impacts, such as toxics bioconcentration in sport fish, cannot be differentiated from among industrial, municipal, and nonpoint source discharges (including atmospheric loadings and toxic sediments). As a result, the aggregate impacts of these problem sources are discussed only once, in this section, but are nevertheless applicable to the following surface water problem areas as well.

Magnitude of the problem

There are approximately 570 major (i.e., facilities discharging over one million gallons per day or those identified as having a potential to adversely impact receiving waters) and 2,750 minor industrial dischargers in the Basin.[1] The distribution of major and minor point source dischargers by lake watershed is presented in Exhibit G-1. Exhibit G-2 further identifies the major and minor dischargers by EPA Region. Exhibit G-3 identifies the major dischargers by facility type (industrial and municipal) within the Basins. Exhibit G-4 distinguishes the Basin industrial and municipal dischargers by the EPA Region in which they are found. Finally, the location of all major dischargers within the Basin are presented in Exhibit G-5.

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[1] 1991 Permit Compliance System (PCS) data.

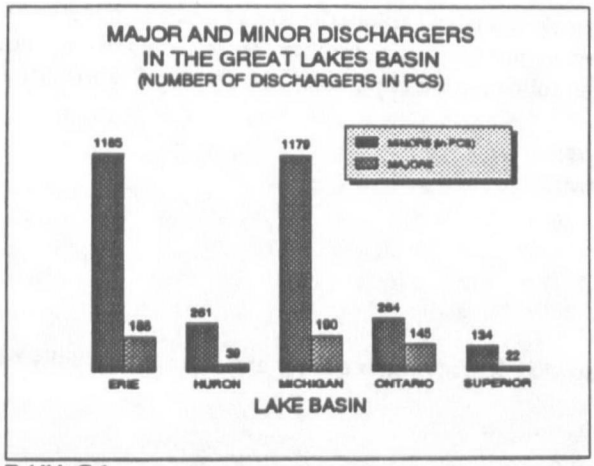

Exhibit G-1

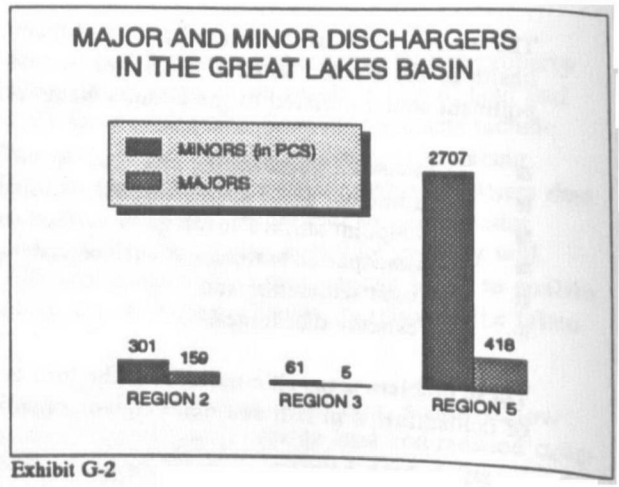

Exhibit G-2

The total daily flow from major electric utility dischargers is approximately 20 billion gallons per day (bgd) and approximately 4 bgd from other major industrial dischargers. The majority of the discharges from electric utilities are "non-consumptive" and involve the pass through of cooling water. The volume of discharge from the other major sources is largely attributed to the iron and steel industry, followed by the pulp and paper, nonferrous metals, and chemical manufacturing industries. The human health risk assessment analysis presented below focuses on these non-electrical utility discharges.

In general, industrial and municipal facilities have made significant progress in reducing their loadings of EPA priority pollutants to the Great Lakes. In the Niagara River, organics, metals, cyanides, and phenols have been

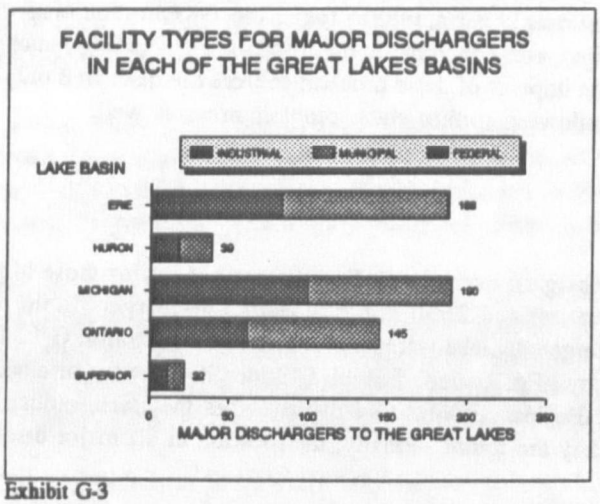

Exhibit G-3

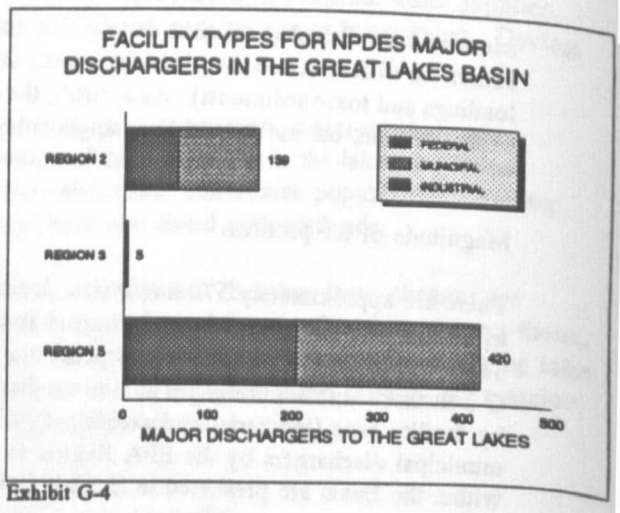

Exhibit G-4

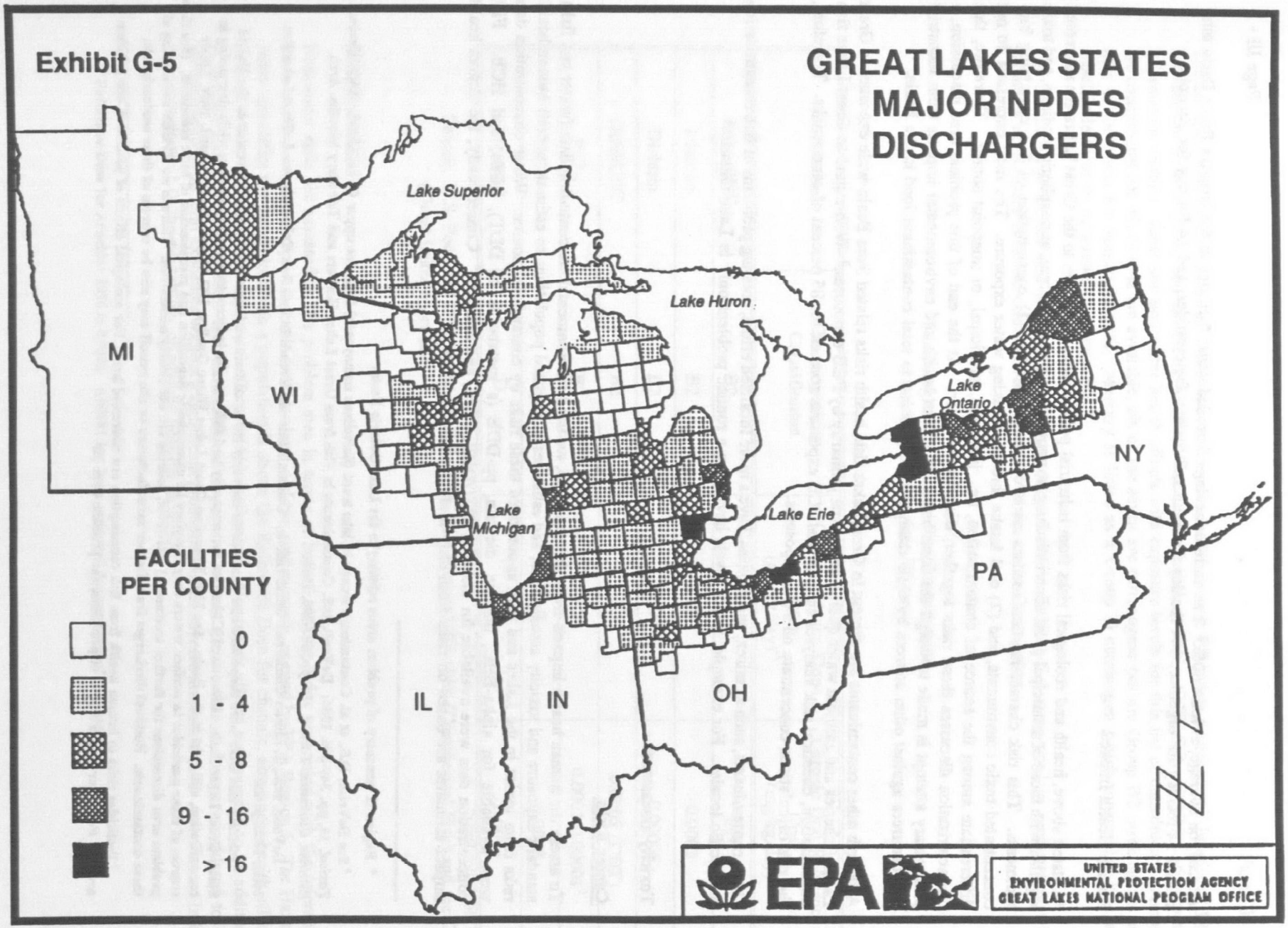
Exhibit G-5
GREAT LAKES STATES
MAJOR NPDES
DISCHARGERS
Lake Superior
Lake Huron
Lake Ontario
Lake Michigan
Lake Erie
MI
WI
IL
IN
OH
PA
NY
FACILITIES
PER COUNTY
0
1 - 4
5 - 8
9 - 16
> 16
EPA
UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

reduced, on average, at least 80%.[2] The current loadings from industrial facilities in the Niagara River Basin total around 14 lbs/day for organics, 104 lbs/day for metals, 2 lbs/day for cyanides, and 14 lbs/day for phenols.

Human Health Impacts

As stated above, health and ecological risks from industrial point source discharges to the Great Lakes are addressed together with those of municipal point source discharges, nonpoint source discharges, atmospheric loadings, and toxic sediments. This risk characterization focuses on two exposure routes: (1) consumption of fish containing bio-concentrated toxic constituents, and (2) oral intake through drinking water exposure. The risks expressed do not differentiate among the source of contamination, i.e., industrial, municipal, or nonpoint source. Therefore, this characterization discusses these risks together, under this section. At the end of this problem area discussion, a preliminary attempt is made to weigh the contribution to human health and environmental impacts from industrial point sources against other sources by their estimated contribution to total contaminant load in the Basin.

Although other contaminants are present in Great Lakes fish, health risks related from Basin-wide exposure to Great Lakes fisheries and ambient water quality are driven primarily by PCB exposures.[3] With regard to Great Lakes fish consumption, chemical risk analyses suggest that PCB exposures account for 85 percent of cancer risks. Therefore, the risk calculations concentrate on PCB exposures.

Other contaminants, such as mirex, and dioxins, have a more localized effect, creating problems of fish contamination in specific locales. For example, mirex levels have been a routine problem only in Lake Ontario.[4]

Toxicity assessment

Cancer Risks

To assess the human health impacts from these sources, we used environmental concentration data (water and fish), standard exposure and toxicity assumptions, and estimates of exposed populations to estimate overall human health risks from toxics in the Lakes and then apportioned these risks by contaminant source. Water concentration data were available for alpha-BHC, lindane, dieldrin, pp-DDE (a metabolite of DDT), PCBs, and HCB. Fish concentration data were available for dieldrin, DDT/DDE, PCBs, and mercury.[5] Consequently, the human health impact estimates are based on risks from only these contaminants[6].

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[2] Region II summary of problem areas relating to the Lake Ontario Basin.

[3] See DeVault, D.S., et al. Contaminant trends in lake trout (Salvelinus namaycush) from the upper Great Lakes. *Arch. Environ. Toxicol.* 15, pp. 349-356, 1986; DeVault, D.S. Contaminants in Fish from Great Lakes Harbors and Tributary Mouths. *Arch. Environ. Contamin. Toxicol.* 14, pp. 587-594, 1985.

[4] DeVault, D.S., J. Milton Clark, and Garet Lahvis. Contaminants and Trends in Fall Run Coho Salmon. *J. Great Lakes Res.* 14(1), 1988. p. 29.

[5] Dieldrin and DDT were suspended and cancelled in the early 1970s, and are no longer used or manufactured in the United States Great Lakes Basin. However, IJC data on water quality and fish samples indicate that such pesticides, while decreasing in concentration, still exist in the Basin. See 1989 Report on Great Lakes Water Quality, IJC, Water Quality Board, 1989. Likely sources of these pesticides in surface waters may therefore be atmospheric deposition and resuspension of toxic sediments. (See these problem area discussions for further treatment.) However, sources are not clearly understood. There is no NPDES monitoring of these contaminants. Residual discharges from former manufacturers or site runoff may also be sources of these contaminants.

[6] Pesticides risks to human health from fish consumption are addressed here. For ecological effects of pesticides, see problem area L. For other health effects of pesticides, see problem area X.

Toxicological data on the chemicals listed above were obtained from two EPA data sources: the Integrated Risk Information System (IRIS) and the Health Effects Assessment Summary Tables (HEAST). Exhibit G-6 presents information relating cancer and noncancer health effects with exposure levels for this list of constituents. Among the constituents for which data are available, six of the seven are carcinogens (all are Group B2 carcinogens) and four of the seven are noncarcinogens. Mercury is listed as a Group D carcinogen which means that it is not classifiable in terms of human carcinogenicity.

The cancer slope factors and the chronic reference doses listed in Exhibit G-6 were used in conjunction with estimates of exposure levels to calculate risks posed by toxics in the Great Lakes.

Exhibit G-6
Toxicological Information for Contaminants
Discharged to Surface Waters

Contaminant	Carcinogenicity Classification	Cancer Potency Slope Factor $(mg/kg/day)^{-1}$	Chronic Oral Reference Dose (mg/kg/day)
alpha-BHC	B2	6.3	na*
Lindane	B2	1.3	0.0003
Dieldrin	B2	16.0	0.00005
DDE/DDT	B2	0.3	0.0005 (DDT)
PCBs	B2	7.7	0.0001/0.00001[7]
HCB	B2	1.7	0.0008
Mercury	D	-	0.0003

* not available

Source: U.S. Food and Drug Adminstration, Total Diet Survey 1987-1989 (Commerical Fish) and the IJC (Great Lakes sport fish)

Noncancer Risks

Noncancer risks are assessed in this problem area in terms of hazard ranking index associated with the reference doses and the estimated exposure levels for chlordane, dieldrin, and mercury, as used by EPA Region 5. The Hazard Index quantifies the extent to which a population is above the Reference Dose for chronic, noncancer health effects such as reproductive impairment, neural effects or kidney damage. Noncancer effects are assumed to be additive. A Hazard Index of 1.0 indicates that environmental exposures are not greater than a dosage considered to be acceptable for long term exposures without a significant probability of an adverse noncancer risk. As a Hazard Index increases above 1.0, the probability of adverse impacts increases.

[7] Reference Dose for Arochlor 1016 is 0.0001; 0.00001 has been estimated for purposes of this paper.

In addition to the hazard ranking, however, additional evidence has recently been developed which indicates that prenatal exposure to PCBs may affect childhood development. Evidence of PCB teratogenicity came from studies of pregnant women in Japan and Taiwan. In the children born to these women, exposure to PCBs and related contaminants was associated with low birth weight, neonatal behavioral anomalies, and poorer recognition memory in infants.[8] A recent study evaluated 236 children whose mothers had consumed Lake Michigan sport fish during their pregnancy. Prenatal exposure was found to affect the children by reducing short-term memory function on both verbal and quantitative tests in a dose-dependent fashion.[9] In this study, PCB levels in breast milk were not predictors of short-term memory function deficits. Therefore, intra-uterine exposure may pose a greater threat to infants than postnatal lactatinal exposure. This may be due to the protective barriers and metabolizing capacities which are lacking in the fetus but which develop postnatally.

Exposure Assessment

Exposures to toxics in the surface waters of the Great Lakes Basin were estimated from two routes: ingestion of drinking water and consumption of fish. Other possible exposure routes include dermal contact through recreation in surface waters and dermal exposure through domestic use of water. These other routes were not considered because because drinking water and fish consumption are considered to be the two major routes.

Data on water quality in the Great Lakes were used to calculate drinking water exposure levels. Data from the 1989 Report on Great Lakes Water Quality (Great Lakes Water Quality Board, Report to the International Joint Commission) were used to characterize water quality in the lakes. The water quality data used in this analysis are presented in Exhibit G-7. Data on concentrations of contaminants in fish were used to calculate fish consumption exposure levels. These data are presented in Exhibit G-8. Concentrations in sport fish are not provided for each lake, but represent averages for the five Great Lakes. However, there can be several orders of magnitude difference between species and lakes.

Exhibit G-7
Approximate Concentrations of Toxics in the Water of the Great Lakes[10]
(lakewide averages, ng/L)

Contaminant	Lake Superior	Lake Huron	Lake Erie	Lake Ontario
alpha-BHC	7.84	5.91	3.82	3.95
Lindane	1.08	0.79	1.02	1.25
Dieldrin	0.29	0.36	0.37	0.31
pp-DDE	--	0.01	0.03	0.05
PCBs	0.33	0.57	1.16	1.20
HCB	0.03	0.03	0.05	0.06

[8] Wong, K.C. and M.Y. Hwang. 1981. "Children born to PCB poisoned mothers." Clin. Med. (Taipei). 7:83-87.

[9] Jacobson, J.L., S.W. Jacobson, and H.E.B. Humphrey. 1990. "Effects of in utero exposure to polychlorinated biphenyls and related contaminants on cognitive functioning in young children." J. Pediatr. 116:38-45.

[10] Data were not available for Lake Michigan.

Source: 1989 Report on Great Lakes Water Quality, Great Lakes Water Quality Board, Report to the International Joint Commission, presented at Hamilton Ontario, October 1989.

Exhibit G-8
Approximate Concentrations of Toxics in Fish
(ppm)

Contaminant	Commercial Fish (FDA)	Great Lakes Sport Fish (IJC)
DDT/DDE	0.009	0.37
Dieldrin	0.005	0.09
PCBs	0.001	1.32
Mercury	--	0.17

Source: U.S Food and Drug Administration, Total Diet Survey 1987-1989 (commercial fish) and the IJC (Great Lakes sport fish).

For drinking water ingestion, we assume that the residents of the Great Lake Basin who derive their drinking water from surface water sources ingest 2.0 liters of contaminated water per day. The estimated duration of exposure is 70 years (lifetime) and the estimated average body weight is 70 kg.

Surveys indicate that about 11% of the population in the Great Lakes basin are licensed sportfishermen.[11] Therefore, 3.36 million persons are considered sportfishermen. The remaining population (27.15 million) are assumed to be non-fishermen.[12] Based upon surveys of sportfishermen and their families, the average sportfishermen consumes an average of 19 grams of fish per day.[11] For the purposes of assessing exposure it will be assumed that 3.4 million people consume 19 grams of Great Lakes basin fish per day,[13] although it should be recognized that the exposed population may be underestimated as only fish consumption by licensed fishermen and not their families has been considered.

U.S. Department of Agriculture national statistics indicate the average person consumes about 19 grams of commercial fish (primarily saltwater fish) per day.[14] The estimates of commercial fish consumption for the Great Lakes States indicate a lower consumption rate of 15 g/day. For the purposes of this assessment it is assumed that the non-fishermen subpopulation consumes 15 grams of commercial fish per day and from zero to four grams per

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[11]West, Patrick, et al. Michigan Sport Anglers Fish Consumptive Survey. University of Michigan, 1989.

[12]A third category, subsistence fishermen, also exists. For example, Tribal members who practice subsistence fishing on reservations and other ceded territories. Indians tend to consume more traditional foods like fish and game than either sport fishermen or non-fishermen populations, and so may be at higher risk. The risks to populations of subsistence fishermen need to be addressed in future risk analyses.

[13]For upper intake sport fisherman or subsistence fishermen, daily fish intakes would be approximately 100 - 150 g/day, and resultant risks would be approximately five times greater. See Dourson, Michael L., and J. Milton Clark. 1990. "Fish Consumption Advisories: Toward a Unified, Scientifically Credible Approach." Regulatory Toxicology and Pharmacology, 12, pp. 161-178.

[14]U.S. Department of Agriculture, Consumption and Family Living, Agricultural Statistics, Hyattsville, MD, 1989

day of Great Lakes sport fish. An exposure duration of 70 years and an average body weight of 70 kg have been assumed.

Human Health Risk Characterization

Cancer Risks

Cancer risks are determined separately for drinking water exposure and contaminated fish consumption.

1. Drinking water consumption.

Cancer risks are calculated below for the additive risk posed by the contaminants evaluated in the water of the Great Lakes. We assume that the concentrations of toxics in the waters of the Great lakes is representative of all surface water sources of drinking water in the Basin. The estimated cancer incidence is based upon a Great Lakes Basin population of approximately 12,700,000 relying on drinking water from surface water supplied systems within Great Lakes counties.[15] Exhibit G-9 shows the distribution of this population. Exhibit G-10 compares Basin populations who use surface waters with overall Basin populations. Based on the contaminant concentrations and exposure assumptions outlined above, we predict an upperbound incremental lifetime cancer risk of 5×10^{-6} for exposure to toxics from surface water-derived drinking water supplies. The potential number of excess cancer cases related to ingestion of drinking water across the Basin totals approximately 66 over a 70 year span.

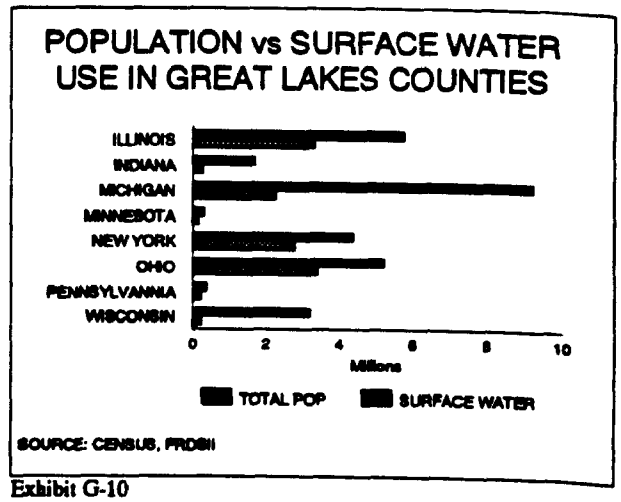


Exhibit G-10

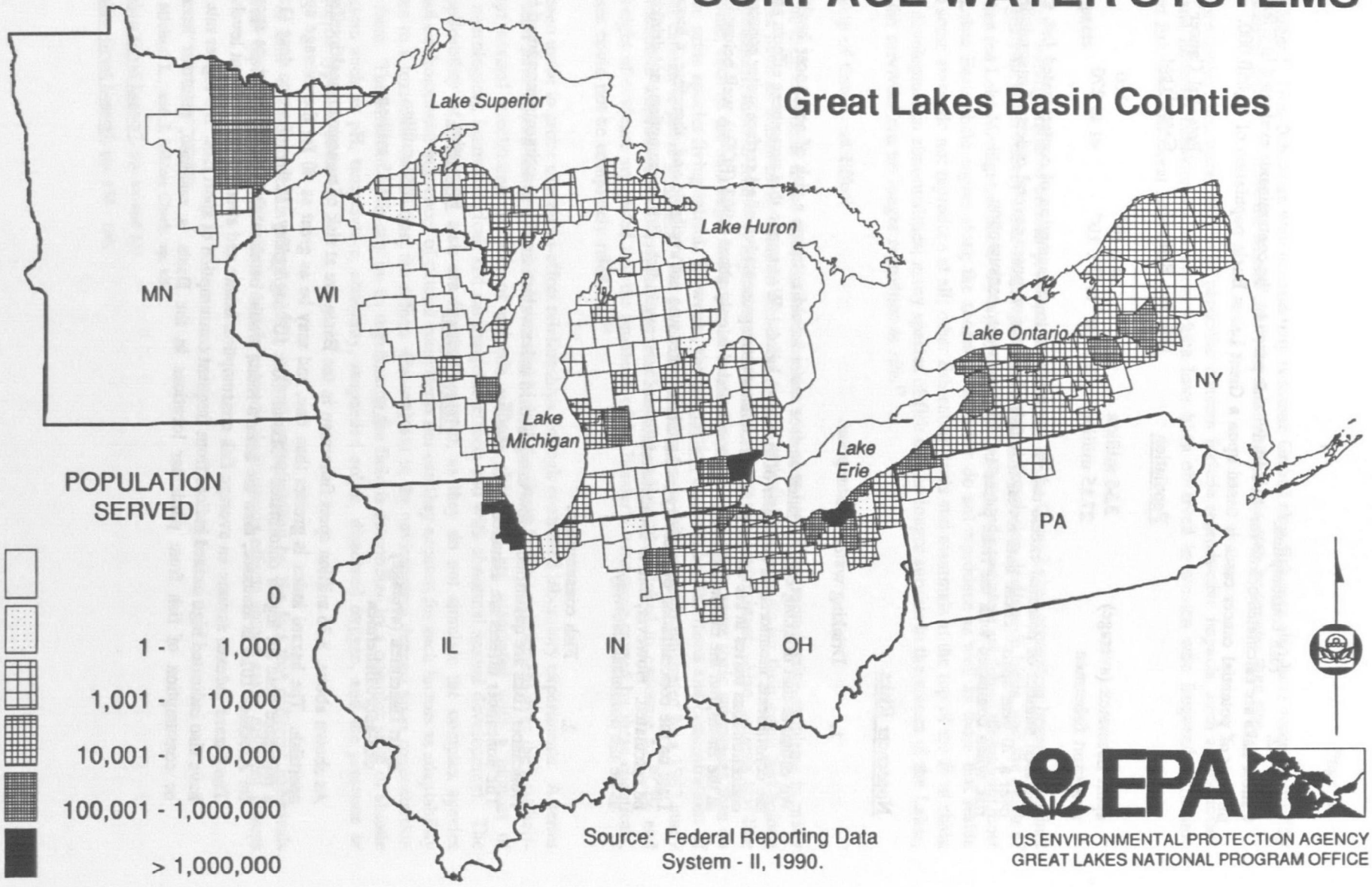
These calculations are based on exposure to drinking water prior to water treatment. Disinfection by chlorination results in the formation of trihalomethanes (THM). A study by Purdue University of small systems (serving less than 10,000 people) in Indiana found an average level of THM, as chloroform, of 60 ppb. The maximum average exposure, obtained from FRDS violation reports, was 101 ppb. These levels would give rise to lifetime excess cancer risks ranging from $1\text{-}2 \times 10^{-5}$. Assuming exposure to the total Great Lakes Basin population, the potential number of excess cancer cases relative to ingestion of treated drinking water is between 130 and 230. Assuming no reduction of contaminants (αBHC, Lindane, dieldrin, ppDDE, PCB, and MCB) the potential number of total excess cancer cases would range between 196 and 296. However, because much of the contaminants would be bound to particles, which will be removed during treatment, these numbers are upper bound estimates of risk.

[15] 1990 FRDS data retrieval.

Exhibit G-9

POPULATION SERVED BY SURFACE WATER SYSTEMS

Great Lakes Basin Counties



Source: Federal Reporting Data System - II, 1990.

EPA

US ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

2. Fish consumption.

Cancer risks are calculated below for the additive risk posed by the contaminants evaluated in Great Lakes fish. The number of potential cancer cases is based upon a Great Lakes Basin population of 30,050,000.

	Population	Lifetime Risk	Potential Cancer Cases/Year
sport fishermen (average)	3.36 million	3×10^{-3}	160
non-sport fishermen	27.15 million	2×10^{-6} to 7×10^{-4}	<1 to 270

The total number of potential excess cancer cases related to consumption of contaminated fish totals 30,000 cases over a 70 year span. These data reveal that fish consumption poses several orders of magnitude of excess cancer risk when compared with the risks posed by drinking water consumption.

Noncancer Risks

1. Drinking water consumption.

We estimate that drinking contaminated surface water would not pose a risk of noncancer health effects based on the constituents monitored in the water of the Great Lakes. We assume that noncancer effects are additive and that concentrations toxics in the waters of the Great lakes are representative of all surface water sources of drinking water in the Basin, but the maximum hazard index calculated is only about 0.003 (PCBs), well below the threshold of 1.0.

Data on the concentration of mercury in the Great Lakes was not available and, therefore, a hazard index could not be calculated. However, due to bioaccumulation of mercury in fish, fish consumption, not drinking water, is judged to be the dominant pathway.

2. Fish consumption.

Noncancer risks are quantified below using hazard index values for the constituents monitored in Great Lakes fish. The noncancer effects are assumed to be additive.

	Hazard Index	Population
sport fishermen (average)	4.0 - 40	3.36 million
non-sport fishermen	0.02 - 8	27.15 million

As shown above, 3.36 million sport fisherman in the Basin are at risk of noncancer health effects from consuming sportfish. The hazard index is greater than one, and may be as great as 40 for the average sport fisherman using a reference dose for higher chlorinated PCBs of 1.0×10^{-5} mg/kg/day. If the reference dose (1.0×10^{-4} mg/kg/day) for Arochlor 1016 is assumed, then the hazard index would be about four for the average sport fisherman.
The hazard indexes assume an average fish consumption intake and average contaminant levels. Other evaluations have also indicated high hazard indices from frequent consumption of sport fish. If a higher rate of fish consumption or consumption of fish from particular locations in the Basin is assumed, resultant hazard indices may be

considerably higher.[16] Non-fisherman who occasionally consume Great Lakes fish may also have some probability of risk of noncancer effects, because the hazard index for these individuals may be greater than one.

As discussed previously, noncancer effects of particular concern include reproductive impacts, such as low infant birth weight and neonatal behavioral anomalies, which have been observed in women who frequently consume particular sport fish from the Great Lakes.

Ecological Impacts

Thirty years ago, warning signs of serious problems in the health of the Great Lakes ecosystem began appearing. These early signals included fishery stock losses, gross defects and population declines in birds, and the death of ranch mink when fed Lake Michigan salmon. Today, symptoms of a damaged ecosystem are found throughout most of the Great Lakes Basin: bald eagles along the shores of the lakes do not reproduce as well as those that reside inland and, in some areas, do not reproduce at all; other fish-eating birds and mammals at the top of the food chain suffer marked developmental abnormalities; many species of fish can no longer survive in the waters of the Lakes, and many of the survivors can no longer reproduce *in situ*.[17]

The Relationship of Cause and Effect

The presence of toxic chemicals in the Great Lakes coincides with poor health and reproductive problems in many species. Studies have identified many cases in which the testing of individual animals (or their eggs) that belong to troubled populations, showed relatively high concentrations of at least one contaminant. Also, animals that live near the shoreline, such as the bald eagle and mink, have been found to accumulate more toxic substances than do members of the same species living inland. However, the association between health effects and concentrations of toxicants is not enough to prove causation. The problem of linking cause with effect is illustrated by a 1983 study in which reproductive impairment in Forster's terns could not be indisputably linked to exposure to PCBs and dioxins; the weight of evidence suggested that the problems of the Forster's terns were caused by these chemicals, but other causes could not be completely ruled out.[18]

Efforts have been made to prove cause-and-effect relationships through controlled laboratory experiments. A series of laboratory tests have shown that the chemicals introduced into the Great Lakes environment over the past half-century disrupt normal functioning in cells of animals. These chemicals are associated with a number of reproductive, neurological, immunological, and carcinogenic effects and with abnormal sexual development. The utility and applicability of laboratory tests are limited, however, as they do not simulate the complex species interactions and environmental influences of natural ecosystems nor can they account for such factors as adaptability or pre-exposure to a toxicant. In addition, the effects of a toxicant in the environment depend upon concentration and chemical form. The effect of a toxicant on an organism in the field is determined by a complex suite of abiotic and biotic factors such as pH, temperature, alkalinity, suspended solids, dissolved oxygen, and the presence or absence of specific types of bacteria.

The analysis of how various toxicants affect wildlife is further confounded by the fact that different chemicals produce different types of toxic effects. Some metals produce similar toxic effects among many different groups

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[16] Dourson, Michael L., and J. Milton Clark. op. cit.

[17] Great Lakes: Great Legacy?, pp. xx and 131.

[18] Great Lakes: Great Legacy?, pp. 133 - 135.

of animals (e.g., mercury is neurotoxic in fish, birds, and mammals), while other inorganic stressors produce different toxic effects in different animal groups (e.g., selenium is teratogenic in birds but does not appear to cause similar abnormalities in mammals).[19] Although it has been difficult to prove that a specific chemical causes a specific effect on a given species, scientists have been able to combine laboratory tests and field observations to make some strong associations.

Toxicity Assessment

Five general categories of impact may be observed in the Great Lakes Basin resulting from point and nonpont source discharges: oxygen-demand from BOD discharges, eutrophication from nutrient discharges, microbiological contamination from viral and bacterial discharges, toxic impacts from organic and inorganic constituent discharges, and heat impacts from thermal discharges.

1. Oxygen Demand:
Oxygen demanding materials are usually described by biochemical or chemical oxygen demand (BOD and COD, respectively). They act on aquatic systems by removing oxygen from the water column either through chemical oxidation (COD) or, most likely, by biological and chemical means (as measured by BOD). Lack of oxygen leads to decreased survival of fish, zooplankton, and macroinvertebrates. As with culturally induced eutrophication a more or less permanent shift in the structure of the ecosystem occurs until the causal agents are removed and the system has an opportunity to return to its natural state.

2. Eutrophication:
Nutrients typically refer to various compounds of nitrogen and phosphorous. Their effect is a stimulation of growth in algae. Such increased growth allows the dominance of less desirable forms of algae, leads to increased turbidity in the water column, and unless controlled, leads to culturally induced eutrophication. Such eutrophication is a vicious cycle of intense algal production, progressive deoxygenation of bottom sediments and then the water column, and ultimately, severe shifts in the natural ecosystem to one dominated by a few species of pollution tolerant organisms.

3. Microbiological contamination:
Microbial pathogens are associated with municipal sewer systems and nonpoint runoff that has been contaminated with septic system waste or waste from animal feeding operations.

5. Heat:
The discharge of heated water from power plants and primary metals manufacturing can cause significant local effects. Aquatic life can be absent from the area because it is simply too hot for them to survive. Shifts in the composition of fish and insect communities can occur so that the natural system is replaced by heat tolerant species. For example, gizzard shad has been observed to overwinter in cold water areas due to the localized heat supplied by such discharges.

5. Toxics:
Inorganic toxicants include heavy metals such as lead, cadmium, mercury, copper and zinc; and other inorganic compounds such as cyanide or dissolved solids. There are numerous toxic effects of these compounds, including

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[19] ICF Incorporated, 1988. Ecological Risk Assessment Documents Produced for Pennsylvania Comparative Risk Project. Chapter II.G., p. 3.

death, impairment of reproductive processes, and changes in plankton, fish and macroinvertebrates. The particular effect depends on the concentration of the toxicant and can be affected by the chemistry of the water bodies: some metals are less toxic in harder water. Ecosystem effects may include minor impacts such as a small change in species diversity (as measured by standard indices that consider the number and richness of species as well as the number or individuals) or major impacts such as loss of certain types of species previously suited to the habitat. Once released into the environment, these compounds partition in bottom sediments, the water column or biological organisms.

Ecosystem-level effects of toxics include:

- reduced primary and secondary productivity;
- loss of top carnivores;
- changes in community composition; and
- modification of nutrient cycling.

The effects of heavy metals in the environment depend on their concentrations and chemical form(s). The chemical form(s) of metals are determined by complex suites of both abiotic and biotic factors including pH, electrical-chemical potential, salinity, alkalinity, the presence of other metals and ligands, dissolved oxygen, and the presence or absence of specific types of bacteria. Toxic compounds that are persistent, such as metals, and that bioaccumulate can have serious adverse effects on species at high trophic levels (e.g., trout) despite low environmental concentrations. Exhibit G-11 lists EPA acute and chronic Ambient Water Quality Criteria (AWQC) and bioconcentration factors for arsenic, cadmium, lead, and mercury. These toxicity values indicate that cadmium, lead, and mercury can produce adverse effects at low environmental concentrations.

Exhibit G-11
Toxicity Reference Values for Aquatic Species for Metals

Metal	EPA Acute Freshwater AWQC (ug/L)	EPA Chronic Freshwater AWQC (ug/L)	Bioconcentration Factor Log(BCF)
Arsenic III	360[a]	190[a]	1.2
Arsenic V	850	48	1.2
Cadmium	3.9[*]	1.1[*]	3.6
Lead	82[*]	3.2[*]	3.4
Mercury	2.4	0.01	3.4

[a] Data insufficient to develop an AWQC. Value listed is a lowest observed effect level.
[*] Criterion is hardness dependent. Value listed is based on 100 mg/L.

Sources: U.S. EPA. 1986. Quality Criteria for Water. and U.S. EPA. 1979. Water-Related Fate of 129 Priority Pollutants.*

Concentrations of toxics in Great Lakes fish are well documented. Exhibit G-12 shows 1987 samples of lake trout show trends in PCB concentrations for Lake Michigan Lake Trout over a twelve year period. PCB concentrations

for Lakes Superior, Huron, Erie and Ontario far exceed acceptable levels outlined by the Great Lakes Water Quality Agreement objective of 0.1 ppm. Organic toxicants, such as PCBs, dioxins, pesticides[20], solvents, chlorination products from municipal sewage treatment plants, and other synthetic organic compounds, have effects similar to the inorganic toxicants discussed above. In addition, many of these compounds can bioconcentrate in an organism and biomagnify through the food web. For example, a zooplankton can bioconcentrate the ambient concentration of PCBs 500 times during its life.[21]

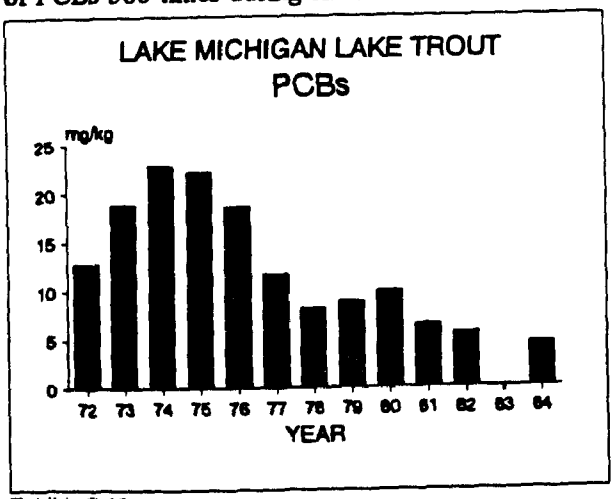

Exhibit G-12

There is growing evidence of the impacts of toxics on wildlife. Piscivorous waterbirds, such as herring gulls and cormorants, have proven to be a reliable, sensitive, indicator for detecting toxic effects and ecosystem changes.[22] The eggs of a herring gull, a piscivore in the Great Lakes ecosystem, show a biomagnification of 25 million times the ambient concentration of PCBs.[23] Thus these compounds have the ability to exert effects in predators even when the ambient water concentration is very low. Predators, even those that are extensively terrestrial, can suffer reproductive disorders, behavioral abnormalities and other ill effects induced by these compounds.

One of the most demonstrable toxic effects is from the Lake Ontario ecosystem where Gilbertson reported on the severe reproductive failure of Scotch Bonnet Island herring gull colonies.[24] Gilbertson reported a low breeding success value of 0.12 fledged young per adult mating pair. This is about one-tenth the success rate for herring gulls found along the New England coast. On the same island in 1973, Gilbertson and Hale found that, on average, only 16 percent of the eggs hatched. The mean breeding success was 0.06 fledged young per adult pair. Gilbertson found the shells of Scotch Bonnet island herring gull eggs thin and highly contaminated (PCBs over 800 ppm and DDE over 200 ppm). These values were the highest found for gull eggs on the Great Lakes and, when compared to more remote colonies in the Gulf of St. Lawrence (14 ppm DDE) and the Bay of Fundy (32 ppm DDE), emphasize the magnitude of contamination in specific areas.

Teeple assessed the breeding failure of herring gulls on Brothers Island in eastern Lake Ontario.[25] On average, only 23 percent of the eggs laid eventually hatched, and the breeding success ranged from 0.06 to 0.18 fledged young per adult pair. Further study by Fox et al.[26] found reproductive failure of herring gulls in the Great lakes was mostly

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[20] The ecological effects of pesticides are addressed in problem area L.

[21] Draft Problem Area Paper, "Municipal, Industrial, and Nonpoint Source Discharges to Surface Waters," page 7, Region 5 Comparative Risk Project, 1990.

[22] Region II summary of problem area impacts on the Lake Ontario Basin.

[23] Ibid.

[24] Gilbertson, M. 1974. "Pollutants in Breeding Herring Gulls in the Lower Great Lakes." Can. Field-Naturalist. 8:273-280.

[25] Teeple, S.M. 1977. "Reproductive Success of Herring Gulls Nesting on Brothers Island, Lake Ontario in 1973." Can. Field-Naturalist. 91:148-157.

[26] Fox, M.E., Carey, J.H. and D.G. Oliver. 1983. "Compartmental Distribution of Organochlorine Contaminants in the Niagara River and the Western Basin of Lake Ontario." J. Great Lakes Research. 9:287-294.

restricted to Lake Ontario. To a degree, the situation has improved. By 1977-78, Weseloh reported the breeding success of the Scotch Bonnet Island colonies to have improved from 1.01 to 1.1 fledged young per adult pair.[27]

Birth defects have been found in double-crested cormorant populations in Green Bay and Saginaw Bay. Crossed beaks and yolk sacs hanging outside of unborn embryos have occurred in this and other piscivorous species.[28] Since 1986, researchers have found deformities in more than 1 of each 100 cormorant chicks born on islands in Green Bay.

Exposure Assessment

The Great Lakes contain approximately 20 percent of the fresh water on our planet. There are nearly 88,000 square miles of surface area associated with Lake Superior (31,700 square miles), Lake Huron (23,000 square miles), Lake Michigan (23,300 square miles), and Lake Erie (9,900 square miles). Hydraulic retention times in the individual lakes range from a high of 200 years in Lake Superior, to a low of 2.6 years in Lake Erie. The ability of the lakes to purge themselves of pollution, therefore, varies dramatically. The Great Lakes contain a vigorous sport fishery, although it is supported by an extensive program of introducing nonresident species, such as Coho salmon in certain areas. The lakes and their shores are especially sensitive to nutrient enrichment, impacts from toxic compounds and oxygen depletion. Bioconcentration and biomagnification of toxic organics present a threat to non-aquatic species such as mink, gulls, and bald eagles.

Some improvements in ecological impacts have been noticed in the Basin. There is clear evidence that the levels of some problem toxics in Lake Ontario biota have been reduced over the past two decades. Levels of PCBs, mirex, DDT and metabolites, dieldrin and hexachlorobenzene in herring gull eggs taken from colonies on Lake Ontario during the period from 1974 to 1986 show significant declines. Levels of PCBs in lake trout, brown trout, and coho salmon collected since 1975 show significant declines.

There is evidence that mercury loadings from industrial sources may be decreasing, while concentrations of mercury at many locations within the Basin are actually increasing, possibly due to atmospheric deposition. This potentially signifcant trend should be considered a high priority. Recent trends in mercury are addressed in Appendix H.

By contrast, the trends in levels of mirex in lake sportfish are not clear. A major concern remains, however, that problem toxics, such as mirex, in Lake Ontario biota may be stabilizing at unacceptably high concentrations. Although toxics concentrations in Lake Ontario appear to have declined over the past decade, reductions are no longer occurring at the rate they have in the past. Current reductions in toxic loading may not be sufficient to sustain corresponding reduction in toxics concentrations. Bioaccumulation, atmospheric deposition, runoff, and resuspension of toxics from contaminated sediments are continuing sources of concern.[29]

Ecological Risk Characterization

There are approximately 4600 miles of Great Lakes shoreline in the Basin. 320 miles (7%) are identified as fully supporting their designated uses in the 1990 305(b) reports, 990 miles (22%) are identified as partially supporting

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[27] Weseloh, D. et al. 1979. "Organochlorine Contaminants and Trends in Reproduction in Great Lakes Herring Gulls, 1974-1978." Trans. 44th N.A. Wildlif. Nat. Resources Conf. 543-557.

[28] Behm, Don, "Bird defects warn humans," page 7 in "The Great Lakes: A Toxic Tragedy," The Milwaukee Journal, 1989.

[29] Region II summary on problem area impacts in the Lake Ontario Basin.

uses, and 3290 miles (71%) are identified as not supporting designated uses.[30] This unique ecosystem is severely disrupted in those areas where the designated uses are not being attained. Native species are often absent, or those that are present are subject to unacceptable levels of other stresses such as reproductive or behavioral abnormalities. Where uses are being partially supported, the long term viability of the system is threatened. In both cases, the timeframes for recovery is extended. Decades to centuries may be required for the systems to recover once the stressors are removed or controlled.

Nutrients are identified as the second most widespread influence on the shoreline areas. Eutrophication has also been a concern since algae blooms began to choke the lakes in the mid 60s and Lake Erie was pronounced dead in the 70s. Presently all of the lakes which receive discharges from the Basin meet the in lake target for phosphorous, the material that effectively controls the production of algae. Lake Erie is the warmest, shallowest and most productive lake and still is threatened by culturally induced eutrophication. At present, that threat is of low severity, as controls are in place that ensure that effects will be marginal, if all other factors such as water levels and atmospheric temperature remain more or less constant. Reversibility of the damage is medium to high based on the experience of phosphorous control in the past and the relatively low hydraulic residence time.

An increase in sodium levels has also been observed over the past 15 to 20 years in the Lake Michigan basin. Cultural uses of sodium, such as the use of road salt for clearing roads in the winter, are major sources. Such increases represent additional ecological risks to the Basin. Increased sodium concentrations favor the growth of blue-green algae, and may enhance eutrophication by stimulating phosphorus transport into algal cells.[31]

While the health of the organisms at the upper end of the food chain depends on the stability of populations at the lower end, little is known about the potentially significant effects of toxic contamination on organisms such as phytoplankton and zooplankton. Although it is known that these organisms are generally sensitive to toxicants, the ability to predict the effects of a toxicant on natural communities is confounded by a variety of physical and biological factors.

Generalizations about the health of animals at the top of the food chain are based mainly on individual studies of specific species or populations and on data from programs that monitor particular species of fish and herring gulls. An analysis of the combined results of these studies summarized several trends and convergences. The table shown below, which was adapted from Great Lakes: Great Legacy?, by the Conservation Foundation and the Institute for Research on Public Policy, summarizes reports in the scientific literature on the state of wildlife populations, focusing on identifiable health effects.

Population, Organism, and Tissue Effects Found in Great Lakes Organisms

Species	Populat. Decline	Reprod. Effects	Eggshell Thinning	Wasting	Birth Defects	Tumors	Target Organs	Immune Suppress.	Behavioral Effects	Generational Effects
Bald eagle	X	X	X	X						X
Black-crowned night heron	X	X		X	X					

[30] These numbers should be considered approximate. 305 (b) reports contain several discrepancies. Because these reports cover statewide water conditions, they may not accurately reflect Great Lakes conditions.

[31] Guerra, Bruna, Paul Horvatin, Vacys Saulys, and David Dolan, "Lake Michigan Sodium Mass Balance and Projections for Future In-Lake Sodium Concentrations," U.S. EPA, August, 1985, p. 2.

Caspian tern	X	X		X	X		X		X	X
Chinook/coho salmon	NA	X	NA			X	X			
Common tern	X			X			X	X	X	
Double-crested cormorant	X	X	X	X	X		X		X	X
Forster's tern	X	X	X	X	X		X		X	X
Herring gull	X	X	X	X	X		X	X	X	X
Lake trout	X	X	NA	X					X	X
Mink	X	X	NA	X			X			
Osprey	X	X	X							
Otter	X		NA							
Ring-billed gull	X		X	X			X			
Snapping turtle	X	X		X	X		X			X

X = Observed effects that have been reported in the literature. Cells not marked do not mean there is not effect; only that no citation was found.
NA = Not applicable.

Summary of Effects:

Population Decline and Reproductive Effects. Scientists have found that animal species at the upper end of the Great Lakes food chain have shown occasional and, in some cases, long-term reproductive problems and/or population declines since the 1950s. The affected species, including birds, mammals, and fish, all derive sustenance from animals in the Great Lakes food chain.

Eggshell Thinning. It is well-documented that organochlorines cause eggshell thinning in many fish-eating birds. In fact, the only specific chemicals to which a cause-and-effect relationship in wildlife has been assigned unequivocally are DDT and its decay product, DDE which have been shown to cause eggshell thinning. Elevated concentrations of DDE and other residues have been found in the eggs of several Great Lakes fish-eating bird species.

"Wasting". Several species showed changes in fat metabolism and disposition of body fat. A condition termed "wasting" was reported in extreme circumstances. Animals in this condition appear lethargic, lose their appetites, and eventually die. In some cases, emaciated and dead birds with low body fat and high concentrations of organochlorines have been found.

Birth Defects. Species of mammals, reptiles, birds, and fish in the Great Lakes basin have also shown significantly more birth defects than control populations with less exposure to toxic contamination. For example, some chicks in colonies of double-crested cormorants were born with deformed bills such that they were not able to feed themselves. Other birth defects seen in double-crested cormorants and other bird species include club feet, shortened appendages, missing eyes, absence of brains, major organs developing outside the body, and edema.

Tumors. An unusual number of facial tumors have been reported in various fish species that dwell in the Great Lakes, such as the brown bullhead, a bottom feeding catfish. Extensive research has shown that liver tumors also

develop in fish in the presence of carcinogens and carcinogen-containing sediments. In addition, tumors have been found in whales that reside in the estuary of the St. Lawrence River.

Target Organ Damage. Target organ damage, as opposed to systemic damage, occurs in specific organs such as the thyroid, liver, kidney, or brain. One study, for example, examined thyroid damage to herring gulls in the Great Lakes and postulated that the cause was environmental contaminants. Another study found that porphyria, a liver condition, is aggravated by the presence of organochlorine chemicals.

Immune Suppression. Immune suppression, or the lowering of an organism's ability to withstand disease, has been found to occur in both the common tern and the herring gull.

Behavioral Effects. The literature also suggests that behavioral changes in species may be attributed to toxic chemicals. Abnormal behavior such as female/female pairing of herring gulls, lake fry swimming upside down, and nocturnal abandonment of nests by terns have been associated with exposure to toxicants.

Generational Effects. The literature implies that, for some species, stress on parents, such as exposure to chemical contaminants, affects the health of an embryo or newborn. These effects include metabolic, hormonal, and target-organ changes that are manifested by "wasting", abnormal development, and immune suppression.

Welfare Impacts

Economic damage due to discharges to surface waters include costs from human health effects, losses in commercial and recreational fisheries, and other costs from impaired uses. Because of the lack of quantitative data on many of these costs, quantified economic damages are based on estimated annual cancer cases.

Risks from point sources result from release of both conventional and hazardous materials into surface waters. Economic damages can occur at levels permitted under the NPDES system, but are more likely when permitted levels are exceeded. Risks are greatest where receiving waters provide the least dilution and dischargers are clustered, enhancing cumulative "down stream" impacts.

Health Costs

Human health risks and related economic damages are associated with direct and indirect contact with polluted receiving waters. In the preceding analysis, we estimated 30,000 potential cancer cases over 70 years resulting primarily from ingestion of contaminated Great Lakes Basin fish. To estimate costs associated with these cancer cases, we multiplied the estimated number of cancer cases by the direct medical cost and foregone earnings per cancer case:

(Annual Cancer Cases)(Direct Costs & Forgone Earnings) = Health Costs

These estimated direct and indirect medical cancer costs are based on a range of cost per case estimates. The lower bound estimate, based on Hartunian, et al., is $80,000, while the upper bound estimate developed by the American Cancer Society is $137,000. These estimates provide differing values for foregone earnings and medical costs associated with cancer treatment. Both estimates are weighted average costs associated with all types of cancers. Neither of these estimates, however, take into account the value of individual pain and suffering associated with cancer and should, therefore, be considered partial economic damage estimates. They also depict costs over a 70 year time period.

Lower bound estimate

HC=(30,000)($80,000)=$2.4 billion (1988 $)

Upper bound estimate

HC=(30,000)($137,000)=$4.11 billion (1988 $).

Non-Health Costs

Estimating non-health economic damage due to surface water pollution entails describing the effects of water pollution on numerous services that society receives from surface water. Quantitative data are not currently available to support estimates of the damage caused by surface water pollution to these services. The services include:

- freshwater recreation;
- water storage;
- navigation;
- irrigation;
- freshwater recreational and commercial fishing;
- drinking water supply;
- industrial water use; and,
- steam power cooling.

In lieu of quantitative damage information, fish advisories can succinctly summarize water quality problems in the Basin, and the effects those problems have had on commercial and recreational fisheries. Exhibit G-13 provides a summary of fish advisories issued by State agencies in Wisconsin, Michigan, and Illinois. Fish advisories fall into three groups, depending upon the amount of health risk involved with eating the fish. Advice to the public differs by group:

- Group 1: Contaminant levels in 10% or less of fish tested are higher than one or more health standards. Eating fish from this group poses the lowest health risk. Advise is to trim fat and skin before cooking and eating.

- Group 2: Contaminant levels in more than 10% but less than 50% of the fish tested are higher than one or more health standards. Nursing mothers, pregnant women, and women who intend to have children should not eat Group 2 fish. Overall consumption of Group 2 fish should be limited. Trim skin and fat from these fish before eating them.

- Group 3: Contaminant levels in 50% or more of tested fish are higher than one or more health standards. No one should eat Group 3 fish.[32]

[32] Descriptions of health advice is taken from Wisconsin Department of Natural Resources, Wisconsin Division of Health's "Health Advisory for People Who Eat Sport Fish from Wisconsin's Waters," October, 1989.

The exhibit shows that there are numerous fish advisories in these states. In fact, all Great Lakes have health advisories on the consumption of some Great Lakes fish. Recent reports indicate that these fish advisories are insufficient protection to human health for those who frequently consume sport fish.[33] However, there are no quantitative data that fully describe the true economic impact of these advisories of recreational fishing and fish consumption.

While these advisories, if followed, may limit the human health risks discussed above, they indicate a considerable welfare impact from contamination of the Lakes. Fishing advisories began on Lake Ontario in 1970 with the discovery of bioaccumulated mercury and DDT. Later, additional advisories were imposed with the discovery of bioaccumulated PCBs, dioxin, and mirex. In 1976, a very unpopular ban was placed on the possession and stocking of seven Lake Ontario species -- it was lifted in 1978. There are no data on the impact these bans had on consumption of Lake Ontario fish.

The decline in valuable commercial fisheries exemplified by the fish advisories has affected a number of communities on the Great Lakes. By the 1960s, New York's reported commercial harvest was only 7 percent of the maximum recorded in 1879.[34] As a result, recreational fishing now dominates use of Lake Ontario fisheries resources. Both recreational and commercial fishing currently make a significant contribution to local and state-wide economies. In 1982, recreational fishing expenditures were valued at approximately $47 million; commercial fish values for 1983 were reported at $184,000. The total value of direct and indirect economic activities of the U.S. Great Lakes fishery has been increasing since the 1970s, and as of 1989, is valued at $3.3 billion.[35] This major economic activity is at obvious risk.

Several sources report a decline in the Great Lakes fishery. However, this decline cannot be presently attributed to any single factor. Those factors which do affect the fishery may include loss of spawning habitat, overfishing, competition between species, introduction of exotic species, and toxic impacts. No information was available to allow a determination of the effect of toxic biomagnification and resulting fish advisories on the fishing industry. At various times, however, several States have insitituted bans on certain fish consumption.

Exhibit G-13
Fish Advisories in Wisconsin, Illinois and Michigan

I. Wisconsin	Fish Species		
	Group 1	Group 2	Group 3
Lake Michigan	Lake trout up to 20" Coho salmon up to 26" Chinook salmon up to 21" Brook trout Rainbow trout Pink salmon	Lake trout 20-23" Coho salmon over 26" Chinook salmon 21 to 32" Brown trout up to 23"	Lake trout over 23" Chinook salmon over 32" Brown trout over 23" Carp Catfish

[33] Michael L. Dourson and J. Milton Clark, op cit.

[34] Region II summary of problem area impacts in the Lake Ontario Basin.

[35] Great Lakes Fishery Commission. 1989. "The Report of the Evaluation of the Great Lakes Fishery Commission by the Bi-National Evaluation Team: an analysis of the economic contribution of the Great Lakes sea lamprey program." p. 6.

	Smelt Perch		
Green Bay south of Marinette and its tributaries	Rainbow trout to 22" Chinook salmon up to 25" Brook trout up to 15" Smallmouth bass Northern Pike up to 28" Perch Walleye up to 20" Brown trout up to 12" Bullhead White sucker	Splake up to 16"	Rainbow trout over 22" Chinook salmon over 25" Brown trout over 12" Brook trout over 15" Splake over 16" Northern Pike over 28" Walleye over 20" White bass Carp
Lake Superior	Lake trout up to 30"		Lake trout over 30"

IL Illinois	Fish Species		
	Group 1	Group 2	Group 3
Lake Michigan	Lake trout up to 20" Coho salmon up to 26" Chinook salmon up to 21' Brook trout Rainbow trout Pink salmon Smelt Perch	Lake trout 20-23" Coho salmon over 26" Chinook salmon 21-32" Brown trout up to 23"	Lake trout over 23" Chinook salmon over 32" Brown trout over 23" Carp Catfish

IIL Michigan		Fish Species	
		Restrict Consumption	No Consumption
Lake Huron		Brown trout up to 21" Lake trout Rainbow trout	Brown trout over 21"
Saginaw Bay		Rainbow trout Brown trout	Carp Catfish
Lake Superior		Lake trout 20-30"	Lake trout over 30"
Lake Michigan		Lake trout 20-23" Coho salmon over 26" Chinook salmon 21-32" Brown trout up to 23"	Rainbow trout over 23" Chinook over 32" Brown trout over 23" Carp and Catfish
Green Bay		Splake up to 16"	Brook trout over 15" Rainbow trout over 22' Chinook salmon over 25" Brown trout over 12" Splake over 16" Northern pike over 28" Walleye over 20"

		White bass Carp
Lake Erie		Carp Catfish
Lake St. Clair	Walleye over 20" White Bass over 12" Smouth. Bass over 14" Yellow Perch over 12" Carp over 22" Rock Bass over 8" Black Crappie over 10" Lmouth. Bass 12-14" Bluegill and Pumpkinseed over 8" Freshwater Drum over 14" Carpsucker over 18" Brown Bullhead over 10" Northern Pike over 22"	Largemouth bass over 14" Muskie Sturgeon Catfish over 22"
St. Clair River	Gizzard Shad over 10"	Carp
Detroit River		Carp

Apportionment of Risk

As mentioned above, most risks resulting from surface water contamination cannot be differentiated from among industrial, municipal, atmospheric or other nonpoint sources. Differences in source proportions from lake to lake, and from harbor to harbor, further obfuscates any attempt at lakewide apportionment of risks. However, while current techniques for the apportionment of risk among these problem areas face significant uncertainties, it nevertheless helps to conceptualize source proportions in order to analyze the wide-ranging methods necessary for reduction of those risks. This study uses a rough apportionment technique and hypothetical results to underscore not only the difficulty in determining sources, but also the need for accurate knowledge of those sources, where real reductions of contaminant loadings begin.

The principal sources of PCB contamination in the Great Lakes will be associated with the greatest human health risks. Sources of PCBs in the environment are varied. While sediments are a known sink for PCBs throughout the Great Lakes, the contribution of PCBs from these sources to fish concentration levels is unknown. This potential source is considered in a following problem area. In many other areas of the Great Lakes, atmospheric deposition appears to be a main PCB source. The percent contribution of PCBs to the Lakes from atmospheric deposition is:

	Super.	Mich.	Huron	Erie	Ontario
percent PCBs from atmospheric dep.[36]	90	58	78	13	7

[36] IJC. 1987. "Summary Report of the Workshop on Great Lakes Atmospheric Deposition." presented at Windsor, Ontario. October 1987. p. 14. See footnote 45 for discussion of accuracy.

Weighting these atmospheric contributions by the populations of the individual lake basins yields a Great Lakes Basin-wide PCB population exposure proportion from air deposition of 38 percent.

Few data are available to differentiate among the remaining contaminant load sources to the Great Lakes Basin. As presented in Exhibit G-14 below, those data that are available tend to focus on phosphorus and other nutrient load. Because of the higher nutrient content in agricultural nonpoint source and municipal point source discharge, these data may not adequately represent many organic and inorganic toxic constituent loads. Limited data estimating load by source for these other constituents are available for selected areas in the lakes.

Exhibit G-14[37]
1986 Approximate Phosphorus Loadings to the Great Lakes

	tons/year	percent
industrial	250	1
municipal	3800	16
atmospheric	2260	9
nonpoint	18,120	74

In terms of PCB load to the Great Lakes, data collected for the St. Clair River[38] in Michigan provide some indication of the relative importance of the various source terms. The data in Exhibit 15 illustrates that although nonpoint sources still predominate PCB load in the St. Marys River, municipal and industrial sources are more important sources than estimated for phosphorus load.

Exhibit G-15
Approximate PCB Load by Source for the St. Clair River

	PCB load (g/day)	Percent Contribution
Industrial point source	0.3	5
Municipal point source	2.5	41
Urban nonpoint source[39]	3.2	54

Exhibit G-16 presents data describing polycyclic aromatic hydrocarbon (PAH) load to St. Marys River. These data illustrate that the contribution of toxic organic constituents from industrial point sources may still be a significant source in certain Great Lakes watersheds. While the relatively high concentration of industrial sources on the St.

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[37] IJC. 1989. "Report on Great Lakes Water Quality."

[38] "Upper Great Lakes Connecting Channels Study." 1988. p. 258.

[39] Nonpoint source load estimate derived from ratio of point source to urban nonpoint source load of 0.86 from Marsalek, J. and H.Y.F. Ng. 1987. Contaminants in Urban Runoff in the Upper Great Lakes Connecting Channels Area. Environment Canada, National Water Research Institute. NWRI #87-112. As reported in "Upper Great Lakes Connecting Channels Study." 1988.

Marys River signify that this load distribution across sources may be somewhat anomalous,[40] these data are reported to illustrate the diversity in load distributions across the Basin.

Exhibit G-16[41]
Approximate PAH Load to the St. Mary's River

Point Source	kg/day	percent[42]
industrial	1.25	48
municipal	0.42	16
tributary	0.05	2
Nonpoint Source		
urban	0.65	26
atmospheric	0.25	8
rural	NA	-

In sum, the data reported in the above three exhibits illustrate the difficulties in apportioning contaminant load across the various sources within the Basin. Nevertheless, for the purposes of this analysis and based on load data reported for the other connecting channels, the Niagara River, and other Great Lakes tributaries, it is apparent that nonpoint sources and municipal point sources are significant sources of toxic organic and inorganic constituent load to the lakes. While this conclusion may not hold for all toxic constituents, the source load proportions described for the St. Clair River and the St. Marys River serve as the basis for a preliminary allocation of the non-atmospheric human health risk estimates to the industrial, municipal, and nonpoint (rural and urban) source problem areas. The toxic constituent load allocations are as follows:

Source	Load percentage
industrial point source	16
municipal point source	18
nonpoint source	28
atmospheric load	38[43]

[40] The St. Mary's River has about seven point sources on the Canadian side. These sources are not subject to the same level of control that they would be in the U.S. portion of the Basin. This increases the uncertainty involved in using such distributions as overall estimates of loadings. The U.S. side of the river is largely rural.

[41] "Upper Great Lakes Connecting Channels Study." 1988.

[42] Percentage of reported sources.

[43] The Basin-wide percent contribution of PCBs from atmospheric deposition was calculated by taking a population-weighted average of the five values. Specifically, each lake's percent contribution was multiplied by the fraction of the total Basin population that resides in that lake's basin. The product of percent contribution and population fraction was summed for each of the five lakes to derive the Basin-wide estimate.

This distribution across source terms will differ for nutrient or total suspended solid load to the lakes by placing greater emphasis on nonpoint sources. Furthermore, this allocation does not account for contaminated sediments or spills as significant sources of toxic constituents. Based on this distribution, Exhibit G-17 provides an apportionment of potential cancer cases (drinking water/prior to treatment* and fish consumption) and welfare costs for industrial and municipal point source discharges, nonpoint source loadings, and atmospheric deposition.

* See preceding section on Drinking Water Consumption under headings of Risk Characterization, Cancer Risks.

Exhibit G-17

Hypothetical Apportionment of Risk to Surface Water Loadings

Source	Potential Cancer Cases/Year Drinking Water Prior to Treatment (Upper Bound Estimates)	Potential Cancer Cases/Year Fish Consumption (Upper Bound Estimates)	Welfare Impacts/Year Fish Consumption (Upper Bound Estimates)
Industrial Point	0.16	69	$ 9 Million
Municipal Point	0.17	77	$10 Million
Nonpoint	0.27	120	$16 Million
Atmospheric	0.34	163	$22 Million
Totals**	0.96	430	$59 Million

** Reflects 95% C.L. for cancer potency slopes

H. MUNICIPAL POINT SOURCE DISCHARGES TO SURFACE WATER

Problem Area Description

This problem area addresses contaminant load and surface water quality impairment resulting from discharges from municipal point sources. These point sources include discharges from publicly-owned treatment works (POTWs) and privately-owned wastewater treatment facilities that manage domestic waste. A significant portion of the wastewater stream entering these treatment facilities may come from industrial indirect dischargers, such as electroplaters, chemical blenders, or pulp and paper manufacturers. As a result, the status of industrial pretreatment programs in the Basin are reviewed as part of this analysis. Finally, this section includes a discussion of impacts from combined sewer overflows (CSOs), which have been recognized as a significant source of urban stormwater and municipal wastewater overflow discharge.

Because many surface water impacts, such as toxics bioconcentration in sport fish, cannot be differentiated from among industrial, municipal, and nonpoint source discharges, human health impacts from fish consumption and oral water intake are discussed in the previous Section G. In that section, the risk derived from this problem area is differentiated by estimating the proportion of total contaminant load discharge to the Basin accounted for by municipal sources.

Magnitude of the Problem

The risks to human health and the environment posed by municipal point sources are a function of the pollutants discharged by these sources, the number of sources in the Basin, and the total pollutant load attributable to this problem area. In addition, the States have recognized CSOs as an additional source of concern in many of their surface waters. These CSO-related impacts are discussed separately.

Pollutants of Concern

A variety of pollutants are discharged from municipal point sources. These substances are generally categorized in two broad classes: conventional and non-conventional or toxic pollutants. The conventional pollutants include those substances that are associated with domestic waste, such as biochemical oxygen demand (BOD), total suspended solids, phosphorus, and nitrogen compounds.

Non-conventional pollutants include toxic substances that may be indirectly discharged from industrial facilities or, to a lesser extent, as part of household hazardous waste disposal. These toxic substances include metals, volatile organic compounds, and other halogenated organics. The International Joint Commission (IJC) reports that, as of 1985, the predominant toxic substances being discharged to the Great Lakes from municipal point sources included zinc, lead, chromium, copper, nickel, and cyanide. In addition, the IJC reports that greater than 50 tonnes/year of several organic compounds were discharged in 1985, including phenol, ethylbenzene, tetrachloroethane, and tetrachloroethylene.[42] Furthermore, although the IJC estimates that less than one ton of PCBs is discharged from municipal point sources per year, this substance poses a substantially greater risk than other compounds (see discussion of PCB risks under Sections G and K). Therefore, PCB discharges may often pose a greater risk than

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[42] Municipal Pretreatment Task Force/International Joint Commission. 1989. A Review of Pretreatment Programs in the Great Lakes Basin.

Note: The IJC reports that the discharge concentration values should be regarded as "order-of-magnitude" estimates.

larger volume discharges of other toxic substances.

Controlling these toxic substance discharges is primarily accomplished through pretreatment programs which require indirect dischargers to reduce toxic concentrations in their effluent. Pretreatment programs were designed to address four concerns within the sewage treatment system: interference with the effective operation of the system; pass through of toxic contaminants to receiving waters; contamination of municipal sludge by toxic substances; and exposure of treatment plant workers to chemical hazards. As of 1989, the IJC reported that over 95 percent of the pretreatment programs at individual United States Great Lakes municipalities were approved by U.S. EPA. Nonetheless, the IJC found that although the framework for an adequate pretreatment program is in place, further resources at the municipal and State level are necessary to adequately track and enforce pretreatment programs. In addition, the failure of some municipal governments to prosecute pretreatment program violators should be rectified, and multijurisdictional variances in requirements and procedures among municipalities resolved.[43]

Number of Municipal Sources and Pretreatment Programs

There are 314 major municipal dischargers in the Basin who discharge approximately 6.91 billion gallons of treated wastewater per day. In addition, approximately 2729 minor municipal dischargers are found within the Basin.[44]

Under 40 CFR Part 403, all POTWs or combination of POTWs operated under the same authority with total design flows of greater than five million gallons per day must establish a pretreatment program as a condition of the National Pollutant Discharge Elimination System permit for the municipal point source. As of 1988, 192 approved programs were in place for dischargers within the Basin. The number of indirect dischargers covered under the programs varied. For example, New York reported that, within the entire State, pretreatment programs in 56 municipalities were in place which affected more than 1,500 indirect dischargers. Wisconsin reports approximately 450 indirect dischargers are regulated under its program.[45]

Pollutant Loadings in the Basin

The load of conventional pollutants in the U.S. portion of the Great Lakes Basin is tracked through regular reporting to EPA's Permit Compliance System (PCS). The average annual discharge flow and mass loading of BOD and nitrogen-ammonia from municipal point sources in each of the five lake basins for 1990 is as follows:

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[43] Great Lakes Water Quality Board/International Joint Commission. 1989. 1989 Report on Great Lakes Water Quality.

[44] U.S. EPA Permit Compliance System data.

[45] Municipal Pretreatment Task Force/International Joint Commission. 1989. A Review of Pretreatment Programs in the Great lakes Basin.

Exhibit H-1 - 1990 Municipal Mass Loading

	Annual Flow (million gallons)	BOD[46] (kilograms)	Total Phosphorus (kilograms)	Nitrogen-Ammonia (kilograms)	Total Mercury (kilograms)
Lake Erie	1,008,127	35,877,087[47]	10,361,012	25,757,489	116
Lake Huron	79,623	3,211,858	193,711	379,030	5
Lake Michigan	376,467	12,859,317	717,284	4,044,107	259
Lake Ontario	59,248	15,045,421	570,841	27,637	16
Lake Superior	23,247	763,894	52,433	48,232	0
Basin Total	1,546,713	67,757,579	11,895,283	30,256,497	396

The above summary (Exhibit H-1) addresses loadings to each of the Lakes from municipal point sources. The data indicate that Lake Erie receives both the greatest volume of municipal point source discharge, and the largest BOD, phosphorus and nitrogen-ammonia mass load. This is largely because the Detroit WWTP, the single largest municipal discharger in the Great Lakes basin, discharges to the Lake Erie basin. Lake Michigan receives the second greatest discharge volume and mass load of BOD, phosphorus and nitrogen, as well as the greatest mercury load. Lake Superior appears to receive the lowest level of discharges.

The annual loading of selected toxic pollutants to the Great Lakes from Canadian and U.S. municipal point sources was estimated by the IJC based on data drawn from a sample of POTWs. These data were used in conjunction with a predictive model and estimates of contaminant removal efficiencies achievable in different treatment plant designs to estimate concentrations of selected contaminants in raw sewage, treated effluents, and municipal facility sludges. These Basin-wide estimates are as follows in Exhibit H-2.

Overall, the volume of conventional pollutant loadings to the Basin exceed the volume of non-conventional or toxic pollutant loadings. Nonetheless, loadings of toxic constituents may foster more severe impacts on human health and ecological receptors within the Basin.

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[46] represents loads from facilities reporting either carbonaceous BOD or BOD 5-day.

[47] The Nitrogen-ammonia loading totals for Lake Erie include a reported mass load of 21,654,155 kilograms from the Detroit River basin.

Exhibit H-2[46]

	% of Total Release via Effluent	% of Total Release via Atmosphere	% of Total Release via Sludge Disp.	Total Release (tonnes/yr)
Arsenic	66%	NS	34%	19
Cadmium	76%	NS	24%	26
Chromium	49%	NS	51%	640
Copper	43%	NS	57%	30
Cyanide	73%	NS	27%	89
Lead	59%	NS	41%	580
Mercury	44%	NS	56%	3
Nickel	79%	NS	21%	130
Zinc	51%	NS	49%	1300
Benzene	61%	39%	NS	2
Toluene	45%	55%	NS	42
Ethylbenzene	31%	69%	NS	55
Chloroform	70%	30%	NS	34
Tetrachloro-ethylene	36%	64%	NS	76
Trichloro-ethylene	58%	42%	NS	26
1,1,1-trichloroethane	49%	51%	NS	76
Hexachloro-benzene	NS	25%	75%	<1.0
PCBs (total)	50%	NS	50%	<1.0
Phenol (total)	94%	NS	6%	85

NS = not significant

[46] Municipal Pretreatment Task Force/International Joint Commission. 1989. A Review of Pretreatment Programs in the Great Lakes Basin, p. 3.

Significance of Combined Sewer Overflows in the Basin

An additional source of municipal effluent in the Basin is derived from CSOs. Combined sewer overflows may discharge a variety of contaminants collected in urban stormwater runoff, as well as conventional and toxic pollutants that by-pass municipal wastewater treatment during periods of peak stormflow. The precise impact of CSO discharges on Basin-wide water quality is unknown at this time. However, in a 1981 study, the IJC Task Force on Urban Drainage and Combined Sewer Overflows concluded that the loadings of BOD and phosphorus from urban drainage and overflows in a municipality were about an order of magnitude less than loadings from a wastewater treatment plant serving the same municipal area. With the decline in municipal point source loadings brought about by improving treatment processes throughout the 1980's, the loads from CSOs may have become more significant.[49]

Despite this lack of precise information on Basin-wide impacts, there is evidence that CSOs may have a significant effect on Great Lakes water quality. For example, in the 1990 Water Quality Inventory Reports prepared by the Basin States under Section 305(b) of the Clean Water Act, the States report that at least 39 miles of Great Lakes shoreline have experienced major impairment and at least 368 miles have experienced moderate or minor impairment from CSO discharges.[50] In total, the eight Basin States reported that 1,834 river and stream miles and 153,102 acres of inland lakes have undergone major impairment from CSO discharges.[51]

The local significance of CSO impacts may also vary regionally. For example, the City of Sault Ste. Marie, Michigan has a combined storm and sanitary sewer system with ten CSOs. A study completed in 1978 indicated that there were no adverse impacts from these CSOs on river water quality, although the presence of the CSOs suggests the likelihood of sporadic stormwater loadings.[52] In contrast, CSO loadings to the Detroit and Rouge Rivers have been found to be significant. There are 188 CSO outfalls on the Rouge River and 243 CSOs discharging to the Detroit River either through direct discharge or through tributaries.[53] In the 1970s, Detroit CSOs accounted for 13 percent of the total phosphorus, 15 percent of the suspended solids, 21 percent of the oil and grease, 25 percent of the cadmium, 29 percent of the chromium, 20 percent of the copper, 32 percent of the lead, 96 percent of the mercury, and 34 percent of the total PCB loading to the Detroit River.[54] CSO loadings to the Niagara River watershed have also been found to be significant. The 16,000 foot long Falls River tunnel was constructed in the early 1900s as a combined sewer for Niagara Falls, New York. It later became a major contributor of toxic load to the Niagara River. In 1985, the City eliminated dry-weather sanitary and industrial flows to the tunnel; however, because the tunnel is unlined, stormwater continues to be discharged directly to the Niagara River.

Human Health Impacts, Ecological Risks, and Welfare Effects

For a discussion of health, ecological and economic risks see Section G.

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[49] Great Lakes Water Quality Board/International Joint Commission. 1989. 1989 Report on Great lakes Water Quality, p. 29.

[50] The reader should note that these figures may significantly underestimate Great Lakes shoreline impairment, as only four Basin States - Michigan, New York, Ohio, and Pennsylvania - reported Great Lakes impairment data.

[51] These totals include all areas of the State, both inside and outside the Great Lakes Basin.

[52] U.S. Environmental Protection Agency and Environment Canada. 1988. Upper Great lakes Connecting Channels Study, p. 170.

[53] Personal communication, John Haugland, U.S. EPA/Region V; and U.S. Environmental Protection Agency and Environment Canada. 1988. Upper Great Lakes Connecting Channels Study, p. 513.

[54] Ibid.

FLOW FROM MAJOR MUNICIPAL AND INDUSTRIAL DISCHARGERS

SELECT COUNTIES
881001-910228

FLOW, IN CONDUIT OR THRU TREATMENT PLANT
81401144
REVISED GREAT LAKES LOAD DATA FOR BILL WARD
MEASUREMENTS REPORTED IN MILLION GALLONS

Source: Permit Compliance System, 1991

BOD LOADS FROM MAJOR MUNICIPAL AND INDUSTRIAL DISCHARGERS

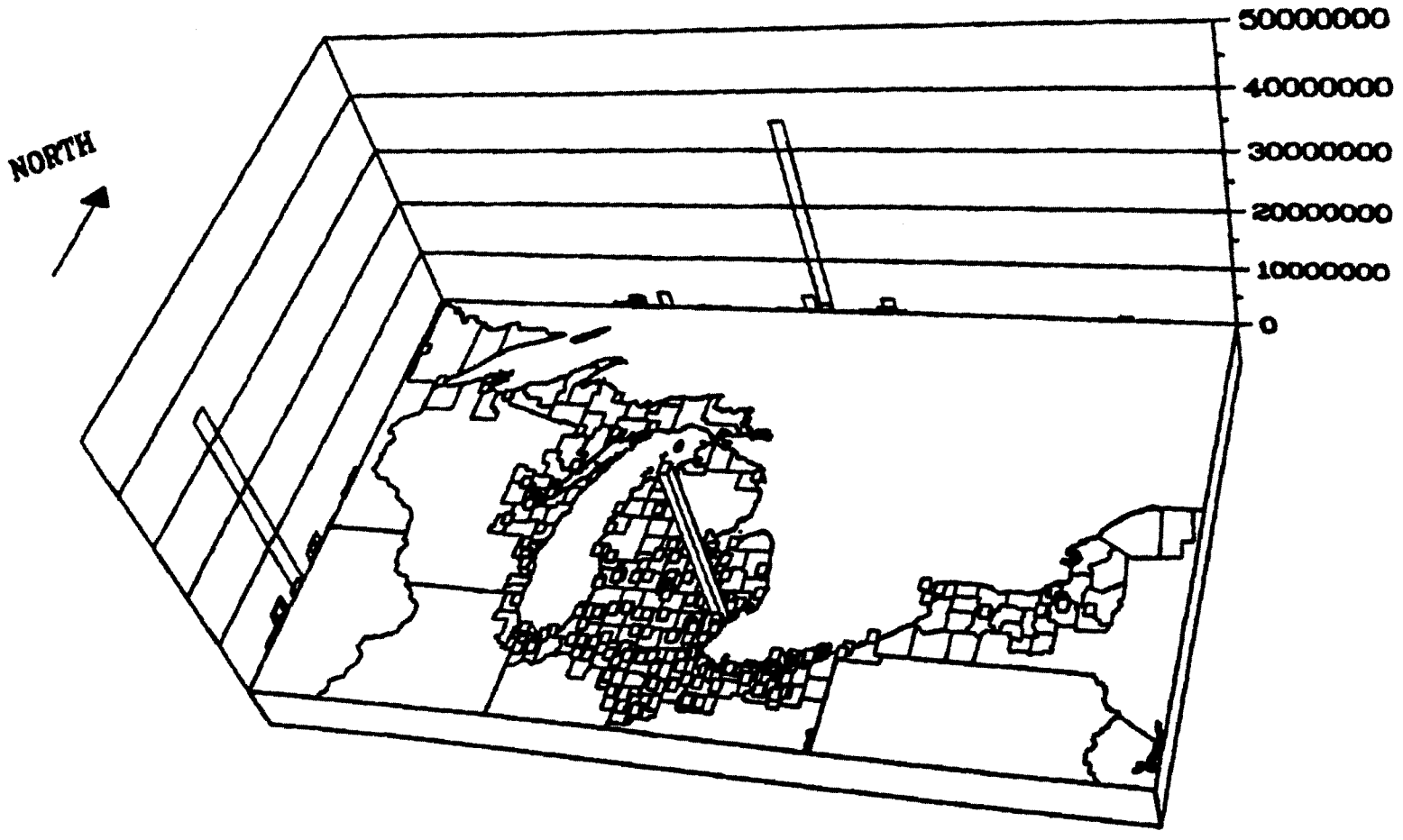
SELECT COUNTIE
881001-9102

BOD, 5-DAY (20 DEG. C) 91401144
REVISED GREAT LAKES LOAD DATA FOR BILL WARD
MEASUREMENTS REPORTED IN KILOGRAMS

Source: Permit Compliance System, 1991

AMMONIA LOADS FROM MAJOR MUNICIPAL AND INDUSTRIAL DISCHARGES

SELECT COUNTIES
881001-910228



NITROGEN, AMMONIA TOTAL (AS N)
881001&4
REVISED GREAT LAKES LOAD DATA FOR BILL WARD
MEASUREMENTS REPORTED IN KILOGRAMS

Source: Permit Compliance System, 1991

I. NONPOINT SOURCE LOADING TO SURFACE WATERS

Problem Area Description

This problem area addresses contaminant load and surface water quality impairment from nonpoint sources. Where possible, environmental degradation resulting specifically from such sources is addressed. However, as noted previously, many surface water impacts, such as pesticide bioconcentration in sport fish, cannot be differentiated from among industrial, municipal, nonpoint, and atmospheric load sources. As a result, human health impacts from fish consumption and drinking water intake are discussed in Problem Area G, Industrial Point Source Discharges to Surface Waters. The risk specifically accounted for by nonpoint sources is differentiated there by weighting the risk by the total contaminant load attributed to nonpoint sources in the Basin.

As defined in this section, nonpoint sources include agricultural runoff and urban runoff which is not discharged through a Combined Sewer Overflow or POTW outfall. Loading from atmospheric deposition is addressed in Problem Area J. In addition, surface water contamination through ground water discharge is discussed in Aggregated Ground Water, Problem Area T.

Magnitude of the problem

Under Section 319 of the Clean Water Act, the States were required to prepare assessments of the magnitude and impact of nonpoint source pollution in their waters. Overall, nonpoint sources were found to be a significant source of surface water contamination in the Basin States. For example, New York reports that 80 percent of the surface waters classified as impaired are affected by nonpoint sources.[55] The following discussion outlines the 319 findings for portions of the Great Lakes Basin found in three States: New York, Michigan, and Minnesota.

New York assessed nonpoint source impacts for the six main drainage basins within the Great Lakes watershed.[56] The results for each of these basins are summarized below:

- The Lake Erie-Niagara River drainage basin drains 2300 square miles of eastern New York, including the metropolitan areas of Buffalo and Niagara Falls. This basin contains the largest concentration of heavy industry in the State and over 50 percent of the Basin contains agricultural land. Eighty-eight stream miles and about 180 acres of surface waters are impaired by nonpoint sources in this basin, with the majority of impairment regarded as moderate. The significant nonpoint sources identified in this basin include on-site wastewater systems, urban runoff, and streambank erosion.

- The Lake Ontario drainage basin drains approximately 2450 square miles and includes the Syracuse and portions of the Rochester metropolitan areas. Six stream miles, 33 acres of inland lake, and about 5130 square miles of Great Lakes bays are impacted by nonpoint sources. In addition, 3560 square miles of Lake Ontario are moderately impaired by contaminated sediments. The major nonpoint sources in this Basin are agricultural runoff, on-site wastewater systems, and inactive landfills. Landfills are addressed in the waste problem areas.

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[55] Note: The nonpoint sources identified by New York State include sources addressed in other problem areas in this Report, such as atmospheric deposition and contaminated sediments.

[56] New York State Department of Environmental Conservation. February 1989. Nonpoint Source Assessment Report.

- The Genessee River Basin flows across the width of western New York and drains into Lake Ontario. This Basin contains portions of the Rochester metropolitan area, but the majority of the Basin is characterized by rural-agricultural land use. Sixty-five stream miles and 670 acres of inland lakes are stressed, threatened, or impaired. The predominant nonpoint sources in this basin are agriculture, on-site wastewater systems, and landfills.

- The Seneca-Oneida-Oswego drainage basin drains about 5120 square miles in central New York, and includes some 200 square miles of inland lakes. Agriculture is the major land use in the basin followed by woodlands. Approximately 91,900 acres of inland lakes are impaired by nonpoint sources, with the predominant source being agriculture. In addition, 54 stream miles are impaired by agriculture, urban runoff, and landfills. Much of this impairment is judged to be severe.

- The Black River basin drains an area of about 1900 square miles, with much of the basin being heavily forested and sparsely populated. Acid rain is regarded as the dominant cause of impairments in this basin, with over 5,000 acres of lakes severely impacted. The impairments range from poor fishing to low fish propagation and survival rates. On-site wastewater systems and agricultural runoff are also identified as sources in this basin.

- The St. Lawrence River Basin drains almost 5540 square miles of forested, sparsely populated land. Acid rain is judged to be severely impairing approximately 160 inland lakes in this basin, with impairments ranging from low fish propagation to poor survival rates. On-site wastewater systems are also regarded as a problem in this basin.

The State of Michigan's Nonpoint Source Assessment Report indicates that over 80 percent of the State's 297 watersheds are impacted by nonpoint sources.[57] The predominant nonpoint sources of concern include septic systems, streambank erosion, agricultural erosion, construction, animal wastes, agricultural fertilizers, and urban runoff. With regard to impacts in the Great Lakes, Michigan reports that persistent toxic substance loading from nonpoint sources is a growing concern. Toxics loading from stormwater discharges has been documented in the State, but the impact on the open lakes is unclear. Michigan also regards phosphorus loading as an important concern in the Basin and identifies conservation tillage as a proven technique to control phosphorus loading from agricultural.

Minnesota's Nonpoint Pollution Assessment Report identifies agricultural runoff, animal feedlots, pesticide and fertilizer application, urban runoff/infiltration, construction, on-site sewage systems, hydrologic modifications, forestry mining runoff, highway runoff, and special erosion problems as important nonpoint sources of pollution.[58] The northern lakes and forest ecoregion of the State contains much of Minnesota's Great Lakes drainage basin. This region contains approximately 5550 lakes, most of which are 100 to 550 acres in size. Although the great majority of the lakes in the region either fully support or partially support swimmable uses, 15 lakes were regarded as not supporting their uses. Ten of these lakes are reportedly impacted by pockets of agriculture, feedlots, pasturing near the waterbodies, on-site septic systems, and ditching which may affect the quantity and quality of runoff to the lake.

In addition to these findings, studies conducted at Heidelberg College, Ohio, show that rural nonpoint source pollution in the Lake Erie basin delivers not only large sediment loads through area rivers, but also both particulate and soluble phosphorus derived from agricultural sources. Also, nitrate concentrations from agricultural runoff

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[57] Michigan Department of Natural Resources. November 1988. Michigan's 1988 Nonpoint Pollution Assessment Report.

[58] Minnesota Pollution Control Agency. September 1988. Minnesota Nonpoint Source Pollution Assessment Report.

frequently exceed drinking water standards in basin rivers.[59]

In sum, the impact of nonpoint sources appears to vary across the Great Lakes Basin with greater impacts associated with areas encompassing more intense agricultural land use, urban development, and residential land use relying on on-site wastewater disposal systems. As demonstrated in the above States, agricultural runoff is recognized as a major nonpoint source of nutrient loading to surface waters. Exhibits I-1 and I-2 show the relative distribution of cultivated cropland and of cropland erosion by section of the Basin. Exhibits I-3 and I-4 show the relative Distribution of pastureland and pasture erosion by those same watersheds. I-5 depicts the geographical distribution of highly erodable land.

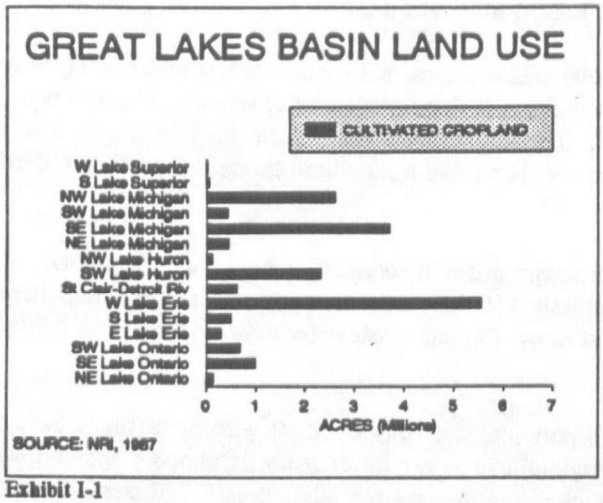


Exhibit I-1

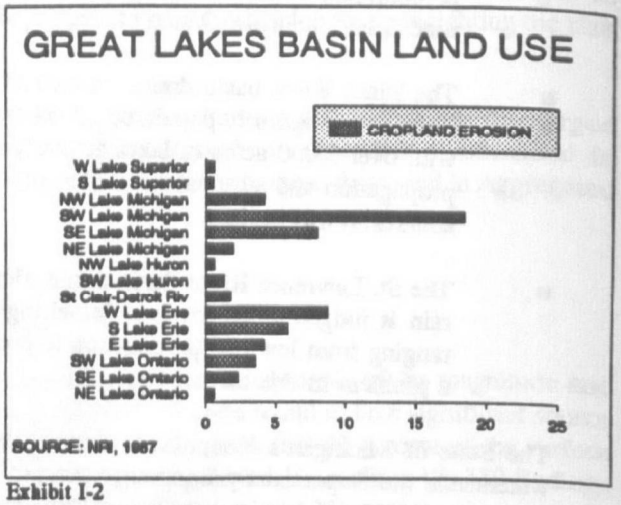


Exhibit I-2

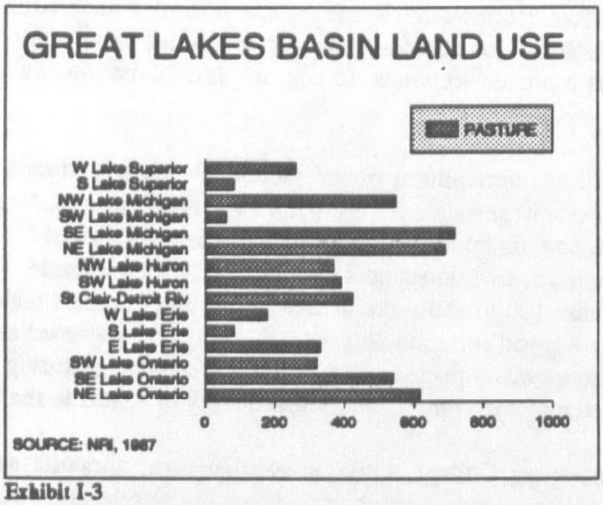


Exhibit I-3

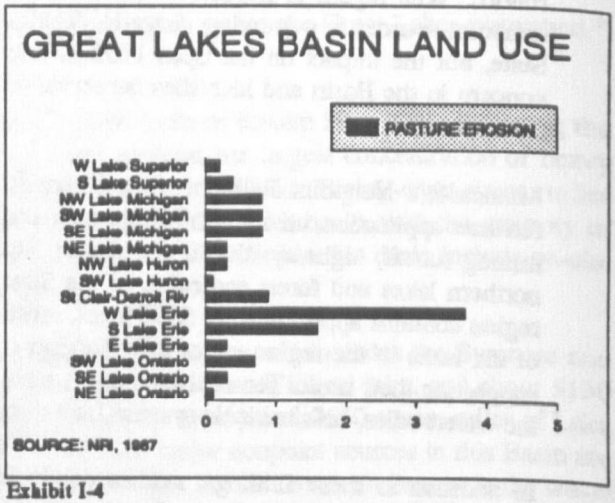


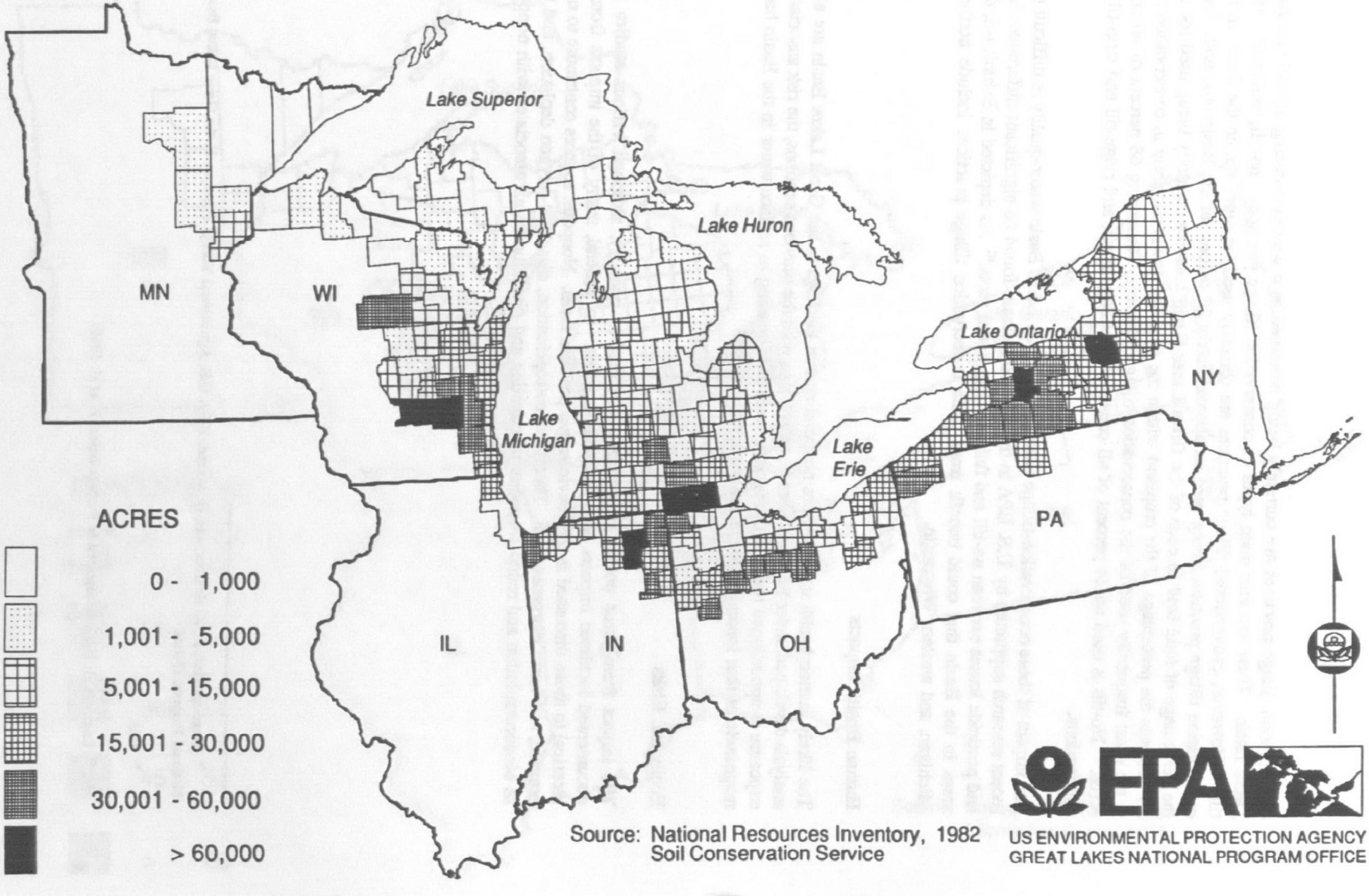
Exhibit I-4

[59] Baker, D.B., "Overview of Rural Nonpoint Pollution in the Lake Erie Basin," Logan, Terry J., et al., eds., Effects of Conservation Tillage on Groundwater Quality: Nitrates and Pesticides, chapter 4, Lewis Publishers, Inc., Chelsea, MI, 1987, p. 81.

Exhibit I-5

TOTAL HIGHLY ERODIBLE LAND

Great Lakes Basin Counties



Source: National Resources Inventory, 1982
Soil Conservation Service

EPA

US ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

Conservation tillage practices are currently being promoted as a way of reducing agricultural runoff in the Great Lakes Basin. There are four main types of conservation tillage practices: no-till, mulch-till, ridge-till, and strip-till.[60] However, conventional tillage practices are currently used far more within the Basin than nationally, with conservation tillage practices being used on approximately 27 percent of the Basin cropland. Exhibit I-6 presents the percentage of total land in each of the Great Lakes Basin counties currently being used for cropland. Exhibit I-7 presents the percentage of the cropland within the counties that is currently in conservation tillage. Mulch-till is the most frequently used of the conservation tillage practices, accounting 68 percent of all conservation tillage acres.[61] No-till is used on 24 percent of all conservation tillage acres, and ridge-till and strip-till have only minor applications.

The impact of these conservation-tillage practices on Great Lakes Basin water-quality is difficult to judge; however, recent research supported by U.S. EPA in the Lake Erie Basin found no significant differences in runoff, tile flow, and pesticide losses between no-till and fall plowing on test plots.[62] As depicted in Exhibit I-8, the corn-producing areas in the Basin that could benefit from these conservation tillage practices include northern Ohio, western Michigan, and western Wisconsin.

Human Health Impacts

The likely human health impacts from nonpoint source loadings to the Great Lakes Basin are also based upon the analysis developed under Problem Area G, above. As with the previous sections, the risk associated to contaminants exposure is apportioned there to the various sources of loading to surface water in the Basin based on the relative magnitude of that loading for selected toxic substances.

Ecological Risks

The impact from these pollution sources is difficult to quantify, although various studies in the Basin have documented localized impacts from nonpoint sources. In general, many of the impacts from these sources are identical to those discussed in the previous two problem areas. Nonpoint sources contribute to nutrient, BOD, toxic organic, and toxic inorganic load. Therefore, eutrophication, dissolved-oxygen depletion, and toxic impacts, such as bioaccumulation and reduced species propagation and diversity are all associated with nonpoint sources.

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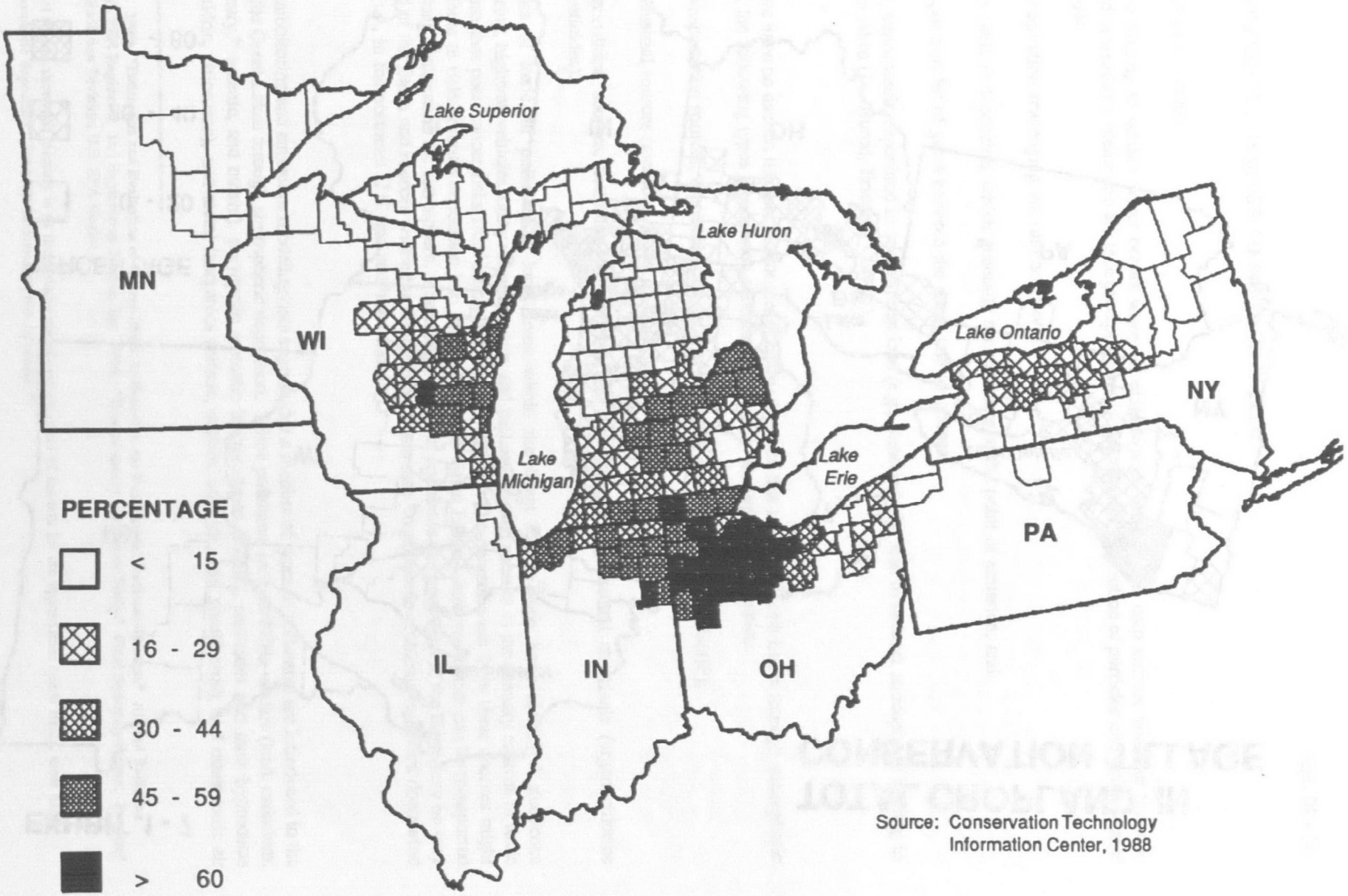
[60] Praskevicius, P., K. Schroer, and B. Manne. 1989. U.S. Agricultural Tillage Practices in the Great Lakes Basin, 1988. Great Lakes National Program Office.

[61] Ibid.

[62] Logan et al. 1989. as reported in Praskevicius, P. et al. 1989.

EXHIBIT I-6

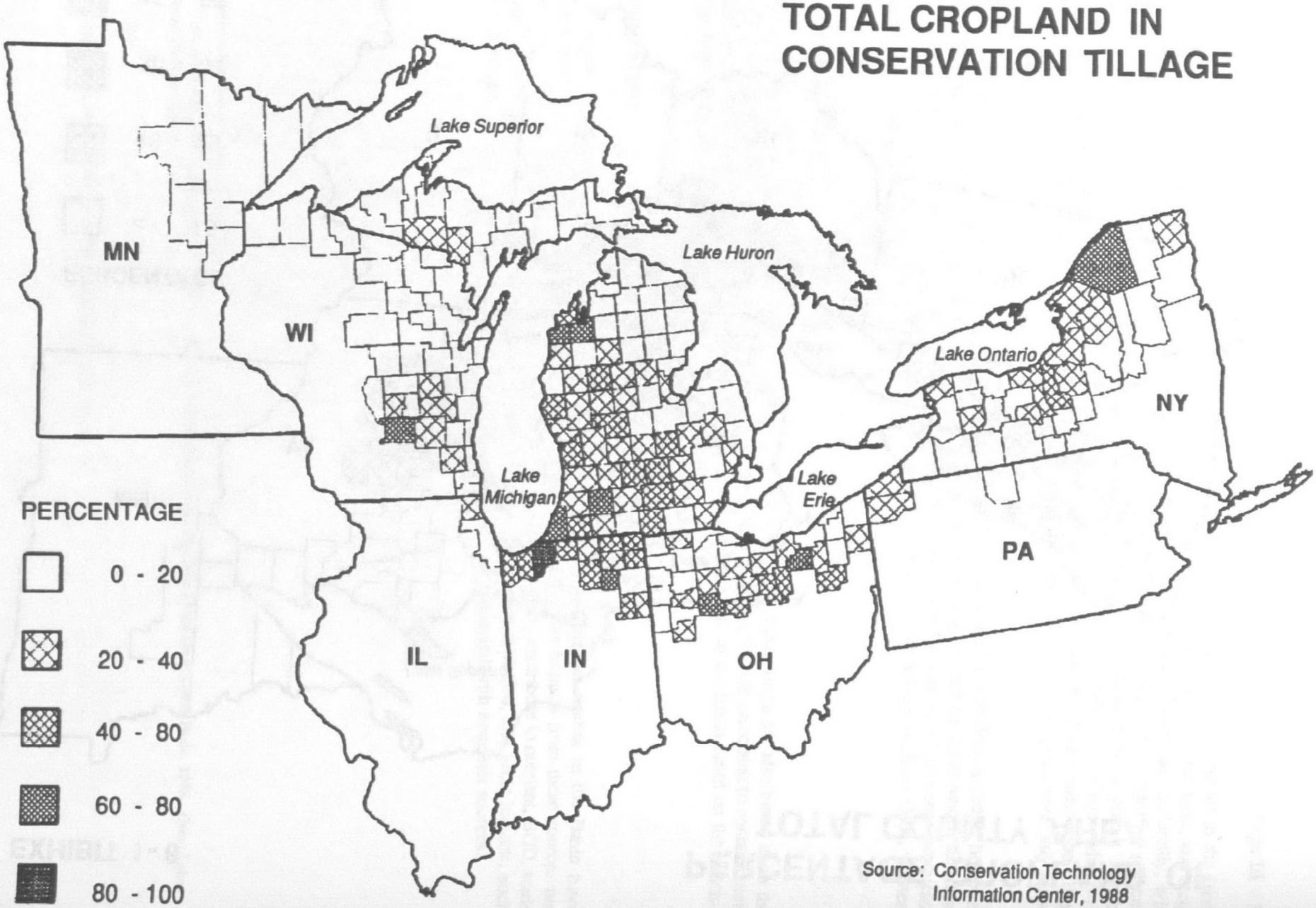
PERCENTAGE CROPLAND OF TOTAL COUNTY AREA



Source: Conservation Technology Information Center, 1988

EXHBIT I - 7

TOTAL CROPLAND IN CONSERVATION TILLAGE



Source: Conservation Technology Information Center, 1988

J. ATMOSPHERIC LOADINGS TO SURFACE WATER

Problem Area Description

Atmospheric loading to surface water occurs when air emissions of toxics settle onto surface water or become incorporated in weather systems and are then precipitated out. Atmospheric deposition of particles and gases occurs in three ways:

- precipitation scavenging via rain or snow;
- dry particle deposition, which generally occurs closer to the point of emission; and
- vapor transfer of gases between the water and air phases.

In addition, atmospheric deposition in an upstream lake (e.g., Superior) can lead to indirect atmospheric loading in downstream lakes (i.e, Huron, Erie and Ontario).

Sources

Although we have no data on the specific sources of toxic emissions that reach the Great Lakes through atmospheric deposition, the following types of emission sources contribute to atmospheric deposition:

- transportation sources, especially cars, trucks, airplanes, and trains (lead and B(a)P);
- industrial sources (mercury, PCBs, HCB, and mirex); and
- agricultural sources, including volatilization and suspension of agricultural chemicals (organochlorine pesticides).

Two studies of toxic air pollution in local areas within the Great Lakes Basin have identified steel/coke manufacturing, highway vehicles, other manufacturing, and fuel combustion sources as the primary sources of toxic air pollutants that pose cancer risks from inhalation of ambient air.[63] The contaminants from these sources might also contribute to risks through deposition into the waters of the Great Lakes. Airborne toxics can be transported over very long distances in the atmosphere. Therefore, sources of pollutants that pose risks in the Basin may be very far upwind of the Basin and sources within the Great Lakes Basin may contribute to problems in distant downwind locations (i.e., in the northeast U.S. and southeast Canada).

Pollutants

Available monitoring and emissions modeling data suggest that a number of types of pollutants are introduced to the waters of the Great Lakes through atmospheric deposition. These pollutants include PCBs, metals (lead, cadmium, zinc, mercury,[64] arsenic, and others), polycyclic aromatic hydrocarbons (PAHs), pesticides and their byproducts (DDT, dieldrin, chlordane), non-metal inorganics (nitrate, sulfate, chloride, and phosphorus), and other toxic air

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[63] EPA. 1989. "Estimation and Evaluation of Cancer Risks Attributed to Air Pollution in Southeast Chicago." Air and Radiation Division, U.S. EPA Region V; and Engineering-Science, Inc. 1990. "Transboundary Air Toxics Study." Final Summary Report. Prepared for Air and Radiation Division, U.S. EPA Region V.

[64] Recent studies show that mercury is an increasingly significant chemical of concern for the upper Great Lakes Basin, most likely through atmospheric deposition. For more information, see Appendix H.

pollutants (gasoline vapors, coke oven emissions, volatile organic compounds, and others). These toxins can pose human health risks via ingestion of drinking water and contaminated fish and can cause disease or death in fish and other aquatic organisms.

The magnitude of atmospheric loadings to surface water is dependent upon the amount of pollutants released into the air, the direction and speed of atmospheric transport, and the fate of toxins in the atmosphere. A 1988 report on the Great Lakes Atmospheric Deposition network provides the following information on atmospheric fluxes of cadmium and lead to the lakes.[45]

- Monitoring data for 1983 indicate highest deposition rates for cadmium occurring along the central portion of the southern shore of Lake Ontario (near Rochester, NY) and at the far eastern and western ends of Lake Erie (near Buffalo, NY and Toledo, OH, respectively). Except for an area of high cadmium flux in the center of Lake Michigan, cadmium fluxes to the upper Great Lakes are low relative to the fluxes to Lakes Erie and Ontario.

- Monitoring data for 1983 indicate highest deposition rates for lead at the southern end of Lake Michigan (near Chicago, IL and Gary, IN), at the central portion of the southern shore of Lake Ontario (near Rochester, NY), and at the eastern end of Lake Erie (near Erie, PA and Buffalo, NY). Lakes Superior and Huron and the northern end of Lake Michigan receive low fluxes of lead relative to the other areas of the Great Lakes.

A recent modeling study of emissions, atmospheric transport, and deposition in the Southeast Michigan/Windsor area indicates that a number of air pollutants emitted in this area are deposited to Great Lakes waterways in significant quantities.[46] Contaminants deposited in the largest quantities include gasoline vapors, benzene, coke oven emissions, styrene, and perchloroethylene.

In addition to these absolute estimates of contaminant loadings, researchers have estimated the relative importance of atmospheric deposition as a source of contaminants to the Great Lakes. The following table shows the relative magnitude of (1) direct atmospheric deposition of PCBs, lead, and benzo(a)pyrene, (2) indirect atmospheric deposition that is from the outflow flux of upstream Great Lakes, and (3) the remainder of the flux into the Lakes that is assumed to be from non-atmospheric sources. The table illustrates the following points about the relative role of atmospheric deposition of toxics in each of the five lakes.

- The upper Great Lakes of Superior, Michigan, and Huron receive almost all of their influx of PCBs from direct and indirect atmospheric deposition. In contrast, Lakes Erie and Ontario, receive the majority of their PCB inputs from non-atmospheric sources. This difference is due to the importance of industrial sources on the lower lakes and the connecting channels (i.e., the Detroit and Niagara rivers).

- Atmospheric deposition is the dominant input pathway for lead and B(a)P into all the lakes, except for lead inputs into Lake Erie. (Atmospheric lead loadings have markedly decreased over recent years, however, because of government controls resulting in the declined use of leaded gasoline in automobiles.)

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[45] Great Lakes National Program Office. 1988. Great Lakes Atmospheric Deposition (GLAD) Network, 1982 and 1983. U.S. EPA, Chicago, IL. EPA 905 4 88 002.

[46] Op. cit. Engineering-Science, Inc. 1990.

Percent Contribution of Atmospheric Deposition to Contaminant Loadings in the Great Lakes

Lake	PCB Loading by Pathway (Percent)			Lead Loading by Pathway (Percent)			B(a)P Loading by Pathway (Percent)		
	Atmospheric		Non-Atmospheric	Atmospheric		Non-Atmospheric	Atmospheric		Non-Atmospheric
	Direct	Indirect		Direct	Indirect		Direct	Indirect	
Superior	90	0	10	97	0	3	96	0	4
Michigan	58	0	42	99.5	0	0.5	86	0	14
Huron	63	15	22	94	4	2	63	17	20
Erie	7	6	87	39	7	54	66	13	21
Ontario	6	1	93	50	23	27	40	32	28

Source: Summary Report of the Workshop on Great Lakes Atmospheric Deposition, International Joint Commission, Science Advisory Board/Water Quality Board/International Air Quality Advisory Board, October 1987, Windsor, Ontario. (Non-atmospheric loading by difference.)

Most of the toxins of concern are resistant to degradation in the atmosphere, and we do not discuss loss through degradation in the atmosphere. The magnitude of the problem is also affected by the water flux among the Great Lakes, allowing the water contaminated from atmospheric inputs to spread throughout the five lakes.

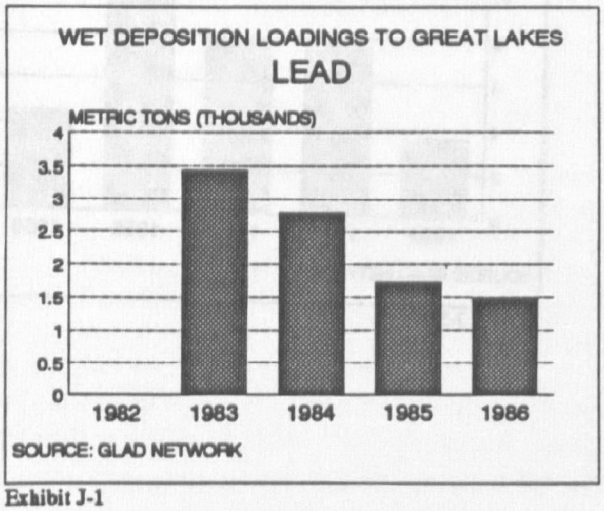

Exhibit J-1

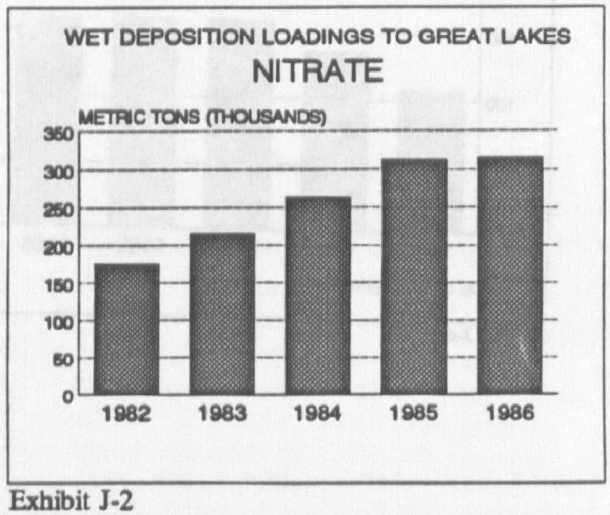

Exhibit J-2

Monitoring data from the Great Lakes Atmospheric Deposition (GLAD) Network provide estimates of the rates of atmospheric loading of metals and some other inorganic pollutants to the waters of the Great Lakes over the years 1982 through 1986. These data for lead, nitrate, sulfate, chloride, and total phosphorus are summarized in Exhibits J-1 through J-5. Other monitoring data provide estimates of the deposition rates of lead, zinc, and chromium into

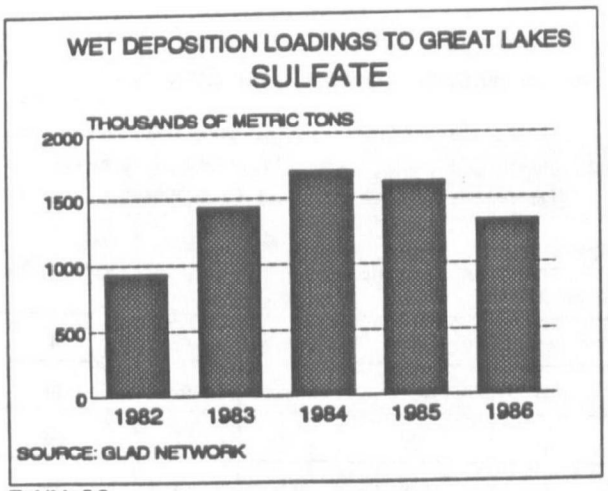

Exhibit J-3

the waters of each of the five Great Lakes.[67] The findings of this study are summarized in Exhibit J-6. This study indicates that total lead loadings from the atmosphere in 1986 range from a low of 153 metric tons in Lake Ontario, to a high of 263 tons per year in Lake Michigan. Zinc loadings (1986) from the atmosphere are estimated to range from 184 netric tons per year in Lake Ontario to 460 metric tons per year in Lake Michigan. This study estimates that cadmium loadings from the atmosphere in 1986 ranged from 2.7 metric tons per year in Lake Ontario to 11.1 metric tons per year in Lake Superior. A 1988 report on the GLAD Network provides the following information on the spatial distribution of atmospheric fluxes of cadmium and lead to the lakes.[68]

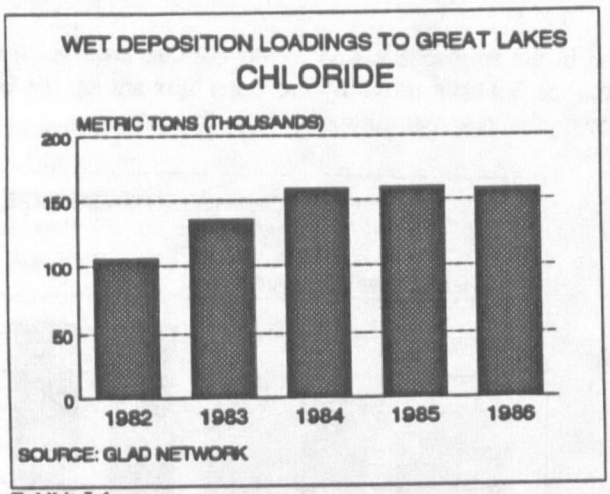

Exhibit J-4

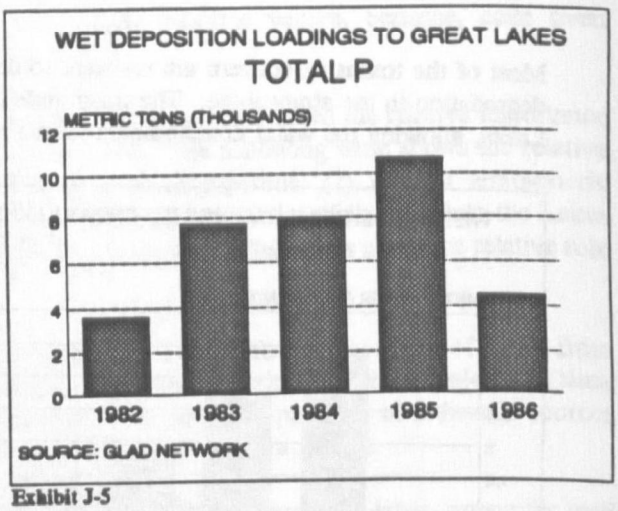

Exhibit J-5

[67] Reid, N.S., Tang A.J.S., Lasis, M.A., Klappenbach, E.W. 1989. "The Deposition of Metals in Ontario." Symposium on Metals Deposition, Air Pollution Control Association, Research Triangle Park, Spring 1989.

[68] Great Lakes National Program Office. 1988. Great Lakes Atmospheric Deposition (GLAD) Network, 1982 and 1983. U.S. EPA, Chicago, IL. EPA 905 4

Exhibit J-6
Estimated Rates of Metal Deposition to the Great Lakes
(1986 data, metric tons)

	Lead	Zinc	Cadmium
Ontario	153	184	2.7
Erie	214	199	3.8
Michigan	263	460	10.0
Huron	244	344	6.8
Superior	204	274	11.1

Source: Reid, N.W., Tang A.J.S., Lusis, M.A., Klappenbach, E.W. 1989. "The Deposition of Metals in Ontario."

For Human health impacts, ecological impacts, welfare effects, see Problem Area G, Industrial Point Source Discharges to Surface Waters.

K. TOXIC SEDIMENTS

Problem Area Description

This problem area is usually considered a component of nonpoint source loadings to surface waters. However, to emphasize the complexity and significance of sediments as both a source and pathway for contamination in the Great Lakes Basin, this section deals separately with this issue. Bottom sediments in a number of areas of the Great Lakes Basin are contaminated with toxic metals, ammonia, and organics. Sediments have been identified as "the major reservoir of pollutants in the Great Lakes system."[69] The toxic sediments problem area addresses the risks to human health and the environment generated by this contamination.

Pollutants that have accumulated in bottom sediments include: lead, mercury, iron, cadmium, chromium, nickel, zinc, barium, copper, phosphorus, arsenic, cyanide, PCBs, polynuclear aromatic hydrocarbons (PAHs), hexachlorobenzene (HCB), chlordane, phenols, DDT and metabolites, phthalate esters, oil and grease.[70] The magnitude of the toxic sediments problem varies with location. In some areas contamination is so severe that sediments have been classified as hazardous and designated for remediation under Superfund (Waukegan Harbor, IL, and Sheboygan, WI.)

Magnitude of the Problem

Of the 31 Areas Of Concern identified in the United States, all have contaminated sediments (For a description of these areas, see Appendix E). In terms of lake-wide contamination, sediment conditions are of greatest concern in Lake Ontario, although specific locations in Lake Michigan and Lake Erie have the highest levels of certain contaminants. Sediments in Lake Superior are the least toxic and contaminant concentrations in Lake Huron, while higher than Lake Superior's, are below those of the lower lakes.[71]

Potential for ecological and human health damage exists due to toxic sediments in the Great Lakes themselves, in connecting channels, and in tributaries. Toxic constituents in bottom sediments are harmful, even lethal, to benthic organisms, aquatic insects, and bottom-dwelling fish. Benthic organisms, in particular, are a food source for higher trophic levels, resulting in transfer of contaminants that bioaccumulate up the food chain (e.g., to fish). This biomagnification creates a potential for human exposure to elevated levels of contaminants through the consumption of fish.

Resuspension of contaminated sediments due to storms, boating, and dredging may also be a source of risk. Sediments are resuspended and distributed by lake currents and turbulence, especially during the winter. The U.S. Army Corps of Engineers is responsible for maintaining navigability in commercial and recreational harbors, channels, and waterways. These maintenance activities require periodic dredging and removal of bottom sediment. Contaminated dredged materials (spoils) have been disposed of in 26 confined disposal facilities (CDFs) throughout the Great Lakes region. The potential of these CDFs to act as contaminant point sources is an ongoing area of investigation. Humans might be exposed to these sediments by a number of routes including: intake through ingestion (especially in children), contact during recreational use of nearshore areas, or drinking tainted water

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[69] International Joint Commission. 1989. "Report on Great Lakes Water Quality". p51.

[70] Sediments are also the primary source of water contamination for radionuclides.

[71] Conservation Foundation. "Great Lakes, Great Legacy?". pp. 102-104.

supplies.[72] Other risks may be created by the inadequate longterm CDF performance, resulting in further bioaccumulation of contaminants through plants and animals in or near CDFs.[73] The physical degradation of water habitats caused by such dredging activities is discussed in Problem Area A, Physical Degradation of Water Habitats and Wetlands.

The U.S. EPA's Great Lakes National Program Office (GLNPO) is responsible for a multi-organization program entitled Assessment and Remediation of Contaminated Sediments (ARCS), scheduled for completion in 1992. The ARCS Program will characterize, sample and map sediment deposits; evaluate sediment toxicity; assess abnormalities and bioaccumulation in fish; assess/model risks and hazards to human health, aquatic life, and wildlife; and evaluate remediation technologies in its five study areas. The ARCS Program will concentrate on five geographic locations: Saginaw Bay, Sheboygan Harbor, the Grand Calumet River, the Ashtabula River, and the Buffalo River.[74] (See Exhibit K-1.) While the results of the ARCS Program should provide much clarification as to the extent of the contaminated sediment problem in the five study areas, data is yet to be released.

Human Health Impacts

This section presents an overview of the potential human health risks posed by contaminated sediments within the Great Lakes Basin. The risk assessment approach described in this paper is drawn primarily from work done by U.S. EPA in a baseline human health risk assessment for the Buffalo River, New York.[75] Study areas for this section were selected to represent sites located across the Great Lakes Basin. In addition, these sites were determined to have sufficient data to at least partially support the risk assessment. All of these study areas have been designated as Areas of Concern. For brief descriptions of these and other AOCs, the reader is referred to Appendix E.

The study areas have all been investigated for the presence of a wide variety of organic and inorganic contaminants in resident fish populations. Nonetheless, previous studies have determined that human health risk from exposure to contaminated sediments fish populations are predominately a function of PCB, and to a lesser extend, DDT, and mercury concentrations. For example, the Buffalo River Baseline Human Health Risk Assessment found that PCB levels accounted for more than 75 percent of the non-carcinogenic risk and more than 95 percent of the carcinogenic risk. The predominance of PCB related risk was also confirmed in the analysis of surface water implants in EPA's Great Lakes Basin Risk characterization study. As a result, this analysis was focused on potential impacts from levels of PCB, DDT, and mercury in the study areas.

The ambient sediment PCB, DDT, and mercury levels in the study areas were determined for this analysis based on data gathered as part of Remedial Action Plan investigation and other ambient water quality studies. In general, the mean sediment concentrations presented in Exhibit K-2 were determined by averaging the most-recent year of available sediment data for all sites sampled within the study areas.

These summary data vary in terms of the number of sites included in the average, the year in which the data were collected, and the reliability of the data as described in the subject reports. Furthermore, no attempt was made to compare the sampling or analytical procedures used to generate the data. As a result, the reliability of the data used

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[72] U.S. EPA, Great Lakes National Program Office. 1990. "Assessment and Remediation of Contaminated Sediments (ARCS) Work Plan". p. 24.

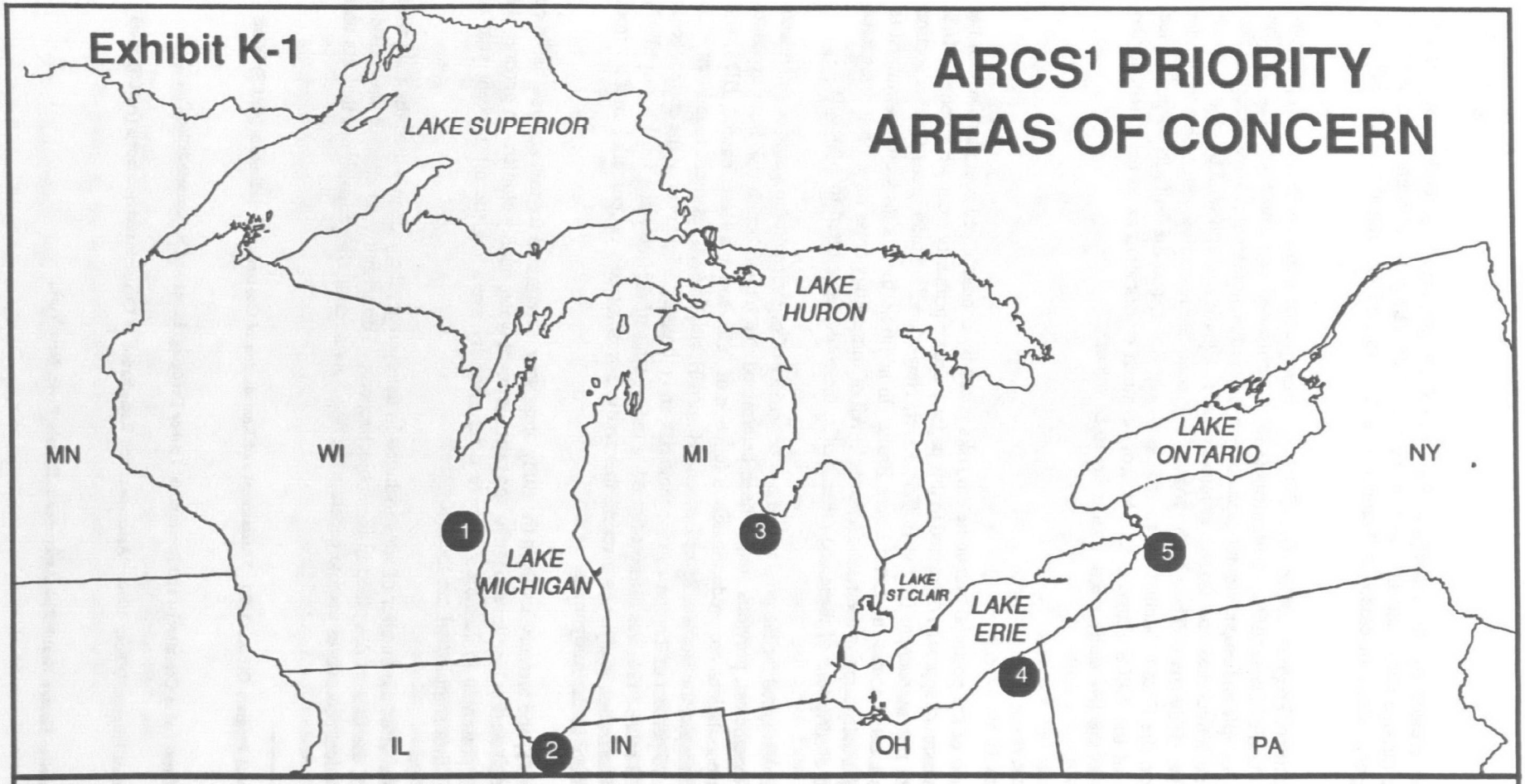
[73] Great Lakes Commission. "Great Lakes Commercial and Recreational Harbor Dredging: Issues and Recommendations".

[74] U.S. EPA, Great Lakes National Program Office. 1990. "Assessment and Remediation of Contaminated Sediments (ARCS) Work Plan".

[75] U.S. EPA, 1990 (Draft). Baseline Human Health Risk Assessment: Buffalo River, New York.

Exhibit K-1

ARCS[1] PRIORITY AREAS OF CONCERN



GREAT LAKES AREAS OF CONCERN

1. SHEBOYGAN HARBOR
2. GRAND CALUMET / INDIANA HARBOR
3. SAGINAW RIVER / BAY
4. ASHTABULA RIVER
5. BUFFALO RIVER

0 50 100 150 200
KILOMETERS

EPA
US ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

[1] Assessment and Remediation of Contaminated Sediments

for the analysis cannot be confirmed.

Exhibit K-2

Representative Sediment Concentrations for Study Areas

	Concentration in Sediment, ppm		
	PCB	DDT	Hg
Buffalo River*[a]	3.8	0.013	1.71
Duluth/St. Louis River[b]	0.15	ND	0.29
Green Bay[c]	3.8	0.020	1.64
Rochester[d]	0.11	0.044	0.22
Saginaw[e]	1.5	ND	0.082
Sheboygan[f]	9.4	ND	0.21

* Reported as 90th percentile sediment concentrations

Sources of Concentration figures

a) U.S. EPA, 1990 (Draft). Baseline Human Health Risk Assessment: Buffalo River, New York.
b) Data report, personal communication, Mr. Frank Snitz, U.S. Army Corps of Engineers.
c) STORET data retrieval, personal communication, U.S. EPA Great Lakes National Program Office.
d) STORET data retrieval, personal communication, U.S. EPA Great Lakes National Program Office.
e) U.S. Army Corps of Engineers, 1988. Report on Saginaw River, Detroit, Michigan.
f) U.S. Army Corps of Engineers, 1988. Remedial Investigation Advanced Screening Report: Sheboygan River and Harbor.

Data summarizing PCB, DDT, and mercury concentrations in carp were also drawn from several different sources. As cited following Exhibit K-3, these sources varied in the number of fish sampled and the year of analysis. Nonetheless, these data represent the best available information concerning contaminant concentrations in fish.

Exhibit K-3

Fish Contaminant Concentrations in Study Areas*

	(ppm)		
	PCB	DDT	Hg
Buffalo River[g]	3.3	0.42	0.12
Duluth/St. Louis River[h]	0.95	-	-
Green Bay[i]	11.42	0.9	-
Rochester[j]	0.70	0.16	0.47
Saginaw[k]	14.0	1.5	0.04
Sheboygan[l]	66.7	-	-

*Whole body concentrations for carp

Sources of Concentrations

g) U.S. EPA, 1990 (Draft). Baseline Human Risk Assessment: Buffalo River, New York.

h) Minnesota Pollution Control Agency and Wisconsin Department of Natural Resources, September 1990 Stage I, Preliminary Draft). The St. Louis River System Remedial Action Plan.

i) Wisconsin Department of Natural Resources, Toxic Substances Management Technical Advisory Committee Report, July 1987. Lower Green Bay Remedial Action Plan.
Source Unknown. "Fish Contaminants - Lake Michigan."

j) U.S. Army Corps of Engineers, 1987. Genesee River/Rochester Embayment Remedial Action Plan.

k) U.S. Army Corps of Engineers, 1990. Information summary, Area of Concern: Saginaw River and Saginaw Bay.

l) U.S. Army Corps of Engineers, 1988. Remedial Investigation Advanced Screening Report: Sheboygan River and Harbor.

Human Health Risk Assessment

This section describes the likely exposure scenarios, exposure concentrations, close-related toxicities, and human health risks associated with the contaminants of concern in the study areas.

Exposure Pathways

Exposure to the hazardous constituents found in contaminated sediments may involve a variety of direct and indirect routes. These direct routes of exposure include dermal contact with sediments and direct ingestion of suspended sediments. Indirect routes of exposure include dermal contact with constituents released from the sediments to the water column, ingestion of such released constituents, and ingestion of fish that have bioconcentrated the constituents. The Buffalo River Baseline Human Health Risk Assessment found that four exposure route were most important to the determination of risk:

1) ingestion of surface water while swimming;
2) ingestion of fish;
3) dermal contact with surface water while swimming; and
4) dermal contact with sediments while swimming.

These four pathways are assessed in this analysis.

Exposure Scenarios

Determining the concentration of a constituent to which an individual may be exposed is a function of the following: 1) the constituent concentration at the point of contact; and 2) the frequency and duration of contract for different age groups.

For the scenarios involving either direct contact with sediments or ingestion of fish, the contaminant concentrations at the point of exposure have already been reported. However, determining exposure to contaminants in the water column requires an estimate of the concentrations of constituents in the water body while at equilibrium with the sediment contaminant "pool." Under this relationship, the concentration of organic contaminants in the water body can be estimated using the following relationship:

$$C_t = C_s/K_d + C_s \cdot TSS$$

where C_s is the sediment concentration (mg/kg), TSS is the concentration of suspended solids (kg/l), and K_d is a partition coefficient. K_d can be estimated using the following relationship:[76]

$$K_d = 0.79 \cdot K_{ow} \cdot f_{oc}$$

where K_{ow} is the octanol:water partition coefficient and f_{oc} is the fraction of organic carbon.[77] For the organic contaminants of concern for this study, the K_{ow} values are as follows:

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[76] Values for K_d, the sediment-water partition coefficient, are determined for a particular contaminant and study site as a function of the organic carbon fraction in the sediment, the octanol:water partition coefficient for the contaminant of concern, and an empirical value determined through observation. The empirical value of 0.79 used in this analysis was the empirical value used to calculate the water column concentrations was taken from the Baseline Human Health Risk Assessment for the Buffalo River, New York, op. cit.

[77] For a more detailed description of this method, see U.S. EPA, 1990 (Draft). Baseline Human Health Risk Assessment, Appendix D.

for PCB:	1.1×10^6
for DDT:	1.55×10^6

In addition, the TSS and f_{oc} values estimated for the study areas are presented in Exhibit K-4. It is important to keep in mind that these values are generally means within wide ranges for specific locations only, and as such, they are not necessarily representative of larger areas.

Exhibit K-4

Total Suspended Solid and Sediment Organic Carbon Fractions for Study Areas

	TSS (mg/l)	f_{oc}
Buffalo River	18	0.024*
Duluth/St. Louis River	(18)	0.041**
Green Bay	12	0.026**
Rochester	(18)	0.001**
Saginaw	30	0.020*
Sheboygan	(18)	0.036*

( ) Values in parentheses indicate that no site-specific data were available for the study areas. As a result, values for the Buffalo River were used as default values.

* Preliminary values from EPA Assessment and Remediation of Contaminated Sediments program.

** U.S. Army Corps of Engineers.

Based on the above relationship, the water column concentrations listed in Exhibit K-5 were derived. Exhibit K-6 was compiled to depict the mercury concentrations in the water column of there study areas. However, at all of the study areas except the Buffalo River, no mercury concentrations were detected in the water or no data were reported.

The second component of the exposure scenario estimate focuses on such factors as the age of the population exposed to the various pathways, the amount of time the individual typically remains exposed in a lifetime, the anticipated intake rate for exposed parts of the body, and the body weight of the typical exposed individual within each age group. Based on these relationships a weighing factor can be determined to estimate the lifetime exposure for each of the four pathways. These weighing factors are presented in Exhibit K-7.[78]

[78] Ibid.

Exhibit K-5

Estimated Water Column Concentrations for the Organic Contaminants of Concern

(mg/l)

	PCB	DDT
Buffalo River	2.5×10^{-4}	6.8×10^{-7}
Duluth/St. Louis River	6.9×10^{-6}	ND
Green Bay	2.1×10^{-4}	8.7×10^{-7}
Rochester	1.3×10^{-4}	3.7×10^{-5}
Saginaw	1.3×10^{-4}	ND
Sheboygan	4.7×10^{-4}	ND

Exhibit K-6

Reported Mercury Water Column Concentrations for the Study Areas

	Hg (mg/l)
Buffalo River	1.7×10^{-4}
Duluth/St. Louis River	-
Green Bay	-
Rochester	-
Saginaw	ND
Sheboygan	ND

- = no data reported
ND = no detections

Exhibit K-7

Lifetime Exposure Weighting Factors[79]

	Weighting Factor
Ingestion of water while swimming	1.58×10^{-4}
Water dermal contact while swimming	3.79×10^{-5}
Sediment dermal contact while swimming	7.25×10^{-6}
Ingestion of contaminated fish	9.28×10^{-5}

The weighting factors used in this analysis encompass a variety of assumptions regarding the patterns of lifetime exposure for each of the four pathways. Determining the wieghting factors essentially involves estimating three sets of variables: 1) the chemical concentration at the point of exposure; 2) the characteristics of the exposed population (e.g., frequency of exposure, duration, age and body weight of exposed individuals); and 3) the time period over which the exposure is averaged. The general form of the equation used to determine the weighting factor is:

$$\text{Intake} = (C^{*}CR^{*}EFD)/(BW^{*}AT) \quad \text{where:}$$

Intake - amount of chemical ingested or absorbed at the point of exposure;
C - chemical contraction, the avarage chemical concentration contacted over the exposure period;
CR - contact rate, the amount of contaminated medium contacted per unit time or event;
EFD - exposure frequency and duration, how long and how often exposure occurs;
BW - body weight, the average body weight of exposed individuals; and
AT - averaging time, period over which exposure is averaged.

The weighting factors used in this analysis were calculated by assessing values for each of the above values for age classes of 0-6, 7-18, and 19-70.

Contaminant Intake/Dose Estimates

The anticipated lifetime exposure for each pathway, study setting, and contaminant can now be estimated by multiplying the estimated exposure concentrations by the weighting factors controlling uptake. The lifetime intake dose for each study area and pathway are outlined in Exhibits K-8 through K-11.

[79] U.S. EPA, 1990 (Draft). Baseline Human Health Risk Assessment: Buffalo River, New York.

Exhibit K-8

Study Area Intake/Dose Summaries

Exposure Pathway: Ingestion of water while swimming

(mg/kg/day)

	PCB	DDT	Hg
Buffalo River	4.0×10^{-6}	1.1×10^{-10}	2.7×10^{-9}
Duluth/St. Louis River	1.1×10^{-9}	-	-
Green Bay	3.3×10^{-6}	1.4×10^{-10}	-
Rochester	1.9×10^{-6}	5.8×10^{-9}	-
Saginaw	2.1×10^{-6}	-	-
Sheboygan	7.4×10^{-6}	-	-

Exhibit K-9

Study Area Intake/Dose Summaries

Exposure Pathway: Dermal contact with water while swimming

(mg/kg/day)

	PCB	DDT	Hg
Buffalo River	9.5×10^{-9}	2.6×10^{-11}	6.4×10^{-9}
Duluth/St. Louis River	2.6×10^{-10}	-	-
Green Bay	8.0×10^{-9}	3.3×10^{-11}	-
Rochester	4.6×10^{-9}	1.4×10^{-9}	-
Saginaw	4.9×10^{-9}	-	-
Sheboygan	1.8×10^{-8}	-	-

Exhibit K-10

Study Area Intake/Dose Summaries

Exposure Pathway: Dermal contact with sediment while swimming

(mg/kg/day)

	PCB	DDT	Hg
Buffalo River	2.8×10^{-5}	9.4×10^{-6}	1.2×10^{-5}
Duluth/St. Louis River	1.1×10^{-6}	-	2.1×10^{-6}
Green Bay	2.8×10^{-5}	1.5 x 10-7	1.2×10^{-5}
Rochester	8.0×10^{-7}	3.2×10^{-7}	1.6×10^{-6}
Saginaw	1.1×10^{-5}	-	6.0×10^{-7}
Sheboygan	6.8×10^{-5}	-	1.5×10^{-6}

Exhibit K-11

Study Area Intake/Dose Summaries

Exposure Pathway: Ingestion of contaminated fish

(mg/kg/day)

	PCB	DDT	Hg
Buffalo River	3.1×10^{-4}	3.9×10^{-5}	1.1×10^{-5}
Duluth/St. Louis River	8.8×10^{-5}	-	-
Green Bay	1.1×10^{-4}	8.4×10^{-5}	-
Rochester	6.5×10^{-5}	1.5×10^{-5}	4.4×10^{-5}
Saginaw	1.3×10^{-3}	1.4×10^{-4}	3.7×10^{-6}
Sheboygan	6.2×10^{-3}	-	-

Human Health Impact Assessment

Two measures of potential human health impact are used in this analysis. The first measures the risk of cancer from exposure to each contaminant and is estimated using a cancer potency factor, which represents the risk of contracting cancer from daily lifetime exposure. The second measure is known as a reference dose (RFD). The RFD is the measure of chronic daily intake that will not result in adverse, non-carcinogenic health effects. The ratio of the exposure intake level and the reference is the measure of potential non-carcinogenic health effects. A ratio greater than one indicates the potential for adverse, non-carcinogenic health effects. Exhibit K-12 presents representative RFD and cancer potency factor values for the contaminants of concern.

Exhibit K-12

Toxicity Values for Contaminants of Concern

	RFD (mg/kg/day)	Cancer Potency factor(mg/kg/day^{-1})
PCB	1.0×10^{-4}	7.70
DDT	5.0×10^{-4}	0.34
Hg	3.0×10^{-4}	-

Estimating Human Health Impact

The potential for adverse human health impacts from exposure to the contaminants of concern in the study areas is reflected in Exhibits K-13 through K-16. These exhibits present the reference dose ratios and lifetime cancer risks for the exposure pathways, study areas, and contaminants investigated in this analysis. Absent values in the summary exhibits reflect data gaps in the source documents. No cancer potency values are reported for exposure to mercury, because it is regarded as Class D, not classifiable as to human carcinogenicity.

Exhibit K-13

Lifetime Human Health Risk Summary
Exposure Pathway: Ingestion of water while swimming

	PCB		DDT		Hg	
	Intake/ RFD	Cancer Risk	Intake/ RFD	Cancer Risk	Intake/ RFD	Cancer Risk
Buffalo River	7.0×10^{-4}	3.1×10^{-7}	2.2×10^{-7}	3.7×10^{-11}	9.0×10^{-4}	N/A
Duluth/ St. Louis River	1.1×10^{-3}	8.5×10^{-9}	-	-	-	N/A
Green Bay	3.3×10^{-4}	2.5×10^{-7}	2.8×10^{-7}	4.8×10^{-11}	-	N/A
Rochester	1.9×10^{-4}	1.5×10^{-7}	1.2×10^{-3}	2.0×10^{-9}	-	N/A
Saginaw	2.1×10^{-4}	1.6×10^{-7}	-	-	-	N/A
Sheboygan	7.4×10^{-4}	5.7×10^{-7}	-	-	-	N/A

N/A--not applicable

Exhibit K-14

Lifetime Human Health Risk Summary
Exposure Pathway: Dermal contact with water while swimming

	PCB		DDT		Hg	
	Intake/ RFD	Cancer Risk	Intake/ RFD	Cancer Risk	Intake/ RFD	Cancer Risk
Buffalo River	9.5×10^{-5}	7.3×10^{-6}	5.2×10^{-12}	8.8×10^{-12}	2.1×10^{-5}	N/A
Duluth/ St. Louis River	2.6×10^{-4}	2.0×10^{-5}	-	-	-	N/A
Green Bay	8.0×10^{-4}	6.2×10^{-5}	6.6×10^{-4}	1.1×10^{-11}	-	N/A
Rochester	4.6×10^{-5}	3.5×10^{-6}	2.8×10^{-4}	4.7×10^{-10}	-	N/A
Saginaw	4.9×10^{-5}	3.8×10^{-6}	-	-	-	N/A
Sheboygan	1.8×10^{-4}	1.4×10^{-7}	-	-	-	N/A

N/A--not applicable

Exhibit K-15

Lifetime Human Health Risk Summary
Exposure Pathway: Dermal contact with sediment while swimming

	PCB		DDT		Hg	
	Intake/ RFD	Cancer Risk	Intake/ RFD	Cancer Risk	Intake/ RFD	Cancer Risk
Buffalo River	2.8×10^{-1}	2.2×10^{-4}	1.9×10^{-4}	3.2×10^{-6}	4.0×10^{-2}	N/A
Duluth/ St. Louis River	1.1×10^{-2}	8.5×10^{-6}	-	-	7.0×10^{-3}	N/A
Green Bay	2.8×10^{-1}	2.2×10^{-4}	3.0×10^{-4}	5.1×10^{-6}	4.0×10^{-2}	N/A
Rochester	8.0×10^{-3}	6.2×10^{-6}	6.4×10^{-4}	1.1×10^{-7}	5.3×10^{-3}	N/A
Saginaw	1.1×10^{-1}	8.5×10^{-5}	-	-	2.0×10^{-3}	N/A
Sheboygan	6.8×10^{-1}	5.2×10^{-4}	-	-	5.0×10^{-3}	N/A

N/A--not applicable

Exhibit K-16

Lifetime Human Health Risk Summary
Exposure Pathway: Ingestion of contaminated fish

	PCB		DDT		Hg	
	Intake/ RFD	Cancer Risk	Intake/ RFD	Cancer Risk	Intake/ RFD	Cancer Risk
Buffalo River	3.1	2.4×10^{-3}	7.8×10^{-2}	1.3×10^{-5}	3.7×10^{-2}	N/A
Duluth/ St. Louis River	8.8×10^{-1}	6.8×10^{-4}	-	-	-	N/A
Green Bay	1.1×10^{-2}	8.5×10^{-6}	2.8×10^{-1}	2.9×10^{-5}	-	N/A
Rochester	6.5×10^{-1}	5.0×10^{-4}	3.0×10^{-2}	5.1×10^{-6}	1.5×10^{-1}	N/A
Saginaw	13	1.0×10^{-2}	4.7×10^{-4}	4.8×10^{-5}	1.2×10^{-2}	N/A
Sheboygan	62	4.8×10^{-2}	-	-	-	N/A

N/A--not applicable

Across all of the study areas, ingestion of contaminated fish served as the greatest risk to human health. All five areas have sport fish consumption advisories in place. The risks were greatest in the Sheboygan, Saginaw, and Buffalo study areas. Risks from PCB exposure also far outweighed risks from DDT or mercury, although this may also result from an absence of DDT and mercury data. Finally, RFD ratio values greater than one were found only for the fish ingestion exposure pathway in Sheboygan, Saginaw, and Buffalo. This indicates that for these three areas, lifetime non-carcinogenic risk is limited to a single exposure route. In contrast, cancer risks of greater than 1×10^{-4} are found in all of the study areas for one or more exposure pathways.

Establishing a direct link between the risk from fish consumption and contaminated sediments is difficult at best. Since this analysis used carp in coming up with the risk, and carp are bottom feeders, we are probably getting the most direct link to the sediments. However, it is probably incorrect to assume that all the risk from fish ties back to the sediments. Sediments are not the sole source of PCBs to fish, but considering that carp were used to calculate risk, the sediments were probably the source for a very large portion of the total PCBs, and thus in turn are a large factor in the overall risk to the specific human populations who consume these fish.

Ecological Impacts

Study of the ecological effects of contaminated sediments has been very limited. Therefore the following discussion of the ecological impacts of toxic sediments will be qualitative in nature.

Severity

There are documented cases of ecological damage in the Great Lakes Basin which are suspected to be due, at least in part, to toxic sediments. For example, sediments in several areas have been shown to be toxic to biota, and some areas of contaminated sediments are reported to be completely devoid of life. In Lake Ontario, poor reproductive success and declines in colony size of herring gulls due to elevated levels of PCBs and mirex were documented in the

early to mid 1970s.[80] More recent data indicate a decline in organochlorine residue levels in herring gull eggs from 1974 to 1983, a decline in dioxin and dibenzofuran levels from 1981 to 1986, and an increase in the reproductive rates of gulls to normal levels.[81]

EPA has developed preliminary interim sediment quality criteria or screening level criteria values for 13 non-ionic organic chemicals (see Exhibit K-5).[82] Maximum sediment concentrations of PAHs, PCBs, DDT, dieldrin, and/or chlordane exceed sediment criteria in several of the AOCs in Lake Erie, several Lake Erie tributaries and harbors outside the AOCs, and Lake Ontario sediments. In some Lake Erie AOCs, average sediment concentrations of these compounds also exceed sediment criteria. Concentrations of PAHs, PCBs, and chlordane exceed sediment criteria, even assuming 20% organic carbon content of the sediments. With the exception of Lake Ontario sediments, concentrations of DDT and dieldrin exceed sediment criteria only when 2% organic content is assumed. These data indicate that contaminated sediments in the Great Lakes Basin are likely to result in adverse chronic effects and/or bioaccumulation in aquatic ecosystems.

While a cause-effect relationship is strongly indicated between contaminated sediments and neoplastic disease in fish, no standardized assessment of carcinogenic potential in fish is available.[83] The following is a list of organisms known to have been affected by contaminated sediments: carp, benthic invertebrates, fathead minnows, aquatic insects, hexagenia, and hydallella. It should be noted that these impacts include only effects due to direct contact with sediments. Even less study has been performed on the impacts of bioaccumulation and possible releases from or contact with CDFs.

Reversibility of Damage

Just as the extent of ecosystem damage is uncertain, so is the speed of ecosystem recovery (assuming the toxic sediments were removed). However, it is known that in some areas the ongoing natural process of sedimentation will eventually cause the burial of contaminated sediments with new material. These new sediments, while still contaminated, tend to be less toxic because of recent reductions in contaminant loadings into the Great Lakes Basin. Evidence of this process is seen in sediment core samples. In several areas, contaminant concentrations are highest at a sediment depth corresponding to the 1960's.[84] In other areas weather and internal lake processes have served to distribute sediments in broad depositional Basins. In these areas (Lake Ontario for example) and in areas where the natural rate of sedimentation is low, contaminant concentrations show little change since the early 1970's.[85] Except for areas in which sedimentation rates are very high and lake currents and turbulence are low, it is unlikely that natural processes would bury or reduce concentrations in toxic sediments in the short term even if loadings were eliminated completely.

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[80] Gilman, A.P. et al. 1977. "Reproductive parameters and egg contaminant levels of great lakes herring gulls". J. Wild. Manage. 41: 458-468.

[81] New York State Department of Environmental Conservation, Division of Water, Bureau of Monitoring and Assessment. 1990. "New York State Water Quality 1990" [New York 1990 305(b) Report].

[82] U.S. EPA, Office of Water Regulations and Standards, Criteria and Standards Division. 1989. "Briefing Report to the EPA Science Advisory Board on the Equilibrium Partitioning Approach to Generation Sediment Quality Criteria" (EPA 440/5-89-002, April, 1989).

[83] International Joint Commission. 1989. "Report on Great Lakes Water Quality". p. 53.

[84] Great Lakes Water Quality Board. 1987. "Report on Great Lakes Water Quality". pp. 2.5-2.14.

[85] Conservation Foundation. "Great Lakes, Great Legacy?". p. 103.

EXHIBIT K-17

INTERIM SEDIMENT QUALITY CRITERIA FOR NON-IONIC ORGANIC COMPOUNDS

Compound	Criterion (ppm OC[1])	Type[2]	Sediment concentration (ppb) based on % OC[1]	
			2% OC	20% OC
PAHs:				
Acenapthene	730.0	CE	14,600.0	146,000.0
Aniline	0.0662	CE	1.32	13.2
Phenanthrene	139.0	CE	2,780.0	27,800.0
Other	10.1	SC	202.0	2,020.0
Pesticides:				
Chlordane	0.098	SC	1.96	19.6
Chlorpyrifos	3.22	CE	64.40	644.0
DDT	0.828	RB	16.56	165.6
Dieldrin	0.130	RB	2.60	26.0
Endrin	0.0532	RB	1.06	10.6
Ethyl Parathion	0.081	CE	1.62	16.2
Heptachlor	0.110	RB	2.20	22.0
Heptachlor Epoxide	0.008	SC	0.16	1.6
Lindane	0.157	CE	3.14	31.4
Other:				
PCBs	19.5	RB	390.0	3,900.0

Source: EPA 440/5-89-002 (April 1989)
[1]OC = organic carbon content of sediment
[2]CE = criterion developed on a chronic effect basis
RB = criterion developed on a residue basis
SC = screening level criterion

A number of technologies for remediating toxic sediments are currently in the developmental stages. The Engineering/Technology Work Group of the ARCS program will be evaluating the effectiveness, technical feasibility, and cost of various technologies as well as estimating the risks associated with each method. Technologies to be evaluated include: solidification/stabilization, inorganic treatment/recovery, bioremediation, potassium-polyethylene glycol (KPEG) nucleophilic substitution, best extraction sludge technology (BEST) extraction process, critical fluids (CF) systems solvent extraction, incineration, low temperature thermal stripping, wet air oxidation, low energy extraction, ecological destruction process, in-situ stabilization, acetone extraction, aqueous surfactant extraction, taciuk thermal extraction, and sediment dewatering methods.[86] None of these technologies has yet been tested even on a pilot-scale.

The only method for the remediation of contaminated sediments which has been used extensively up to this time is dredging and removal to CDFs. Because the impacts of resuspension of sediments during dredging and the risks associated with CDFs are largely unknown, it is uncertain how effective this method of remediation is at reducing ecological risk. The risk created by dredging possibly might be greater than the risk posed by leaving sediments in place. Leaving sediments, dredging them, and disposing of them all create risks which are currently being assessed in order to weigh remediation options.

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[86] U.S. EPA, Great Lakes National Program Office. 1990. "Assessment and Remediation of Contaminated Sediments (ARCS) Work Plan." p. 36.

Based on the information above, reversibility of damage can be characterized as low. Although the rate at which the ecosystem would recover to its original state is not known, it is known that the elimination of contamination through natural processes is not likely in the short term, and that the reduction of risk through currently available remediation technologies is not yet certain. The effectiveness and costs of other remediation technologies has yet to be fully evaluated.

Welfare Impacts

Health Care Costs

It is not possible to estimate health care costs, because no information is available about the human health impacts that treats toxic sediments separately from other source of surface water contamination. The reader is referred to the welfare discussions in Problem Area G for a general assessment.

Environmental Costs

The environmental costs of toxic sediments include the values of lost fish and other aquatic organisms, as well as economic losses from commercial and sport fishing activities. The extent of damage caused to aquatic life in the Great Lakes by contaminated sediments is not wholly quantifiable at this time. Therefore, it is difficult to assess the total environmental cost of this damage. However, for a general assessment of such impacts, the reader is referred to Problem Area G.

Economic losses are similarly hard to estimate. The following data from the 1990 Statistical Abstract of the United States provide some insight into the size of the effected industries. The total fish catch from the Great Lakes in 1988 was 40 million pounds (representing 0.6 percent of the total domestic fish catch,) and had a value of $19 million dollars (representing 0.5 percent of the value of the total domestic catch.) The total catch from the Great Lakes has declined both in absolute terms and as a percentage of the domestic catch since 1980. 3,766,000 Americans (2 percent of the population) engaged in sport fishing in the Great Lakes in 1988, spending a total of $1,560,000 on food, lodging, transportation, licenses, and equipment. The Great Lakes Fishery Commission estimated the total annual regional economic impact of the Great Lakes fisheries (commercial and sport) to be between $2 billion and $4 billion for 1985.[87] However, without an estimate of the reduction in fish population or edibility, it is difficult to assign a dollar value under the heading of environmental costs even though toxic sediments are known to have a negative impact on fisheries and on the commercial and sport fishing industries.

Toxic sediments also cause economic damages to the shipping industry because of restrictions on dredging. For example, in some harbors, such as Indiana Harbor and the lower Maumee River, transportation has been impaired because contaminated sediments have halted dredging activities. Indiana Harbor has not been dredged since 1972, and as a result of the sediments deposited since then, ships have been forced to reduce their drafts by up to ten feet.

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[87] Great Lakes Commission. "Great Lakes Commercial and Recreational Harbor Dredging: Issues and Recommendations". p. 28.

L. PESTICIDE DISCHARGES AND ENVIRONMENTAL RISK

Problem Area Description

The Great Lakes Basin is one of the major agriculturally cultivated areas in the U.S. As a result, it receives large applications of pesticides. This section will address discharges and the environmental risks resulting from the use of 21 herbicides and insecticides in the Great Lakes Basin. Human health impacts from pesticide applications, food residues, and other uses of pesticides are discussed in Problem Area X, Pesticides: Human Health. Human health impacts from pesticide accumulation in fish are addressed in the discussion of health impacts from point and nonpoint sources, and is found in Problem Area G, Industrial Point Source Discharges to Surface Waters. For a discussion of pesticide loading to surface water from atmospheric deposition, see Problem Area J, Atmospheric Loadings to Surface Water.

There are a number of primary sources of pesticide exposure in the Basin. These sources include:

- agricultural applications;
- lawn care and household uses;
- manufacture and blending of pesticides;
- storage of pesticides; and
- accidental releases and spills.

The Great Lakes Basin produces a number of major crops such as corn and soybeans to which farm workers apply large volumes of herbicides and insecticides. Suburban spraying of property, often with high pressure systems, can result in contamination of neighboring property, residents, pets, and livestock. The Basin also houses thousands of pesticide producing and custom blending establishments. There is also a number of storage facilities that house the canceled pesticide, dinoseb.

Data are most available on pesticides applied for agricultural purposes. Therefore, the discussion of this problem area will focus mainly on risks posed by this major source. Some summary data on levels of exposure to pesticides from the other sources are also available and will be presented. At risk from exposure to pesticides are terrestrial animals, plants, and insects, as well as fish and other aquatic animals, and aquatic plants and insects.

Magnitude of the Problem

Agricultural Applications

Cropland in the Great Lakes Basin comprises 18.5 million acres or 18 percent of the total area of the Basin. Major cropland areas of the Basin include northwest Ohio in the Lake Erie drainage Basin, the Saginaw River and Bay area in Michigan in the Lake Huron drainage Basin, and east-central Wisconsin in the Lake Michigan drainage Basin.[88] Exhibit L-1 compares the total cropland and major crops in the Basin and in Region 5. The Basin represents 17 percent of the cropland in Region 5 States. Proportions of cropland are similar in both Basin and Region, with corn representing the major crop in both, and soybeans the next major crop.

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[88] U.S. EPA, Great Lakes National Program Office, U.S. Agricultural Tillage Practices in the Great Lakes Basin, 1988.

Exhibit L-1

Major Crops in Basin
(millions of acres)

Crop	Basin	%
Corn	7.8	42
Soybeans	4.5	24
Small Grains	3.1	17
Total	18.5	100

Tillage practices in the Basin were examined in 1988 by the Great Lakes National Program Office (GLNPO) and the Conservation Technology Information Center (CTIC). Based on the draft report, agricultural landowners are applying conventional tillage methods more extensively than conservation tillage methods, which are used on 27 percent of the cropland in the Basin. Conservation tillage is used for 38 percent of the corn crop but only 25 percent of the soybean crop. It is interesting to note that two counties in northwest Indiana have 95 and 89 percent, respectively, of the acres used for corn production in conservation tillage. The counties showing the highest proportion of acres in cropland, found in Ohio, also show the lowest rates of conservation tillage in the Basin.

Exhibit L-2 shows the geographic distribution of total conservation tillage use by acreage in Basin counties. The GLNPO and CTIC report indicates it would be difficult to evaluate the effect of conservation tillage on agrichemical runoff, including pesticides, on a regional or lake-wide scale. Research done by the U.S. EPA in the Lake Erie Basin found no significant differences in runoff, tile flow, and pesticide losses between conservation tillage and conventional test plots. However, the report underscores the difficulty in gathering accurate information on soil type, tillage practices, and runoff in the Great Lakes Basin.

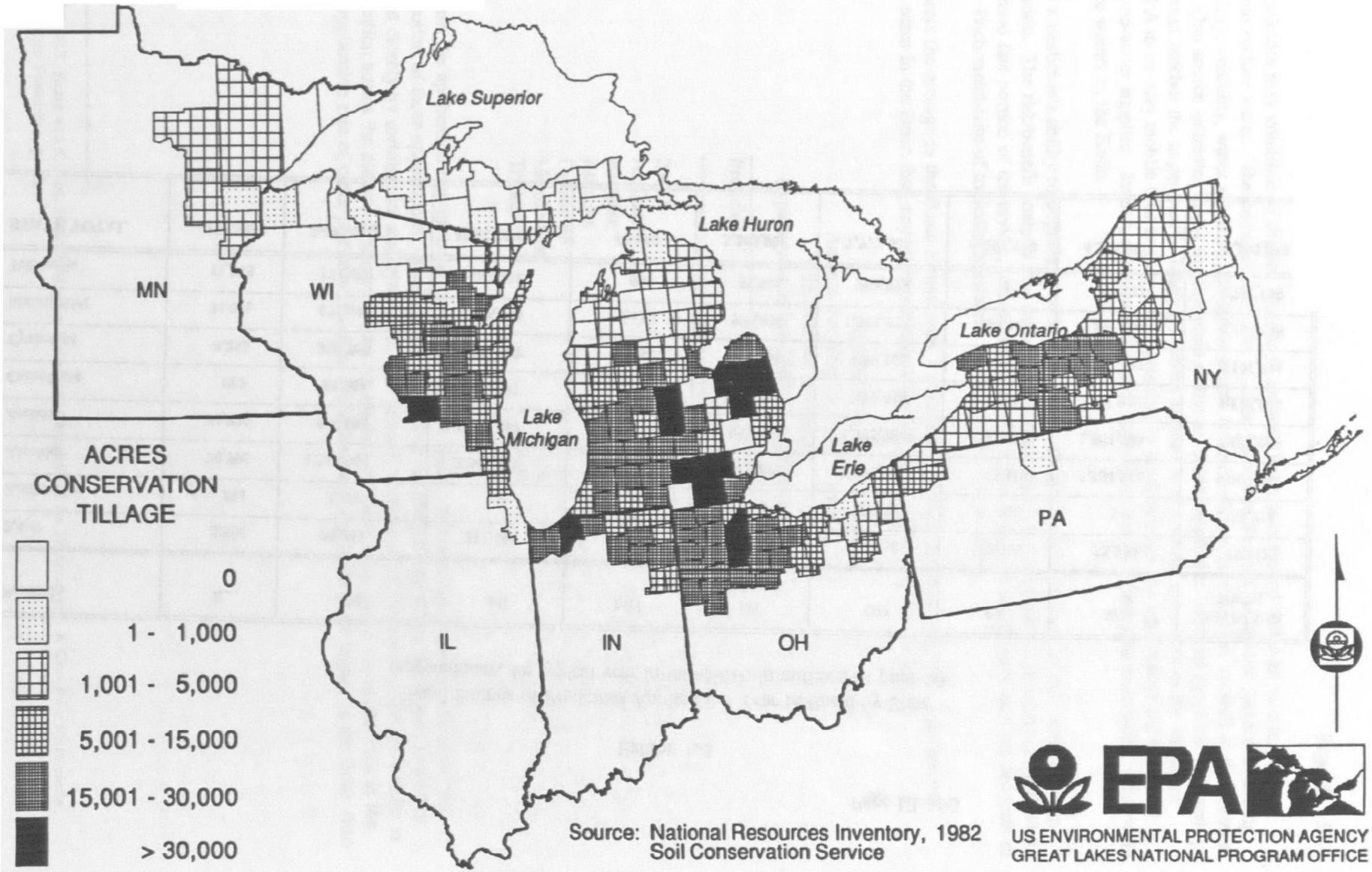
More research and information on tillage practices on all agricultural acres can be expected over the next few years as best management practices improve and are implemented into farm operations in the Basin. Developing and implementing methods which reduce erosion, such as conservation tillage practices, is important for many reasons, for example, soil erosion from agricultural activities can transport contaminants such as pesticides into the Lakes. Once the contaminants reach the sediments of the Great Lakes they can leach into the water degrading water quality and impacting aquatic life. It is probably not coincidental that some of the same areas of the Basin that are most intensively farmed -- northwest Ohio and the Saginaw River and Bay area in Michigan -- are plagued with some of the highest rates of erosion in the Basin.

Agricultural landowners in the Basin apply large volumes of pesticides on their crops to control a wide variety of pests. Exhibit L-3 presents the total pounds of active ingredients applied in the Basin for 8 different pesticides. The data were gathered from 213 counties in the Basin for a typical year in the mid-1980's. Data are weighted by the area of land within the Basin. Applicators utilize large quantities of the herbicides alachlor, atrazine, and cyanazine and the insecticide carbofuran in the Basin. With over 9,500,000 pounds of alachlor applied per year, it exceeds other pesticides applied in the Basin. Following next are atrazine and metolachlor with over 7,000,000 and 6,000,000 pounds respectively applied per year in the Basin. Perhaps the most widely used chemical in the Basin is 2,4-D, which is used in agriculture, turf treatment, industrial vegetation control, and by homeowners, although, by volume 2,4-D does not equal the major agricultural herbicides.

Exhibit L-2

TOTAL CONSERVATION TILLAGE USE

Great Lakes Basin Counties



Source: National Resources Inventory, 1982
Soil Conservation Service

EPA

US ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

Exhibit L-3

Total Pounds of Pesticides Applied Per Year in Basin by State
(approximate, for typical year in late-1980s in millions of pounds)

Pesticide	IL	IN	MI	MN	NY	OH	PA	WI	PESTICIDE TOTAL
2,4-D	3,385	29,245	212,548	27,669	59,666	81,018	2,769	35,879	452,179
Acifluorfen	784	3,871	0	3	0	53,691	316	549	59,214
Alachlor	28,796	1,313,967	3,345,989	19,744	705,269	2,877,806	43,519	1,334,894	9,669,984
Atrazine	31,925	899,083	1,945,597	10,814	951,309	1,775,784	55,698	1,811,748	7,481,958
Carbofuran	862	64,261	577,187	119	197,988	179,352	7,891	87,949	1,115,609
Cyanazine	8,253	336,766	1,035,687	5,032	527,168	600,165	27,609	657,211	3,197,891
Metolachlor	34,041	671,801	2,726,006	5,115	770,836	1,941,632	59,110	545,354	6,753,895
Trifluralin	11,173	171,400	183,956	601	55,306	263,532	179	48,852	734,999
STATE TOTAL	**119,000**	**3,490,000**	**10,027,000**	**69,000**	**3,268,000**	**7,773,000**	**197,000**	**4,527,000**	**29,500,000**

Once applied, pesticides may volatilize to the air, degrade in the soil, leach into ground water or be transported through runoff into surface water. The environmental fate of these pesticides depends on several factors, including persistence, mobility, volatility, water solubility, ability to adhere to soil particles, formulation, as well as the amount of precipitation. One source estimates that 4 to 20 percent of the pesticides applied is taken up by plants and perhaps less than 0.1 percent reaches the target pest[89]. Many pesticides applied in significant quantities in the Basin are considered by EPA to be very mobile thus having a high potential to leach through the unsaturated soil zone and contaminate ground-water supplies. Indeed, a number of studies have found several pesticides in drinking water wells as well as surface waters in the Basin.

Consideration of a pesticide's ability to degrade is an important part of the risk/benefit analysis that takes place in pesticide registration. The risk/benefit analysis also considers the metabolites and degradation products of pesticides in the environmental fate portion of the review, which includes aerobic and anaerobic metabolism and the products of these processes. Each metabolite of toxicologic concern enters into the risk analysis.

Exhibit L-4 presents the acreage in the Basin treated with 7 pesticides that data was available for. Atrazine was applied on more acres in the Basin than any other pesticide followed by Alachlor and Metolachlor.

Exhibit L-4
Acreage Per Year in Basin Treated
with Selected Pesticides
(typical year in late 1980s in millions of acres)

Pesticide	Acres
2,4-D	1.0
Acifluorfen	0.2
Alachlor	4.7
Atrazine	5.7
Cyanazine	1.9
Metolachlor	3.3
Trifluralin	0.9

Exhibit L-5 presents the application rate of these 7 pesticides in the Basin. Exhibits L-6 through L-12 show the geographic distribution of these applications. Alachlor was applied at the highest rate in the Basin than any other pesticide, followed closely by metolachlor and cyanazine. The rates of application of these pesticides are similar to the rates of application across the nation. Some pesticides are applied at higher rates across the nation than in the Basin, while the application rate of other pesticides, such as cyanazine and metolachlor, are higher in the Basin than across the nation.

[89] Waddell, T.E., B.T. Bauer, and K. Cox. 1988. "Managing Agricultural Chemicals in the Environment: A Case for a Multi-media Approach," Conservation Foundation, p. 42.

Exhibit L-5

Selected Pesticide Application Rates[90]
in the Great Lakes Basin for 1987
(lbs AI/acre/year)

Pesticide	Basin Application Rate
2,4 - D	0.5
Alachlor	2.1
Acifluorfen	0.3
Atrazine	1.2
Cyanazine	1.8
Metolachlor	1.9
Trifluralin	0.8

An analysis of total pounds of pesticides applied for agricultural purposes as well as their rates of application shows a general high usage of a number of pesticides in various counties within the Basin.

Non-agricultural Uses

Several of the pesticides used for agricultural purposes are also used in the care of lawns, turf, and golf courses. On an area basis, EPA estimated that homeowners alone apply from 5 to 11 pounds of active ingredients per acre.[91] Compared to agricultural application rates, lawns and gardens receive greater rates of pesticide applications than agricultural land. The General Accounting Office, using a 1988 EPA estimate, found that 67 millions pounds of active ingredients are applied on lawns by lawn care operators and homeowners each year, across the U.S. Although lawn pests are not distributed evenly across the country, an approximation of the amount of lawn care pesticides applied in the Basin can be determined using the proportion of the U.S. population residing in the Basin (30,050,000/243,300,000), or 12 percent. Using this approximation, over 8 million pounds of active ingredients are used annually on lawns in the Great Lakes Basin.

Ecological Impacts

Severity

Although the fate of applied pesticides in not well known, two phenomena have been described in the scientific literature: (1) the bioaccumulation of pesticides in fish, and (2) the effects of increased nutrient and pesticide loadings on the balance of aquatic life forms. Pesticides and nutrients can enter the Great Lakes ecosystem through sediment transport produced

[90] Application rates depend on the crop and on pest problems. In some cases, maximum label rate of application should be assumed.

[91] Water Quality Board, International Joint Commission. 1987. "1987 Report on Great Lakes Water Quality," p. 181.

by soil erosion from agricultural activities. Once these substances reach the sediments of the Great Lakes, they can gradually leach into the water and enter the food chain or upset the balance of aquatic life in the lake. Several studies have documented the bioaccumulation of chemicals including such suspended and canceled pesticides as aldrin, dieldrin, chlordane, heptachlor, DDT, and mirex in large sport fish species in the Great Lakes.

Applications of the insecticide carbofuran presents a risk to non-target species, which include many avian species. More than 1,100,000 pounds of carbofuran were applied primarily on corn and soybean crops in the Basin in one recent year. There are a number of documented cases in the United States of bird poisonings after use of the granular formulation of the pesticide.[92] Although documented cases of carbofuran poisonings in the Basin are relatively few, it is reasonable to assume the potential exists for more bird poisoning incidents in the Great Lakes Basin, even when the pesticides are used in accordance with existing regulations.

A potentially severe ecological impact of pesticide usage in the Basin involves the deleterious effects of these chemicals on endangered species. However, EPA's comparative risk project found impacts to endangered species in Region 5 from pesticides as "low". To project future needs for endangered species in Region 5, Temple, Barker and Sloane used U.S. Fish and Wildlife Service listings and the Nature Conservancy listings to determine potential candidates for protection under the OPP endangered species protection program.

There are a number endangered species in the Basin including, but not limited to:

- white cat's paw pearly mussel in Indiana and Ohio;
- piping plover in Michigan;
- Kirtland's warbler in Michigan; and
- prairie bush-clover in Illinois.

The preferred habitat for the prairie bush-clover is northern facing slopes, often bordering on agricultural fields or pasturelands. These areas present a high risk of exposure from spray drift application of pesticides.

Unfortunately, the impacts of pesticides on wetlands are largely unknown. The major agricultural impact in the Basin have been due to the drainage of wetlands to make cropland. This has resulted in reduced critical habitat in the Basin and could potentially impact the survival of critical species if left unchecked. A thorough assessment of wetlands appears in Problem Area A, Physical Degradation of Water Habitats and Wetlands.

Other species-level effects of concern from pesticide contamination include, but are not limited to:

- insecticide-induced mortality among the aquatic juvenile life stages of many insect species (e.g., dragonflies, mayflies);
- herbicide-induced reduction of submerged aquatic vegetation;
- impaired reproduction of fish; and
- fish kills.

Ecosystem-level effects include:

- reduced biomass and diversity of invertebrate and vertebrate communities;
- herbicide-induced reduction of submerged aquatic vegetation; and
- concomitant loss of invertebrate communities as well as fish that utilize plant cover for spawning or protection

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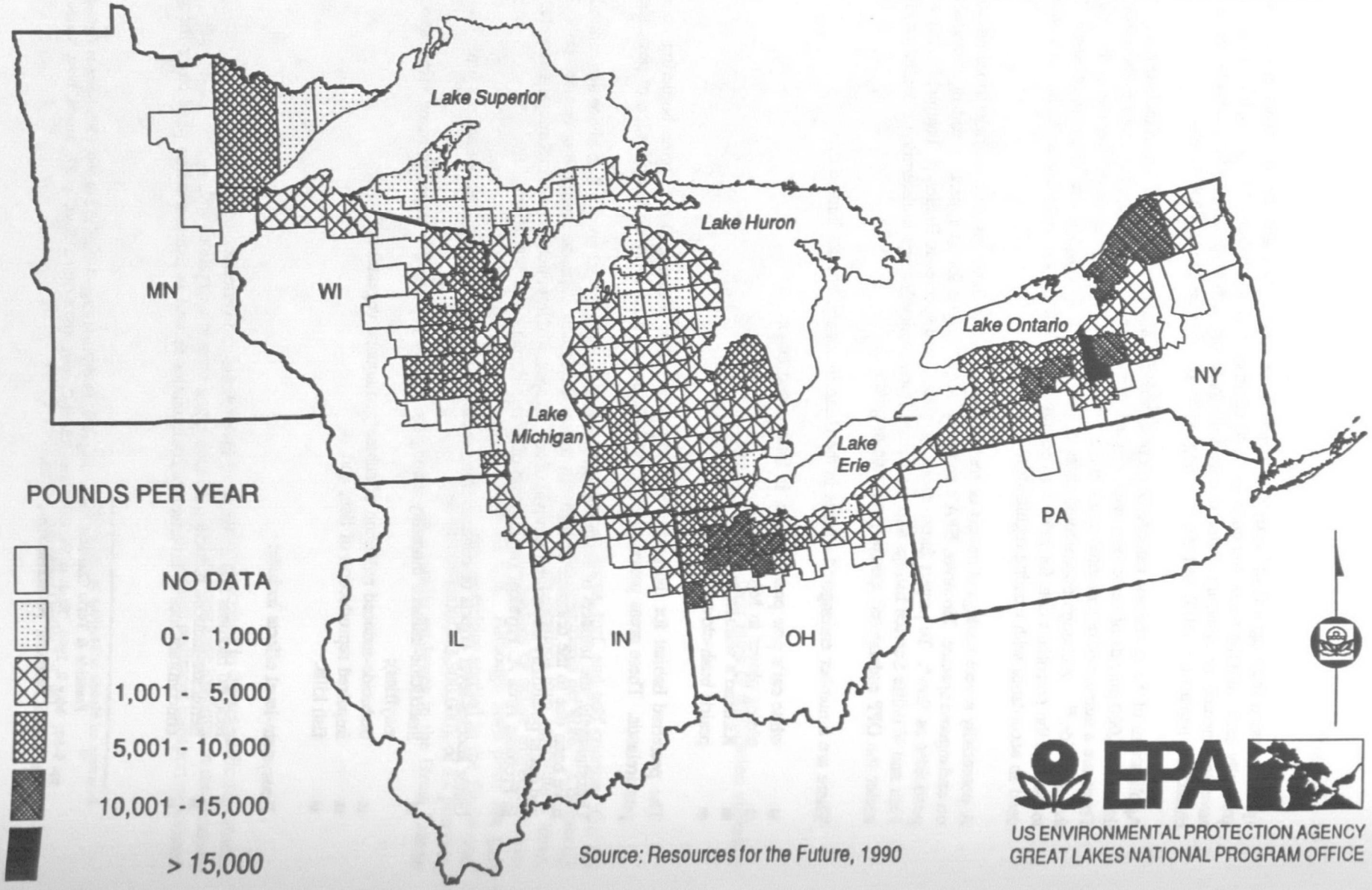
[92] Pesticide & Toxic Chemical News: August 8, 1990, "Bald Eagle Valued at $40,000, FWS Notes in Carbofuran-Predator Case," pp. 9-10; May 2, 1990, "Birds in Va. Carbofuran Kill of Concern, USDI Official Says," p. 27; June 6, 1990, "Carbofuran Linked to Two Bird Kills in Delaware; No Misuse Seen," p. 23.

Exhibit L-6

2,4 - D Application, 1986

Great Lakes Basin Counties



Source: Resources for the Future, 1990

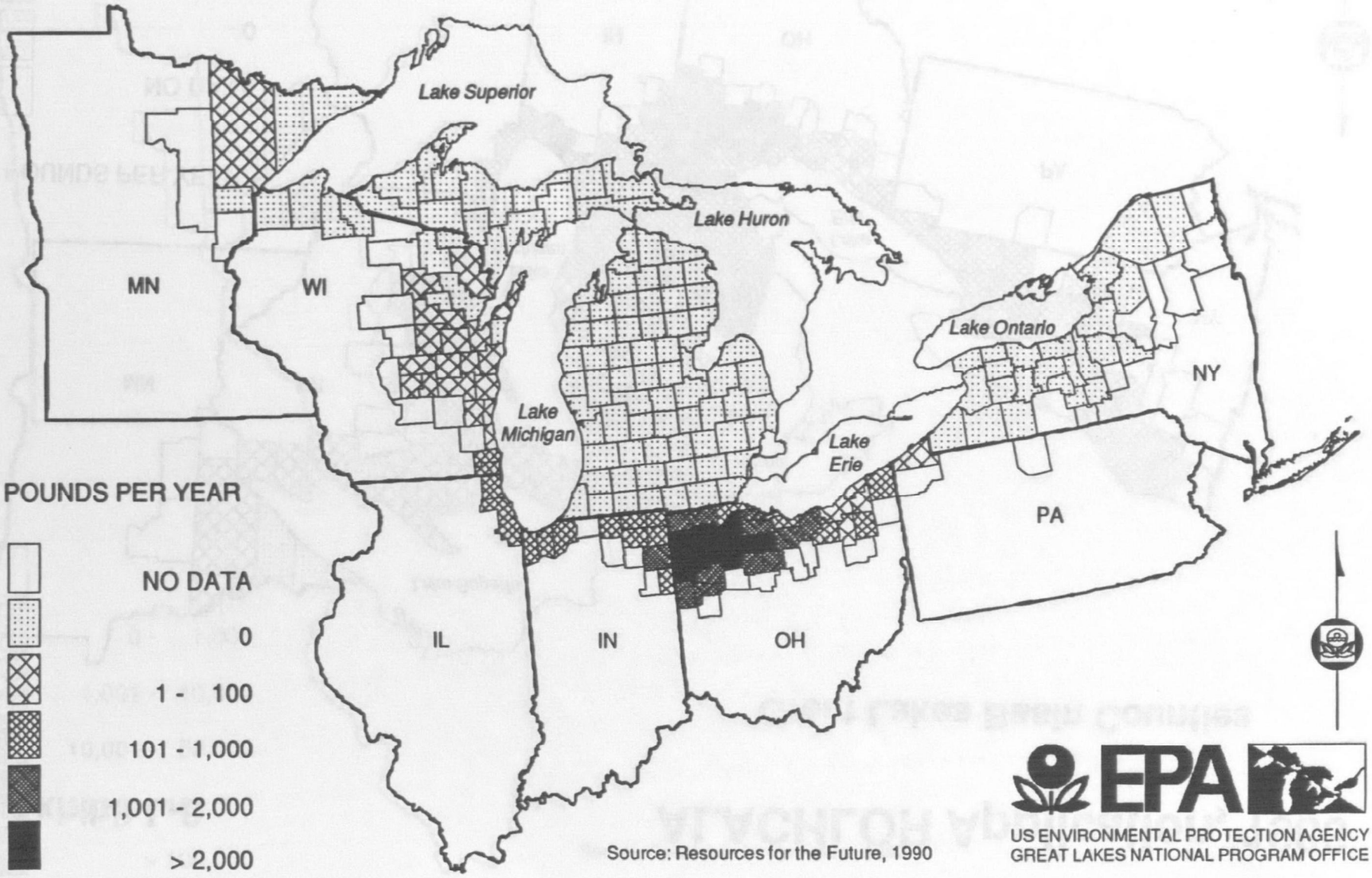
EPA

US ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

Exhibit L-7

ACIFLUOR Application, 1986

Great Lakes Basin Counties



Source: Resources for the Future, 1990

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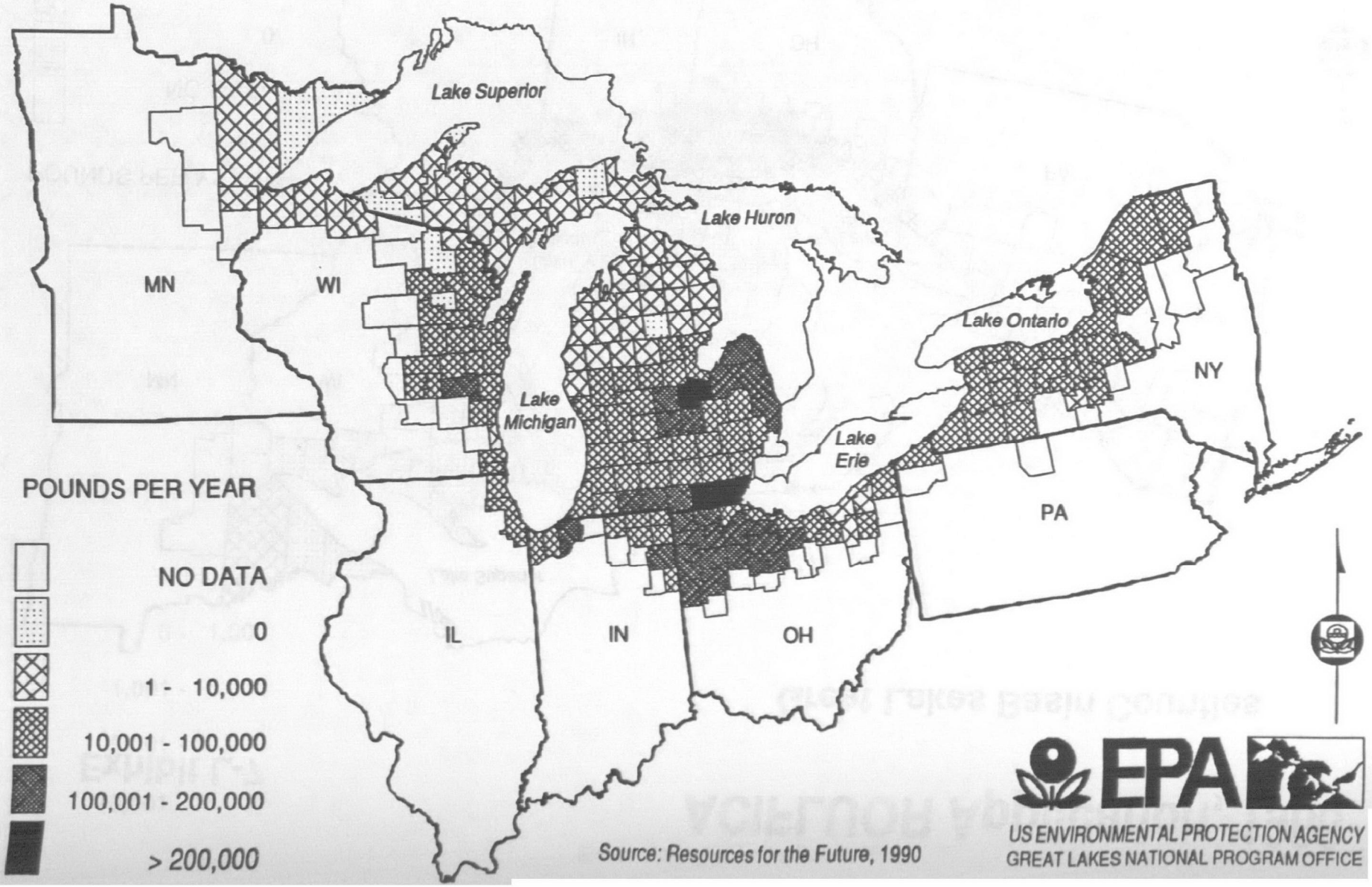
Exhibit L-8

ALACHLOR Application, 1986

Great Lakes Basin Counties



Source: Resources for the Future, 1990

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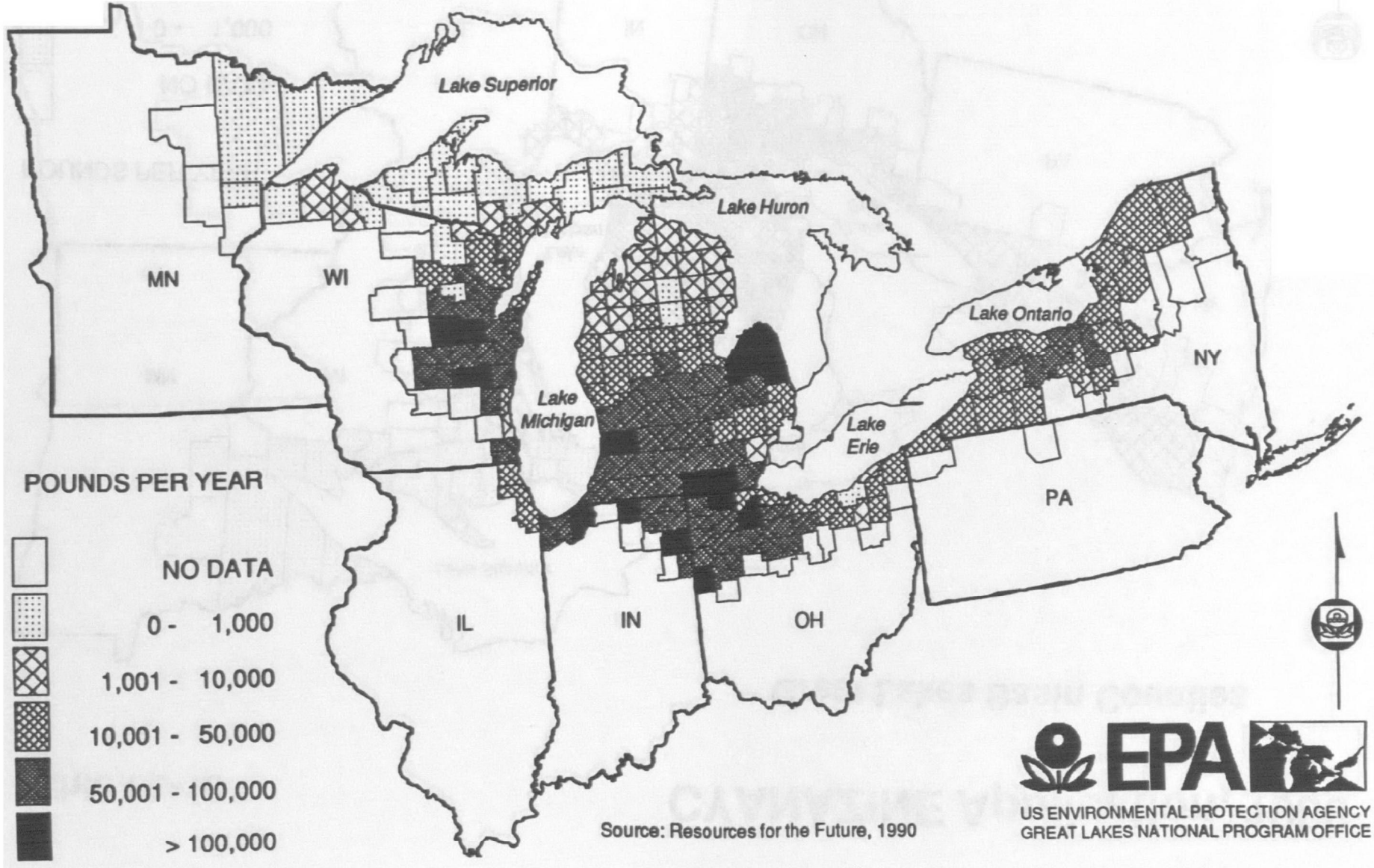
Exhibit L-9

ATRAZINE Application, 1986

Great Lakes Basin Counties



Source: Resources for the Future, 1990

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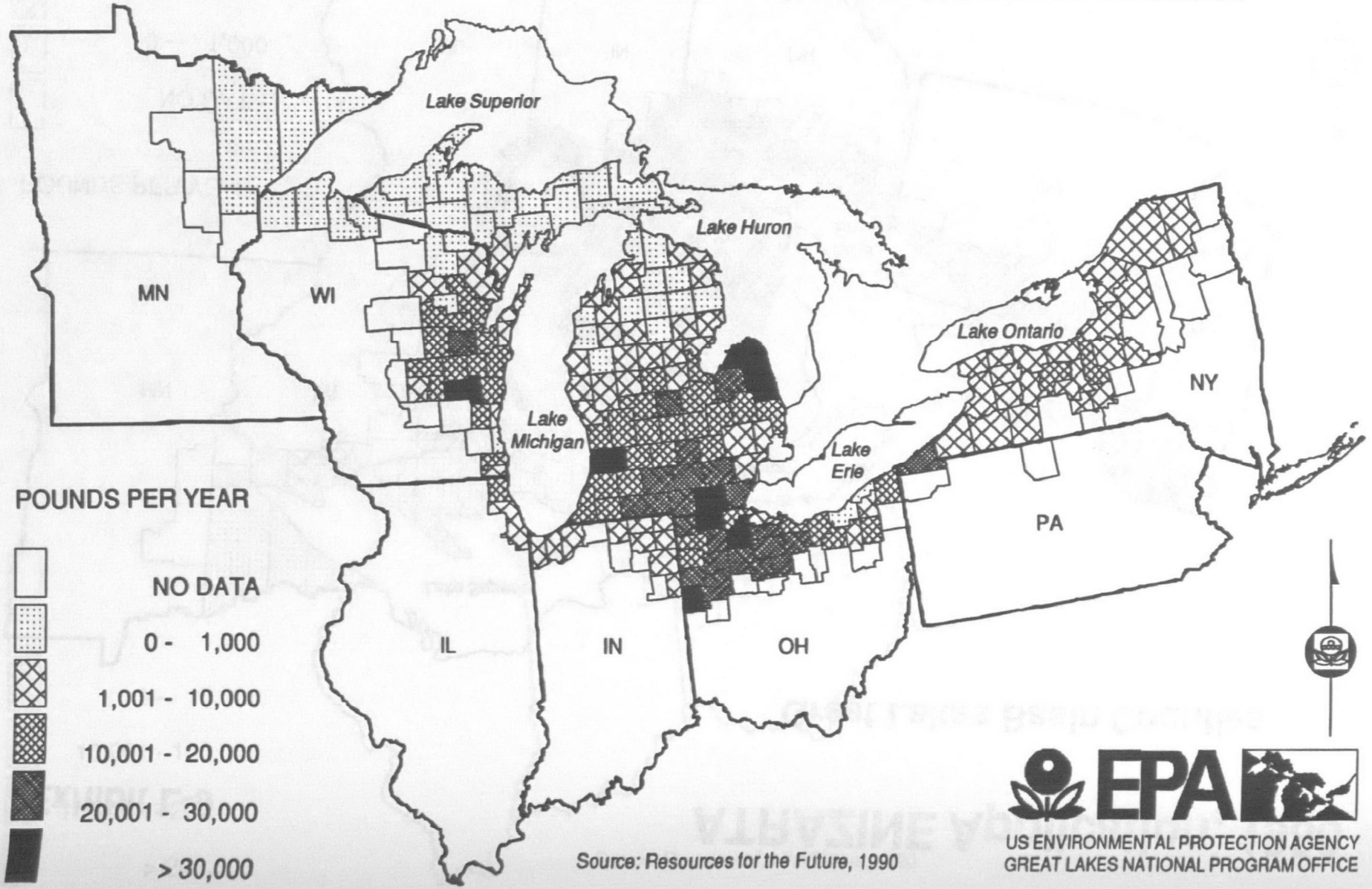
Ehibit L-10

CYANAZINE Application, 1986

Great Lakes Basin Counties



Source: Resources for the Future, 1990

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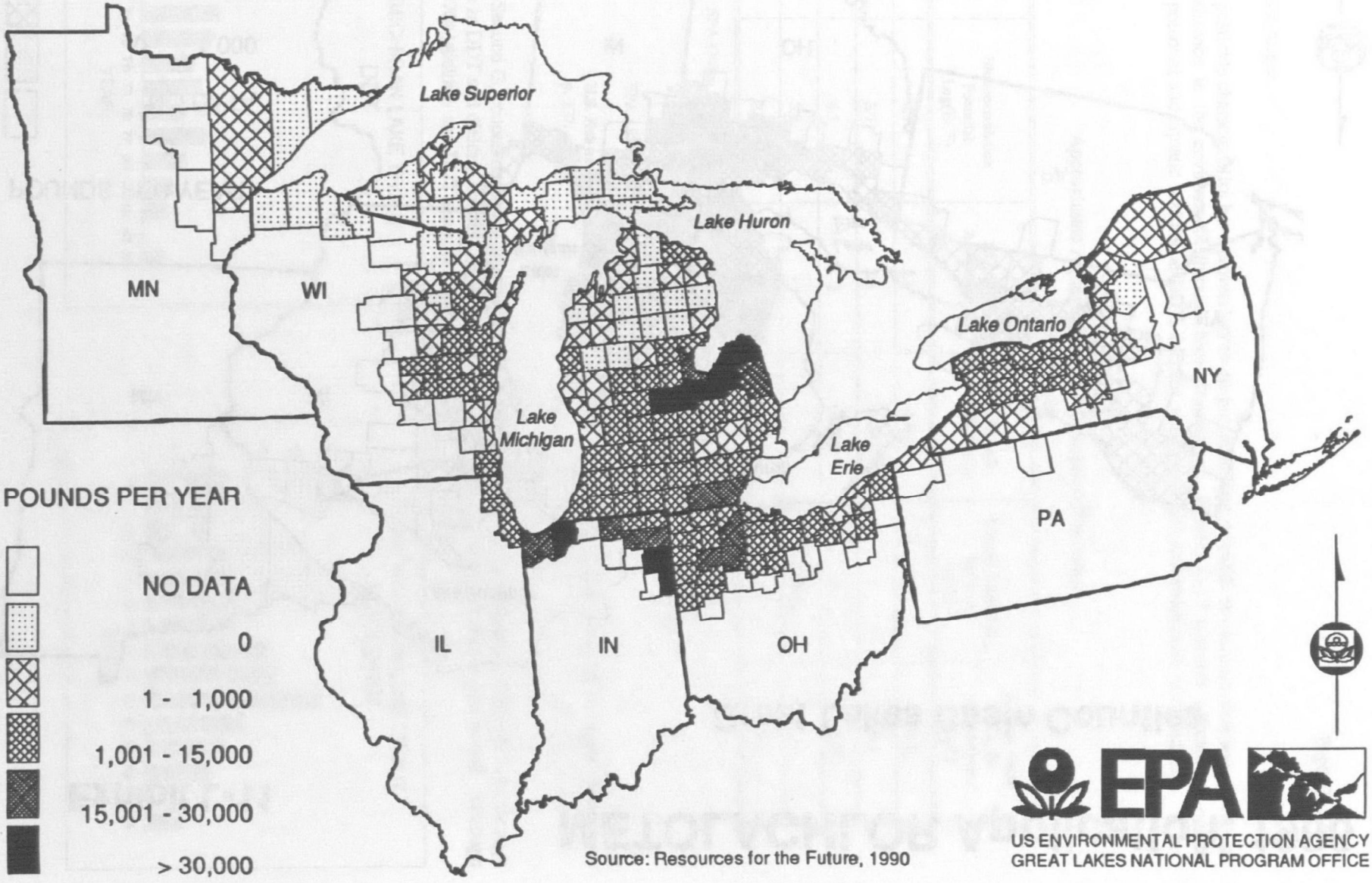
Exhibit L-12

TRIFLURALIN Application, 1986

Great Lakes Basin Counties



Source: Resources for the Future, 1990

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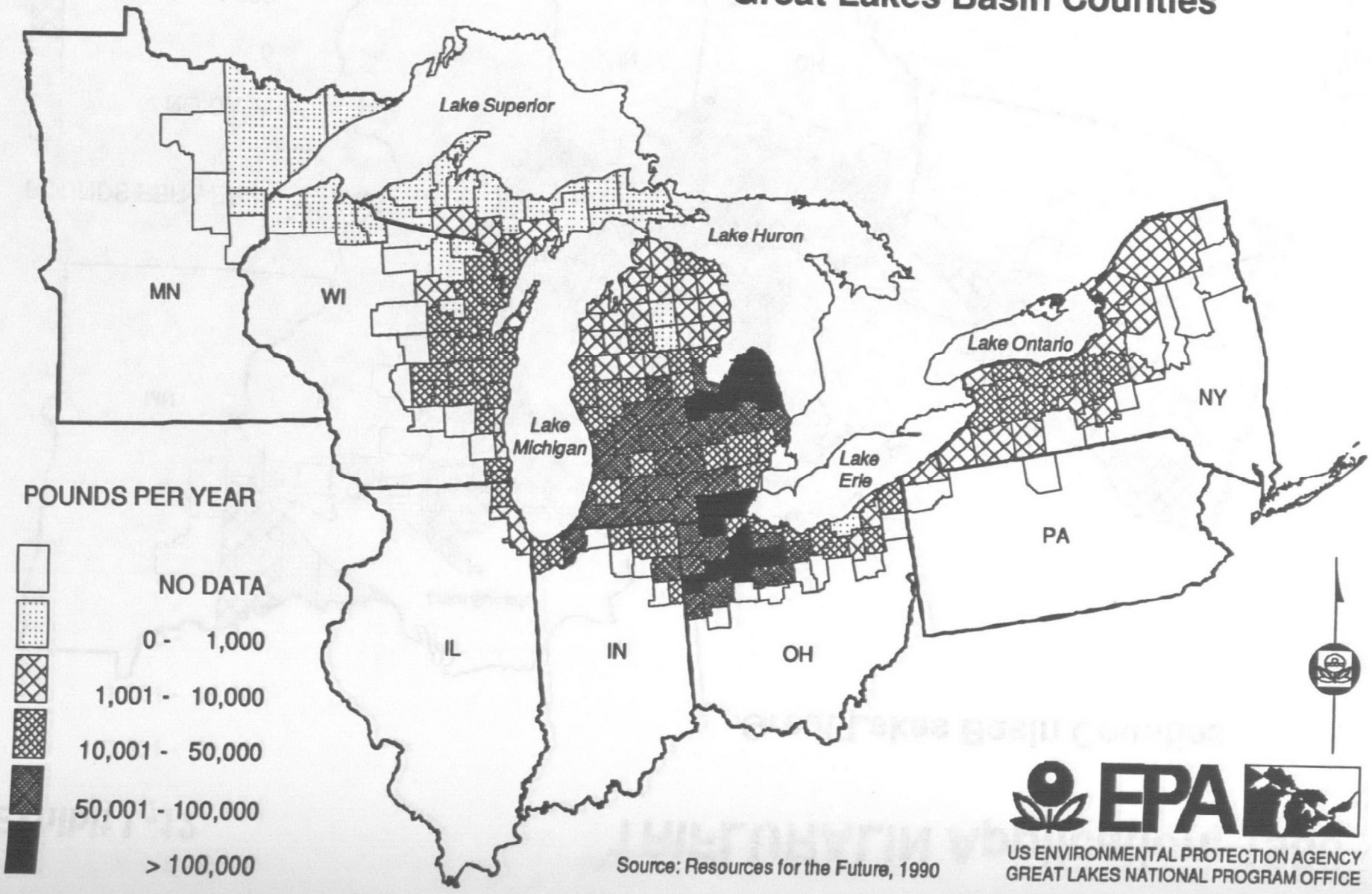
Exhibit L-11

METOLACHLOR Application, 1986

Great Lakes Basin Counties



Source: Resources for the Future, 1990

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of juvenile stages.

Historically, two pesticide characteristics have proven key to the potential for a pesticide to cause adverse aquatic effects: toxicity and persistence in the environment through bioaccumulation. Exhibit L-13 presents information on the bioaccumulation potential and aquatic toxicity of DDT, dieldrin, toxaphene, hexachlorobenzene, and lindane.

Exhibit L-13
Approximate Aquatic Toxicity for Selected Pesticides

Pesticide	Bioaccumulation Potential Log(BCF)	EPA Acute AWQC (ug/L)	EPA Chronic AWQC (ug/L)	Lowest Acute LC_{50} for Fish (ug/L)	Lowest Acute LC_{50} for Invertebrates (ug/L)
DDT	4.7	1.1	0.001	2	0.2
Dieldrin	3.7	2.5	0.002	1	0.5
Toxaphene	4.1	0.72	<0.001	2	1.3
HCB	3.9	-	-	12,000	-
Lindane	2.7	-	-	2	3.2

Sources: EPA Office of Solid Waste and Emergency Response Directive 9285.4-1. October 1986.

Verschueren, K. 1986. Handbook of Environmental Data on Organic Chemicals.

EPA. 1986. Quality Criteria for Water.

U.S. Fish and Wildlife Service. 1980. Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates. p. 137.

As mentioned in Section G, concentrations of pesticides in Great Lakes fish are well documented. Exhibits L-14 through L-15 show trends in DDT and dieldrin concentrations for Lake Michigan Lake Trout over a twelve year period. Although banned in the 1970s, dieldrin and DDT are still found in samples.

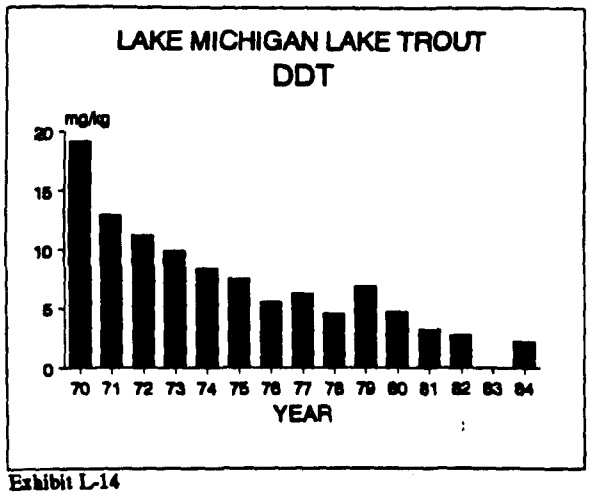

Exhibit L-14

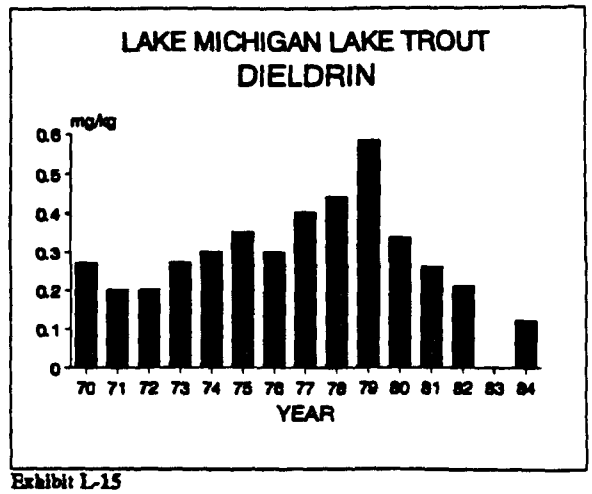

Exhibit L-15

Reversibility

The reversibility assessment for the bioaccumulation of pesticides in fish is assumed to be low. Many of the pesticides found in fish tissues are very persistent. DDT has been banned for a number of years but is still found in fish and birds. The concentration of these pesticides in sediments in the Basin are still significant, and therefore will continue to present risks of exposure through the food chain. Recent fish monitoring data does suggest, however, that pesticide residues in fish may be declining.[93]

Welfare Impacts

Due to a lack of information the assessment of environmental costs from pesticide exposure in the Basin will be primarily based on a qualitative discussion of such costs.

The bioaccumulation of pesticides in sport fishes in the Great Lakes has probably resulted in fewer fish caught due to the necessity of fish advisories, fewer viable fish species, and a decrease in the aesthetic appeal to fisherman of catching contaminated fish. The Great Lakes Sport fishery has been estimated to be worth $1.56 billion(US).

The cost of replacing one adult bald eagle was estimated to be approximately $40,000. The Fish and Wildlife Service estimated the value of a bald eagle based on the need to "hack" at least eight eagles to gain one adult bird. The estimate was made in conjunction with a kill of 7 eagles that ingested and died from the pesticide carbofuran.[94] However, estimates such as these should not be interpreted as suggestions that the replacement of impacted species is even possible or that replacement can be considered in the formulation of policy.

Other environmental costs include lost habitat from pesticide contamination. These costs are particularly severe if endangered species habitat is involved.

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[93] Schmitt, Zajicek, and Peterman, "National Contamination Biomonitoring Program: Residues of Organochlorine Chemicals in U.S. Freshwater Fish 1976-1984, Arch. Environ. Contamin. Toxicol., 19, 1990, pp. 748-781.

[94] Pesticide & Toxic Chemical News. August 8, 1990. "Bald Eagle Valued at $40,000, FWS Notes in Carbofuran-Predator Case," p. 9.

IV. PRIMARY AIR AND WASTE PROBLEM AREAS

M. SULFUR AND NITROGEN OXIDE EMISSIONS

Problem Area Description

Sulfur and nitrogen oxides cause a variety of primary and secondary effects. Primary effects include health, visibility, and welfare impacts. A major secondary effect is acid deposition, which results from the chemical transformations of oxides of sulfur and nitrogen to sulfates and nitrates. This process results in the production of acid rain, snow, and fog, as well as dry deposition of acidic particulate matter. Acid deposition alters the chemistry of affected aquatic and terrestrial ecosystems, damaging plant and animal life. Sources of sulfur and nitrogen oxides include a variety of industrial, commercial, and residential fuel and related combustion sources.

Sulfur dioxide (SO_2) is emitted primarily from the combustion of fossil fuels, particularly coal. The use of coal-fired power plants by the electric utility industry accounts for approximately 63 percent of nationwide emissions of SO_2. Other sulfur dioxide sources include industrial processes such as petroleum refining, pulp and paper manufacturing, iron and steel production, and industrial boilers. Nitrogen oxide (NO_x) emissions are also the result of fossil fuel combustion, namely the combustion of coal, natural gas, oil, and gasoline. Major emitters include the utility industry, industrial sources, and motor vehicles.

Sulfur and nitrogen oxides and acid aerosols can be transported over very long distances in the atmosphere. Therefore, problems in the Great Lakes Basin resulting from these pollutants are probably due to sources both inside and outside the Basin. Similarly, sources within the Basin probably contribute to acid deposition problems outside the Basin (i.e., in the northeast U.S. and southeast Canada). Nevertheless, in order to provide information on the potential sources of sulfur and nitrogen oxide pollution problems, we present information on the location of major concentrations of emitters within the Basin. Keep in mind, however, that these and other sources are responsible for problems in the Basin, and some emissions from the Basin produce effects far downwind of the Basin.

EPA's Aerometric Information Retrieval System (AIRS) data management system lists 1,434 stationary sources of sulfur and nitrogen oxide emissions in the Great Lakes Basin. Exhibit M-1 illustrates the geographic distribution of these sources by estimated SO_x and NO_x emissions in the Basin counties. Exhibit M-2 illustrates the geographic distribution of SO_x and NO_x monitoring sites within Basin counties. These sources are spread throughout 140 of the 213 Great Lake Basin counties. The counties with the greatest numbers of sources include:

- Milwaukee county, Wisconsin;
- Cook county, Illinois (Chicago);
- Lake county, Indiana (East Chicago, Gary);
- Wayne county, Michigan (Detroit);
- and numerous other counties in Wisconsin and Indiana.

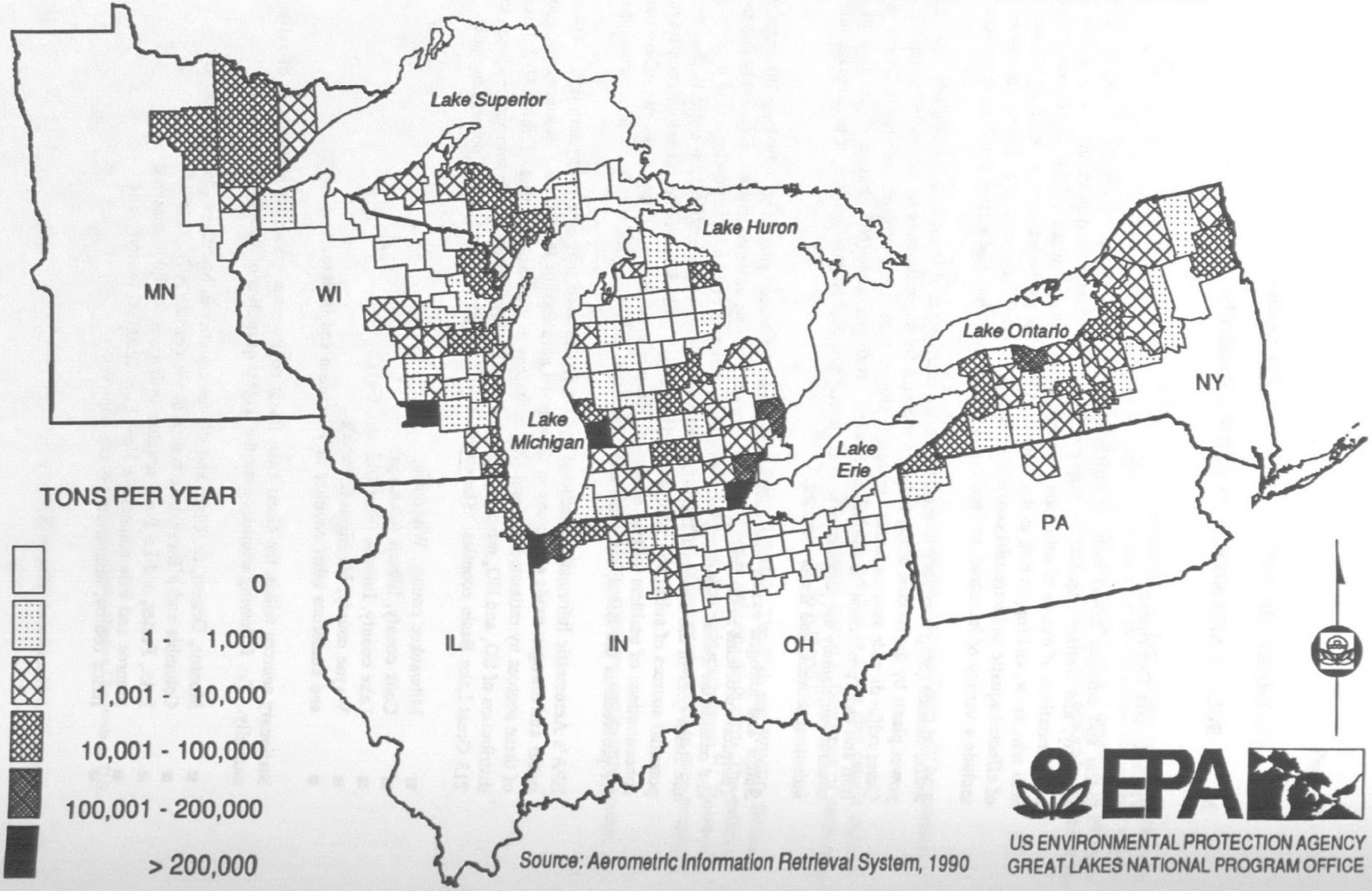
Stationary sources within the Great Lake Basin counties emit nearly 3 million tons of sulfur and nitrogen oxides annually. The following counties emit the largest quantities of these pollutants:

- Monroe, Ottawa, St. Clair, and Wayne counties in Michigan (757,000 tons/yr);
- Columbia and Milwaukee counties in Wisconsin (307,000 tons/yr);
- Lake, Porter, and La Porte counties in Indiana (475,000 tons/yr);
- Monroe and Erie counties in New York (260,000 tons/yr); and
- Itasca county, Minnesota (99,000 tons/yr).

Exhibit M-1

Estimated SO_x and NO_x Emissions

Great Lakes Basin Counties



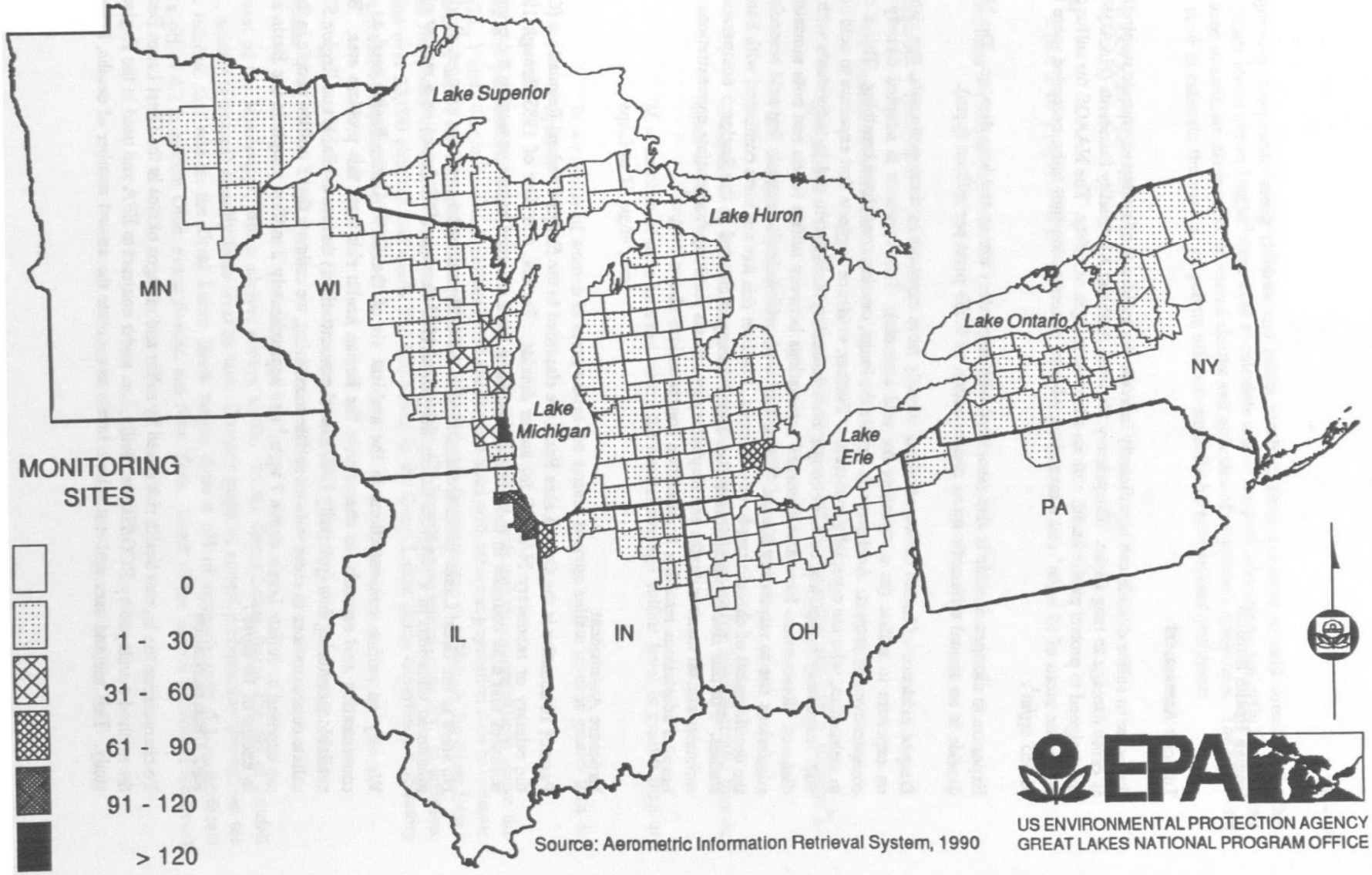
Source: Aerometric Information Retrieval System, 1990

US ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

Exhibit M-2

SO_x and NO_x Emissions Monitoring Sites

Great Lakes Basin Counties



Source: Aerometric Information Retrieval System, 1990

EPA

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GREAT LAKES NATIONAL PROGRAM OFFICE

Human Health Impacts

Toxicity Assessment

Exposure to sulfur dioxide can significantly increase the incidence of acute and chronic respiratory diseases as well as cause damage to lung tissue. The primary National Ambient Air Quality Standards (NAAQS) for sulfur dioxide, are designed to protect public health with an adequate margin of safety. The NAAQS for sulfur dioxide is an annual arithmetic mean of 80 ug/m^3 and a maximum 24-hour concentration (not to be exceeded more than once per year) of 365 ug/m^3.

Exposure to nitrogen dioxide is also associated with respiratory illness and lung damage. The NAAQS for nitrogen dioxide is an annual arithmetic mean concentration of 0.053 parts per million (ppm).

Despite evidence of health effects resulting directly from exposure to these pollutants, this risk evaluation focuses on exposure to sulfate (as a surrogate for acid aerosols). This approach is adopted directly from the Region 5 comparative risk project. Acid aerosols irritate the lungs, causing constricted breathing. This is of particular concern to asthmatics, who are especially vulnerable. Further, evidence suggests that exposure to acid aerosols is associated with respiratory symptoms, such as cough, both in healthy individuals and in individuals with chronic respiratory diseases. Researchers have also observed associations between sulfate levels and both mortality rates and hospital admissions due to respiratory illness. Laboratory work with animals suggests that acid aerosols could be related to the development of chronic respiratory diseases, however this has not been confirmed with human epidemiological studies. For this risk characterization, we apply the approach used in the Region 5 comparative risk work, which estimates annual number deaths and respiratory symptoms resulting from sulfate concentrations above 10 ug/m^3 and hospital admissions resulting from sulfate concentrations above 7 ug/m^3.

Exposure Assessment

Parts of 10 counties in the Great Lakes Basin are classified in the Code of Federal Regulations (CFR) as not attaining the primary or secondary NAAQS for sulfur dioxide. Further, a review of 1985 through 1989 monitoring data indicates that nine counties in the Great Lakes Basin have recorded values exceeding the primary NAAQS.

No areas in the Great Lakes Basin are classified in the CFR as nonattainment for nitrogen dioxide and no areas had monitored violations of a NAAQS during the period 1985 through 1989 (based on a review of AIRS reports).

We rely on sulfate concentrations in the ambient air of the Great Lakes Basin, used as a surrogate for the concentration acid aerosols, to characterize the human health risk from this problem area. Based on the limited available monitoring data (primarily 1989 annual concentrations) that are available and Region 5's assumptions about sulfate concentrations in areas without sulfate monitoring, we estimate that 5 million people in the Great Lakes Basin are exposed to sulfate levels above 7 ug/m^3 and approximately 2 million people in the Basin are exposed to levels in excess of 10 ug/m^3.

Risk Characterization

To characterize the human health risk posed by sulfur and nitrogen oxides in the Great Lakes Basin, we have adopted the method developed by RCG/Hagler, Bailly, Inc. under contract to EPA and used in the Region 5 comparative risk study. This method uses ambient sulfate levels to estimate the annual number of deaths, hospital admissions, and

episodes of respiratory symptoms among children and adults resulting from exposure to acid aerosols. In this approach, only sulfate levels above 7 ug/m^3 were used to calculate annual hospital admissions, and only levels above 10 ug/m^3 were used to estimate the number of annual deaths and episodes of respiratory symptoms. The following equations were used to estimate the number of people affected annually by acid aerosol pollution:

Annual Deaths = (3.7×10^{-5}) $(S_j - 10)$ (POP_j),

Annual Hospital
Admissions = (8.6×10^{-5}) $(S_j/9)$ (POP_j),

Children with
Respiratory Symptoms = (0.035) (C), and

Adults with
Respiratory Symptoms = (0.05) (M) + (0.02) (W),

where, j = location of monitoring site,

S_j = annual average sulfate concentration recorded at monitoring site j (if > 10 ug/m^3),

POP_j = exposed population at monitoring site j,

C = number of children in areas where the annual average sulfate level is greater than or equal to 10 ug/m^3,

M = number of men in areas where the annual average sulfate level is greater than or equal to 10 ug/m^3, and

W = number of women in areas where the annual average sulfate level is greater than or equal to 10 ug/m^3.

Monitoring data and professional judgment were used to identify locations with sulfate concentrations above the critical levels (i.e., 7 and 10 ug/m^3). The equations listed above were used with relevant population data to estimate the health impacts of sulfur and nitrogen oxides pollution. We estimate that exposure to sulfate in the Great Lakes Basin results in 148 premature deaths annually, and approximately 470 hospital admissions annually. In addition, we estimate that over 33,000 children and nearly 110,000 adults in the Great Lakes Basin experience respiratory symptoms as a result of exposure to sulfates.

Ecological Impacts

In the states east of the Mississippi, rain is almost always acidic. In the Great Lakes Basin, the pH of rainfall decreases (i.e., acidity increases) steadily from west to east. Contour maps of annual precipitation throughout the United States indicate that rain in the Great Lakes Basin ranges from a pH of approximately 5.1 in northeast Minnesota to a pH of 4.2 in eastern Ohio, Pennsylvania, and New York. Much of the central portion of the Great

Lakes Basin receives precipitation with an average pH of approximately 4.3 to 4.7.[1]

A number of scientific studies have clearly linked adverse effects on aquatic ecosystems to acid deposition. For example, considerable evidence suggests that numerous lakes and headwater streams in the Appalachian mountains have been acidified as a result of atmospheric deposition, either directly as deposition to the water surface or indirectly by interaction with soils in the watershed to enhance transport of hydrogen and aluminum ions to surface waters. Fish and other aquatic organisms are adversely affected by acidification and the increased concentrations of aluminum that frequently accompany it.

In contrast, there is no direct evidence linking observed adverse effects on terrestrial (forest) ecosystems to acid deposition and/or its precursors. Researchers have demonstrated a variety of potential adverse effects of acid deposition on foliar integrity, foliar leaching, root growth, soil properties, microbial activity in soil, resistance to pests and pathogens, germination of seeds, and establishment of seedlings. Adverse effects also might result from the combination of acid deposition, other gaseous pollutants such as ozone, natural biotic stresses (e.g., pests and pathogens), and natural abiotic stresses (e.g., sever climatic conditions). While there are many ways in which acid deposition might affect forests, no proposed linkage between deposition and effects on trees in North America are adequately supported by current data.[2]

In this section we first describe the severity of the effects of acid deposition on aquatic and terrestrial ecosystems and then discuss the reversibility of these effects.

Severity

Effects of acid deposition on aquatic ecosystems include changes in population density, community diversity, and species compositions of bacterial, algal, and macroinvertebrate communities and a decline in fish populations. Exhibit M-3 summarizes some major effects of acidification on the biotic components of freshwater aquatic ecosystems.

As shown in the exhibit and summarized in the Region 5 comparative risk report, acid deposition can severely affect aquatic systems by lowering the pH of surface waters. Based on field observations, most fish populations tolerate pH levels above 6 without apparent difficulty. At pH levels of 5.5, however, some species of fish are significantly affected and biotic diversity decreases. In some cases, certain species of fish can be lost through death or inability to reproduce. When waters have an acid neutralizing capacity (ANC) less than zero and a pH less than five, they are considered to be acidic. At this level, most fish die or cannot reproduce, and almost all species sustain serious damage. In addition, many other aquatic organisms cannot survive. Waters that are sensitive to acid but are not yet acidified may also experience episodic acidification during spring snow melt or heavy rainstorms. Generally, young fish and eggs will not survive these episodes.

The degree to which waters will be affected depends on both the level of acid deposition within the watershed and the ability of the soil and bedrock to act as a buffer.

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[1] National Atmospheric Deposition Program. 1987. "NADP/NTN Annual Data Summary: Precipitation Chemistry in the U.S." Ft. Collins, CO.

[2] Johnson, A.H. and McLaughlin, S.B. 1986. "The nature and timing of the deterioration of red spruce in the northern Appalachian mountains." pp. 200-230 in Acid Deposition -- Long-Term Trends. Natural Research Council, Washington D.C.

Erb. C. 1987. "The jury is still out." Penn State Agriculture, Fall 1987: 2-11.

In addition to acidifying surface waters, acid rain can leach toxic metals, including mercury, from the soil and deposit them in waterways. This problem is particularly evident in Michigan, Minnesota, and Wisconsin, where biologists have found unsafe levels of mercury in inland lakes.[3]

Studies have also indicated that the nitrogen compounds present in acid rain may act as a fertilizer, causing excessive growth of algae. When the algae die, the decaying algae depress oxygen levels, thus contributing to eutrophication. This, in turn, can threaten fish populations.

Exhibit M-3

Notes on Effects of Acidification on Freshwater Aquatic Ecosystems

pH	Effect
7.0	Reduced reproduction in most sensitive species (Daphnia)
6.6	First species lost (snails)
6.1	Reduction in zooplankton species
6.0	Loss of Daphnia, reduction in crayfish species
5.9 - 5.8	First fish species lost
5.8 - 5.7	Major crustaceans lost
5.6	First substantial change in phytoplankton density, crayfish lost
5.5	Most species of rotifers lost
5.5 - 5.0	Large reduction in decomposition rates
5.5 - 4.7	Most fish species lost
4.7	Major reduction in phytoplankton density
4.7 - 4.6	Major reduction in zooplankton density
4.2	Last fish species lost

Source: EPA (1986)[4]

The effect of acid deposition on lakes in the Great Lakes Basin has been evaluated in EPA's Eastern Lake Survey conducted by the National Acid Precipitation Assessment Program. In this study, the effects of acid deposition on

[3] Region 5 comparative risk report.

[4] For a more detailed summary over a broader hydrogen ion concentration range, see p. 141, Water Quality Criteria 1972, A Report of the Committee on Water Quality Criteria. Prepared by the National Academy of Science, National Academy of Engineering for EPA. March 1973. EPA-R3-73-003.

lakes in the following five areas in the Great Lakes Basin are evaluated:

- northeast Minnesota,
- the upper peninsula of Michigan,
- north central Wisconsin,
- "the upper Great Lakes" (i.e., land areas of Minnesota, Wisconsin, and Michigan), and
- the Adirondacks.

Exhibit M-4 summarizes the survey's findings regarding the pH of lakes in these five study areas. Note that NAPAP surveyed only lakes between 4 hectares (10 acres) and 2,000 hectares (4,940 acres). The results of the survey are applicable only to lakes falling within this size range. Consequently, the results shown in Table 2 underestimate the extent of acidification. This discrepancy is evident for the Adirondacks where the NAPAP study found that 11 percent of the lakes were already acidic, while a New York State study found that over 25 percent of the lakes were already acidic.[5]

As shown in Exhibit M-4, NAPAP's findings indicate that approximately 3,100 hectares of lake area in the Great Lakes Basin have been acidified (i.e., pH is less than or equal to 5). Another source of information, the state's reports to EPA under section 305(b) of the Clean Water Act, indicates that as many as 6,200 hectares of lakes and 42 river miles in the Great Lakes Basin are affected by acid deposition.

Exhibits M-5 and M-6 illustrate some of the observed effects on fish population associated with acidification of Adirondack lakes.

[5] The lakes that were studied in this report are not all in the Great Lakes Basin. However, because a large portion of the Adirondacks lies within the Basin, it is believed that many of these findings are germane as well to Basin lakes. Furthermore, virtually all of the region experiencing the highest hydrogen ion deposition in the NAPAP study area does fall within the Great Lakes Basin.

Exhibit M-4
pH Levels in NAPAP Eastern Lake Survey Lakes in the Great Lakes Basin

		Northeast Minnesota	Upper Peninsula of Michigan	North Central Wisconsin	Upper Great Lakes	Adirondacks
pH ≤ 5.0	Number of Lakes	0	95	30	0	129
	Percent of Lake Area	0 %	2 %	0.5 %	0 %	2 %
	Area in Hectares (Acres)	0	680 (1,680)	0	0	2,380 (5,880)
pH ≤ 5.5	Number of Lakes	0	137	163	0	258
	Percent of Lake Area	0 % [1]	3 %	2 %	0 %	8 %
	Area in Hectares (Acres)	0	1,200 (2,520)	1,960 (4,843)	0	9,520 (23,500)
pH ≤ 6.0	Number of Lakes	14	189	414	180	348
	Percent of Lake Area	0 % [1]	5 %	6 %	1 %	10 %
	Area in Hectares (Acres)	0	1,700 (4,200)	5,880 (14,530)	2,270 (5,610)	11,900 (29,400)

Source: NAPAP. 1988. NAPAP Interim Assessment: The Causes and Effects of Acidic Deposition. Volume IV: Effects of Acidic Deposition.

Exhibit M-5
Water Chemistry and Fish Population Status for 289 Adirondack Lakes

Fish Population Status	pH < 5.0	5.0 < pH < 6.0	pH > 6.0	Total
Waters with trout/salmonid species	15	77	122	214
Waters with only nontrout species	5	11	35	51
Waters without fish	13	5	6	24
Total	33	93	163	289

Source: Colquhoun, J., Kretzer, W., and Pfeiffer, M. 1984. Acidity status update of lakes and streams in New York State. New York State Department of Environmental Conservation Report WM (P-83(6/64)). Albany, N.Y.

Exhibit M-6
Effects of Acidification on Fish Populations in 604 Adirondack Lakes

Species	No Evidence for Loss of Population	Loss Apparently Unrelated to Acidification	Loss Apparently the Result of Acidification	
			Marginal Evidence	Adequate Evidence
Brook trout	409	86	114 [1]	98
Lake trout	68	25	10	8
Rainbow trout	54	34		2
Lake whitefish	28	24		1
Smallmouth bass	92	42		2
Largemouth bass	49	12		1
Chain pickerel	29	12		0
White sucker	336	66		10
Brown bullhead	420	74	13	13
Pumpkinseed sunfish	240	104		7
Yellow perch	185	80		2
Golden shiner	213	83	18	12
Creek chub	147	100		7
Lake chub	6	12		0

[1] Includes 71 lakes considered typical brook trout habitat, with only recent survey data available and no fish caught.

Source: Baker, J., and Harvey, H. 1985. Critique of acid lakes and fish population status in the Adirondack region of New York State. Draft final report for NAPAP Project E3-25. U.S. EPA, Washington, D.C.

Forests are also threatened by acid deposition. The Region 5 comparative risk report states that exposure to highly acidified rain or fog can injure leaves and needles. Further, tree growth may be stunted by alteration in soil chemistry caused by leaching of nutrients, such as magnesium and calcium, from the soil and by contamination of the soil with heavy metals, such as aluminum, that are released from soil particles. In addition, acid deposition can destroy flora and kill nitrogen-fixing microorganisms that nourish plants.

A paper in Penn State Agriculture summarizes the major hypotheses regarding the potential adverse effects of acid deposition (and other factors) on terrestrial ecosystems.[6] Acid deposition and ozone together might be leaching nutrients out of tree foliage and soil, weakening the tree, and stunting its growth. This, in turn, can make the tree more susceptible to biotic stresses from insects to fungi and abiotic stresses such as drought or nutrient-poor soil. An increasingly acidic soil can inhibit germination of seeds and establishment of seedlings, thus slowing the rate of replacement of dead trees. Acidic soil can have a direct effect on soil microorganisms, insects, and competing plants. At the cellular level, ozone causes reactions that move nutrients such as magnesium and potassium from inside the cell to the cell and leaf surface. When it rains, those nutrients wash off the leaf and into the soil. On steep slopes and in certain soils, these nutrients can be carried away from the tree instead of remaining where the root system could recapture them. The result can be a deficiency of nutrients to the tree.

Reversibility of Damage

The panel of scientists convened by the Cornell Ecosystems Research Center to assist EPA's national comparative risk study judged the impacts of acid deposition on aquatic and terrestrial ecosystems to be reversible in terms of decades.

Welfare Impacts

As in the Region 5 comparative risk study, we quantify the following economic damages from nitrogen and sulfur oxides pollution, including acid deposition:

- health effects due to sulfate levels;
- materials damage attributable to nitrogen oxides; and
- aesthetic damages associated with reductions in visual range.

Health Effects

EPA's Region 5 comparative risk study presented information on the costs of health effects associated with exposure to sulfate aerosols. We have applied the same approach to our findings for health effects in the Great Lakes Basin. Each premature death is valued at approximately $77,000 (in 1988 dollars) and hospital admissions are valued at $4,400 each (also in 1988 dollars). Consequently, the costs for the 148 predicted premature deaths is $11 million and the costs for the 470 hospital admissions is $2.1 million.

Materials Damage (Nitrogen Oxides)

As presented in the Region 5 comparative risk study, the primary materials damage associated with nitrogen dioxide

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[6] Erb, C. 1987. "The jury is still out." Penn State Agriculture, Fall 1987: 2-11.

results from the fading of dyes exposed to the pollutant. The EPA assumed the national cost of dye fading due to nitrogen dioxide is approximately $280 million per year. On a per capita basis, this equals roughly $1.20. To estimate the economic value of dye fading due to nitrogen oxide in the Great Lakes Basin, we multiplied the Basin population, 21 million people, by $1.20 for a total cost of $24.8 million.

Visibility Effects

Evaluation of the value of visibility effects also uses the approach presented in the Region 5 comparative risk study. Review of visual range data indicates that the only portions of the Basin with visibility reduced to approximately 15 km or less is northeastern Indiana, far southeastern Michigan, the entire portion of Ohio that is in the Basin, and Erie and Crawford counties in Pennsylvania.[7] The affected population in these areas is estimated to be 6.6 million people, which corresponds to 2.5 million households. Applying the value of $220 per household to this number of affected households in the Basin gives a cost of visibility effects of $560 million.

[7] Isopleth map from EPA (1979) provided by Kathleen D'Agostino, Region V. Source unknown. Figure 2-5: Median Summer Visual Range and Isopleths for Suburban/Nonurban Areas 1974 - 1976.

N. HAZARDOUS/TOXIC AIR POLLUTANTS

Problem Area Description

This problem area covers outdoor exposure to airborne hazardous air pollutants from routine or continuous point and non-point source emissions. This problem area covers exposure through both inhalation and air deposition of these pollutants to land areas. Runoff of deposited pollutants to surface waters and direct deposit to surface water is addressed in Section J (Atmospheric Loading to Surface Water). This category excludes, to the extent possible, risks from pesticides, radioactive substance, chlorofluorocarbons, emissions from waste treatment, storage and disposal facilities, storage tanks, and indoor air pollutants.

Two recent EPA studies on the risks of hazardous or toxic air pollutants in local areas of the Great Lakes Basin (Southeast Chicago, and Detroit/Windsor) have found the following pollutants to be the most significant contributors to cancer risk: coke oven emissions, formaldehyde, chromium, 1,3-butadiene, carbon tetrachloride, polynuclear aromatic hydrocarbons (PAHs), dioxin, benzene, gasoline vapors, arsenic, beryllium, and asbestos.[8] Toxic air pollutants with noncancer health effects include lead, arsenic, beryllium, and a number or organic compounds (such as acrolein, carbon tetrachloride, and methyl ethyl ketone).

Major sources of hazardous and toxic air pollutants include large industrial facilities, motor vehicles, chemical plants, commercial solvent users, and combustion sources. The Southeast Chicago and Windsor studies mentioned above found the following types of activities to be the most significant sources of these air pollutants: steel and coke manufacturing, motor vehicles, other manufacturing, fuel combustion (E.G., home heating).[9]

Lead gasoline additives, nonferrous smelters, and battery plants are the most significant contributors to atmospheric lead emissions. Transportation sources in 1988 contributed 34 percent of the annual emissions. This contribution has decreased substantially from approximately 83 percent in 1975, due to regulations issued in the early 1970's and mid 1980's which required gradual reduction of the lead content in all gasoline.

Human Health Impacts

Data presented in the Office of Air Quality, Planning and Standards' (OAQPS) "Cancer Risk from Outdoor Exposure to Air Toxics" (September 1989) was used in this report to estimate cancer risk. This approach parallels that used in the Region 5 comparative risk study. Noncancer effects, including risks from airborne lead, were also calculated in a manner that parallels the Region 5 comparative risk effort.

Toxicity Assessment

Cancer Risk

The carcinogens selected for evaluation include acrylonitrile, arsenic, asbestos, benzene, 1,3-butadiene, cadmium,

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[8] EPA. 1989. "Estimation and Evaluation of Cancer Risks Attributed to Air Pollution in Southeast Chicago." Air and Radiation Division, U.S. EPA Region V; and Engineering-Science, Inc. 1990. "Transboundary Air Toxics Study." Final Summary Report. Prepared for Air and Radiation Division, U.S. EPA Region V.

[9] Op. Cit., EPA, 1989, and Engineering-Science, Inc. 1990.

carbon tetrachloride, chloroform, chromium (hexavalent), coke oven emissions, dioxin, ethylene dibromide, ethylene dichloride, ethylene oxide, formaldehyde, gasoline vapor, hexachlorobutadiene, hydrazine, methylene chloride, perchloroethylene, products of incomplete combustion, trichloroethylene, vinyl chloride, and vinylidene chloride.

As necessary, OAQPS updated the cancer rates presented in the studies used in its report based on unit risk factors used by EPA. Although the pollutants studied varied from proven human carcinogens to probable human carcinogens to possible human carcinogens, all were treated equally in the analyses.

Noncancer Risk

Pollutants selected for evaluation of noncancer effects include acetaldehyde, acrolein, arsenic, benzene, beryllium, carbon disulfide, carbon tetrachloride, chloroform, ethylene oxide, formaldehyde, hydrogen sulfide, lead, methyl ethyl ketone, methyl methacrylate, methyl isocyanate, nitrobenzene, perchloroethylene, phenol, phthalic anhydride, styrene, tetraethyl lead, toluene diisocyanate, and vinyl chloride.

Exposure to these pollutants in ambient air can result in noncancer health effects ranging from subtle biochemical, physiological, or pathological effects to the pulmonary, nervous, gastrointestinal, cardiovascular, and hematopoietic systems. In addition, hepatic, renal, reproductive, and developmental toxicity have been observed, although not at levels present in ambient air. Although air levels of lead have greatly declined, atmospheric lead can contribute to the overall body burden of lead. Children six years old or younger are generally considered to be most vulnerable to the adverse health effects of lead. The NAAQS for lead is an arithmetic average over a calendar year of 1.5 ug/m^3.

Exposure Assessment

Cancer Risk

The OAQPS study used as the basis for the characterization of cancer risks for this problem area is based on information contained in 10 area specific or national air quality based risk-related reports on air toxics, 14 EPA source category and pollutant specific studies, risk assessments performed for the development of National Emission Standards for Hazardous Air Pollutants, and source specific risk data contained in the EPA Air Toxic Exposure and Risk Information System data base. National data was apportioned to the Great Lakes Basin by population using the following equation:

Great Lakes Basin Data = (National Data) (Population of Great Lakes Basin)/(Population of Nation)

In the national study, cancer risk estimates were derived giving equal consideration to measured and modeled data, provided that one estimate was not clearly preferable. Cancer rates for a pollutant and source category were extrapolated to total nationwide estimates based on the geographic scope of each study examined. Direct extrapolation to total nationwide estimates was possible for most pollutants due to their inclusion in at least one study of nationwide scope. In instances where a pollutant was included in a study of limited geographic scope, the concentration of the pollutant/source category in the area studied relative to the national concentration was considered. This information was then utilized to extrapolate to nationwide estimates.

It is specifically noted that Region 5 conducted a risk assessment in Southeast Chicago for a variety of air toxicants. Those results were not independently utilized, however, they were incorporated in the national study that was used as the basis population risk estimate for this problem area.

The national population utilized in the OAQPS report is 243,400,000. The population assumed in this analysis for the Great Lakes Basin is 30,050,000 or approximately 12 percent of the national population. Further, information from the Toxic Release Inventory indicates that the Great Lakes Basin emits about 350,000,000 pounds of air toxics per year while approximately 2,420,000,000 pounds per year are emitted nationally.[10] This corresponds to a Basin contribution of approximately 14 percent. Therefore, while this comparison is reasonably similar, the use of population may somewhat underestimate the cancer effects of air toxics.

Noncancer Risk

The preliminary results of an OAQPS Broad Screening study of non-carcinogens indicate that: 1) approximately 48 percent of the chemicals studied exceeded the health reference levels for chronic exposure; 2) long-term (annual) exposures were estimated for the Lowest Observed Adverse Effect Level (LOAEL) for 3-5 percent of the chemicals studied; 3) more frequently, 58 percent of the exposures exceeded health reference levels for short term (24-hour) exposures; and 4) in hundreds of U.S. cities, exposure to multiple pollutants was of concern, with concentrations in 260 cities exceeding the hazard index.

The preliminary results of OAQPS's Urban County study indicate that: 1) using long-term modeling of both average and maximum emissions, a substantial number of facilities were estimated to cause exceedances of health levels, with 31 percent of 131 facilities exceeding chronic health effect levels for 9 chemicals; 2) using short term modeling, more pollutants and facilities were associated with exceedances of LOAELs with and without uncertainty factors applied, with 75 percent of 131 facilities exceeding acute health effects levels for 442 chemicals; and 3) for chemicals of concern, substantial numbers of facilities were associated with exceedances of the health reference level, and a small percentage of facilities emitted pollutants in quantities exceeding the LOAELs.

Based on a review of 1985 to 1989 AIRS monitoring data, only 1 of 33 Great Lakes Basin counties that were monitored for lead reported exceedances of the lead standard. The exceedances occurred in Lake county, Indiana, where a total five monitoring stations reported exceedances including two monitors located in East Chicago and three in the city of Hammond. Seven violations occurred in Lake county in 1985, two in 1987, and one in 1989.

Risk Characterization

Cancer Risk

In the studies used in OAQPS's "Cancer Risk from Outdoor Exposure to Air Toxics", aggregated maximum lifetime individual risks exceeding 10^{-4} were reported in almost every case. Risks of 10^{-3} or greater from individual pollutants were reported adjacent to many types of sources. Average lifetime individual risks in urban areas from exposure to many pollutants were generally between 10^{-4} and 10^{-5} but ranged from 10^{-3} or 10^{-6}. These levels were the result of combined exposure to mobile and stationary sources. The two EPA studies on local effects estimated overall individual risks of $2x10^{-4}$ in Southeast Chicago[11] and $9x10^{-5}$ in the Southeast Michigan/Windsor area[12]

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[10] U.S. EPA. 1990. Draft of "Second Annual Report on U.S. Progress in Implementing the Great Lakes Water Quality Agreement with Canada."

[11] Op. Cit., EPA. 1989.

[12] Op. Cit., Engineering-Science, Inc. 1990.

In the OAQPS study, estimates of annual cancer incidence were initially derived by estimating the annual cancer case per million population for each pollutant source category combination reported in the data sources. These estimates were then modified as necessary to reflect updated unit risk and emission factors. Total nationwide annual incidence was then estimated by summing across all pollutant/source categories.

The procedure outlined above results in an estimate of 1,580 to 2,540 cancer cases per year, nationally, caused by exposure to the pollutants listed previously.[13] With the Great Lakes Basin comprising approximately 12 percent of the Nation's population, apportioning national data to the region by population results in a projection of 190 to 310 cancer cases per year in the Great Lakes Basin. The two local area risk assessments discussed above (i.e., Southeast Chicago and the Transboundary area) estimated approximately 1 case per year in Southeast Chicao and 5 cases per year in the Southeast Michigan/Windsor area.

Noncancer Risk

Noncancer risks from exposure to toxic pollutants that are routinely emitted to the air by industrial or commercial sources are being evaluated by the OAQPS in a Broad Screening Urban County Study. Based on analysis of the preliminary data available from the study, it is reasonable to conclude that acute and chronic environmental exposures to toxic air pollutants have the potential to adversely impact public health, although the exact magnitude of the increased risks identified in this project is unclear. It is expected that short-term intermittent releases may be expected to affect greater numbers of individuals than long-term emissions.

There is some uncertainty associated with characterizing noncancer health risks at exposures greater than the reference dose and less than the LOAEL. Nevertheless, using the Broad Screening portion of the study, it is estimated that 58 million people and 38 million people nationally are exposed to levels of pollutants that are greater than health reference levels for acute effects and chronic effects, respectively.

Provided that Basin characteristics are similar to national characteristics, an estimate of the Great Lakes Basin values can be determined using population as an indicator. National data was therefore apportioned to the Basin population resulting in an estimate of 7.2 million people and 4.7 million people in the Great Lakes Basin exposed to levels of pollutants which are greater than health reference levels for acute and chronic effects, respectively.

All of the five monitors registering violations of the lead standard in the Great Lakes Basin were located in two cities in Lake County, Indiana (i.e., East Chicago and Hammond). The populations of these cities were therefore considered to be reasonable representation of the number of people potentially at risk of experiencing adverse health effects due to exposure to airborne lead. Using 1980 population data, the total number of people considered to be at risk in the Great Lakes Basin is approximately 134,000.

Ecological Impacts

With respect to terrestrial ecosystems, air toxics may have similar effects on animal populations as they do on humans. However, studies on wildlife cannot readily be performed either through epidemiological or laboratory approaches. Further, sufficient information could not be found to characterize the effects of air toxics on other flora and fauna.

Atmospheric deposition is generally believed to be the major pathway for many toxicants reaching the Great Lakes,

[13] These national numbers are different than those presented in the OAQPS report since the risks due to waste treatment, storage and disposal facilities, radionuclides, and radon have been subtracted. This is consistent with the problem area definition and description.

this pathway is discussed in Section J (Atmospheric Loading to Surface Water).

Welfare Impacts

Quantified economic damage due to hazardous and toxic air pollutants are based on estimates of health effect costs associated with the number of annual cancer cases presented above. This method was developed by RCG/Hagler, Bailly, Inc. under contract to EPA and was used in the Region 5 comparative risk study. Economic effects associated with noncancer health endpoints were not estimated, but based on the large population exposed to pollutant levels greater than health reference levels, these effects could be significant in the Great Lakes Basin.

To estimate costs, the estimated annual cancer cases in the Great Lakes Basin from air toxics were multiplied by the direct medical cost and foregone earnings per cancer case according to the following equation:

HC = (Annual Cancer Cases) (Direct Costs and Foregone Earnings)

where:

HC = health costs

Estimated direct and indirect medical cancer costs are based on a range of cost per estimates. The lower bound estimate, based on Hartunian, et al., is $80,000, while the upper bound estimate developed by the American Cancer Society is $137,000. These estimates provide differing values for foregone earnings and medical costs. Both estimates are weighted average costs associated with all types of cancer. Loss of earnings estimates ranged from a lower bound of $11 million to an upper bound of $32 million.

O. ACTIVE HAZARDOUS WASTE MANAGEMENT FACILITIES

Problem Area Definition

The Active Hazardous Waste Management Facilities problem area evaluates the risks to human health and the environment posed by facilities that generate, store, treat, and/or dispose of hazardous wastes. Specific facilities and activities covered in this problem area are:

- hazardous waste generating sites, including industrial plants and other facilities producing and accumulating hazardous wastes;
- hazardous waste storage and treatment facilities;
- land disposal units including landfills, land treatment units, waste piles, and surface impoundments;
- hazardous waste incinerators;
- boilers and industrial furnaces using hazardous waste as fuel;
- hazardous waste recycling units currently exempted from RCRA; and
- inactive solid waste management units at active hazardous waste facilities;

The types of risks to human health and the environment resulting from active hazardous waste facilities include those resulting from accidental or non-accidental releases of hazardous waste and waste constituents to air, soils, surface water, and ground water. This analysis focuses on releases of hazardous waste constituents to ground water and the resulting risks to human health and the environment posed by these releases. The analysis does not address risks from air and soil contamination, nor does it address the risk posed by the transportion of hazardous waste to and from RCRA hazardous waste facilities.

There are approximately 450 hazardous wastes including solvents, process wastes, and discarded commercial chemical products generated, stored, treated, or disposed at RCRA Subtitle C facilities and which pose a potential threat to human health and the environment.[14]

The total number of estimated operating and corrective action units for the Great Lakes Basin is seen below in Exhibit O-1. Exhibit O-2 depicts the land disposal facilities throughout the eight Great Lakes States. Exhibits O-3 through O-9 provide the geographic distribution for RCRA facilities of different sizes and types.

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[14] The Region 5 problem area paper was examined to determine whether it could be applied to the Great Lakes Basin. The Region 5 analysis evaluated a sample of 49 RCRA facilities and used the results to characterize the remainder of Region 5 RCRA facilities. Because a majority of the Region 5 sample sites (52%) as well as a majority of all Region 5 RCRA sites are located in the Great Lakes Basin, these same facilities were determined to be representative of the Great Lakes Basin RCRA sites. Thus the Region 5 methodology was used as a basis for the Great Lakes Basin risk analysis.

EXHIBIT O-1
RCRA Units in the Great Lakes Basin Region

	Land Disposal Units (LDUs)	Storage and Treatment Units (STUs)	Incinerators
Operating[a]	183	407	18
Corrective Action[b]	284	977	NA

[a] SOURCE: HWDMS, 1991, for Great Lakes Basin.
[b] Estimated using ratio of corrective action units to operating units in Region 5.

Human Health Risk Assessment

Toxicity Assessment

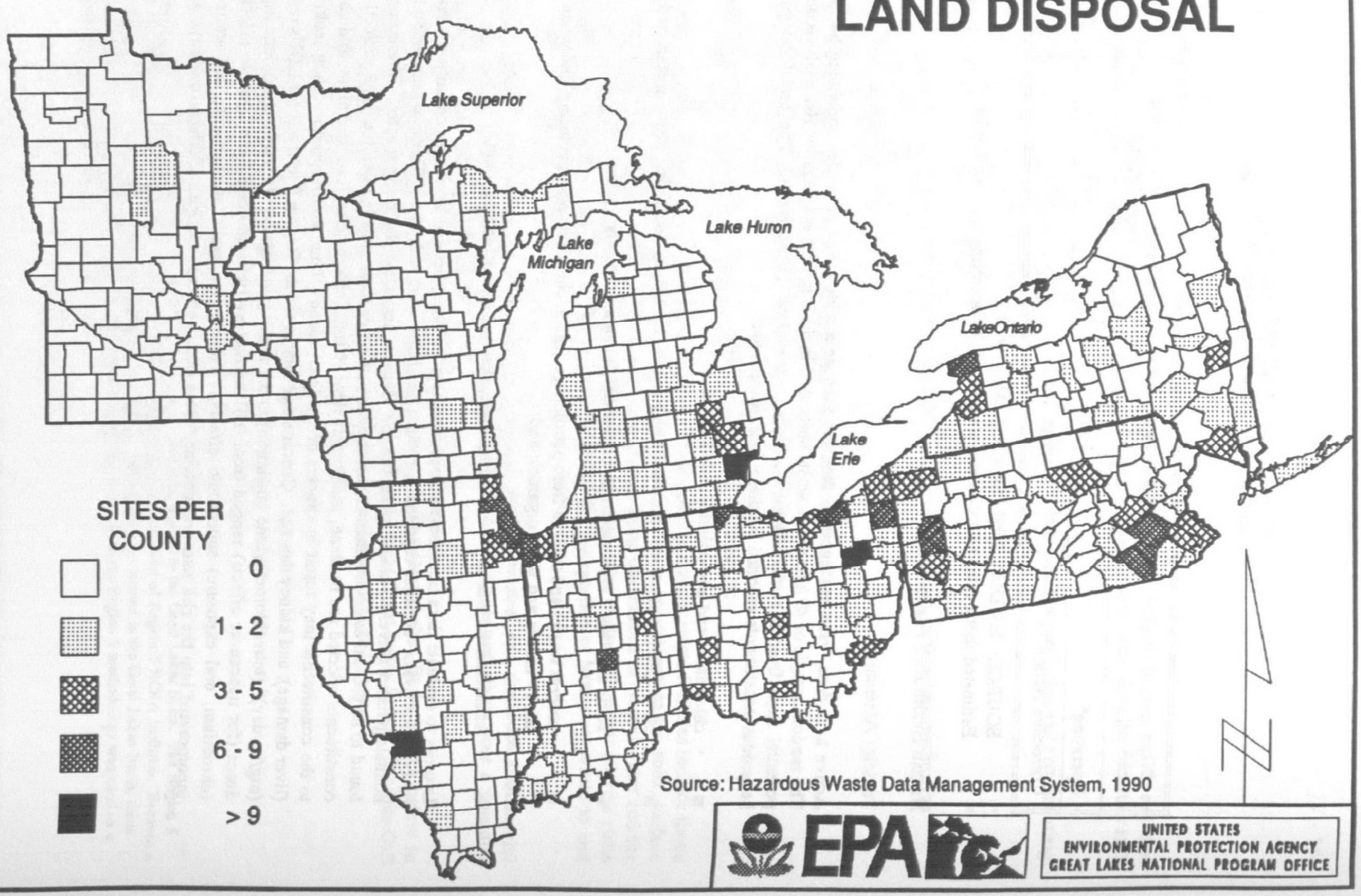
Active hazardous waste management facilities manage a wide range of wastes containing hazardous constituents. The random sample of 49 hazardous waste units used in the Region 5 comparative risk analysis was used to evaluate potential risks from hazardous waste facilities in the Great Lakes Basin. The broad categories of waste and hazardous constituents reported by these facilities include:

- chlorinated and non-chlorinated solvents;
- electroplating solutions and wastewater treatment sludges containing heavy metals and cyanides;
- acids and bases from electroplating, metal finishing and other processes;
- process wastes and sludges from petroleum refining, chemicals manufacturing, and wood treating containing heavy metals and toxic organics; and
- characteristic wastes which are ignitible, reactive, corrosive and toxic.

In order to evaluate risks from these hazardous waste facilities, several hazardous constituents that are representative of common waste streams reported for these facilities were selected. These wastes include halogenated and nonhalogenated solvents, heavy metal bearing sludges, and metal finishing wastes. These constituents were also found to be present as environmental contaminants at six or more sites in a sample of 19 corrective action sites. The constituents selected are benzene, trichloroethylene, tetrachloroethylene, lead, cadmium, and chromium. Exposure to the constituents may result in cancers of the liver, kidney, lung, and respiratory tract; leukemia; hepatotoxicity (liver damage); and kidney damage. Cancer slope factors for the Region 5 analysis for LDUs ranged from 9.5×10^{-7} $(mg/kg/day)^{-1}$ (tetrachloroethylene inhalation) to 5.1×10^{-2} $(mg/kg/day)^{-1}$ (tetrachloroethylene ingestion). Reference doses (for noncancer effects) ranged from 0.01 mg/kg/day (tetrachloroethylene, chronic effects) to 10 mg/kg/day (chromium, oral exposure) subchronic effects. Toxicity for tanks, incinerators, and waste fuel burners were incorporated into the risk numbers obtained from other sources (see Risk Characterization).

Exhibit O-2

RCRA FACILITIES LAND DISPOSAL



Source: Hazardous Waste Data Management System, 1990

EPA

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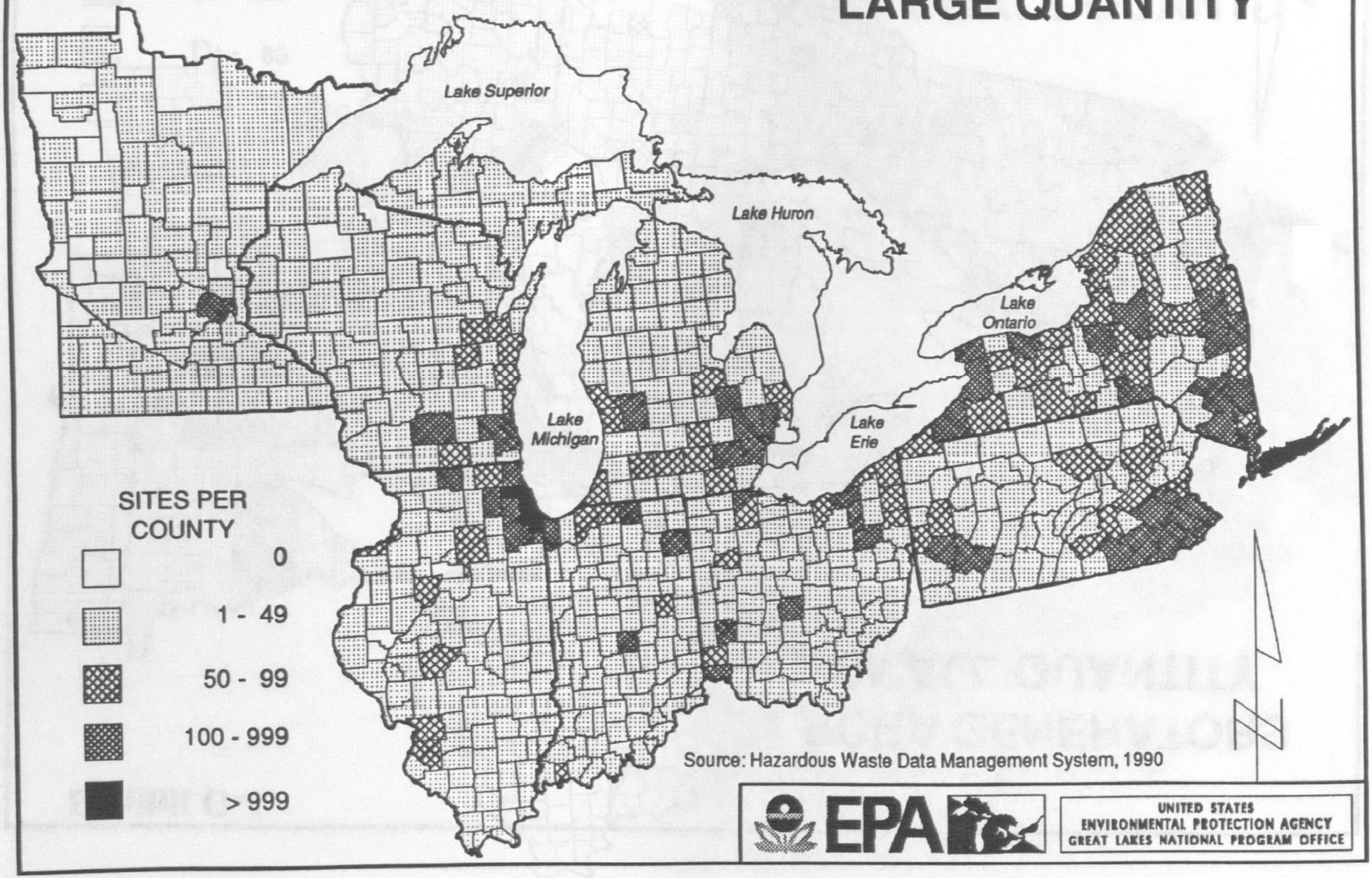
ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

Ehibit O-3

RCRA GENERATORS LARGE QUANTITY



Source: Hazardous Waste Data Management System, 1990

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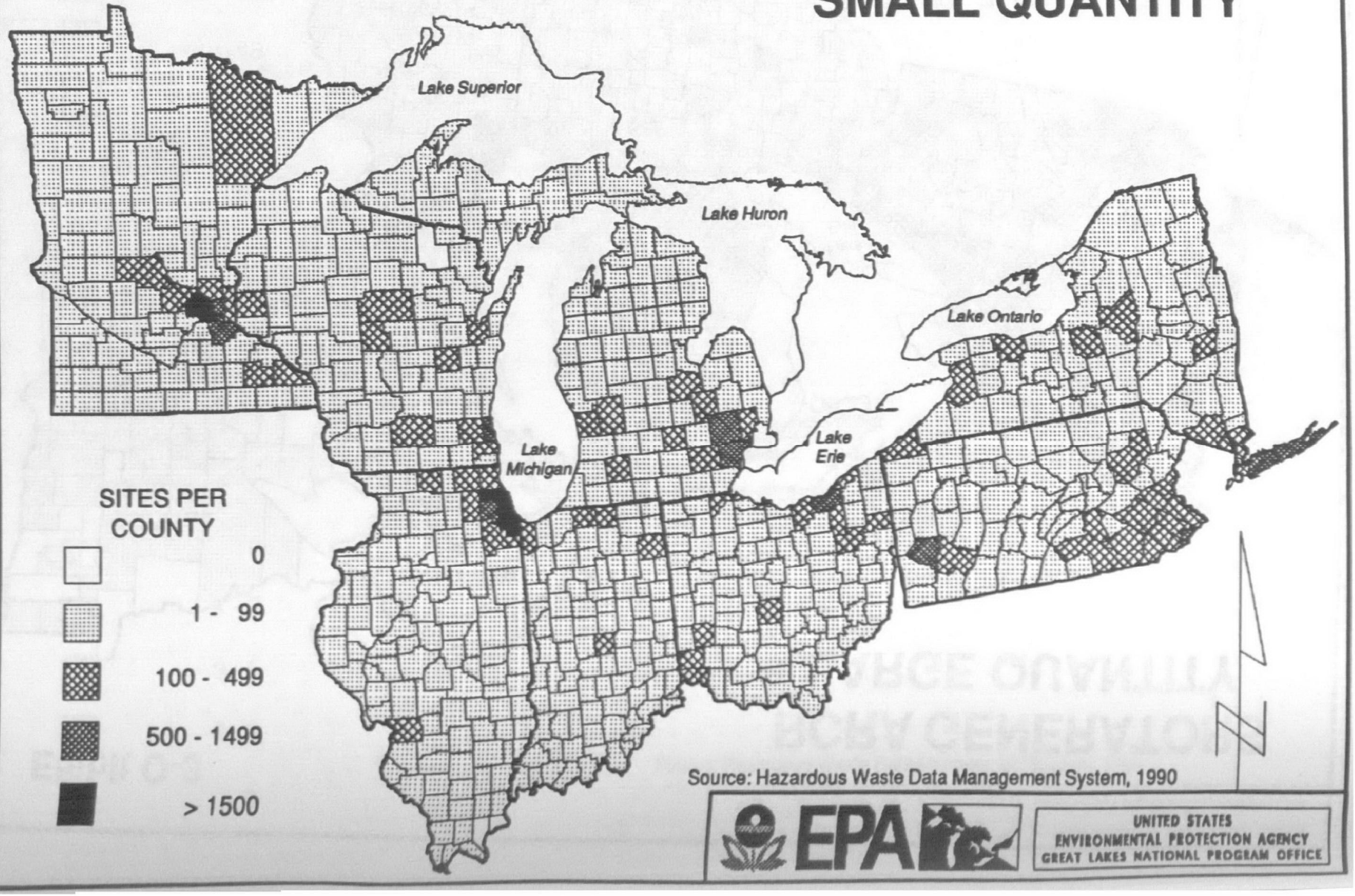
Exhibit O-4

RCRA GENERATORS SMALL QUANTITY



Source: Hazardous Waste Data Management System, 1990

EPA

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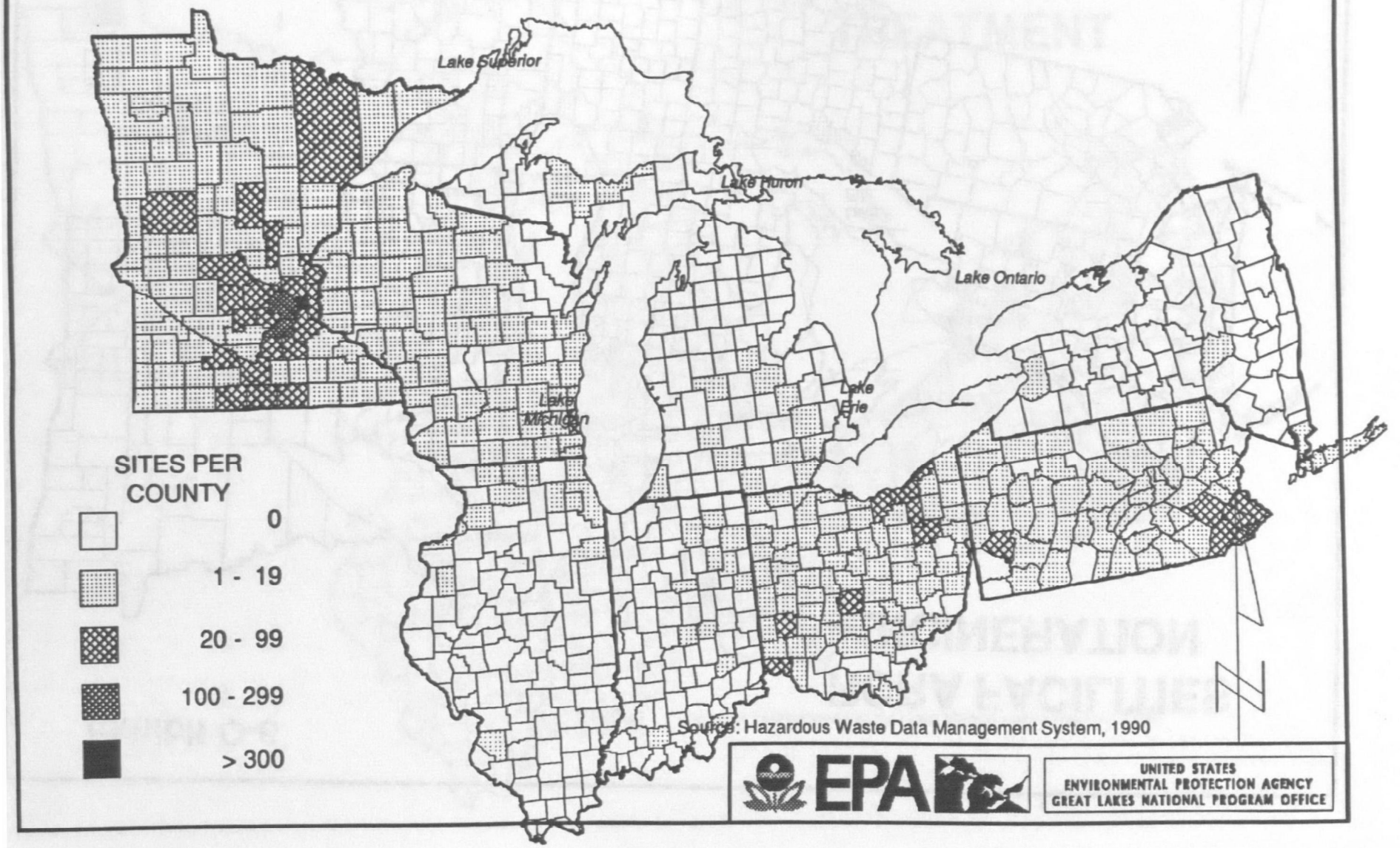
Exhibit O-5

RCRA GENERATORS VERY SMALL QUANTITY



Source: Hazardous Waste Data Management System, 1990

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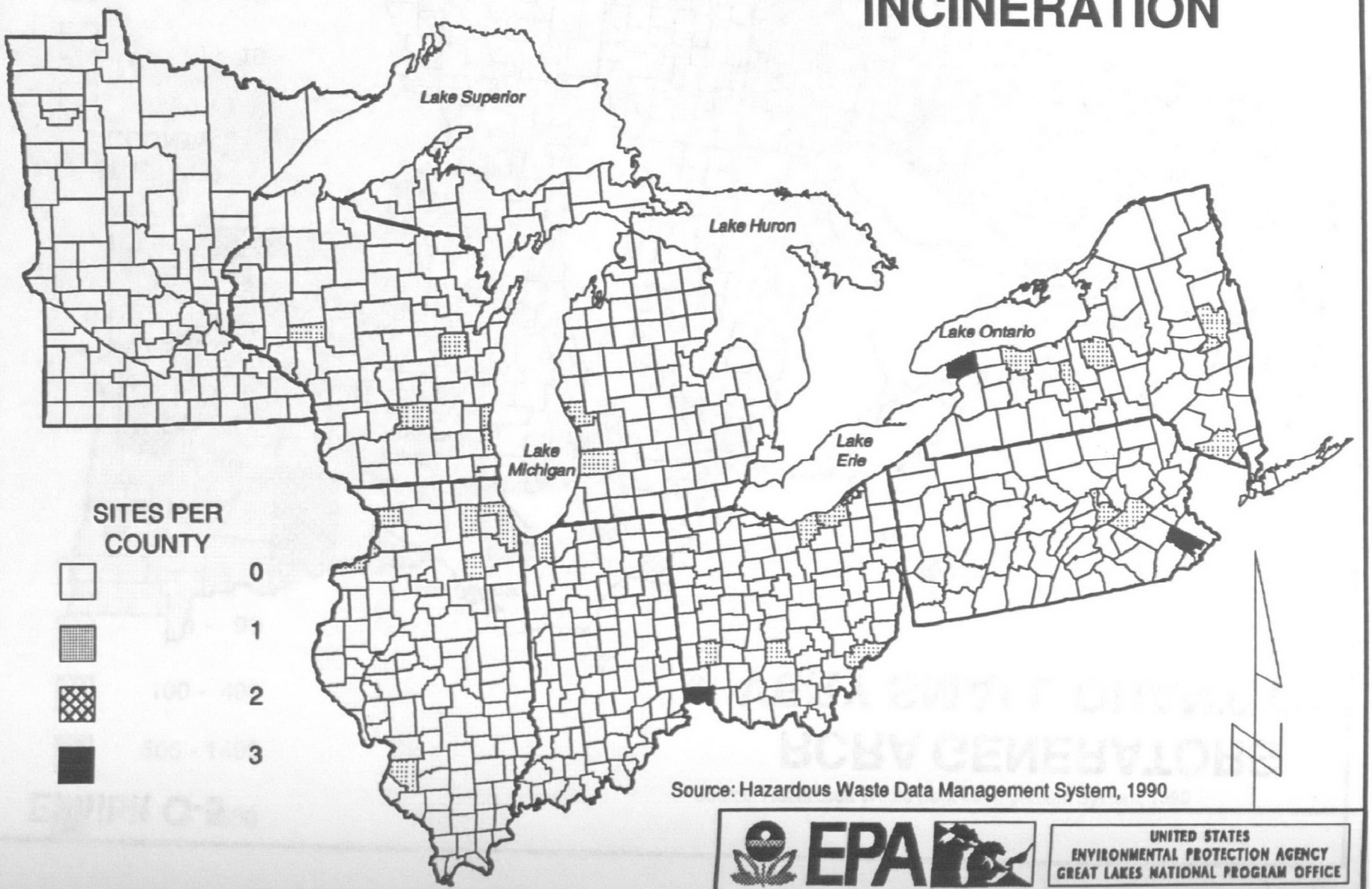
Exhibit O-6

RCRA FACILITIES INCINERATION



Source: Hazardous Waste Data Management System, 1990

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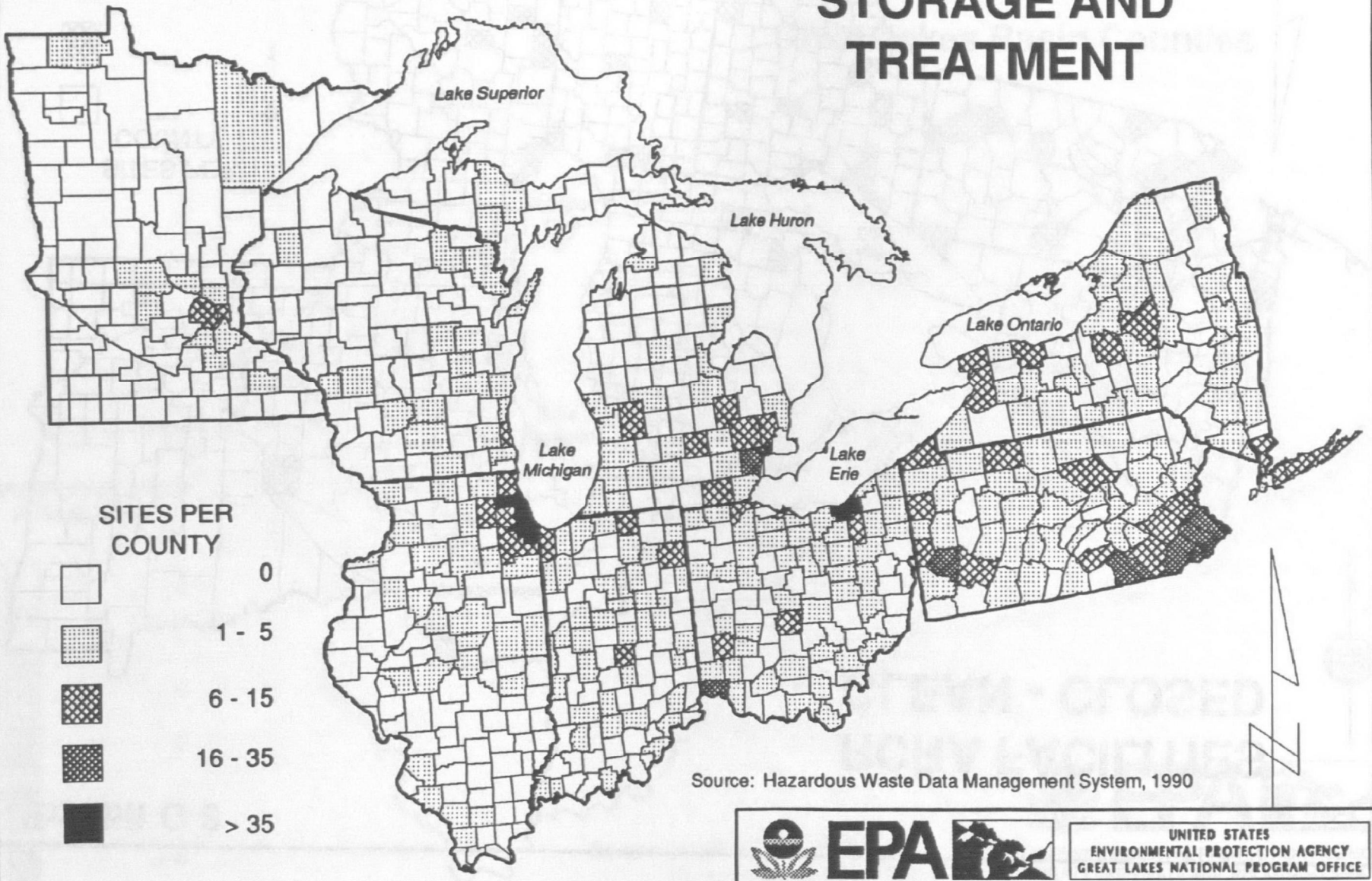
Exhibit O-7

RCRA FACILITIES STORAGE AND TREATMENT



Source: Hazardous Waste Data Management System, 1990

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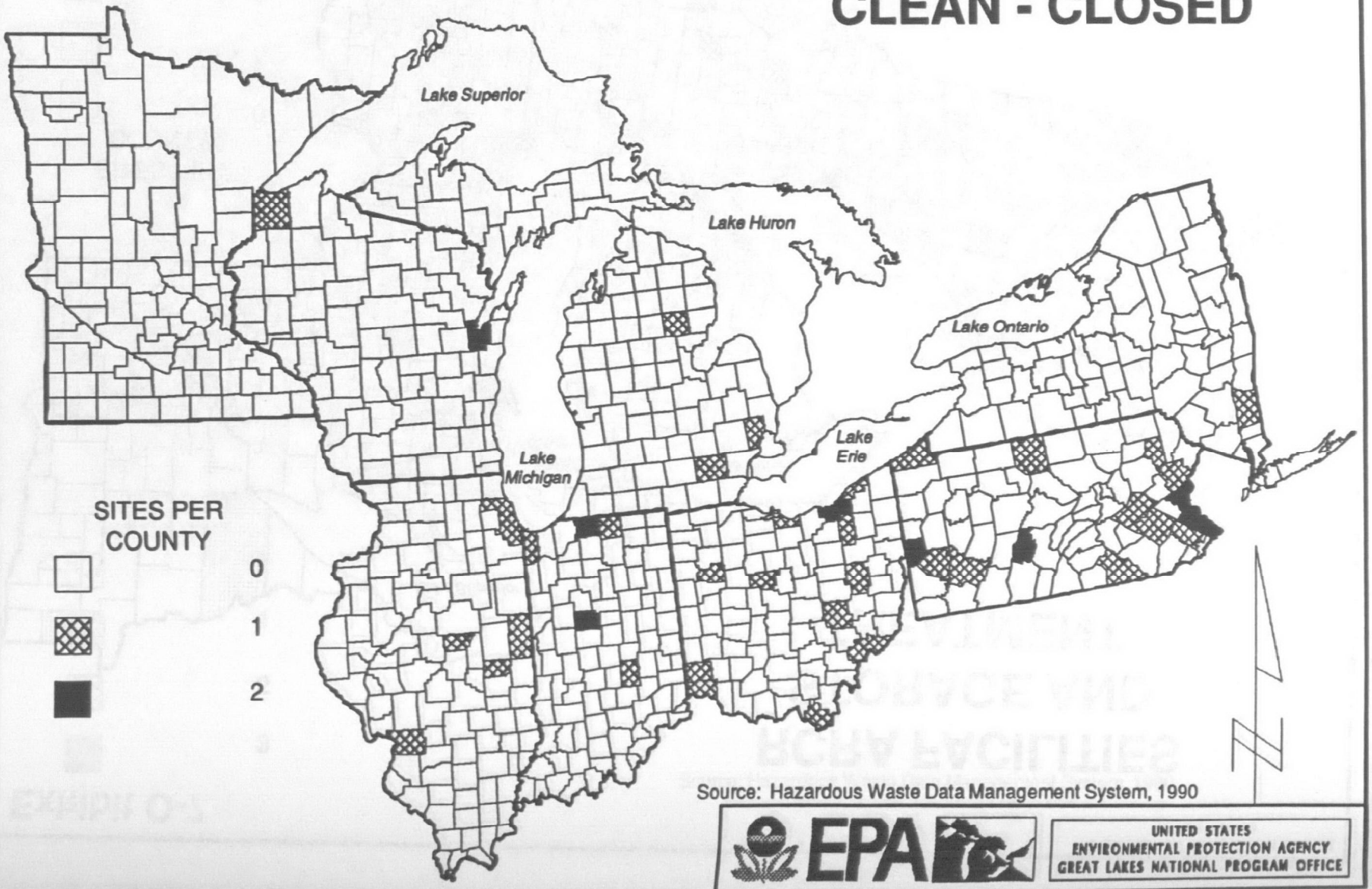
Exhibit O-8

RCRA FACILITIES
CLEAN - CLOSED



Source: Hazardous Waste Data Management System, 1990

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Exhibit O-9

HAZARDOUS WASTE FUEL BURNERS

Great Lakes Basin Counties

Source: Hazardous Waste Data Management System, 1990.

US ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

Exposure Assessment

Potential routes of exposure to releases of hazardous constituents from hazardous waste sites include exposure through ground-water contamination, surface water contamination, air emissions, and direct contact with hazardous wastes. In general, exposure through ingestion of drinking water has been assumed for this analysis as the most important route of exposure to hazardous constituents from operating hazardous waste facilities and corrective action sites. Therefore, this assessment is focused on exposures through ground water for evaluating risks from operating LDUs, storage and treatment units (STUs), and for evaluating risks from all units projected to undergo corrective action. It is also focused on exposures through air for evaluating risks of operating incinerators.

Surface water has not been included as a significant route for human exposure to contaminants from active hazardous waste facilities. Public water supply systems generally are used when the water supply is surface water, and these systems are highly regulated. Hence, the probability of significant exposure to hazardous constituents from drinking water from these systems is assumed to be quite low, since any contamination of these public drinking water supplies would be greatly reduced as a result of dilution and contaminant reduction through treatment.

From the Region 5 analysis, concentrations in water for LDUs and corrective action sites are assumed to range from 0.01 mg/l for benzene, to 0.02 mg/l for trichloroethylene, to .35 mg/l for tetrachloroethylene. These concentrations then were adjusted by a factor of 10 for the 1 km distance and 1000 for the 5 km distance to reflect dilution and attenuation between the facility boundary and the wells (see below). Exposure concentrations for tanks, incinerators, and waste fuel burners were incorporated into the risk numbers obtained from other sources.

The potentially exposed population from RCRA units described above was estimated for the Great Lakes Basin through a process of extrapolating the data used in the comparative risk analysis performed for Region 5. The methodology used in that analysis also was applied. The Region 5 comparative risk analysis estimated the potentially exposed populations using the following assumptions:

- Exposures through ground water would occur through private residential wells, and not through public wells supplying public systems due to Safe Drinking Water Act requirements for public system safety.

- Areas with residential populations of less than 1,000 within 1 km of the hazardous waste unit, or less than 25,000 within 5 km are primarily rural/suburban in nature and drinking water for these residents would be provided by private wells.

- About 25 percent of the people residing within 5 km of facilities located in a rural/suburban area (i.e., using private wells) could be potentially exposed to ground-water contamination based on potential plume size:

    - Those residing within 1 km would be exposed at contaminant concentrations equal to the fenceline concentration divided by a dilution/attenuation factor of 10.

    - Those residing within 5 km but greater than 1 km would be exposed at contaminant concentration equal to the fenceline concentration divided by a dilution/attenuation factor of 1000.

Using these assumptions, the potentially exposed population was calculated by:

- determining the percentage of units in the sample with populations of less than 1,000 within 1 km, and 25,000 within 5 km;

- assuming an average population of 500 within 1 km, and 12,500 within 5 km, of facilities within these

categories; and

- scaling up the universe of operating units and units projected to undergo corrective action by using the resulting percentages.

75 percent of LDUs were assumed to eventually result in ground-water contamination (based on a sample of Region 5 Environmental Priority Initiative [EPI] scoring results). This is a conservative assumption in that:

- Operating units meeting requirements for liners and leachate collection systems, and land disposal restrictions, are not expected to result in environmentally significant ground-water contamination; and

- Confirmed ground-water contamination exists at a much lower number of LDUs than that estimated using the 75 percent assumption.

One percent of operating STUs and 100 percent of corrective action STUs were assumed to eventually result in ground-water contamination.

This methodology was applied to the universe of operating and corrective action units in the Great Lakes Basin with certain modifications due to data gaps and the fact that the Great Lakes Basin is more urban than Region 5 and therefore has greater population density. That is, the Region 5 analysis assumed that 66% of the LDUs are located in rural areas where private wells are used. Because the population density of Region 5 is about 80% of the Great Lakes Basin (140 people per square mile in Region 5 versus 180 people per square mile in Great Lakes Basin), and therefore the Great Lakes Basin is assumed to have fewer of its LDUs in rural areas where private wells are used, the percentage of LDUs located in rural Great Lakes Basin areas was estimated to be 0.8 x 0.66 = 53 percent. A similar adjustment was made for STUs and incinerators. The estimated potentially exposed populations within 1 km and 5 km of operating or corrective action units is shown in Exhibit O-10.

Human Health Risk Characterization

This section addresses cancer and noncancer risks from RCRA hazardous waste management facilities.[15] The following subsections discuss land disposal units, storage and treatment units, incinerators, and hazardous waste fuel burners.

Operating and Corrective Action Land Disposal Units

For operating corrective action and LDUs, cancer risks were calculated for the Region 5 analysis based on contaminant levels observed in ground water at a sample of LDUs requiring corrective action. The concentrations used are pre-cleanup levels, which exceed applicable ground-water protection standards for operating units and for corrective action units. Under the current RCRA program, these levels of contaminants would not be allowed to occur over a long time period without remediation. Therefore, the estimate prepared is an upper bound risk.

The estimated individual incremental lifetime cancer risk resulting from these units and corrective action sites ranges from 2×10^{-4} to 3×10^{-6} (see Exhibit O-11). Individual risk estimates for operating and corrective action LDUs were apportioned by risk level, based on the percentages determined in the sample (i.e., some sites are represented by tetrachloroethylene and some by both benzene and trichloroethylene; see Exhibit O-11).

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[15] Due to time constraints, noncancer health effects were not addressed.

Calculations of individual cancer risks for ground-water contamination from these operating units are shown in Exhibit O-12.

When applied to the exposed population, these risk levels result in an estimate of 0.77 additional cancer cases from operating units over a 70-year period (0.01 cases per year) and 1.2 additional cancer cases from corrective action units over a 70-year period (0.02 cases per year).

EXHIBIT O-10
Approximate Potentially Exposed Populations[a]

	Land Disposal Units		Storage & Treatment Units		Incinerators[b]
	Operating	Corrective Action	Operating	Corrective Action	Operating
Exposed Population, 1 km	9,089	14,090	224	5,374	NA
Exposed Population, 5 km	227,293	352,424	5,482	1,343,116	1,200,000

[a] Estimates of populations are based on a sample of 49 operating RCRA Subtitle C facilities in Region 5. Population characteristics of these facilities were applied to all RCRA facilities located in the Great Lakes Basin.

[b] Estimate of exposed population was derived using per unit exposure in Region 5 and adjusting for greater urbanization of Great Lakes Basin.

EXHIBIT O-11

Calculation of Individual Carcinogenic Risks: LDUs

Constituent	Slope Factor $(ppm/d)^{-1}$		Concentration in water	Chemical Specific Risk	
	Oral	Inh.	(mg/l)[a]	Oral[b]	Inh.
Tetrachloro-ethylene	5.1×10^{-2}	9.5×10^{-7}	0.35	2×10^{-4}	2×10^{-9}
Benzene	2.9×10^{-2}	8.3×10^{-6}	0.01	4×10^{-6}	5×10^{-10}
Trichloro-ethylene	1.1×10^{-2}	1.7×10^{-6}	0.02	3×10^{-6}	2×10^{-10}
Total Pathway Risk				2×10^{-4}	3×10^{-9}
Total Exposure Risk					2×10^{-4}

[a] Concentrations are based on average of maximum concentrations observed in monitoring wells at corrective action sites in Region 5. Concentrations have been adjusted by a factor of 10 to reflect dilution/attenuation between the facility boundary and residential wells for populations within 1 km.

[b] Assumes oral exposure through drinking water.

EXHIBIT O-12*
Cancer Risk Levels From LDUs

Percent of LDUs	Distance to Private Well (D)	Risk
32%	D < 1 km	2×10^{-4}
68%	D < 1 km	7×10^{-6}
32%	1 km < D < 5 km	2×10^{-6}
68%	1 km < D < 5 km	7×10^{-8}

*For distances under 1 km to a private well, a dilution/attenuation factor of 10 is assumed. For distances between 1 km and 5 km, a factor of 1000 is assumed.

Storage and Treatment Units

For STUs, cancer risks were estimated based on risk levels projected in the "Hazardous Waste Tanks Risk Analysis, Draft Report." This report provides estimates of cancer risk ranges for hazardous waste storage units where both the primary and secondary containment fail. The individual incremental lifetime cancer risk in these cases is estimated to be 1×10^{-3} in about 10 percent of the cases, 1×10^{-4} in 10 percent of the cases, and 1×10^{-7} in 20 percent of the cases (it is assumed to be less than 1×10^{-7} in the remaining cases). The resulting cancer risk estimate for operating STUs is approximately 0.02 additional cancer case over a 70-year period. For corrective action LDUs the resulting cancer risk estimate is 5.9 additional cancer cases over a 70-year period, or 0.08 per year.

The estimate of the percentage of tanks with non-zero risk is a conservative estimate based on professional judgement. It is probable that the actual percentage of tanks experiencing long term failure of primary and secondary containment will be less than 1 percent.4444[16]

Incinerators

Risk assessment for three incinerators in Region 5 were sampled. The maximum individual lifetime cancer risk calculated for these incinerators was 1×10^{-6}. This estimate was then used to project 2.0 additional cancer cases over a 70-year period, based on exposure at the level for all residents within 5 km of operating incinerators, or 0.03 per year. For the Great Lakes Basin analysis, estimates of additional cancers were derived using the same individual risk level (1×10^{-6}) and the Region 5 population per unit (adjusted for the greater population density of Great Lakes Basin) scaled up for the number of incinerators in the Great Lakes Basin (17).

Hazardous Waste Fuel Burners

Cancer risks from hazardous waste fuel burners were calculated by adjusting national estimates of cancer risks from these facilities reported in the OSWER comparative risk assessment to the population of fuel burners in the Great Lakes Basin on a proportional basis. The estimated number of cancer cases over the 70-year period is 1.0 case, or 0.01 per year.

[16] Note, however, that the Storage Tanks problem area assumes a much higher failure rate (i.e., 20 percent).

Cancer Risk Summary

Exhibit O-13 shows the calculations of cancer risks for operating units and corrective action sites. The total estimated incremental annual cancer rates associated with this problem area is about 0.16 cases per year, with a total of about 10.9 cases attributable to this area over a 70-year period. Seventy-two percent of these cases are attributable to sites requiring corrective action, rather than to operating units.

Certain caveats need to be pointed out in order to put these estimates in proper perspective. First, virtually all the estimated additional cancer cases are attributable to ground water contamination at "pre-remedial" concentrations, and the risk calculation assumes continual exposure to contaminated ground water from operating units and corrective action sites over a long period. However, the RCRA program is designed to be a virtual "zero discharge" program with respect to ground water. That is, the program is designed to prevent any future discharges of hazardous constituents from operating facilities to ground water, and to require the cleanup of any past environmentally significant discharges of constituents to ground water.

Therefore, continued permitting, inspection, and enforcement of current standards into the future should drive actual risks from both operating land disposal units and corrective action sites towards very low levels; however, without this activity to inspect facilities and enforce standards, risks could be significant.

Second, risk from discharges to the environment allowed under the program, such as emissions from incinerators and hazardous waste fuel burners, are relatively low even under conservative assumptions if emissions meet applicable requirements. Incinerators and hazardous waste fuel burners account for an estimated additional 3 cancer cases in the Great Lakes Basin. Third, the estimate does not include risks arising from a variety of activities generally thought to pose relatively low levels of risk, such as hazardous waste generation, accumulation at generator facilities, and storage in containers. The number of generators greatly exceeds the number of TSDFs, and generators are frequently located in densely populated cities. Generally, these generators accumulate wastes in containers or tanks before shipping them off-site; in fact, the number of tanks estimated to exist at generator sites in the Region for waste accumulation exceeds the number estimated to exist at TSDFs. Although the facility-specific risks from accumulation in containers and tanks is probably very small, the cumulative risk may be found to be significant if data are developed to better characterize potential hazards.

Exhibit O-13
Estimated Potential Cancer Cases From Operating Sites

Unit	Life-Time Cancer Risk Level	Estimate Population Exposure (Oper)	Potential Addit. Cancer Cases (Oper)	Estimate Population Exposure (CA)	Potential Addit. Cancer Cases (CA)
Land Disposal Units (1 km)	2×10^{-4}	2,908	5.8×10^{-1}	4,509	0.906
Land Disposal Units (1 km)	7×10^{-6}	6,181	4.3×10^{-2}	9,581	0.067
Land Disposal Units (5 km)	2×10^{-6}	72,734	1.4×10^{-1}	112,858	0.22
Land Disposal Units (5 km)	7×10^{-8}	154,559	1.1×10^{-2}	239,566	0.016
Storage and Treatment	1×10^{-3}	22.4	2.2×10^{-2}	5,374	5.4

Unit	Life-Time Cancer Risk Level	Estimate Population Exposure (Oper)	Potential Addit. Cancer Cases (Oper)	Estimate Population Exposure (CA)	Potential Addit. Cancer Cases (CA)
Land Disposal Units (1 km)	2×10^{-4}	2,908	5.8×10^{-2}	4,509	0.906
Storage and Treatment	1×10^{-4}	22.4	2.2×10^{-3}	5,374	0.54
Storage and Treatment	1×10^{-7}	44.8	4.8×10^{-3}	107.5	1×10^{-5}
Incinerators	1×10^{-6}	1,200,000	2.0	NA	NA
Haz. Waste Fuel Burners	NA	NA	1.0	NA	0.00
Total Additional Cancers			3.80		7.15

Non-Cancer Effects

Chemicals causing non-cancer health effects are presumed to act via a different mechanism than carcinogens. A threshold below which adverse effects do not occur can generally be demonstrated to exist for such compounds. The lifetime daily dose which is likely to be without appreciable risk of deleterious effects to the human population is defined as the Reference Dose (RfD). Potential non-cancer health effects of constituents are evaluated through the use of hazard quotients. The hazard quotient is defined as the ratio of the exposure dose to the RfD. The sum of hazard quotients for all constituents is the hazard index.

Potential non-cancer health effects from RCRA sites in the basin were extrapolated from the Regional analysis using the same assumptions described above. Of the six selected constituents, only the potential estimated concentration for tetrachloroethylene exceeded its RfD for chronic exposure. Assuming a concentration in water of 3.5mg/l, the hazard quotient for chronic exposure to tetrachloroethylene was calculated to be 4.29. The health effect that may occur due to exposure to tetrachloroethylene in excess of the Rfd is liver damage. Of the remaining five selected compounds, lead deserves special mention. The well documented association between lead exposure and learning disabilities in children makes lead a compound of great concern, but the lack of a Rfd for this metal makes it difficult to assess the problem quantitatively.

Ecological Impact[17]

The extent of ecological threats posed by RCRA sites has been identified in many regulatory impact analyses, but has not been quantitatively discussed. Most ecological threats have been caused by unlined landfills and surface impoundments, storage in waste piles, improper disposal, and waste water discharges. All of these can produce toxic leachate which can then contaminate both ground and surface waters.

Severity and Toxicity

[17] USEPA Office of Policy Analysis and Office of Policy, Planning, and Evaluation's "Summary of Ecological Risks, Assessment Methods, and risk Management Decisions in Superfund and RCRA," June 1989, p.II-5.

both the severity and Toxicity of RCRA sites on the environment are dependent upon:

- environmental setting;
- facility size;
- toxicity of released constituents; and,
- the nature and extent of the release.

These releases can impact surface water, wetlands, and special habitats.

Ecological Risk Assessment

The effects on ecosystems can include:

- fish kills;
- diseased benthic invertebrates;
- chronic or behavioral effects on aquatic plants and animals;
- reduced floral and faunal species diversity;
- sediment contamination;
- decreased productivity in the wetlands; and,
- impaired health and fertility of plants and animals.

Perhaps the most fragile ecosystem in the Basin is the wetland habitat. Wetlands are heavily impacted by leachate waters, and often times the habitat is destroyed.

Reversibility

Destruction of the wetlands and special habitats is a serious concern because many ecosystems cannot be restored. Consequently, these effects are virtually irreversible. Contaminated ground water can be treated, although this process is very expensive.

Welfare Assessment

Economic damages associated with active hazardous wastes include damages resulting from diminished property values adjacent to these sites and the costs associated with human health effects attributable to these sites.

Property Value Damage

To estimate the value of losses associated with active hazardous waste facilities in the Great Lakes Basin, the following equation was used:

$$\$ \text{ Damages}^{18} = (\text{households residing within 1 km of active sites}) (\$ \text{ damage per household})$$

Empirical research suggests that values of residential properties increase as the distance from active hazardous waste

[18] Not corrected for 1991 U.S. dollars.

facilities increases. These studies use econometric analyses to estimate the difference in value of residences near a site compared to homes further from the site. The study results indicate the following:

- Homeowners in the Boston area are willing to pay from $300 to $500 per mile for a location more distant from a hazardous waste landfill (Smith and Desvouges, 1986.)

- The mean willingness to pay of homeowners in the Boston area for an increase of 0.8 miles in distance from a Superfund site was $69 in the average housing market (Michaels et al., 1987).

- McClelland, et al. (1989) determined that, on average, housing prices were about $4,800 lower for residents concerned about the proximity of a Superfund site than they would have been if residents were not concerned about the site.

To estimate a range in potential damage to property values resulting from active hazardous waste facilities in the Great Lakes Basin, a lower bound cost of $69 and an upper bound cost of $500 per home residing within a kilometer of a site, was assumed. A worst case of $4,800 per home was assumed. These costs were taken from the previously mentioned studies. Exhibit O-14 summarizes the property value damages associated with these costs.

Health Care Costs

To estimate the health care costs (HCC)[19], the annual cancer cases previously determined were multiplied by the direct medical cost and foregone earnings per cancer case.

HCC = (Annual Cancer Cases) (Direct Costs and Foregone Earnings)

Lower bound estimate:

HC = (10.3) ($80,000) = $824,000

Upper bound estimate:

HC = (10.3) ($137,000) = $1,411,100

[19]ICF Incorporated. 1988. "Office of Solid Waste Emergency Response (OSWER) Comparitive Risk Project: Ground Water Valuation Task Force Report." Prepared for U.S. EPA, Office of Underground Storage Tanks.

EXHIBIT O-14
Estimated Property Value Damages in the Great Lakes Basin

Facility Type	Number of Sites	Population[a]	Households[b]	Lower Bound Damage	Upper Bound Damage	Maximum Damage[c]
Land Disposal Unit	191	347,700	130,200	$8,986,000	$65,116,000	$625,108,800
Storage and Treatment Tanks	296	712,200	266,800	$18,406,000	$133,376,000	$1,280,409,600
Incinerator	17	34,800	13,000	$900,000	$6,525,000	$62,635,200

[a] Great Lakes Basin population within 1 km of all facilities = (Region 5 population within 1 km of Region 5 facilities/number of facilities in Region 5) (number of facilities in the Great Lakes Basin)

[b] Number of households = population/2.67 people per household. Average household size estimated by the U.S. Department of the Census.

[c] Maximum estimated property damages is $4,800 per household.

P. ABANDONED HAZARDOUS WASTE SITES

Problem Area Description

Abandoned Hazardous Waste Sites covers the risks posed to human health and the environment by abandoned waste treatment, storage, disposal, and recycling facilities, illegal dumpsites, and other abandoned waste sites. Specific categories of sites covered here included:

- Superfund National Priority List (NPL) sites (including Federal facilities);
- State Superfund sites;
- other sites reported to EPA and listed in CERCLIS (including Federal facilities, sites scored using the Hazard Ranking System [HRS], and sites remaining to be scored); and
- other unmanaged hazardous waste sites that are no longer in operation.[20]

Magnitude of the Problem

There are currently about 4,100 sites[21] within the Great Lakes Basin that have either been assessed for inclusion on the NPL or that have been targeted for assessment in the future.[22] One hundred and forty (140) of these sites are on the NPL and 23 have been proposed for the NPL. Exhibit P-1 presents the distribution of National Priorities List sites across the Basin, and Exhibit P-2 depicts the distribution of all sites in the CERCLIS system.

Human Health Risk Assessment[23]

Toxicity Assessment

Potential carcinogens found at significant concentrations at a majority of the 51 Region 5 sites included polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), benzene, nickel, methyl chloride, vinyl chloride, and trichloroethene. The cancer slope factors for these chemicals range from 0.011 $(ppm/day)^{-1}$ for trichloroethene to 7.7 $(ppm/day)^{-1}$ for PCBs.

For noncarcinogenic effects, arsenic, chromium, cadmium, lead, nickel, toluene and zinc were studied. The reference doses (RfDs) for these chemicals range from 0.01 ppm/day for nickel to 5.0 ppm/day for chromium.

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[20] The Region 5 draft problem area paper was examined to determine whether that methodology could be used as a basis for the Great Lakes Basin analysis. Region 5 evaluated a sample of 51 Regional sites (49 on the NPL and two non-NPL) and used them as the basis for characterizing the remainder of the Region's sites. Because Region 5 contains most of the Great Lakes Basin sites (over 75 percent), these same 51 sites were determined to be representative of the Great Lakes Basin sites. Therefore, the Region 5 analysis was determined to be applicable as a basis for this Great Lakes Basin analysis.

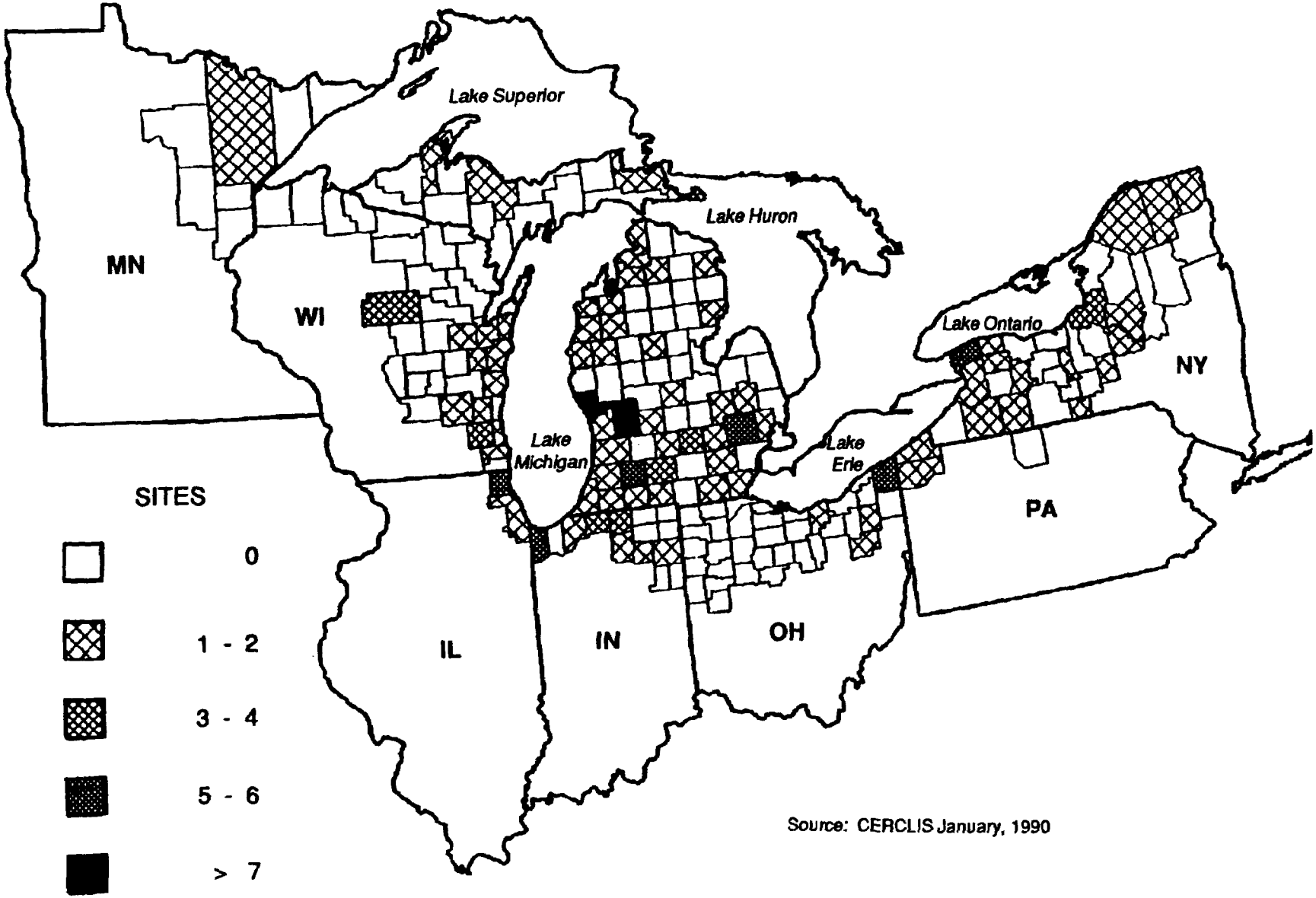
[21] 4,109 sites listed in January 1990 CERCLIS report.

[22] Draft 1990 Great Lakes Basin Report to Congress.

[23] The discussion of human health effects is a summary of the analysis conducted by Region 5.

Exhibit P - 1

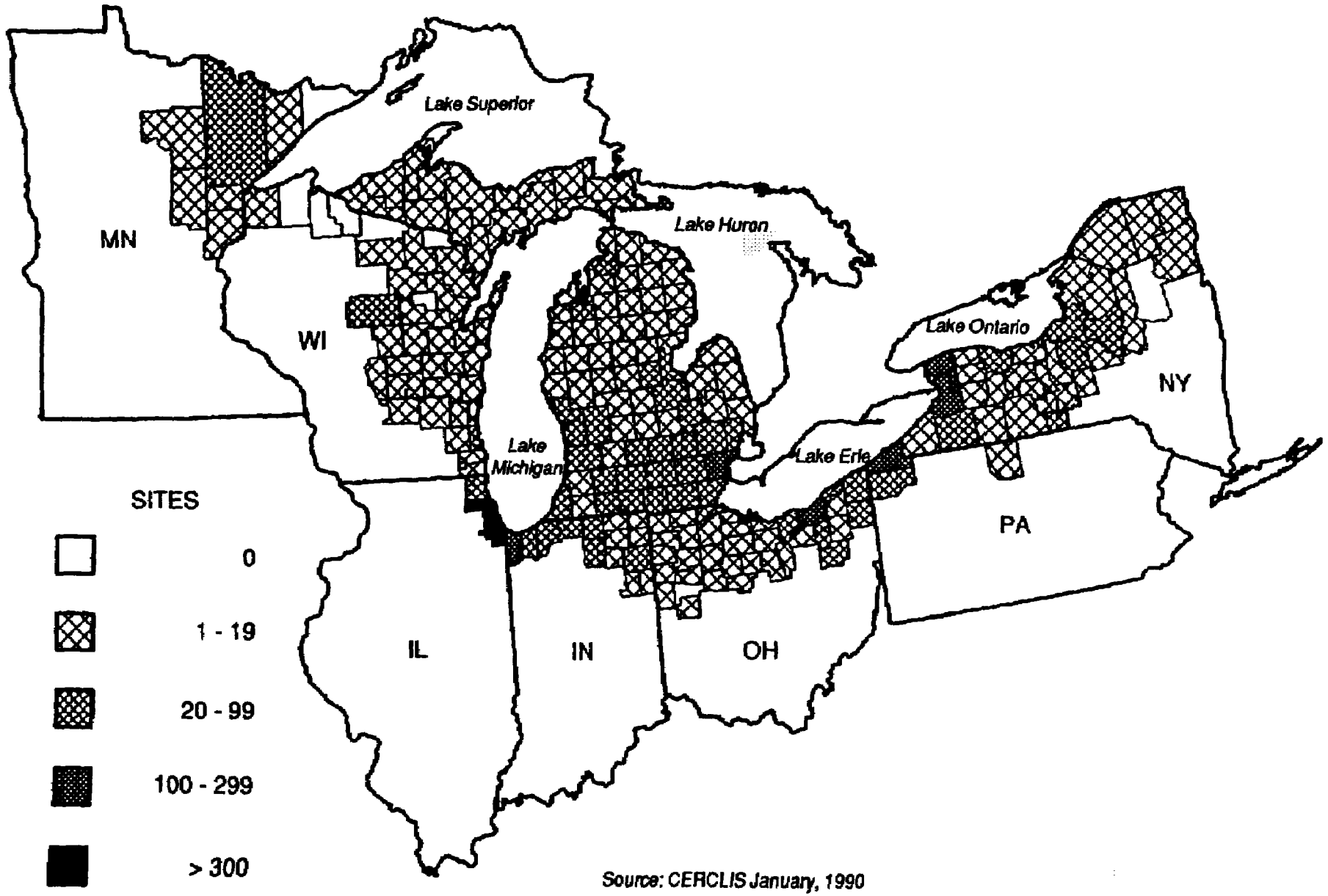
FINAL AND PROPOSED NPL SITES



Source: CERCLIS January, 1990

Exhibit P - 2

CERCLIS SITES



Source: CERCLIS January, 1990

Exposure Assessment

Ground-water contamination was the exposure pathway of concern at the overwhelming majority of the sample of sites (91.3 percent). Ground water was withdrawn for drinking water within three miles of 86 percent of the sites, and there were operable wells within one mile of 96 percent of the sites. Of those drinking water wells within three miles, the population served was greater than 10,000 in 45 percent of the cases, from 3,000 to 10,000 in 26 percent of the cases, from 1,000 to 3,000 in 21 percent of the cases, and less than 1,000 in the remaining (eight percent) of the cases. The next most frequent pathway was air (4.7 percent), and then surface water (4.5 percent). The estimates of population exposed at the 51 sites ranged from 38 persons drinking ground water up to 34,000 with a threatened water supply. The types of exposures assessed within this problem area include those via air, surface water, ground water, the food chain, and direct contact.

Risk Characterization

Cancer Risks

Cancer risks were calculated based on the most probable cases, not the maximum. The values selected were based on reasonable exposure pathways now and in the future, but not on such worst cases as a residential well in the middle of a site, or landfill leachate being used for drinking water. Wherever appropriate, a reasonable aggregate risk number was selected.

The results of the analysis of 51 sites were extrapolated to the universe of Region 5 sites by assigning them risk values in proportion to their perceived potential for human health effects, as follows:

- The 267 NPL and proposed NPL sites were assigned risks in the same proportion as that found for the 51 reviewed sites. That is, excess lifetime cancer cases per site were 0.97 for sites with HRS scores > 45, 0.58 for sites with scores in the range of 35 to 45, and 0.16 for sites with scores < 35. The resulting total cancer cases were 100.

- 15 percent of the remaining sites (900) were determined to be high priority for further action. These sites were assigned risks equal to the average risk level of the 51 sites that had HRS scores of 35 to 45. The resulting total cancer cases were 520.

- 35 percent of the non-NPL or proposed NPL sites (2070) were determined to be medium priority for further action. These sites were assigned risks equal to the average risk level of the 51 sites with HRS scores < 35. The resulting total cancer cases were 330.

- 50 percent of the non-NPL or proposed NPL sites (2970) were determined to require no further action. These sites were assigned risks equal to 25 percent of the average risk level of the 51 sites with HRS scores < 35. The resulting total cancer cases were 120.

The Region 5 analysis estimated 1,070 excess cancer cases for the approximately 6,150 sites in the Region. This results in about 0.17 cases per site. Because the breakdown of Great Lakes Basin sites (i.e., NPL, high priority,

medium priority, no further action; see discussion below) is similar to that of Region 5,[24] a direct extrapolation from Region 5 to the Great Lakes Basin is considered reasonable. However, because site selection for the Region 5 analysis was not random, scaling from the Region to the Basin limits the statistical validity of the results.

The average cases of 0.17 per site is multiplied by the 4,100 sites in the Great Lakes Basin to result in about 700 excess cancer cases. On an annual basis, this represents approximately 10 additional (above background) cancer cases per year.[25]

Noncancer Effects

Using the sample of 51 sites in basically the same way as with assessing cancer risk, the total universe of Region 5 sites were assessed for noncancer effects by assigning HIs in the same proportions as in the sample of sites.

- An HI of 1.1 was applied to a certain proportion of NPL and proposed NPL sites, with the resulting population exposed at this HI estimated at about 10,110.
- An HI of 1.7 was applied to a proportion of high priority sites, with the resulting population exposed at this HI estimated at about 27,480.
- All other sites were assumed to have an HI of less than 1.

The Region 5 analysis estimated that a population of 10,110 is potentially exposed to a hazard index (HI) of 1.1, and that a population of 27,480 are potentially exposed to an HI of 1.7. Extrapolating these populations to the Great Lakes Basin (by multiplying these populations by the ratio of the number of sites in the Great Lakes Basin [4,109] to the number of sites in Region 5 [6,150]) results in approximately 6,750 people potentially exposed to an HI of 1.1, and 18,360 potentially exposed to an HI of 1.7.

Ecological Risk Assessment

As with the human health risk assessment, this Great Lakes Basin analysis relied on the Region 5 study of 51 sites. The analysis used Region 5's estimate that from 17 to 33 percent of all sites (not counting those sites requiring no further action) have the potential for significant ecological effects. Continuing with the Region 5 methodology, it is estimated that Great Lakes Basin sites are responsible for up to 16 stream miles of contaminated surface waters, 224 stream miles of fish kills, 1,090 stream miles of contaminated sediments, 8,330 acres of contaminated soil, 2,950 acres of defoliation, and 2,950 acres of contaminated wetlands.[26]

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[24] For example, the percentages of Region 5 and Great Lakes Basin sites that are not on the NPL or proposed for the NPL and that are determined to need no further action is approximately 50 percent.

[25] An attempt was made to adjust the number of people exposed based on the higher density of people within the Great Lakes Basin as compared to Region 5. This adjustment was not done, however, because of the complexity of effects on exposure from this population density difference. For example, although the population exposed via air is expected to increase with increasing population density, the population exposed via ground water is expected to decrease because of fewer users of untreated ground water in urban areas.

[26] These results are a direct extrapolation from the Region 5 analysis. However, it is not clear exactly how the Region 5 analysis used the numbers in the EPA 1989 report. The methodology, therefore, is being checked.

Toxicity Assessment

Three general types of stressors are released from abandoned hazardous waste sites: metals, pesticides, and organic chemicals. Specific hazards associated with each type of stressor to aquatic and terrestrial ecosystems are summarized below.

Species level effects of metals on fish include neurotoxicity, impaired reproduction, reduced growth, damage to gill surfaces and impaired respiration, mortality, and other effects. Ecosystem-level effects in aquatic systems include reduced primary and secondary productivity, loss of top carnivores, changes in community composition, and modification of nutrient cycling. In terrestrial systems, high concentrations of heavy metals are known to impede root growth, nutrient uptake, and seed germination in plants. Some metals are known to cause eggshell thinning and teratogenesis in birds. Airborne toxic metals can lead to death of almost all plant life growing immediately near an emission source. Metals in high concentration put intensive selective pressure in favor of resistant biotypes, eventually resulting in colonization by resistant species or subspecies.

In aquatic systems, species-level effects associated with pesticides include mortality among the aquatic juvenile life stages of many insect species, herbicide-induced reduction of submerged aquatic vegetation, teratogenicity in fish, impaired reproduction of fish, and fish kills. Ecosystem-level effects include reduced biomass and diversity of invertebrate and vertebrate communities, herbicide-induced reduction of submerged aquatic vegetation, and concomitant loss of invertebrate communities as well as fish that utilize plant cover for spawning or protection of juvenile stages. In terrestrial systems, species-level effects associated with pesticides include bioaccumulation and egg-shell thinning in birds, neurotoxicity, oncogenesis, teratogenesis, acute mortality (i.e., bird kills), mortality of insect pollinators (e.g., honey bees), and non-target plant injury. Ecosystem-level effects include destruction of non-target species key to ecosystem structure and function (e.g., parasites, pollinators), release of secondary pests from the constraints of natural enemies, and loss of plant communities dependent upon pollinators.

In both aquatic and terrestrial systems, the possible species-level and ecosystem-level effects of toxic organic compounds are diverse. In addition to producing adverse effects on reproduction, growth, and/or survivorship or inducing organ dysfunctions, many organic compounds are carcinogenic. Organic compounds that are persistent and bioaccumulate (e.g., PCBs, phenols) generally are of greatest concern.

Exposure Assessment

In the study of ecological effects from Region 5 sites, limited quantitative information was available. Over half of the 51 study sites had no detailed ecological assessment, although some of these did list species and surrounding land uses. Generally, the endangerment assessments focused on ground water because of its human health implications. Ground water, however, typically is a less important pathway for ecological effects compared to other pathways such as surface water, unless of course the ground water discharges to surface water.

Several endangerment assessments evaluated the ingestion of fish as a human health exposure pathway because fish near the sites had elevated levels of contaminants in their fat tissues. Such contamination is a persistent problem in the Great Lakes. Other sites were associated with contamination of livestock and milk as far as a mile or more away. These observations are more of a concern for human health, although they do indicate exposure to ecological systems is occurring.

Ecological Risk Characterization

Roughly 33 percent of those sites that had an ecological assessment indicated significant ecological impacts or potential for impacts. For sites with no ecological assessments, lower and upper limits of the number of sites with significant impacts were estimated as follows:

- For a lower limit for the sites with no assessment, assume no significant ecological impacts are expected.
- For an upper limit, assume 33 percent of the sites with no assessments are expected to have significant ecological impacts (as with sites that have ecological assessments).
- Combine the lower and upper limits for sites with no assessments (0 to 33 percent, respectively) with the 33 percent estimate for sites with assessments to obtain a range of 17 to 33 percent.

Applying the range of 17 to 33 percent of sites expected to have significant ecological impacts to the 3,226 Region 5 sites (not including those needing no further action) resulted in 550 to 1,100 sites in Region 5 having the potential for significant ecological effects. Applying this to the 2,137 Great Lakes Basin sites (not counting those sites requiring no further action), results in 363 to 705 Great Lakes sites having the potential for significant ecological effects.

The effects were quantified further by projecting the above results to a nation-wide Superfund study.[27] Using the upper limit on the number of Region 5 sites that have the potential for significant ecological effects (1,100), it was estimated that Region 5 sites are responsible for up to 25 stream miles of contaminated surface waters, 350 stream miles of fish kills, 1,700 stream miles of contaminated sediments, 13,000 acres of contaminated soil, 4,600 acres of defoliation, and 4,600 acres of contaminates wetlands.

Some sites in Region 5 were found to exceed several of the Hazard Ranking system (HRS) measures of risk: the acute acceptable concentrations (AACs), the chronic acceptable concentrations (CACs), lethal concentration 50s (LC50s), and lowest-observed-adverse-effect-level (LOAEL). Nine of the 51 sites listed ground water or surface water concentrations that exceeded at least one of the standards. At one site, discharges to a river from site leachate violated AACs or CACs for six different contaminants. Two violated CACs even after dilution in the river. In virtually all of these cases, the contaminants were metals -- copper, zinc, chromium, and lead. PCBs exceeded a standard at one site, and the endangerment assessment for that site noted that the immediate population of several small animals were facing reproductive failure due to the PCBs.

Severity

The Great Lakes Basin sites have been ranked for severity of ecological effects as potentially high for local effects and low to medium when the highly localized nature of the effects are factored in. Some sites appear to threaten the long-term viability and stability of the local ecosystems, and reduce the population of one or more critical species. Other sites may result in the loss of an entire ecosystem or the loss of several critical species.

Reversibility of Damage

The reversibility of damage to ecosystems, once source control measures are implemented, is a function of two key

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[27] EPA, 1989, Summary of Ecological Risks, Assessment Methods, and Risk Management Decisions in Superfund and RCRA, Office of Policy, Planning, and Evaluation.

factors: the time required for the existing contamination to abate, and the time required for the biological community to be reestablished once the contamination levels subside. Some types of contamination (e.g., metal contamination of soils or sediments) leave significant residual contamination that can require decades to decline to no-effect levels. Once sources of new and residual contamination have been eliminated, the time required for an aquatic community to recover will depend upon many additional factors.

There are several factors that influence the speed with which a healthy community can become reestablished once contamination is removed (i.e., all sources including sediments). One key factor is the severity of the effects incurred. If entire trophic levels were eliminated, a healthy biotic community would take longer to develop than if only a few species had been eliminated or removed. The time required for full recovery also would depend upon the areal extent of the contamination and the distance that would have to be travelled by recolonizing individuals from uncontaminated areas. Fish, birds, flying insects, and some plants can recolonize rapidly from long distances provided that the intervening habitat is suitable. Most invertebrates and some plants recolonize more slowly. Another factor is the level of residual contamination in biota.

Decades or centuries would be required for ecosystems to recover from metal contamination of soils or sediments because these media continue to be a source of contamination of biota. Moreover, episodic acute exposures to soil/sediment contaminants can occur when storms or other infrequent events cause soil erosion or resuspension of contaminated sediments. Animals that have been exposed to heavy metals and that have developed significant body burdens will remain contaminated for years or for life. Thus, biotic recovery after residual metal contamination subsides will generally be slow because body burdens of the metals can contribute to lifetime depression of reproductive success and other continuing sublethal effects in the longer-lived organisms. In the absence of remediation, therefore, it can be assumed that reversibility is low.

For pesticides that bind to soils or sediments, reversibility of ecological damage can be slow following the institution of control measures at the source because the soil/sediment can serve as a continuing source of contamination for decades. Animals that have been exposed to persistent pesticides and that have developed significant body burdens will remain contaminated for years or for life. In the absence of remediation, therefore, it can be assumed that reversibility is low for moderate to highly persistent pesticides (i.e., DDT and other organochlorines). For less persistent pesticides, the time required to reverse ecological damage is reduced. In the case of non-persistent pesticides, recovery of an ecosystem can begin soon after the source of contamination is eliminated.

The potential reversibility of ecosystem damage resulting from releases of toxic organics to surface waters is less for the persisitent, bioaccumulating compounds than for the nonpersistent compounds. Similar considerations to those discussed above for pesticides apply.

Welfare Risks

Welfare risks associated with abandoned hazardous waste sites are estimated on the basis of damages resulting from human health effects (i.e., health care costs), the costs of replacing contaminated drinking water supplies (i.e., environmental costs), and diminished property values (i.e., materials and property damage).

Health Care Costs

To estimate damages resulting from human health effects, the 10 annual cancer cases estimated previously are multiplied by the direct medical cost and forgone earnings per cancer case. Estimated direct and indirect medical

cancer costs are based on a range of costs per case estimates. The lower bound estimate, based on Hartunian, et al.[28], is $80,000 (1988 $), while the upper bound estimate developed by the American Cancer Society is $137,000 (1988 $). Both estimates are weighted average costs associated with all types of cancers. When combined with the number of annual cancer cases, the result ranges from $800,000 to $1,370,000 annually.

Environmental Costs

These costs are estimated by assessing the costs of replacing contaminated drinking water supplies. Given the number of private well replacements and public water supply hook ups associated with ground-water contamination due to abandoned hazardous waste sites, the cost of replacing contaminated drinking water supplies can be estimated by multiplying this number by the costs of such replacements and hook ups.

The capital costs are assumed to be $3,500 for replacing a private well by digging a new well, and $300,000 for replacing a public supply well by extending a hook up from another public supply. These were the upper bound costs associated with replacing these two types of supplies in Region 34. These costs do not include the annual operating costs for private and public systems.

Using data from the Region 5 report that indicates 86 percent of the sites are within three miles of operable wells, and that in 71 percent of these cases the population served is greater than 3,000 (probably indicating a public well system), the following assumptions are made.

Assuming as an upper bound that of the NPL, proposed NPL, and high priority sites (a total of approximately 755), 86 percent would result in the need for replacing either one public well system (71 percent of the cases) or 100 private systems (the remaining 29 percent of the cases), the following equation is used to estimate environmental costs:

$$EC = F_3 \times S \times [(F_{Pu} \times Pu \times C_{Pu}) + (F_{Pr} \times Pr \times C_{Pr})]$$

where

EC = environmental costs
F_3 = 0.86 (ratio of sites within 3mi. of wells)
S = 755 sites (NPL, proposed NPL, and high priority)
F_{Pu} = 0.71 (ratio of sites with public wells)
Pu = 1 public well/site
C_{Pu} = $300,000/public well
F_{Pr} = 0.29 (ratio of sites with private wells)
Pr = 100 private wells/site
C_{Pr} = $3,500/private well.

Solving for EC results in approximately $204 million (1988 $).

This result was compared to results derived from the OSWER comparative risk study.[29] In that study, an estimate

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[28] Referenced, as is, in a memorandum from Don Peterson to Rosalie Day, August 2, 1990.

[29] ICF Incorporated, OSWER Comparative Risk Project: Ground-water Valuation Task Force Report (Draft), prepared for EPA, Office of Underground Storage Tanks, February 4, 1988.

of $9.7 million in resource damages per NPL site was obtained. Multiplying this by the 163 NPL or proposed NPL sites in the Great Lakes Basin results in $1.6 billion. This figure does not include high priority sites as in the previous calculation. Therefore, the range of costs for replacing wells due to abandoned waste sites in the Great Lakes Basin is estimated at from $204 million to over $1.6 billion.

Materials and Property Damage

The Region 5 results were used to estimate property value losses associated with abandoned hazardous waste sites in the Great Lakes Basin. For 6,250 sites in Region 5, the lower bound estimate of total damages was estimated at $391,713 and the upper bound was $3,000,443. This translates into approximately $260,000 to $2,000,000 for the 4,109 Great Lakes Basin sites. The following is a summary of the Region 5 analysis.

The equation used to estimate total damages was as follows:

$$DC = DH \times HS \times S$$

where

DC = total damage cost
DH = damage cost per home
HS = number of homes per site
S = number of sites.

Results of a growing body of empirical research suggest that values of residential properties increase as the distance of those properties increases from active hazardous waste facilities and other solid waste disposal sites. Using (1) estimates ranging from $69 to $500 in damages per exposed home, (2) data from the health effects section on populations potentially exposed, and (3) an estimate of 0.375 residences per individual potentially exposed, the following was obtained:

- No further remedial action sites were assumed to result in $0 in damages per residence (total damages = $0).
- Medium priority sites were assumed to result in $0 to $69 in damages per residence, with 2,347 residences potentially exposed (total damages = $0 to $161,943).
- High priority sites were assumed to result in $69 to $500 in damages per residence, with 2,937 residences potentially exposed (total damages = $202,653 to $1,468,500).
- Proposed NPL and NPL sites were assumed to result in $69 to $500 in damages per residence, with 2,740 residences potentially exposed (total damages = $189,060 to 1,370,000).

Q. MUNICIPAL SOLID WASTE FACILITIES

Problem Area Definition

The Municipal Solid Waste Facilities problem area covers the risks to human health and the environment posed by open or closed land disposal facilities, landfills, and open dumps used to dispose of municipal refuse; municipal water and sewage treatment sludges; and municipal incinerator ash. This problem area also includes the risks from municipal waste incinerators and municipal surface impoundments.

These facilities can threaten human health and the environment through air emissions of volatile toxic chemicals and methane gas, subsurface methane migration resulting in potentially explosive conditions in structures, and ground and surface water contamination by landfill leachate containing organic and inorganic toxic contaminants and pathogenic substances. Contamination may occur through subsurface migration, runoff, evaporation or wind erosion.

The types of substances disposed at these facilities include mixed municipal and commercial refuse, household hazardous waste, hazardous waste from conditionally exempt small quantity generators, sewage treatment sludge, incinerator ash, and water treatment sludge. These wastes may include some toxic contaminants, including solvents and heavy metals.

Industrial waste disposal sites are covered in a separate problem area. Additionally, this problem area excludes municipal solid waste sites that have been included on the National Priorities List.

Magnitude of the Problem

There are approximately 6,034 operating municipal solid waste landfills in the United States and its 5 territories.[30] These data are not organized by county; therefore, a precise census of the number of municipal solid waste facilities in the Basin counties is not available. As a result, population size serves as a proxy indicator of the number of the municipal solid waste facilities in the Basin. The Great Lakes Basin contains approximately 30 million persons or 12 percent of the U.S. population resulting in an estimate of 724 municipal solid waste landfills in the Basin. This estimation may be low since Wisconsin contains 12.2 percent of the national operating municipal solid waste landfills.

In addition to these operating landfills, there are approximately 1919 closed municipal landfills in the Basin, based on reductions in the population of operating municipal facilities reported by the states between 1981 and 1989. Although there are many small landfills, national statistics show that over 40% of the waste is handled by very large landfills averaging over 1,125 tons of waste per day.

Although there are many municipal solid waste facilities in the Great Lakes Basin, EPA has taken action to control both active landfills and the siting and design of new landfills. EPA guidelines for municipal solid waste facilities include that they:

(1) cannot be located in flood plains;
(2) cannot impact endangered species;
(3) must comply with the Clean Water Act;
(4) cannot contaminate ground water;

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[30] Subtitle D Regulatory Impact Analysis

(5) cannot be near food chain crops;
(6) must apply a cover material; and,
(7) cannot burn waste openly.

Additionally, states have also instituted requirements which include, but are not limited to:

(1) administrative licensing;
(2) design standards;
(3) operation standards;
(4) location standards;
(5) monitoring;
(6) closure requirements; and,
(7) financial responsibility.

These emerging controls may limit the environmental risks posed by the municipal facilities. Nonetheless, the following discussion focuses on the baseline risks present at facilities active during the mid-to-late 1980s.

Human Health Impacts

The municipal solid waste facilities problem area for the Great Lakes Basin are estimated at 724. Human health risks have been estimated quantitatively only for operating municipal solid waste landfills, due to limitations in available data. Human health risks for closed municipal solid waste landfills in the Basin were not estimated due to a lack of available data on these facilities. These risks are discussed qualitatively below.

Toxicity Assessment

Documented contaminants from municipal landfills encompass approximately 200 constituents, including:

- Conventional pollutants, such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), iron, chloride, and ammonia.
- Heavy metals, such as arsenic, antimony, cadmium, and chromium.
- Organic chemicals, including vinyl chloride, tetrachloroethylene, dichloromethane, carbon tetrachloride, and phenol.

Risks to human health and the environment by selected hazardous constituents found in municipal landfill leachates were based on:

(1) their prevalence in samples of leachate taken from multiple facilities;
(2) average concentrations found in leachate;
(3) toxicity;
(4) mobility; and
(5) persistence.

The constituents selected for risk modeling were vinyl chloride, arsenic, iron, tetrachloroethane, dichloromethane, carbon tetrachloride, antimony, and phenol. Five of the contaminants are carcinogens. The noncancer effects of these contaminants are neurotoxicity, cardiovascular changes, and kidney and liver damage. Information on the carcinogenicity and the toxicity of these compounds is presented in Exhibits Q-1 and Q-2.

Exhibit Q-1

CARCINOGENIC EFFECTS OF MSW LEACHATE CONSTITUENTS

CONSTITUENT	CARCINOGEN	ROUTE	CARCINOGENIC WEIGHT OF EVIDENCE	SLOPE FACTOR - ORAL (ppm/d)-1	SLOPE FACTOR - INHALATION (ppm/d)-1	TUMOR SITE - ORAL	TUMOR SITE - INHALATION
1,1,2,2-Tetrachloroethane	Y	Oral, Inh	C	0.2	0.20	Liver	Liver
Carbon Tetrachloride	Y	Oral, Inh	B2	0.1	0.13	Liver	Liver
Vinyl Chloride	Y	Oral, Inh	A	2.3	0.295	Liver	Lung
Arsenic	Y	Oral, Inh	A	NA	50	Skin	Resp. Tract

NA = not applicable.
Source: "Health Effects Assessment Summary Tables - Third Quarter, FY 1990", U.S. EPA, OSWER, July, 1990.

Exhibit Q-2
SUBCHRONIC AND CHRONIC EFFECTS OF MSW LEACHATE CONSTITUENTS
Route: Oral

CONSTITUENT	RFD (ppm/d)	EFFECT OF CONCERN	UNCERTAINTY FACTOR
Carbon Tetrachloride			
Subchronic	7E-03	Liver Lesions	100
Chronic	7E-04	Liver Lesions	1000
Antimony			
Subchronic	4E-04	Blood	1000
Chronic	4E-04	Blood	1000
Arsenic			
Subchronic	1E-03	Keratosis	1
Chronic	1E-03	Keratosis	1
Phenol			
Subchronic	0.6	Reduced Fetal Body Weight	100
Chronic	0.6	Reduced Fetal Body Weight	100

Source: "Health Effects Assessment Summary Tables - Third Quarter, FY 1990", U.S. EPA, OSWER, July, 1990.

Two principle routes of exposure or risk were considered in this analysis: exposure due to migration of contaminants from municipal solid waste landfills through ground water, and risk arising through subsurface methane gas migration. Although exposure risk can be due to evaporation or wind erosion, these routes were selected based on data availability and previous risk assessments. Other studies indicate that migrations of contaminants and subsurface methane migration are the principle routes through which risks to human health may occur.

Risk Characterization

Cancer Risks

Cancer risks were estimated using the cancer risk ranges developed in the Regulatory Impact Analysis (RIA) for municipal solid waste landfills. Risk estimates from the RIA were used for facilities located in a "Migration Potential (MP) IV" category location. This category represents facilities located in areas of high net precipitation and short ground-water travel times due to shallow ground water and relatively permeable subsurface conditions.

Cancer risk estimates presented in the RIA represent average individual lifetime cancer risks due to exposure to

leachate contaminated ground water. The analysis calculates ground water concentration averages based on a 300 year modeling period, in order to provide time for risks to be manifested (e.g., for cap failure, leachate release, and contaminant migration) under a variety of different design and location scenarios.

The RIA apportions facilities by risk range. For MP IV facilities, the distribution of facility risk is as follows:

- Approximately 10 percent of facilities have risks greater than 1×10^{-5} (high)
- 17 percent have risks in the range of 1×10^{-5} to 1×10^{-6} (medium)
- 9 percent have risks in the range of 1×10^{-6} to 1×10^{-8} (low)
- 10 percent have risks lower than 1×10^{-8} (very low)
- 54 percent had zero risk because no wells were in the vicinity of the facility

For calculating the risks for this assessment, facilities and exposed populations were apportioned to risk ranges based on these percentages, adjusted to eliminate the zero risk category since the risk ranges were applied to an actual estimate of the potentially exposed population. Risks were then calculated by applying the midpoint of the risk range to the exposed population.

In summary, the estimate indicates approximately 0.02 additional cancers over a 70 year operating period, or 1.5 additional cancers per year in the potentially exposed population. This estimate can increase if new wells are drilled near landfills or in leachate paths.

Closed municipal solid waste landfills probably pose a similar or greater threat of environmental contamination and resulting risks than operating landfills. The population at risk from closed facilities was not estimated due to data limitations. However, as a group, closed landfills in the Great Lakes Basin are likely to be smaller and more rural than currently operating landfills, due to increases in landfill costs associated with a higher level of environmental protection and resulting economies of scale. For example, in 1981 there were approximately three times the number of currently operation municipal solid waste landfills. Closed landfills may have an average exposed population similar to the sample facilities, which were predominantly located in rural areas.

Noncancer Risks

Noncancer health effects were initially evaluated in developing the RIA criteria for municipal solid waste landfills. Modeled exposures were found to be substantially lower than the Reference Doses (RfDs) for the constituents due to the low concentrations of the constituents in leachate. Since noncancer health effects demonstrate threshold doses below which no health effects are observed (No Observed Adverse Effect levels, or NOAELs), and RfDs are based on these levels, no cases of noncancer health impacts were projected.

Risk from Explosions

There is a risk of explosion due to methane gas migration from municipal waste landfills to nearby structures. Methane may collect in confined spaces within structures at levels exceeding the Lower Explosive Limit (LEL) and result in an explosion if provided a source of ignition. There are documented cases of such explosions.

In general, horizontal methane migration in the subsurface environment is limited because methane vents through the ground surface. Typically, only structures located in proximity to a landfill, or on a filled area, are at risk. However, where venting is prevented by pavement, locally saturated surface soils, or frozen surface soils, or

where sewers or underground utilities provide a highly permeable pathway, methane may migrate substantial distances (up to approximately 1000 yards). Great Lakes Basin states typically will have frozen ground conditions for a portion of the year. This climatic condition will place the Basin at greater risk for explosions than more temperate areas.

Based on the sample of facilities reported in Region 5, it is estimated that approximately 17,500 structures are within 500 meters of municipal solid waste landfills in Region 5 and may be susceptible to methane gas collection. Assuming these are residences with an average of four inhabitants, approximately 70,000 people may be at risk of injury due to an explosion from methane gas. We assume the Region 5 data to be comparable to situations found in the Basin.

Ecological Impact

The major routes of contaminant releases from municipal solid waste landfills are surface runoff of leachate (e.g., discharged from surface seeps in above-ground landfills) and leachate discharge to ground water. In both cases, the ecological damages associated with these facilities would occur in surface waters or wetlands through surface runoff or discharge of contaminated ground water from hydraulically connected surficial aquifers.

There is very limited documentation available on environmental damages resulting from municipal solid waste landfills. One documented damage case reported by EPA identified damages to wetlands and nearby lakes from a 300 acre landfill leaching into these waters. Projected ecological damages from these releases included toxic effects on freshwater and estuarine fish and macroinvertebrates.

Prevention of ground-water and fresh water contamination is primarily dependent upon the thickness of the unsaturated zone and the type of soil. To minimize the potentials for environmental contamination, a landfill should have an unsaturated zone of more than 20 feet and clay substrate. Since clay enhances surface runoff, leaching would be minimal and would have a long distance to travel to reach the ground-water supply.

In response to the ecological impact on some areas, the EPA has imposed location restrictions on active seismic zones, unstable areas where conditions prevent year round monitoring, wetlands, and 5 and 10 year flood plains. Additionally, the EPA may close down active facilities in these areas.

Toxicity Assessment

Municipal solid waste landfills may release a large variety of contaminants to surface or ground waters. Constituents released include BOD, COD, chlorides, ammonia, aluminum, arsenic, barium, vinyl chlorides, heavy metals, pesticides, and volatile organics. Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) affect aquatic environments by depleting oxygen which may affect fish and other aquatic organisms. Other constituents, including ammonia and aluminum, are toxic to marine organisms.

The effects of any release of leachate to surface waters will largely depend on the ultimate concentration of the contaminants in the receiving body of water. In general, the volume of leachate flowing from an average landfill is low, but the relative concentrations of constituents are high compared to other sources of surface water contamination.

Exposure Assessment

The number of surface waters or wetlands at potential risk of damage due to municipal solid waste sites in Region 5 were estimated based on the sample of 31 operating facilities. Ninety three percent of the study set of 31 facilities, or an extrapolated total of 991 sites were determined to be located within one kilometer of surface water such as lakes, ponds, rivers, creeks, or intermittent streams. Thirty one percent of the sample sites, or an extrapolated total of 335 sites were determined to be located within one kilometer of wetlands. Adjusting for the Basin, 620 sites were determined to be located within 1 kilometer of surface water and 211 sites were determined to be within 1 km of a wetland. These extrapolations may be underestimated since the Basin has a considerably higher percentage of wetland and surface water areas than Region 5.

Ecological Risk Characterization

Ecological risks from municipal solid waste sites are, in general, poorly documented. Limited case study information exists for relatively large landfills, but most landfills are substantially smaller than these sites. For example the case cited above was for a 300 acre landfill; the average landfill in Region 5, and presumably the Great Lakes Basin, is 20 acres.

To obtain a relative gauge of the ecological hazard from municipal solid waste sites, an estimate was developed of the average daily and annual pollutant loadings through leachate discharge from an average landfill. The assumptions on which this estimate is based are:

- Average landfill size is 20 acres;
- Average net filtration for the Basin is 2.5 inches;
- The landfill is unlined and does not have a leachate collection system;
- All leachate generated flows to surface water through surface runoff or ground water without attenuation or transformation in route;
- Concentrations of constituents are mean values obtained from a large sample of leachates.

The average daily flow of leachate from the landfill, assuming the landfill is at moisture equilibrium (outflow=inflow), is about 37,500 gallons per day.

In general the calculated pollutant loadings from leachate would not be anticipated to pose a serious water quality problem if discharged to even a relatively small sized stream (e.g., 5,000,000 gal/day, or 8 ft^3/s) due to dilution. For example, the discharge would only raise the BOD level in a 5 million gallon per day stream by about 2 ppm, and the chloride level by about 0.6 ppm. However, discharges to relatively static water bodies such as wetlands or ponds may significantly degrade quality due to the relatively concentrated nature of the leachate, poor mixing, and lack of dilution.

An estimated 93 percent of the landfills in the Region 5 area are within one kilometer of surface water bodies. Thus, about 2800 open and closed municipal landfills are estimated to be within one kilometer of surface waters through surface runoff and ground-water discharges. Potentially more important, is an estimate of 31 percent of open and closed landfills, or about 925, which appear to be located within one kilometer of a wetland. This estimate is assumed to be lower than the situations found in the Basin, since the Basin contains a higher percentage of surface water and wetlands than Region 5.

Reversibility

No information on the reversibility of ecological damages is available; however, experience shows us that some

practices are irreversible. Landfilling of the wetlands is one such practice. Once the wetlands are destroyed, we have no way of restoring the land to its original state. This has become a problem in Illinois and Wisconsin where the wetland areas are disappearing. When the wetlands are landfilled, we also lose the habitats that the wetland supported, and many species may cease to exist. Another crisis in landfilling the wetlands is the contamination of ground water. Since the wetlands are so close to other wetlands and the freshwater supply, leachate and surface water runoff can become contaminated and endanger the habitats of other wetlands as well as the fresh water creatures.

Other problems such as ground-water contamination are reversible, though the welfare impact is high. Ground-water and sediment treatment is expensive and may not be implemented in time to save an ecosystem. Furthermore, BOD loading to surface waters is reversible depending upon the waste assimilation capacity at the receiving stream.

Welfare Impacts

Quantified welfare risks associated with the Municipal Solid Waste Sites problem area address damages resulting from diminished property values adjacent to these sites and the costs associated with human health effects attributable to these sites. Ecological welfare risks were not quantified due to lack of data.

Health Care Costs

To estimate health effects costs, the annual cancer cases estimated in the Human Health Risks section of this problem area were multiplied by the direct medical cost and forgone earnings per cancer case:

(annual cancer cases)(direct costs plus forgone earnings)= $health costs

Estimated direct and indirect medical cancer costs are based on a range of case estimates. The lower bound estimate is $80,000, while the upper bound estimate developed by the American Cancer Society[31] is $137,000. These estimates provide differing values for forgone earnings and medical costs. Both estimates are averages of costs associated with all types of cancer.

Annually, the lower bound estimate is $120,000.00, and the upper bound limit is $205,500.00.

Environmental Costs

To estimate property value losses associated with municipal solid waste sites, the following equation was used:

(damage/home)(#MSWF)(homes/MSWF) = $ damages

Results of a growing body of empirical research suggest that values of residential properties increase as the distance of those properties increases from active hazardous waste facilities and other solid waste disposal sites. These studies use econometric analyses to estimate the difference in value of residences near a site and

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[31]ICF Incorporated. 1988. "Office of Solid Waste Emergency Response (OSWER) Comparitive Risk Project: Ground Water Valuation Task Force Report." Prepared for U.S. EPA, Office of Underground Storage Tanks.

comparable homes further from the site.

Results from these studies indicate that homeowners in the Boston area are willing to pay from $300 to $500 per mile for a location more distant from a hazardous waste landfill, and that this amount was significantly higher when considering a Superfund site.

Results of some other recent studies do not consistently indicate that there is an impact on nearby property values. As a result a lower bound of property value damage due to municipal solid waste facilities was set at zero for both active and closed facilities. Upper bound damages were estimated to be $500 for residences proximate to open facilities and $69 for those near closed facilities.

To estimate the distribution of rural and urban municipal solid waste facilities, we assumed that the geographic distribution of municipal solid waste sites is proportional to the population distribution of the states. As noted before, this assumption may be in error since Wisconsin holds 2 percent of the nation's population and over 12 percent of its municipal solid waste landfills.

R.INDUSTRIAL SOLID WASTE FACILITIES

Problem Area Description

The industrial solid waste facilities problem area includes all waste sites such as landfills, surface impoundments, land application units and waste piles which are used for the disposal of industrial waste.

Magnitude of the Problem

Industrial solid waste facilities generally fall into four groups: landfills, surface impoundments, land application units and waste piles. These four types of facilities handle a variety of waste such as: organic chemicals; primary iron and steel byproducts; fertilizer and agricultural chemicals; plastics and resins manufacturing waste; inorganic chemicals; stone, clay, glass and concrete; pulp and paper waste; primary nonferrous metals; food and kindred product waste; water treatment sludge; petroleum refining waste; rubber and rubber related byproducts; transportation equipment waste; selected chemicals and allied products; textile manufacturing waste; and leather and leather related waste.

In 1985 there were nationally:

- 2760 landfills managing 78.4 million metric tons of waste
- 15250 surface impoundments managing 6.7 billion metric tons of waste
- 4300 land application units managing 90.1 million metric tons of waste
- 5330 waste piles storing 69.9 million metric tons of waste.

Weighting this for the Great Lakes Basin population gives the following estimates:

- 331 landfills managing 9.4 million metric tons of waste.
- 1830 surface impoundments managing 804 million metric tons of waste.
- 516 land application units managing 10.8 million metric tons of waste.
- 640 waste piles managing 8.4 million metric tons of waste.

These figures may be underestimated due to the high concentration of industry around the southern lakes.

Human Health Risk Characterization

Cancer Risks

Toxicity Assessment

The Screening Analysis methodology for assessing human cancer risk is presented below. The Screening analysis reviewed 87 chemicals found at industrial solid waste facilities and classified each constituent as belonging to one or more of the four facility types. The highest cancer risks were found associated with: acrylonitrile, aniline, ethylene oxide, vinyl chloride, arsenic, benzene, chloroform and tetrachloroethylene.

Exposure Assessment

Concentrations of the selected substances were calculated for the boundary of the facility taking into account attenuation and dilution, and a constant was calculated.

To relate these results to the Great Lakes Basin, we depended upon the following assumptions:

- The average landfill area is 20 acres. The average surface impoundment area is 1.6 acres. The average land application unit area is 50 acres. The average waste pile area is 1 acre.

- 25.5 percent of the Great Lakes Basin industrial solid waste facilities pose an exposure risk.

- 1.6 people drink from wells per acre.

- The exposure risk is confined to 400 meters from the site of the facility.

- The exposure risk at 400 meters is the same as the exposure risk at the boundary of the facility.

Risk Characterization

From the data provided by the Screening analysis and our assumptions, we were able to compile excess cancer estimates for each of the four types of industrial solid waste facilities. The total excess cancer in the Basin due to industrial solid waste facilities is estimated to be 1.687 for a 70 year period. Exhibit R-1 shows the distribution of cancers over the various types of facilities as well as the acreage at risk, people at risk, cancer risk ratios, and waste accumulated, all adjusted for the Great Lakes Basin.

This risk assessment is tentative since:

- The nation wide data was adjusted for the Basin. The Basin may have more industrial waste sites than the data would indicate since the Basin is known for the extent of heavy industry along the lakes' shores.

- We assumed that the exposure risk at 400 meters is the same as the exposure risk at the boundary of the facility. The exposure risk at 400 meters would probably be less than the exposure risk at the boundary of the facility due to attenuation and dilution.

- The average areas of the facilities were estimated. We do not know how Basin facilities would compare to the national average.

Ecological Impacts

Severity

There is very limited documentation available on environmental damages resulting from industrial solid waste facilities. As with municipal solid waste facilities, the main ecological impact of industrial solid waste facilities results from leaching. Surface water runoff from leachate and leachate discharge to ground water from the facilities can contaminate surface water and wetlands.

The severity of the impact is dependent upon the types of chemicals contained in the leachate, the amount of leachate reaching the surface water or ground water, the concentrations of the constituents in the leachate, and

the duration of the discharges. The component of the ecosystem adversely affected will depend on the media into which the chemicals are released. Aquatic life will be impacted by releases to surface waters, whereas plants and avian species will be affected by releases to air and water.

Both acute and chronic effects may be observed. Ecological impacts such as fish kills, impairment of health and reproductive capabilities, and bioaccumulation in the food chain may result from discharges to the environment. The severity of their effects will depend on the resiliency of the ecological system impacted and the presence of any fragile or endangered species in that system. Ecological impacts can be evaluated only if information on the type and population of the exposed species, its stability, chemicals they are exposed to and duration of exposures is available. Such data relevant to industrial solid waste facilities were not available. As a result, no attempt was made to quantitatively evaluate risk assessments for ecological exposures

It is assumed that larger ecological impacts will result from surface impoundments handling mining waste because of their size relative to other industrial solid waste facilities. At this point in time, such impacts cannot be quantitatively evaluated.

Reversibility

No information on the reversibility of ecological damages is available, although some environmental damage appears to be irreversible. Wetland destruction is one such irreversible impact. Landfilling or contamination destroys the wetland habitat and the species that live in the wetlands. Wetlands are prevalent in the Basin, and much of the Basin's industry was built in landfilled wetlands, so wetland destruction poses an immediate concern.

Ground and surface water contamination is another ecological impact. Contaminated water can be treated and this condition is reversible, although the welfare impacts are costly. BOD loading to surface waters can also impact the ecosystem. BOD loading is reversible depending upon the waste assimilation capacity of the receiving stream.

Welfare Impacts

Quantitative estimates of welfare risks due to Industrial Solid Waste Facilities in Region 5 are severely constrained by the absence of data concerning the number and distribution of these sites. Quantitative risk estimates have been developed only for estimated annual cancer cases. Limiting the welfare analysis to this one quantitative estimate results in a downward bias of the "true" damage magnitude.

Health Effects

To estimate health effects costs, the annual cancer cases estimated were multiplied by the direct medical cost and foregone earnings per cancer case:

(annual cancer cases)(direct costs and foregone earnings)=$health costs

Estimated direct and indirect medical cancer costs are based on a range of cost per case estimates. The lower bound estimate, based on Hartunian, et al, is $80,000, while the upper bound estimate developed by the

American Cancer Society is[32] $137,000. these estimates provide differing values for foregone earnings and medical costs. Both estimates are average costs associated with all types of cancer.

Over a 70 year period, the lower bound estimate is: (1.687)($80,000)= $134,960.00 for the Basin

Over a 70 year period, the upper bound estimate is: (1.687)($137,000)= $231,119.00 for the Basin

[32]ICF Incorporated. 1988. "Office of Solid Waste Emergency Response (OSWER) Comparitive Risk Project: Ground Water Valuation Task Force Report." Prepared for U.S. EPA, Office of Underground Storage Tanks.

Exhibit R-1

Facility	Facilities in Basin	Waste in Million Metric tons in Basin	Average Area of Facility in Acres	Cancer Risk Ratio	Acreage at Risk in Basin	Population at Risk in Basin	Excess Cancers in Basin
Landfills	331	9.4	20	.000053	2,169.2	3,470.7	.180
Surface Impoundments	1,830	804	1.6	.000085	3,406.5	5,450.4	.463
Land Application Units	516	10.08	50	.000012	5,394.8	8,631.7	1.036
Waste Piles	640	8.4	1	.000053	979.2	1,566.7	

V. SECONDARY PROBLEM AREAS

S. AGGREGATED DRINKING WATER

Problem Area Description

Recognition that a reliable and safe water supply is necessary for a healthy, thriving community was not a special insight for the United States or any other country. Instead, disease and epidemics, the results of unsafe drinking water supplies, prompted communities to provide clean drinking water. Most States have operated drinking water programs since the early 1900s that have improved public health by providing safe and reliable drinking water in major communities. Whenever possible, consumers are encouraged to obtain water from a public water system in order to enjoy the advantages of supervised water supply under the control of a responsible public agency. This philosophy, along with advancements in water supply engineering and treatment, have significantly improved the quality, safety, and reliability of drinking water over the past century.

Magnitude of the Problem

The federal Safe Drinking Water Act (SDWA) of 1974, which was amended in 1987, recognized the importance of drinking water quality. The original Act encouraged all States to adopt the minimum federal drinking water standards that EPA considered at that time to provide minimal protection of public health. The amendments of 1987 expanded the scope of the original Act to account for the risks identified by an improved understanding of hydrogeology, water chemistry, environmental degradation, and health effects. While the risk of a drinking water-related epidemic may be regarded as unlikely in most large public water systems in the Great Lakes Basin, some threat continues to exist in smaller communities. Rural and private water supply systems continue to present a significant risk for several reasons, including the following.

Many small water supplies are not regulated under an enforceable well construction code, resulting in the construction of systems that fail to provide even minimal protection of the water supply. Unenforceable well construction codes may foster

- Substandard well construction, which may allow contaminated surface water to enter the well;
- Improper well abandonment, which may allow unfiltered surface water to enter the aquifer;
- Siting of septic tanks, drainage fields, and dry wells within the zone of influence of water supply wells;
- Siting of agricultural chemical mixing sites at or near well heads;
- Siting of small production wells that tap the upper portion of shallow aquifers where nitrates and other surface contaminants are concentrated; or
- Makeshift repairs using inadequate materials and procedures that can result in the infiltration of contaminants and pressure loss, allowing holding tanks to flow back into distribution lines and threaten consumers when water pressure is restored.

Inadequate or infrequent flushing of distribution lines along with a lack of bacterial disinfection (e.g., residual chlorine) are threats to public health. Also, inadequate line flushing following routine repairs to distribution lines can have similar effects.

The majority of small water supplies are without benefit of a competent, certified water supply operator. All public and drinking water facilities are subject to mechanical failure. Larger water utilities constantly inspect all components and are prepared to maintain those that fail. Smaller utilities, having at least minimal safeguards like proper well construction, may lack incentive to provide surveillance, and most of the smallest systems lack the finances necessary to fund surveillance. These systems usually discover problems that present serious health risks only through regulatory procedures that most water supply experts consider inadequate. As a result, all States in the Basin support operator recruiting, training, and certification and outreach to those communities unable to procure technical expertise. All States, including Indiana, which is only now adopting a federally recognized drinking water program, continue to devote a substantial portion of their resources to maintaining a field staff and providing outreach.

As stated above, States identify problems associated with public drinking water supplies through compliance monitoring programs. The fact that States are addressing acute incidents of noncompliance should not suggest that those violations considered to be relatively insignificant should be ignored. Intermittent monitoring violations may present a small risk that contamination goes undetected in a single water system, but the sheer number of violations occurring in unrelated systems is cause for concern. The Region 5 office issues, on average, more than 250 quarterly and 1,000 annual violation letters to small public water supplies in Indiana alone. The majority of these violations arise from failure to monitor water supplies, which can be further attributed to ignorance of SDWA regulations. Enforcement can alleviate some ignorance, but actions must be timely, appropriate, and consistent. While the lack of monitoring data does not in itself constitute a public health problem, it is necessary to insure that public health is not compromised.

Small water systems often avoid the issue of non-compliance by stating that their facilities serve only a minor portion of the population. This statement is largely true, but most non-community water supplies serve transient populations (travelers), which may potentially affect a significant portion of an area's population. Other non-community water supplies serve schools and factories, locations where a person may consume most of his drinking water during a 24-hour period. When relative risks within the single arena of drinking water are weighed, EPA finds that it is more important to address violations affecting the largest populations and direct available resources toward this goal; however, this focus should not downplay the significance of non-compliance by small utilities. Given the potential for health-related problems at these systems, the overall risk presented by non-compliance is potentially large.

The above discussions identify what EPA believes are the most significant risks to public health by drinking water. Additional risks arise from inadequate response to these situations. Perhaps the most visible threat is the increasingly common use of home water treatment devices. Many consumers are aware of the findings of environmental groups, and the lack of timely and effective State response to recognized situations serves to fuel public concern. The home water treatment devices and bottled water industries are growing at an unprecedented rate that far exceeds the development of appropriate health regulations. Home treatment devices have an undeniable place in public health protection, but they are not without risk. In almost every case, the risk presented by reliance upon a home treatment system far exceeds that of a public water supply violation. Lack of consumer education encourages inappropriate use of these devices (as well as a lack of confidence with the local public water supply), often leading to a false sense of security. The primary issue is the availability of sufficient resources to operate a comprehensive public water supply program.

Another source of risk to drinking water supplies is the increase in sodium concentration in the Great Lakes. In the Lake Michigan basin, for example, sodium from anthropogenic sources, including road salt (whose winter use began in the late 1940s), has been increasing and now far exceeds sodium from natural weathering sources. Sodium concentrations

for Lake Michigan could eventually approach those of drinking water standards under present growth trends.[1]

SOURCES, CONTAMINANTS, EXPOSURE PATHWAYS, AND EFFECTS

Selection of Representative Contaminants

EPA has promulgated primary regulations for 30 drinking water contaminants that are expected to have adverse impacts on human health and secondary regulations for contaminants that affect the aesthetics of drinking water. EPA has also established monitoring requirements for other contaminants. Under the 1986 amendments to the SDWA, Congress stipulated that EPA set monitoring and MCL requirements for 83 additional contaminants by June 1989.

Since it is not possible to quantitatively assess the risks for all drinking water contaminants or even a subset of those that are regulated, EPA planned to select representative drinking water contaminants by reviewing quantitative information from its Federal Reporting Data System (FRDS) national data base for public drinking water supplies within the Great Lakes Basin. EPA retrieved the following general information for the Great Lakes Basin from FRDS:

number of public water systems by county for each of the eight states within the Great Lakes Basin and the populations they serve and their source of water (e.g., ground water or surface water);

number of public water systems by county with at least one MCL violation for each of the past five years;

distribution of these violations among ground water-based and surface water-based combined systems for each of the 213 counties within the Great Lakes Basin;[2]

specific contaminants associated with the violations, as well as the monitored concentrations; and

sizes of the populations affected by each contaminant violation.

Ideally, contaminants of concern for this analysis would depend upon those constituents for which MCL violations were noted in the FRDS retrieval; however, due to time constraints, EPA was unable to fully examine the data retrieved from FRDS. Instead, EPA reviewed the Region 5 comparative risk study and, where appropriate, scaled risk estimates down to reflect populations potentially at risk within the Basin. Where possible, EPA supplemented this analysis with data retrieved from FRDS for the Basin. (We provide as an addendum to this chapter a list of the numbers of MCL violations from 1985 through 1989 for each county in the Basin as well as the population impacted by violations in 1989.) A review of the Region 5 comparative risk study indicated the following potential contaminants of concern within the Great Lakes Basin.

Total Coliform/Microbiological Contaminants

There are many historical records with reported cases of disease transmission from microbial agents in drinking water

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[1] Guerra, Bruna, Paul Horvatin, Vacys Saulys, and David Dolan, "Lake Michigan Sodium Mass Balance and Projections for Future In-Lake Sodium Concentrations," U.S. EPA, August, 1985.

[2] Some public water supply systems utilize both ground water and surface water; however, FRDS does not acknowledge these combined systems but designates them as surface water-based systems. FRDS also does not specify the percent contributions of ground water or surface water to a combined system; therefore, a system that is largely ground water-based would be designated a surface water-based system in FRDS. Only systems that rely solely on ground water are designated as ground water-based.

supplies. Pathogenic and nonpathogenic bacteria, viruses, protozoa, and cysts can all be transmitted via ingestion of contaminated ground water. Cases of waterborne disease in the Basin have involved such diverse contaminants as Giardia lamblia, camphylobacter, and a multitude of other pathogenic coliforms and viruses. Since there are literally hundreds of possible microbial agents, agent-specific monitoring of water supplies is not practiced. Instead, the indicator organisms of the coliform bacteria group are used to evaluate the bacteriological quality of water. Turbidity is also an important parameter since it is believed to shield bacteria during the disinfection process, thus making disinfection less effective; however, available information seems to indicate that there may be no direct relationship between turbidity levels and coliform in finished drinking water and the incidence of waterborne disease.[3] In addition to violation data for total coliform, regulatory agencies need data to relate disease incidence to drinking water. This additional data would consist of the following:

Disease incidence reports by State;

Surveys of water systems that experienced a contamination problem;

Special investigations by State, local, or federal health agencies that involved data collected from drinking water supplies.

Nitrate as Nitrogen

Nitrate present in drinking water in excess of 45 mg/L (10 mg/L as nitrogen) is associated with the incidence of methemoglobinemia, which can cause "blue baby" syndrome. This problem is confined mainly to infants less than 6 months of age and in agricultural areas. According to the Region 5 comparative risk study, there have been no cases of methemoglobinemia reported in the Region in recent years; because the Great Lakes Basin is largely within Region 5, it is assumed that no cases of methemoglobinemia have been reported in the Great Lakes Basin in recent years.

Lead

EPA set the MCL for lead at 0.05 mg/L in 1976. Since then, toxicological information indicates that lead concentrations in drinking water that are far lower than the MCL are capable of producing adverse health effects, particularly in younger children, infants, and fetuses. Lead causes damage to the nervous system, blood-forming processes (hemopoietic), the gastro-intestinal system, and the kidneys. More recent studies show that lead also causes cognitive damage, retards growth, and can raise blood pressure in adult males, even at low exposure levels. Health effects range from relatively subtle biochemical changes at low doses to severe retardation or death at higher levels.

The MCL for lead is currently being lowered to reflect the increasing knowledge of the adverse effects of lead in drinking water to human health and its widespread occurrence in water supply distribution systems. According to the Region 5 comparative risk study, there have been few violations of the lead MCL in Region 5, primarily because the presence of lead in sources of drinking water is relatively rare. Most lead in drinking water results from corrosion of distribution systems. Since most distribution systems are flushed before sampling, elevated lead concentrations are often not measured through compliance monitoring and go unnoticed in the FRDS data base.

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[3] Turbidity is an important indicator of the effectiveness of surface water treatment and is currently regulated for surface-water supplies. Because its significance throughout the Basin is not known, it will not be evaluated in this report.

Trihalomethanes

Trihalomethanes (THM) are volatile organic compounds that are formed when chlorine used in the disinfection process comes in contact with organic humic and fulvic acids. While four different by-products are formed (chloroform, bromoform, dichlorobromomethane, and dibromochloromethane), chloroform is the species found in the highest concentration. THMs are regulated collectively as total THMs. The MCL is set at 1.0 mg/L and applies for the total concentration of any combination of THMs present. Projections regarding THMs could be based on the mean chloroform exposure levels for chlorinated surface-water supplies. The population exposed to THMs would be those surface-water systems serving populations of 10,000 or more customers (as per the regulations these systems are required to chlorinate) and any other surface supplies that chlorinate.

The Office of Drinking Water (ODW) is preparing a mandatory disinfection treatment rule for ground water. The anticipated proposal date is January 1991, with promulgation approximately one year later. ODW is also preparing a rule that will limit the levels of disinfectants and their by-products in finished drinking water. EPA expects that the rule will be proposed by September 1991 and promulgated in 1992.

Radionuclides

EPA regulated the radionuclides radium-226 and radium-228 under a combined MCL of 5 picocuries per liter (pCi/L) under the SDWA of 1976. This MCL used gross alpha as a screen (15 pCi/L) for these regulated alpha emitters. ODW is developing new regulations and is expected to publish a Notice of Proposed Rulemaking in January 1991. In this Notice, EPA will propose Maximum Contaminant Level Goals (MCLG); MCLs; Best Available Technologies (BAT) for monitoring requirements for radon-222, radium-226, radium-228, gross alpha, natural uranium, and beta particle and photon emitters. Because all radionuclides under consideration are known human carcinogens (i.e., classified as Group A), MCLGs for these radionuclides will be proposed as zero. EPA is also considering proposing a separate MCL for each radium isotope, possibly at 5 pCi/L.

Data on the average occurrence of radium in public water supplies in the Great Lakes Basin is not available in FRDS since only MCL violations and associated concentrations are reported. EPA's Office of Radiation Programs conducted a nationwide survey in 1980-81 of 2,500 public, ground water-based drinking water supplies in 27 States that represent 45% of all drinking water consumed nationally.[4] The survey estimated that the population-weighted average value for radium-226 and radium-228 ranged between 0.3 pCi/L and 0.8 pCi/L and between 0.4 pCi/L and 1.0 pCi/L, respectively.

Radon

The Region 5 comparative risk study estimates that radon levels in indoor air are responsible for between 5,000 and 20,000 cases of lung cancer annually in the United States. Approximately one to seven percent of these cases result from domestic uses of drinking water, such as showering, bathing, cooking, and washing clothes and dishes. The study further estimates that in an average lifetime of 70 years, between 2,000 and 40,000 deaths by lung cancer will occur in the United States due to radon levels in public water supplies that are primarily served by ground water. The risk assessment estimates that the nationwide population-weighted average concentration for radon in public drinking water supplies served by ground water is about 420 pCi/L. For systems served by both ground and surface water, the concentration is estimated to range between 50 pCi/L and 300 pCi/L.

ODW plans to propose an MCL for radon in the Notice of Proposed Rulemaking anticipated in January 1991.

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[4] **Federal Register, Volume 51, Number 189, September 30, 1986.**

Trichloroethylene

EPA regulated trichloroethylene as a primary drinking water contaminant at 0.005 mg/L in July 1987. It is classified as a Class B2 probable human carcinogen based on the weight of toxicological evidence. Acute oral exposures (15-25 ml) to TCE in humans has resulted in vomiting, abdominal pain, and transient unconsciousness, while longer-term occupational exposures suggest damage to the liver. The major source of TCE released to the environment is from its use as a metal degreaser. Since TCE is not spent during its use, the majority of all TCE produced is released to the environment. TCE released to the air is degraded within a few days. TCE released to surface water volatilizes within a few days or weeks and degrades. However, TCE that released to land migrates readily to ground water where it remains for months to years. TCE does not easily degrade in ground water, but under certain conditions, it may degrade to dichloroethylene and vinyl chloride. EPA selected TCE as a constituent of concern because it is a common contaminant in ground and surface water, with higher levels found in ground water. National surveys of drinking water supplies have shown that three percent of all public water systems using ground water contain TCE at levels of 0.5 g/L or higher. Approximately 0.4% have levels greater than 100 g/L. In Region 5, about 3.5% of the wells contained some measurable level of TCE, with 0.5% of all wells exceeding a 10^{-5} lifetime cancer risk. Unlike other chlorinated compounds, TCE does not bioaccumulate in animals or food chains.

Tetrachloroethylene

Tetrachloroethylene (PCE) is also classified as a VOC. After slating PCE for promulgation along with TCE in July 1987, EPA withdrew PCE from the group due to available bioassay data. This data created a controversy surrounding its weight of evidence classification as a B2 or C carcinogen. Currently, PCE is classified as a B2 carcinogen and is scheduled for promulgation of a MCL and MCLG in December 1990. The MCL and MCLG will be 0.005 mg/L and zero, respectively. PCE also has many industrial uses and, like TCE, is not spent during use but is released directly back into the atmosphere. PCE is usually discharged directly to land and surface water and degrades slowly. PCE released to the atmosphere degrades within days or weeks. It is very mobile in soil and travels easily to ground water where it remains for months or years. Under certain conditions, PCE degrades to TCE and then to dichloroethylene and vinyl chloride. National surveys of drinking water supplies have shown that 3% of all public water systems using ground water contain PCE at levels of 0.5 g/L or higher. About 0.7% have PCE levels above 5 g/L. In Region 5, about 3% of all public water systems supplied by ground water have measurable levels of PCE, with one percent of all wells exceeding a 10^{-5} lifetime cancer risk.

1,1,1-Trichloroethane

EPA regulated trichloroethane (TCA) as a primary drinking water contaminant at 0.2 mg/L in July 1987. It has been placed in the category of class D carcinogens that have not been evaluated as to their human carcinogenic potential due to insufficient data. The major source of TCA released to the environment is from its use as a metal degreaser. As with the other two previously discussed VOCs, TCA is not consumed during metal degreasing but is released to the environment. TCA released to air degrades slowly with an estimated half life of one to eight days. TCA release to surface water volatilizes in a few days or weeks. TCA released to land does not sorb onto soil and travels quickly to ground water. It slowly hydrolyses in ground water with an estimated half life greater than 6 months. As with TCE, TCA does not bioaccumulate in animals or food chains. TCA is a good representative chemical because it occurs widely in the environment. It is a common contaminant in ground water and surface water, with higher levels measured in ground water. National drinking water surveys have found that 3% of all public water systems using ground water contain TCA at levels of 0.5 g/L or higher. Approximately 0.1% have TCA levels above 100 g/L. In Region 5, about two percent of the public water wells showed measurable levels of TCA.

Alachlor

The MCL and MCLG for alachlor are scheduled for promulgation in December, 1990. The proposed MCL is 0.002 mg/L, and the MCLG is zero. Alachlor has been classified as a B2 carcinogen due to the weight-of-evidence of human carcinogen properties. Alachlor had one of the largest production volumes of any pesticide. It is applied to the soil either before or just after the crop has emerged and is rapidly metabolized by crops after application. It is widely used for corn and soybean crops. In the soil, alachlor is degraded by bacteria under both anaerobic and aerobic conditions. Alachlor is not photodegradable and does not hydrolyze under environmental conditions. Alachlor is moderately mobile in sandy and silty soil and has been shown to migrate to ground water. On a national basis, alachlor has been measured in both surface and ground waters. Federal and State surveys of surface water have reported occurrences of alachlor at levels of one part per billion. Alachlor is used extensively in Region 5 and the Great Lakes Basin due to high corn and soybean production. In Region 5 (and most likely the Great Lakes Basin), available data indicates that alachlor has the potential to contaminate both ground and surface water widely.

Atrazine

The MCL and MCLG for atrazine are scheduled for promulgation in December 1990. The proposed MCL and MCLG are both 0.003 mg/L. EPA has classified atrazine as a C carcinogen (i.e., a possible human carcinogen) because of a lack of evidence of potential carcinogenicity to humans and incomplete evidence of potential carcinogenicity to animals. According to the STORET 1988 national data base, atrazine has been detected in 4,123 of 10,942 surface-water samples and in 343 of 3,208 ground-water samples. These samples were collected at 1,659 surface-water locations and at 2,510 ground-water locations, respectively, across the nation. Atrazine was present at the 85th percentile of all non-zero samples at concentrations of 2.3 g/L in surface water and 1.9 g/L in ground water. [5] Atrazine is moderately to highly mobile in soils that range in texture from clay to gravelly sand. Atrazine degrades in soils by photolysis and microbial processes. It is widely used in the Basin for corn.

Other Contaminants

The Region 5 comparative risk study does not include several inorganic contaminants, such as fluoride, in its analysis because FRDS data and national monitoring data show that MCLs for these contaminants are violated infrequently and are remedied quickly when they are violated.

EPA is scheduled to regulate several synthetic organic contaminants other than pesticides, including PCBs and nonvolatile organic solvents, but these contaminants have not been included in this analysis. National monitoring data indicate that these contaminants do not occur frequently in public water supplies and would, therefore, present a small risk in comparison to other contaminants. Numerous contaminants that are currently regulated, such as inorganics and pesticides, are also not included. The Region 5 comparative risk study indicates that FRDS reports very few MCL violations for most regulated inorganics, pesticides, and radionuclides. Therefore, EPA has chosen not to include these parameters in this analysis, and these assumptions are applied to the Great Lakes Basin as well.

Exposure Pathways

Three possible routes of exposure from drinking water as a source of contaminants exist: ingestion, inhalation, and

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[5] This information comes from the Health Advisory for Atrazine, p. 44. The section warns that the individual data "...have not been confirmed as to their validity. STORET data are often not valid when individual numbers are used out of the context of the entire sampling regime...Therefore, this information can only be used to form an impression of the intensity and location of sampling for a particular chemical."

dermal contact. The major route of exposure from most drinking water contaminants is through ingestion; however, depending on the physical properties of a contaminant (e.g., volatility, octanol-water partitioning), inhalation of volatile organic compounds (VOCs) such as trichloroethylene can occur as the compound is released to the air from use of hot water in showering, bathing, or dishwashing. The Region 5 comparative risk study indicates that some studies have shown that exposure to VOCs via inhalation of indoor air can be as significant as exposure via ingestion.

Inhalation is also a possible exposure pathway for radon that has been liberated from drinking water. Radon is released from drinking water in the same manner as from VOCs. Radon has the potential to cause lung cancer through inhalation and radiotoxicity through ingestion. EPA's Office of Drinking Water is developing maximum contaminant levels (MCLs) and monitoring requirements for radon, and it will be a regulated parameter under the Public Water Supply program; however, EPA estimates that the regulatory levels being considered for radon in drinking water (200 - 500 Pci/L) would contribute less than one percent to the total amount of indoor radon. EPA did not have adequate information to assess risks from ingestion and inhaling radon in the Great Lakes Basin, but nationwide risk data has been scaled down to estimate risk within the Basin.

Human Health Risk Characterization

In analyzing the public health risk posed by drinking water, we examined cancer and noncancer risks for both individual and population risks using Region 5's exposure assumptions described in the comparative risk study. We define population risk as the risk posed to all persons in the Great Lakes Basin exposed to each of the above contaminants at the assumed exposure point concentrations. Individual risk is the risk posed to an individual potentially exposed to the chemicals at these average concentrations. In both the individual and population risk analyses, we considered reasonable average exposures instead of worst case or most exposed individual scenarios. In addition, we examined typical exposures for both chronic and sub-chronic adverse health effects.

The methodology outlined in the Region 5 comparative risk study essentially encompasses the following five major steps:

(1) determine the environmental concentrations for selected contaminants in the Basin water supply;

(2) evaluate the hazard or toxicity for the selected chemicals;

(3) determine the population exposed assessment to the identified concentrations;

(4) characterize the chemical's potency or dose-response relationship; and

(5) quantify the risk associated with exposure levels.

In addition, uncertainties and results are discussed. The individual purposes, methods, assumptions, and limitations are discussed under each section of the risk analysis.

Toxicity Characterization

In this section, we present both cancer and noncancer toxicity information for the contaminants of concern described in the previous section. Of the contaminants examined, radionuclides are human carcinogens (Class A). Chloroform is the predominant compound among the trihalomethanes (THMs) formed by the chlorination of drinking water.

Chloroform is regarded as a probable human carcinogen (Class B2). The Cancer Potency Factor (CPF) or unit slope factor that will be used for this analysis was assumed to be the same as that for chloroform (6.1 E-3 ppm/day-1). Other contaminants that are B2 carcinogens are lead, trichloroethene, tetrachloroethene, and alachlor. Atrazine and alachlor were evaluated for both carcinogenic and noncarcenogic risks. Coliform and nitrate are noncarcinogens and were evaluated with respect to noncancer endpoints. Trichloroethane has not yet been evaluated with respect to evidence of human carcinogenicity (Class D) and was assessed only for noncarcinogenic risks.

For the carcinogens, the purpose of this step is to determine the relationship between the dose and the probability of developing cancer. This relationship predicts the level of risk associated with a certain exposure. The information presented Exhibit S-1 includes EPA's weight-of-evidence carcinogenicity classification, the cancer potency factors, the Maximum Contaminant Level (MCL) for drinking water, and the acute and chronic toxicological endpoints. All values presented in Exhibit S-1 are taken from the Region 5 comparative risk study.

For noncarcinogens, the purpose of this step was to determine the relationship between doses of a contaminant and the probability of developing an adverse health effect. Unlike the dose-response relationship for carcinogens, these relationships are thought to involve a threshold below which an adverse health effect will not likely occur. This is because the human body is able to detoxify and repair systemic damages up to a certain point. Toxicity information for noncarcinogens is also listed in Exhibit S-1 and includes the oral reference doses (RfDo) for chronic exposures, the MCLs, Health Advisories (exposure doses considered by the Agency to be acceptable for acute and less than lifetime exposures), and the acute and chronic toxicological endpoints.

EXHIBIT S-1
Carcinogenic and Toxicological Parameters of Drinking Water Contaminants

Contaminant	Carcinogen Class	Oral CPF (slope factor) $(ppm/d)^{-1}$	Inhal. CPF (slope factor) $(ppm/d)^{-1}$	Oral RfD (ppm/d)	MCL (mg/L)	HA, Longer Term (7-yr) (mg/L)	HA, Level 1-day & 10-day (mg/L)	Toxicological Endpoints (Acute/Chronic)
Coliform and microbiological agents	NA	NA	NA	NA	varies	NA	NA	GI irritation
Lead	B2 (tentative classification)	1.4×10^{-4}	Not Determined	Not Determined	0.005 source, treatment technology at tap	NA	NA	neurological: subtle biochem. changes, impaired mental performance, circulatory system effects
Nitrate	NA	NA	NA	1.0	10.0	NA	10.0	methemoglobine mia in infants less than 6 months/death
Total Trihalomethanes (expressed as chloroform)	B2	6.1×10^{-3}	8.1×10^{-2}	0.010	0.100	NA	NA	hepatotoxicity/ cancer
Trichloroethene	B2	1.1×10^{-2}	1.7×10^{-2}	0.007	0.005	NA	NA	hepatotoxicity/ cancer
Tetrachloroethene	B2	5.1×10^{-2}	3.3×10^{-3}	0.010	0.005 (proposed)	5.0	2.00 & 2.00	hepatotoxicity, nephrotoxicity, CNS effects/ cancer
Trichloroethane	D	NA	NA	0.090	0.200	100.0	100 & 40	CNS effects, hepatotoxicity,

Atrazine	C	Not Determined	Not Determined	0.005	0.003 (proposed)	0.200	0.100 & 0.100	kidney, liver damage/possible reprod., devel., mutag. effects
Alachlor	B2	Not Determined	Not Determined	0.010	0.002 (proposed)	NA	0.100 & 0.100	hepatotoxicity, ocular effects/cancer
Radium 226-228	A	3.6×10^{-5}	Not Determined	NA	5 pCi/L	NA	NA	bone, mastoid cancer
Radon 222	A	Not Determined	1.8×10^{-6}	NA	Not Determined	NA	NA	lung cancer

* MCL varies based on analytical method, sample volume, and number of samples collected per month. Two types of MCLs exist for coliform: (1) for a monthly average, and (2) for a single sample. After December 12, 1990, no more than five percent of samples may be positive.

Exposure Characterization

As described above, our approach was to scale the results of the Region 5's exposure assessment to a level that approximates risks posed to the Great Lakes Basin population. The purpose of the exposure assessment step was to estimate the concentrations in drinking water at which exposure occurs, identify and estimate the sizes of the exposed populations, and identify the pathways of exposure and delivered doses. The assessments for carcinogens and noncarcinogens for both individuals and for populations were based on realistic maximum and average exposures utilizing data from the Region 5 comparative risk study. Exposures were assumed to be constant over a 70-year lifetime. The risk assessment included the derivation of average risks by weighting to the exposed populations. We made the following additional assumptions in estimating the risks posed by both carcinogens and noncarcinogens:

The estimates embrace Region 5's exposure assumptions for its comparative risk study;[6]

All Basin population values used in the analysis were extrapolated from Region 5 values by the ratio of overall Basin population to overall Regional population; and

The concentrations used in the analysis were taken directly from the Region 5 comparative risk study.

Exhibit S-2 presents the populations in the Basin served by public and private drinking water supplies. Human population numbers for the Great Lakes Basin used in the assessment are based on the 1988 estimate from the Bureau of Census. Rather than using population estimates retrieved from FRDS, which were found to reflect populations impacted by MCL violations only and not total populations regardless of quality of water, estimates of populations served by each of the source categories were used as presented in the USGS report, National Water Summary 1987 -- Hydrologic Events and Water Supply and Use, Water-Supply Paper 2350, which describes 1985 water use. This report presented, for each state, percentages of the population served by public water supply systems and by private wells. These percentages are assumed to apply to the portion of the Basin in each state and scaled the total population in each State-portion of the Basin by these percentages. It is possible that this approach underestimates the population served by public water supply systems because populations within the Basin are more likely to receive drinking water from treated withdrawals from one of the Great Lakes. The USGS report did not provide percentages of populations served by surface- and ground-water based systems for the Basin states (with the exception of New York), so percentages for the quantities of surface water and ground water used by PWS systems in the states were applied to calculate the populations served by each source. This approach may underestimate the population served by surface-water based systems, because systems in the Basin are likely to use Great Lakes water.

Exhibit S-3 presents a summary of the exposure assessments used in this analysis. Exposure assumptions are consistent with those made in the Region 5 comparative risk study.

Risk Characterization

Exhibit S-4 presents the approach and results of the carcinogenic risk characterization. We combined the estimated drinking water concentrations and exposure assumptions (encompassed in the Oral Chronic Intake Factors) to produce a range of chronic daily intakes (dosages). We then multiplied the dose by the cancer slope factor to calculate the individual chemical-specific lifetime cancer risks presented by each chemical. The individual risk was then multiplied by the estimated exposed population to obtain an estimate of the average number of cancer cases expected over a 70-year lifetime. We also calculated chemical-specific average population-weighted cancer risks. We estimate the following

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[6] For the noncarcinogens, we used an averaging time equal to the exposure duration. Assumptions used in the assessment are questionable for lead, because its carcinogenicity has not been determined.

total numbers of cancer cases presented by all of the contaminants of concern (with the exception of lead because its carcinogenicity has not been determined):

	Total Cancer Cases 70-year lifetime	Annual Cancer Cases
Minimum	45	0.64
Maximum	114	1.63
Average	80	1.14

EXHIBIT S-2
Population on Public and Private Drinking Water Supplies in the Great Lakes Basin

State	Total Population in Basin [1]	Population Served by Public Water Supply Systems [2]	Population Served by Surface Water Systems [3]	Population Served by Ground-Water Systems [4]	Population Served by Private Wells [5]
Illinois	5,779,600	4,912,700	2,996,700	1,916,000	866,900
Indiana	1,699,300	1,138,500	603,400	535,100	560,800
Michigan	9,239,800	7,576,600	6,212,800	1,363,800	1,663,200
Minnesota	320,700	205,200	90,300	114,900	115,500
New York	4,377,800	3,896,200	2,883,200	1,013,000	481,600
Ohio	5,227,500	4,338,800	3,123,900	1,214,900	888,700
Pennsylvania	381,000	262,900	220,800	42,100	118,100
Wisconsin	3,206,900	2,084,500	1,083,900	1,000,600	1,122,400
Great Lakes Basin	30,232,600	24,415,400	17,215,000	7,200,400	5,817,200

[1] Total population in all counties with any land area in the Great Lakes Basin. 1988 estimate from "U.S. Great Lakes: Drainage Basin County Summary," U.S. EPA, Great Lakes National Program Office, July 1990.

[2] Estimated Basin population served by public water supply systems, calculated by scaling populations in Basin by factors obtained from National Water Summary 1987 -- Hydrologic Events and Water Supply and Use, U.S. Geological Survey Water-Supply Paper 2350.

[3] Estimated Basin population that is served by surface-water based public water supply systems, calculated by scaling populations served by public systems by factors obtained from USGS report.

[4] Estimated Basin population that is served by ground-water based public water supply systems, calculated by scaling populations served by public systems by factors obtained from USGS report.

[5] Estimated Basin population that is served by self-supplied sources, the majority of which are assumed to be private wells, calculated by scaling total populations in Basin by factors obtained from USGS report.

EXHIBIT S-3
Exposure Assessment Summary

Contaminant	Source Type	Population Characteristics	Potential Exposed Population[1]	Average Exposure Concentration (mg/L)[2]	Exposure Route
Total Coliform/ Microbiological Agents	Ground and Surface	Users of PWS in violation[3] of MCL and users of private wells	7,100,000	NA	Ingestion
Nitrate as Nitrogen	Ground and Surface	Fetuses and infants less than 6 months using PWS in violation of MCL and private wells in areas likely to be affected by agriculture	167,000*	15.75	Ingestion
Total Trihalomethanes as Chloroform	Surface	Users of PWS serving >10,000 with MCL violation	15,600*	0.101	Ingestion Inhalation
		Users of PWS serving <10,000 currently not regulated	1,540,000*	0.060	
Lead	Ground and Surface	Fetuses, infants, and children using PWS with MCL violations	1,950*	0.05	Ingestion
		PWS users with positive detections below MCL	370,000*	0.03	
		PWS users and private well users with no or minimal detections	30,232,600	0.003	
Radium 226-228	Ground	Users of PWS in violation of MCL	37,500*	9.62 pCi/L	Ingestion
		Users of PWS serving >1,000 persons	7,200,000	0.70 pCi/L	
		Users of PWS serving <1,000 people and private well users	5,817,200	1.1 pCi/L	
Radon	Ground	Users of PWS serving >1,000 people	7,200,000	165 pCi/L	Ingestion Inhalation
		Users of PWS serving <1,000 people and private well users	5,817,200	245 pCi/L	
Volatile Organics: Trichloroethene Tetrachloroethene Trichloroethane	Ground and Surface	Users of PWS in violation of MCLs	49,800*	TCE: 0.011 PCE: 0.014 TCA: 0.008	Ingestion Inhalation
		Users of PWS serving <3,300 currently not regulated	130,000		
		Users of private wells subject to commercial,industrial, and active hazardous and municipal waste sites, etc.	310,000*	TCE: 0.03 PCE: 0.007 TCA: 0.20	
Alachlor	Ground and Surface	Users of PWS with levels over the pMCL in highly vulnerable areas	26,700*	0.002	Ingestion Inhalation
		Users of private wells near agricultural areas	37,100*	0.002	
Atrazine	Ground and Surface	Users of PWS with levels over the pMCL in highly vulnerable areas	26,700*	0.003	Ingestion
		Users of private wells near agricultural areas	37,100*	0.003	

[1] Exposure assumptions are consistent with those made in the Region V comparative risk study. For those populations identified by an asterisk, we assumed that the Basin potentially exposed population is similar to that in Region V and estimated the affected population in the Basin by applying a factor of 0.651 (i.e., the ratio of Basin population to Region V population). The remaining populations are estimated from Exhibit S-2 and from the FRDS retrieval.
[2] Average exposure concentrations are those determined to be appropriate for Region V and are assumed to also be appropriate for the Basin.
[3] "Violation" in the case of coliform refers to both types -- MCL and monitoring/reporting.

EXHIBIT S-4

Calculation of Carcinogenic Risks

Contaminant	Cancer Slope Factor ($mg/kg/d)^{-1}$	Drinking Water Concentration (mg/L)	Chronic Daily Intake (mg/kg/day)	Chemical-specific Lifetime Risk	Estimated Exposed Population	Potential Cancer Cases (70-yr lifetime)	Chemical-specific Avg. Population-weighted Cancer Risk
Lead	1.4×10^{-4}	0.051	3.1×10^{-3}	4.3×10^{-7}	1,950	8×10^{-4}	2.8×10^{-8}
		0.029	1.7×10^{-3}	2.4×10^{-7}	370,000	0.09	
		0.003	1.8×10^{-4}	2.5×10^{-8}	30,232,600	0.76	
Total Trihalomethanes	6.1×10^{-3}	0.101	2.9×10^{-4}	1.7×10^{-6}	15,600	0.03	1.0×10^{-5}
		0.060	1.7×10^{-3}	1.0×10^{-5}	1,540,000	16	
Trichloroethene	1.1×10^{-2}	0.011	3.1×10^{-5}	3.5×10^{-7}	49,800	0.02	8.4×10^{-6}
		0.030	8.6×10^{-4}	9.4×10^{-6}	130,000	1.2	
		0.030	8.6×10^{-4}	9.4×10^{-6}	310,000	2.9	
Tetrachloroethene	5.1×10^{-2}	0.014	4.0×10^{-5}	2.0×10^{-6}	49,800	0.10	9.4×10^{-6}
		0.007	2.0×10^{-4}	1.0×10^{-5}	130,000	1.3	
		0.007	2.0×10^{-4}	1.0×10^{-5}	310,000	3.2	
Alachlor	8.0×10^{-2}	0.002	5.7×10^{-5}	4.6×10^{-6}	26,700	0.12	4.6×10^{-6}
		0.002	5.7×10^{-5}	4.6×10^{-6}	37,100	0.17	
Atrazine	2.2×10^{-1}	0.003	8.6×10^{-5}	1.9×10^{-5}	26,700	0.50	1.9×10^{-5}
		0.003	8.6×10^{-5}	1.9×10^{-5}	37,100	0.70	
Radium 226-228	3.6×10^{-5}	9.62 pCi/L	2.7×10^{-2}	9.9×10^{-7}	37,500	0.04	8.9×10^{-7}
		0.70 pCi/L	2.0×10^{-2}	7.2×10^{-7}	7,200,000	5.2	
		1.06 pCi/L	3.1×10^{-2}	1.1×10^{-6}	5,871,200	6.5	
Radon[1]	ND	165 pCi/L	ND	2×10^{-6}	NA	3.7	3.0×10^{-6}
		245 pCi/L		to		to	
				6.0×10^{-6}		73	

[1] The lifetime cancer risk and potential number of cancer cases from radon exposure were not calculated from the exposure data provided above. The range of estimates of the cancer risk was obtained from the Federal Register (51(189):34845, September 30, 1986) and includes inhalation exposure. The number of nationwide cancer cases was also provided in this source, and we scaled these numbers to the Basin by applying a multiplier of 12.2 percent.

As shown in Exhibit S-4, the contaminant that contributes the greatest number of potential cancer cases over a 70-year period is radon, followed successively by total trihalomethanes, radium, tetrachloroethene, and trichloroethene.

Exhibit S-5 presents the approach and results of the noncarcinogenic risk characterization. As for the carcinogenic estimates, we combined the estimated drinking water concentrations and exposure assumptions to produce a range of chronic daily intakes. To calculate the Hazard Index, we divided the chronic daily intake by the oral reference dose. We also include in Exhibit S-4 the population exposed to each contaminant. As shown by the Hazard Indices, nitrate presents the most significant risk, which is manifested as methemoglobinemia in infants of less than six months of age. It is also expected that lead would pose a significant individual and population noncancer risk through subtle biochemical changes in infants and small children; however, neither an oral RfD nor Health Advisory levels have been developed for subchronic exposure to lead through drinking water. Although not included in the noncarcinogenic risk estimates, it is also estimated that microbiological agents may cause between 5,500 and 27,500 cases of waterborne disease.

Welfare Impacts

In this section, we present estimates for health care and environmental costs due to contaminated drinking water within the Great Lakes Basin. We base our health care cost estimates on the number of annual cancer cases associated with public sources of drinking water estimated in the aggregated drinking water risk assessment. These damages do not account for the costs associated with replacement of contaminated drinking water supplies; instead, we present these costs separately. In addition, we did not estimate costs of installing residential water purification systems and the cost of bottled water.

EXHIBIT S-5
Calculation of Noncarcinogenic Risks

Contaminant	Oral Reference Dose (mg/kg/day)	Drinking Water Concentration (mg/L)	Daily Intake (mg/kg/day)	Hazard Index	Population Exposed
Nitrate as Nitrogen	1.0	15.75	2.25	2.25	167,000
Trichloroethane	0.09	0.008	2.3×10^{-4}	0.0025	49,800
		0.2	5.7×10^{-3}	0.063	440,000
Atrazine	0.005	0.003	8.6×10^{-5}	0.017	63,800
Lead [1]	ND	0.05	3.1×10^{-3}	ND	1,950
		0.03	1.7×10^{-3}	ND	370,000
		0.003	1.8×10^{-4}	ND	30,232,600
Total Trihalomethanes as Chloroform	0.01	0.10	2.9×10^{-3}	0.29	15,600
		0.06	1.7×10^{-3}	0.17	1,540,000
Trichloroethene	0.007	0.01	3.1×10^{-4}	0.044	49,800
		0.03	8.6×10^{-4}	0.12	440,000
Tetrachloroethane	0.01	0.014	4.0×10^{-4}	0.04	49,800
		0.007	2.0×10^{-4}	0.02	440,000
Alachlor	0.01	0.002	5.7×10^{-5}	0.0057	63,800

ND = Not determined

[1] Neither an oral RfD nor Health Advisory levels have been developed for subchronic exposure to lead through drinking water. Such a level could be developed by converting lead concentrations in drinking water to a child's blood-lead level (PbB). The difference in child's PbB level from drinking water contributions alone could then be estimated.

[1] The lifetime cancer risk and potential number of cancer cases from radon exposure were not calculated from the exposure data provided above. The range of estimates of the cancer risk was obtained from the Federal Register (51(189):34845, September 30, 1986) and includes inhalation exposure. The number of nationwide cancer cases was also provided in this source, and we scaled these numbers to the Basin by applying a multiplier of 12.2 percent.

Health Care Costs

Given the lower and upper bound cost per case estimates, we calculate the lower and upper bound health costs as follows:

Lower bound cost per case estimate = HC_L = (1.14)($80,000) = $91,200

Upper bound cost per case estimate = HC_U = (1.14)($137,000) = $156,000

Environmental Costs

Replacement Costs

Using RCG/Hagler, Bailly, Inc.'s approach, we can estimate the cost of replacing contaminated drinking water supplies given the number of annual private well replacements and public water supply hookups associated with ground-water contamination. We use RCG's estimated capital costs of $3,500 to replace a private well by digging a new well and $300,000 to replace a public water supply well by extending a hookup from another public supply. These costs do not include annual operating costs.

EPA Region 5's Safe Drinking Water Branch estimates that about 4 percent of households served by private wells have replaced these wells. To estimate the Basin-wide cost of replacing private water supplies, we will assume that 4 percent of households in the Basin served by private wells have also replaced their wells. To estimate the total number of households in the Basin served by private wells, we will subtract the number of people served by public water systems in the Basin (obtained from FRDS) from the total Basin population and divide this difference by four, the number of people per household, to estimate the number of households. Then, the Basin-wide cost of replacing private water supplies will be

(Number of private wells replaced)($3,500) = Basin-wide cost of replacing private wells

To estimate the Basin-wide cost of replacing contaminated public water supplies, we can utilize violations data retrieved from FRDS. First, for each MCL violation recorded in FRDS, the number of months the system was out of compliance is also recorded. For our upper bound, we could assume that all systems in violation would need to be connected to an alternative system; this estimate would most likely be very high and, possibly, highly inaccurate. For our lower bound, we could select a cut-off for the number of months of noncompliance for which an alternative system would be needed. We will investigate this proposed method by speaking with our FRDS contact and reviewing the FRDS data element dictionary.

Treatment Costs

In general, superintendents for sample drinking water supply systems reported no significant changes in treatment costs between 1987 and 1990.

T. AGGREGATED GROUNDWATER

Problem Area Description

Aggregated ground-water contaminant source risks have been analyzed on a qualitative basis to assess the cumulative impact on ground-water resources within the Great Lakes Basin and to provide an estimate of the relative contaminant contribution of the major sources to human health, ecological impacts, and welfare costs. The major sources of contamination include waste disposal facilities (e.g., landfills, septic systems, land spreading), direct discharge to ground water (i.e., injection wells), storage facilities, spills, and pesticide and fertilizer applications.

Magnitude of the Problem

Because of the high level of industrial activity, and agricultural activity to a lesser extent, there are a variety of sources of ground-water contamination within the Basin. Ground water is used intensively in the Basin as a source of drinking water: Approximately 43 percent of the population of the Basin relies on ground water for potable water supplies.[7] Although ground-water resources are generally high in quality, numerous incidents of contamination and the large number of potential sources of contamination pose a chronic risk to the integrity of ground water within the Basin.

The Office of Technology Assessment (OTA) conducted a survey of scientific literature regarding sources of ground-water contamination and compiled a list of thirty-three potential sources of ground-water contamination. The following list applies to the nation as a whole and is not meant to suggest that each source is present in the Great Lakes Basin; however, several of the sources presented in the list may exist in the Basin:

(1) subsurface percolation from septic tanks and cesspools,
(2) injection wells, (Exhibit T-1)
(3) land application of wastes,
(4) landfills,
(5) open dumps,
(6) residential (local) disposal,
(7) surface impoundments,
(8) waste tailings,
(9) waste piles,
(10) materials stockpiles,
(11) graveyards,
(12) animal burial,
(13) aboveground storage tanks,
(14) underground storage tanks,
(15) containers,
(16) open burning and detonation sites,

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[7] This percentage was derived from our estimates of the Basin-wide populations relying on public and private drinking water supplies as presented in Exhibit S-2 of this memo. This percentage accounts for populations that receive drinking water from either ground-water based public water supply systems or from private wells. This percentage may be low because a portion of the surface-water based public water supply systems that serve the remaining 57 percent of the Basin population may receive part of their raw water from ground-water sources.

(17) radioactive disposal sites,
(18) pipelines,
(19) material transport and transfer operations,
(20) irrigation practices,
(21) pesticide applications,
(22) fertilizer applications,
(23) animal feeding operations,
(24) de-icing salts applications,
(25) urban runoff,
(26) percolation of atmospheric pollutants,
(27) mining and mine drainage,
(28) production wells,
(29) other wells,
(30) construction excavation,
(31) ground-water/surface-water interaction,
(32) natural leaching, and
(33) salt-water intrusion/brackish-water upconing.

Chemical spills may also pose a hazard to ground water. In 1989, 51 chemical spills that impacted ground water were reported in EPA's Emergency Response Network System (ERNS) data base of chemical spills in counties within the Great Lakes Basin. Twenty of these spills occurred in Michigan, nine occurred in Illinois, seven occurred in both New York and Ohio, five occurred in Indiana, and three occurred in Wisconsin.[8]

The types of chemicals associated with these sources of ground-water contamination include volatile organic compounds (VOCs), non-aqueous phase liquids (NAPLs), pesticides, heavy metals, inorganic salts, and nutrients. In its Region V comparative risk study, EPA used the following representative chemicals to evaluate residual and potential risk to populations and ecosystems due to ground-water contamination; we include them here as examples of the types of chemicals that may pose risk to those populations in the Basin utilizing ground water:

tricholoroethene,
toluene,
chromium,
nitrates,
alachlor,
atrazine, and
fecal coliform.

Geographic Analysis of Contaminant Sources

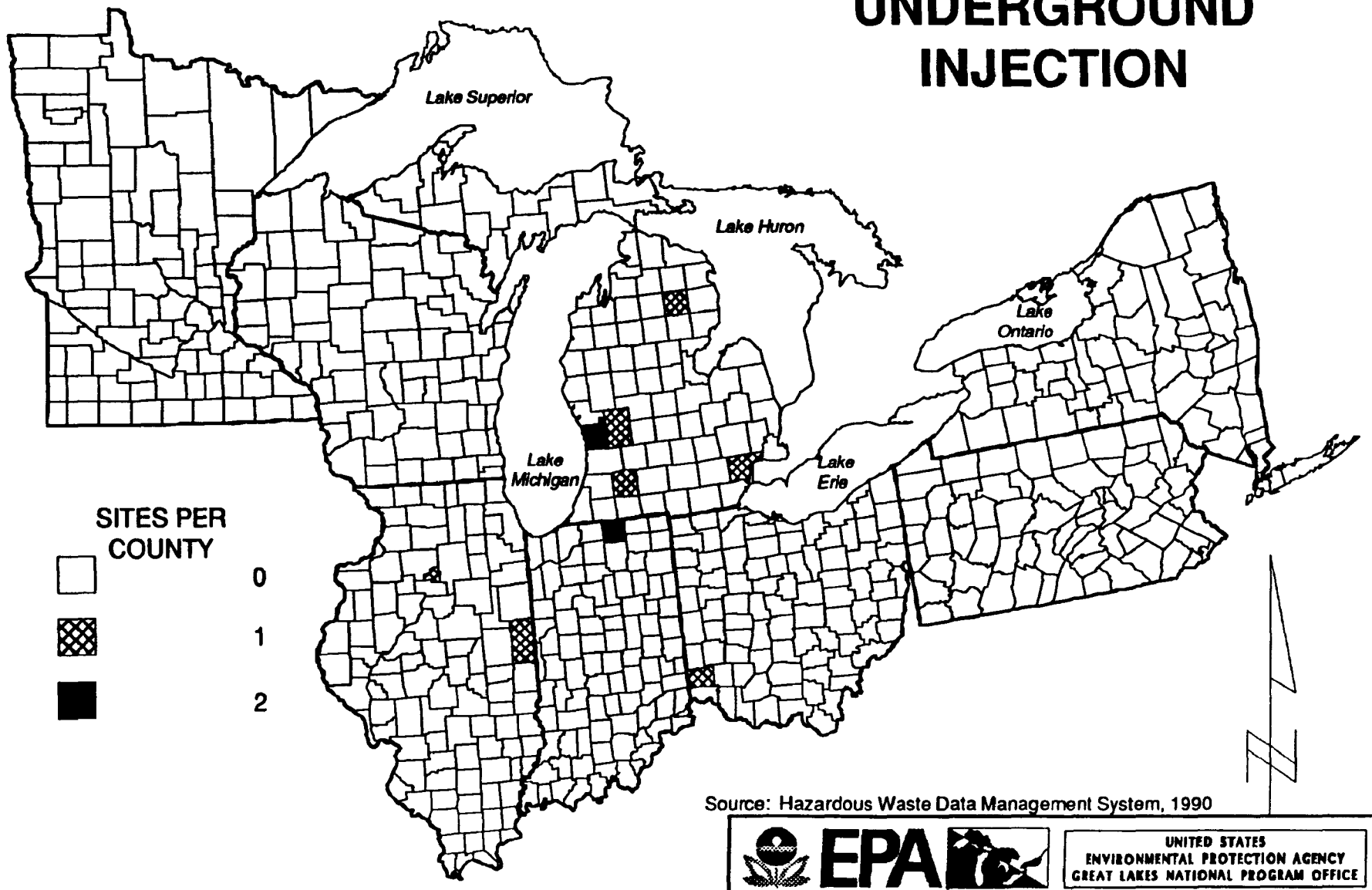
Region 5, in its comparative risk study, concluded after preliminary assessment of existing data that the Great Lakes Basin would have lower overall residual public health risks due to ground-water contamination than would Region 5. EPA's conclusion was based on the following factors:

Major population centers within the Basin use lake water, rather than ground water, for their potable

[8] Spills and other accidental releases are addressed more fully in Section D.

Exhibit T-1

RCRA FACILITIES UNDERGROUND INJECTION



Source: Hazardous Waste Data Management System, 1990

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water supplies;

Much of the vulnerable and productive farmland in Region V lies outside the Great Lakes Basin, thus reducing the impact to ground water within the Basin to contamination by agricultural chemicals; and

Most CERCLA sites in Region 5 lie outside the Basin.

In terms of ecological impacts, however, the Great Lakes Basin has several harbors and associated rivers that are severely polluted; contaminated ground water contributes to pollution of surface water as well as sediments in many of these cases. The percentage of the total impact is difficult to estimate, but it appears to be as high as 20 percent of the problem in some areas, such as the Grand Calumet Basin and connecting channels, according to Region 5's comparative risk study.

Human Health Impacts

Although ground water is the source of drinking water for as much as 43 percent of the Basin population, major population centers within the Basin use lake water for their potable water supplies. Contaminated ground water principally affects human health when it impacts drinking water supplies. In this section, both residual and potential risk will be discussed. In general, residual carcinogenic and noncarcinogenic risks due to contaminated ground water are negligible for the population at large. In Section C, Aggregated Drinking Water Risk Assessment, we estimated the average annual number of cancer cases presented by all contaminants of concern in drinking water supplies within the Basin to be 1.14 and the average total cancer cases over a 70-year lifetime to be 80. There are two factors responsible for this low incidence of excess cancers due to drinking water:

According to analysis of FRDS data for Region 5, less than four percent of public water supplies within Region V are contaminated with carcinogens above the MCL level; it is assumed here that this percentage applies also to the Great Lakes Basin; and

Usually, it takes less than three years to install treatment systems or replace wells, therefore the time of the exposure is minimized.

However, there are subpopulations, namely small community water systems and residential wells where the risks are greater due to longer exposure times and the potential for higher concentrations of contaminants. This is due primarily to the lack of resources to replace contaminated water supplies, use of shallow wells, and, in the case of residential wells, a lack of periodic monitoring that can lead to longer term exposures to contamination. These subpopulations are significant, as Exhibit T-2 demonstrates.

EXHIBIT T-2
Great Lakes Basin Population Relying on Ground Water

Population Type	Percent of Total Population (30,232,600)
Population relying on ground water	43%
Population using small (<3,300 people served) community PWS systems	15%*
Population served by private wells	19%

* This percentage is based on estimates for Region 5; we assume that a similar population within the Great Lakes Basin also receive drinking water from small community PWS systems.

Given the percentages presented in Exhibit T-2, we estimate that as much as 52 percent of the Basin population that uses ground water relies on small community and private wells. Since the numbers of MCL violations are generally greater for these subpopulations according to the Region 5 comparative risk study, there are small communities and single residents exposed to a significantly higher risk than the general population.

As an example, exposure to pesticides is greater in residential wells and small community systems. From EPA's analysis of available pesticides contamination data, atrazine and alachlor are representative of the most widely used and toxic pesticides in Region 5 and possibly within the Basin. Because of their extensive use they are the most commonly detected pesticides in ground water. The greatest frequency of detections of pesticides and MCL violations occur in areas rated highly vulnerable to ground water contamination and where wells less than 100 feet deep are commonly used. For example, 38 percent of such wells tested in Minnesota had at least trace levels of atrazine (2 percent above MCL). However, less than two percent of the vulnerable public water supply wells in Illinois had detectable levels of pesticides. It is important to remember, however, that much of the vulnerable and productive farmland in Region 5 lies outside the Great Lakes Basin, and, thus, the risks posed to small community systems and private wells by pesticides is likely to be lower in the Basin than in the Region as a whole.

A detailed discussion of cancer and non-cancer risks can be found in the aggregated drinking water risk assessment discussion. Both the cancer and non-cancer residual risks are not considered large due to the stringent standards and regulatory infrastructure. The potential health risks would be much greater if no action was taken to mitigate and prevent ground water contamination.

Ecological Impacts

Ground water impacts ecological systems via the discharge of contaminated ground water to surface water bodies and wetland areas and, in some cases, underlying sediments. As described above, the Great Lakes Basin has several harbors and associated rivers that are severely polluted; it is likely that contaminated ground water contributes to pollution of surface water as well as sediments in many of these cases. In its comparative risk study, EPA Region 5 estimates that as much as 20% of overall contaminant sources to the Grand Calumet Basin and connecting channels may be atributed to contaminated ground water.

From current analyses it is evident that ground water can have a significant impact in localized areas but is not likely to be the major contributor of nonpoint source contamination within the Basin. Most of these impacts would be reversible, provided the sediments could be remediated. Region 5 estimated in its comparative risk study that ground water could be responsible for up to 15 percent of the total contaminant contribution to surface water in the Region; it is possible that this percentage would be less for the Great Lakes Basin, given the lesser degree of agricultural activity in the Basin.

In addition, chemical spills on land could adversely impact local habitat directly or via contaminated ground water that leaks away from the spill and discharges into wetlands. Effective response to spills is essential to minimize ecological damage.

Welfare Impacts

Estimates of health care and environmental costs of contaminated drinking water as well the costs of treating drinking water are presented in Section C, Aggregated Drinking Water Risk Assessment.

Summary and Uncertainties

As for the drinking water risk assessment, we relied on the Region 5 comparative risk study for much of our analysis of risk posed to ground water within the Basin; therefore, the uncertainties associated with the use of the FRDS data base and the USGS data apply also to this analysis.

U. OZONE AND CARBON MONOXIDE

Problem Area Description

Pollution of ambient air by ozone and carbon monoxide (CO) is significant in many areas of the Great Lakes Basin. Ozone is formed in the ambient air as a result of a series of complex chemical reactions involving volatile organic compounds (VOCs) and nitrogen oxides emitted from both stationary and mobile sources, atmospheric oxygen, and sunlight. Ozone can adversely affect human health, agricultural crops, forests, ecosystems, and materials. Interactions of ozone with nitrogen oxides and sulfur oxides can also contribute to the formation of acid precipitation. CO is formed as a result of incomplete combustion and is emitted from both stationary and mobile sources. CO adversely affects human health and the health of other organisms because of its ability to reduce oxygen absorption capacity, transport, and utilization.

Ozone and CO are relatively short-lived pollutants. Consequently, ozone and CO pollution problems in the Great Lakes Basin generally arise from pollution sources in the Basin.[9]

We do not discuss the geographical distribution of ozone because this pollutant is not emitted but is the product of a series of chemical reactions dependent on emissions of ozone precursors (i.e., VOCs, CO, and nitrogen oxides). VOCs are emitted from sources including automobiles, dry cleaners, bakeries, auto body paint shops, household cleaning products, and any sources using solvents. Nitrogen oxides are emitted in the combustion of fossil fuels; motor vehicles are the predominant source. Consequently, ozone precursor emission and ozone pollution problems are likely to be concentrated in densely populated and highly commercialized areas of the Great Lakes Basin.

CO pollution arises from mobile and stationary sources. The major source of CO is motor vehicle exhaust, particularly when engines are burning fuel inefficiently as they do when engines are started, idling, or moving slowly. Other sources include incinerators and industrial processes. Mobile sources of CO are likely to be concentrated in densely populated and highly commercialized areas of the Great Lakes Basin. According to EPA's Aerometric Information Retrieval System (AIRS), stationary sources of CO in the Great Lakes Basin are concentrated in the following areas:

Milwaukee county, Wisconsin;
Cook county, Illinois (Chicago);
Lake county, Indiana (East Chicago, Gary);
Wayne county, Michigan (Detroit); and
numerous other counties in Wisconsin (i.e., Waukesha, Brown, Winnebago, Sheboygan, Outagamie, Dodge, Manitowoc, and Washington) and Indiana (i.e., Allen, Elkhart, St. Joseph, and La Porte).

Exhibit U-1 illustrates the geographic distribution of CO emissions monitoring sites by county throughout the Basin. Exhibit U-2 shows the geographic distribution of estimated CO emissions by Basin county. AIRS reports 1,511 stationary sources of CO emissions in 139 of the 213 Great Lakes Basin counties. Great Lake Basin counties with the greatest quantities of CO emissions from stationary sources include the following:

Porter and Lake counties in Indiana;
Cook county, Illinois;
Gratiot, Macomb, Wayne, Saginaw, Muskegon, Delta, and Charlevoix counties in

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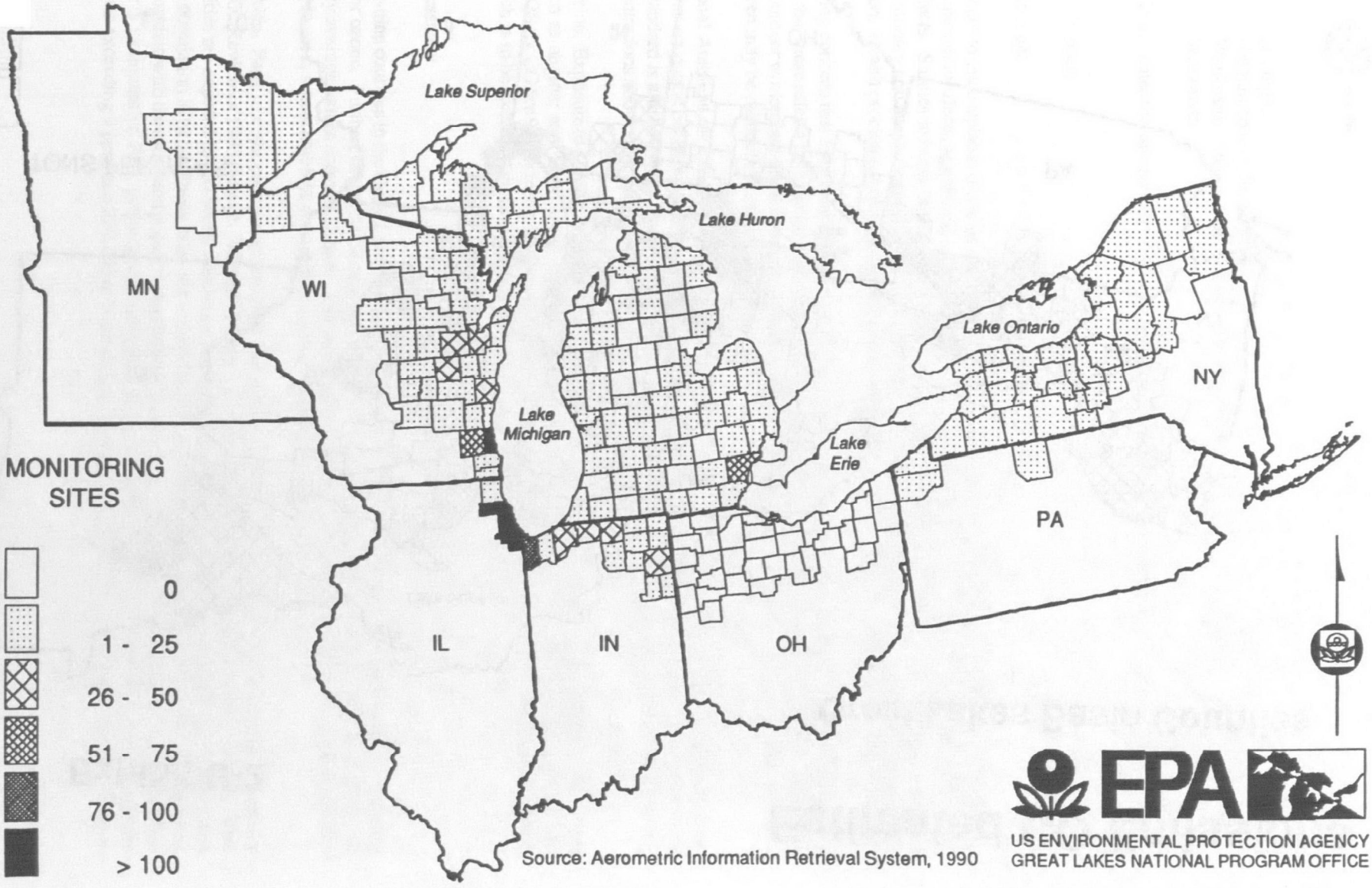
[9] Sources from beyond the Basin are also important, however, in areas such as northeastern Illinois. Much of Chicago lies outside the Basin, but is nevertheless a source of these pollutants to the Basin. Such loadings are not addressed in this analysis.

Exhibit U-1

CO Emissons Monitoring Sites

Great Lakes Basin Counties



Source: Aerometric Information Retrieval System, 1990

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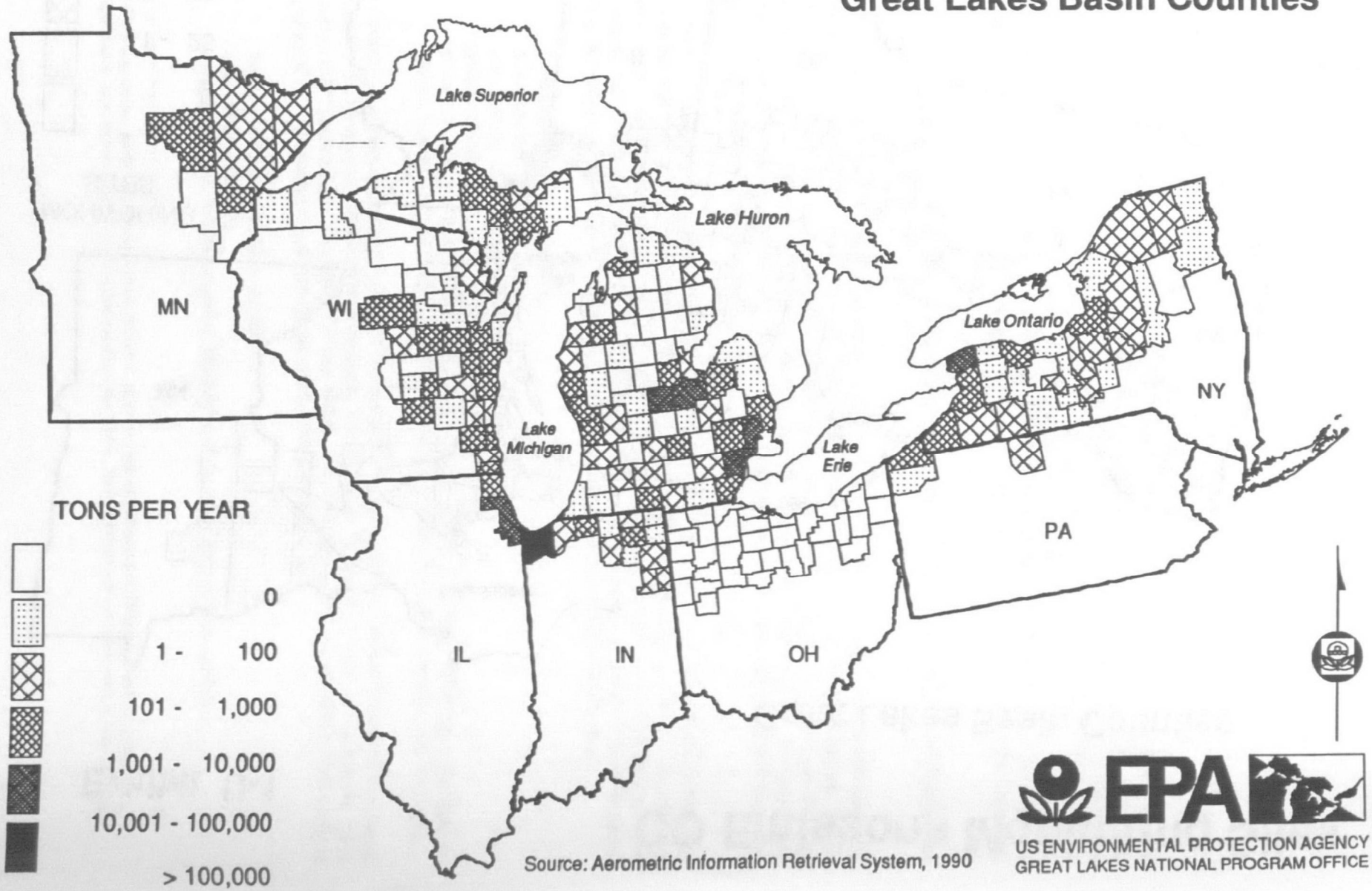
Exhibit U-2

Estimated CO Emissions

Great Lakes Basin Counties



Source: Aerometric Information Retrieval System, 1990

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Michigan;
Niagara county, New York; and
Waukesha, Milwaukee, Outagamie, Columbia, and Manitowoc counties in Wisconsin.

Data from AIRS indicates that an estimated 610,000 tons of CO are emitted annually from stationary sources in the Great Lakes Basin.

Human Health Impacts

Toxicity Assessment

Ozone. Exposure to unacceptable levels of ozone can cause various health effects including alterations in pulmonary functions, symptomatic effects, aggravation of preexisting respiratory disease, altered host defenses systems, and extra-pulmonary effects. Studies indicate that healthy individuals exposed to ozone may experience chest pain, coughing, wheezing, pulmonary and nasal congestion, labored breathing, sore throat, nausea, increased respiratory rate, and loss of lung function. Health problems are exacerbated for individuals who exercise, because of the increased intake of air.

There is growing concern that long-term exposure to ozone at current levels may lead to chronic effects. Preliminary data indicates that these effects take the form of irreversible lung injury and/or lung disease such as lesions in the lung. Children and outdoor workers are considered to be most susceptible because, on average, they spend more time outdoors. Further, children may be particularly sensitive because their lungs are still developing.

Primary National Ambient Air Quality Standards (NAAQS) were established to define levels of air quality that are necessary to protect public health with an adequate margin of safety. The NAAQS for ozone is 0.12 parts per million (ppm). The standard is attained when the average expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than one.

Carbon Monoxide. Exposure to CO can impair breathing, vision, alertness, and mental function; aggravate preexisting conditions such as angina; and, under acute conditions, cause nausea, dizziness, unconsciousness, and death. The primary NAAQS for CO are 9 ppm for an 8-hour average concentration and 35 ppm for a 1-hour average concentration, neither of which is to be exceeded more than once per year.

Exposure Assessment

Ozone. Thirty-nine counties in the Great Lakes Basin are classified in the Code of Federal Regulations as not attaining the NAAQS for ozone. Further, of the 60 Great Lakes Basin counties that were monitored in 1985 through 1989, 48 recorded hourly average values above 0.12 ppm. This corresponds to over 14 million people in the Great Lakes Basin who are living in areas where ambient concentrations exceed the primary NAAQS for ozone.

Carbon Monoxide. Parts of eight counties in the Great Lakes Basin are listed in the CFR as not attaining the primary NAAQS for CO. Review of 1985 through 1989 monitoring data indicates that portions of the population of eight Great Lakes Basin cities are exposed to CO levels violating the NAAQS of 9 ppm (i.e., concentrations are $\geq$ 9.5 ppm), and portions of the population in two of those cities are exposed to levels exceeding 15 ppm (i.e., $\geq$ 15.5 ppm). Combining these monitoring data with the estimated population associated with each monitoring location (using the method applied for the Region 5 Comparative Risk project), it is estimated that approximately 1.1 million people were potentially exposed to levels exceeding 9 ppm and 220,000 of these people were potentially exposed to levels exceeding 15 ppm.

Risk Characterization

Ozone. To characterize the human health effects resulting from exposure to ozone, we applied a method developed by RCG/Hagler, Bailly, Inc. under contract to EPA. (This method was used in the Region 5 Comparative Risk project.) In this approach, the annual number of asthma attacks and the annual number of people days of respiratory restricted activity are calculated as follows:

Annual Number of Asthma Attacks at Location j = (0.04) (POP_j) ($EXDAY_j$) (0.00037)

Annual Number of People Days of Respiratory Restricted Activity at Location j = (0.96) (POP_j) ($EXDAY_j$) (0.00116)

where, j = location of monitoring site,

POP_j = exposed population at monitoring site j, and

$EXDAY_j$ = number of days where hourly average ozone concentration exceeded 0.12 ppm at monitoring site j.

Using 1989 monitoring data with 1988 county populations (as estimated by the U.S. Bureau of the Census), we estimate that 1,300 annual asthma attacks and 98,200 annual people days of respiratory restricted activity in the Great Lakes Basin result from exposure to ozone.

Carbon Monoxide. Methods developed by RCG/Hagler, Bailly, Inc. under contract to EPA were also used to characterize public health effects resulting from exposure to CO. In this approach, it is assumed that at CO concentrations greater than 9 ppm but less than 15 ppm, 10 percent of the exposed population are at moderate risk of increased angina pain and 90 percent of the exposed population are at low risk of mild symptoms. At concentrations above 15 ppm, 10 percent of the exposed population are at high risk of increased angina pain and the remaining 90 percent of the population are at moderate risk of mild symptoms. Results based on review of the 1987 through 1989 monitoring data indicate that 22,000 people in the Great Lakes Basin are estimated to be at high risk of experiencing increased angina pain and an additional 115,000 people are at moderate risk of experiencing increased angina pain. In addition, we estimate that 200,000 people in the Basin are at moderate risk of experiencing mild symptoms, while 1 million people are at low risk.

Ecological Impacts

Data on the ecological impacts of CO are not readily available. Consequently, the following discussion focuses on the ecological impacts of ozone pollution.

Ozone is generally considered to be the most phytotoxic air pollutant adversely affecting terrestrial vegetation. Damage often begins with degeneration of feeder roots and mycorrhizae and later progresses to the onset of above ground symptoms.[10] The following subsections discuss the severity of the effects of ozone exposure and the reversibility of

[10] Manion (1981) as cited in Review of the National Ambient Air Quality Standards for Ozone, Preliminary Assessment of Scientific and Technical Information (EPA, Office of Air Quality Planning and Standards, Research Triangle Park, N.C., 1986).

these effects.

Severity

The following species level effects of ozone on herbaceous and woody vegetation observable above ground have been well documented:

injury to foliage;
reduction in growth;
reduction in yield;
increased susceptibility to pests and pathogens; and
alterations in reproductive capacity.[11]

Several tree species are particularly susceptible to the effects of ozone. Observed species effects include:

reductions in the size of annual rings in Ponderosa, Jeffrey, and white pine stands in southern California, attributed to exposure of trees to ozone over a period of 10 to 20 years; and

reduced growth rates of the eastern white pine, red spruce, balsam fir, and Fraser fir in West Virginia.

Ecosystem-level effects observed from exposure to ozone include

overall declines in primary productivity of coniferous and mixed deciduous forests; and

significant changes in community structure and composition due to increased mortality of sensitive species.

In general, the response of vegetation to phytotoxic gaseous inorganics such as ozone is a function of both the ambient chemical concentration and the exposure duration. The higher the ambient concentration, the shorter the exposure required to produce a specified level of damage. (Although mathematical formulations have been developed to relate damage to both duration and intensity of exposure, they are not appropriate for the level of effort associated with this analysis.) In a recent assessment of the scientific and technical information relevant to the NAAQS for ozone, EPA categorized selected tree species according to three ranges of sensitivity to ozone exposure: sensitive (i.e., significant growth reduction at 0.03 to 0.12 ppm); intermediate (i.e., growth reduction at 0.12 to 0.20 ppm); and resistant (i.e., growth reduction at greater than 0.20 ppm).[12] Sensitive species include American sycamore, loblolly pine, pitch pine, eastern white pine, and green ash. Intermediate species include sweet gum, white ash, and sugar maple. Resistant species include black cherry and white spruce.

The Region 5 comparative risk project states that damage to white pine in the eastern United States and Canada has been associated with repeated exposure to peak ozone concentrations of 0.08 ppm or greater. In addition, it is believed that ozone is a major contributor to the decline in growth rates of red spruce at numerous high-elevation sites throughout the Appalachian mountains.

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[11] Unfinished Business: A Comparative Assessment of Environmental Problems. Appendix III. EPA, Ecological Risk Workgroup, Office of Policy, Planning, and Evaluation. Washington, D.C. 1987.

[12] Review of the National Ambient Air Quality Standard for Ozone, Preliminary Assessment of Scientific and Technical Information, EPA, Office of Air Quality Planning and Standards, Research Triangle, NC, 1986.

Reversibility of Damage

The panel of scientists convened by the Cornell Ecosystems Research Center to assist EPA's national comparative risk study judged the impacts of ozone on forests and grasslands to be reversible in terms of decades. However, full recovery from severe damage (i.e., total elimination of many species) to a mixed species climax deciduous forest could require more than a century.

Welfare Impacts

Welfare effects associated with ozone and CO pollution include health care costs and damages to agricultural crops and materials. In the subsections below we present costs of health care, agricultural crop losses, and costs of material damages resulting from ozone pollution. Welfare effects from CO pollution are not quantified.

Health Care Costs of Ozone Exposure

Ozone pollution in the Great Lakes Basin presents a risk to human health. The costs associated with health care necessitated by the adverse effects of exposure to ozone are estimated as one measure of the welfare impacts of ozone pollution. The method used to estimate health care costs was developed by RCG/Hagler, Bailly, Inc. under contract to EPA. In general, their approach applies unit costs for the two health effects predicted from ozone exposure:

annual asthma attacks, valued at $44 in 1988 dollars; and
annual respiratory restricted activity days, valued at $11 in 1988 dollars.

Multiplying these unit costs by the frequency of occurrence of these effects, we estimate that the total annual cost of health care resulting from ozone exposure is $1.2 million. $1.1 million of this total results from costs associated with restricted activity days, and the remaining $0.1 million results from costs associated with asthma attacks.

Effects of Ozone of Agricultural Crops

The Region 5 comparative risk project estimated the effects of ozone exposure on agricultural crops. The following discussion borrows heavily from the Region 5 report and consists of relatively little information developed specifically for the Great Lakes Basin.

The majority of the evidence available on the effects of ozone exposure on agricultural crops focuses on reduction in growth and yield resulting from long-term exposure to various ozone concentrations. Although the actual amount of yield loss due to decreased aesthetic value or appearance is important for some crops (such as tobacco, spinach, and ornamentals), it is difficult to quantify. Consequently, ozone induced yield loss is primarily quantified in terms of reduction in weight or volume. It is noted, however, that plant appearance can be affected by exposure to concentrations as low as 0.041 ppm for several weeks or 0.10 ppm for two hours.

In the Region 5 comparative risk report, data presented in a report from the staff at EPA's Corvalis, Oregon laboratory and exposure response relationships developed by EPA's Office of Air Quality Planning and Standards (OAQPS) were used to predict the impact of current ozone exposure on crop yield, for those crops that are most susceptible to ozone and are grown in significant quantities in Region 5. Monitored ambient ozone concentrations were combined with composite predicted relative yield loss functions to estimate soybean and wheat loss at specific geographic sites. Using these point estimates, crop losses were projected for all areas where the crop is cultivated in Region 5. The area-weighted yield loss was determined to be approximately 7 percent for soybean and 12 percent for wheat.

To estimate ozone effects on soybean and wheat production in the Great Lakes Basin we applied the Region 5 findings to the Great Lakes Basin acreage planted in soybeans and wheat. In 1988, 4,519,000 acres of soybeans and 3,140,000 acres of wheat were planted in the counties in the Great Lakes Basin.[13] This corresponds to an annual yield of approximately 168 million bushels of soybeans and 153 million bushels of wheat. Applying the Region 5 area-weighted yield loss estimates to these quantities results in an estimated loss of 12 million bushels of soybeans, with a value of approximately $90 million, and 18 million bushels of wheat, with a value of approximately $64 million, in the Great Lakes Basin.

Materials Damage

The final type of welfare impact from ozone pollution that can be easily quantified is the cost of materials damage due to this pollution. To estimate the cost of material damage in Region 5, RCG/Hagler, Bailly, Inc. provided EPA with an estimated cost of $0.94 per capita for anti-ozonant additions to materials that could be damaged by ozone. Applying this per capita cost to the population of the Great Lakes Basin, we find that the estimated cost of materials damage from ozone pollution is approximately $19 million per year.

[13] Based on data for 1988 from the Conservation Technology Information Center (CTIC).

V. PARTICULATE EMISSIONS

Problem Area Description

Airborne particulate matter smaller than 10 microns in diameter (PM_{10}) causes adverse health, welfare, and ecological effects. Major sources of PM_{10} include a variety of industrial and commercial processes, motor vehicles, wind blown dust, and residential heating. In this problem area we address particulate matter generally, excluding sulfate aerosols (see Problem Area M, Sulfur and Nitrogen Oxide Emissions) and air toxics that may be in particulate form (see Problem Area N, Hazardous and Toxic Air Pollutants) from this discussion. This problem area parallels the Region 5 discussion, and some of the analysis presented in this section is borrowed directly from the Region 5 work.

The following are significant sources of PM_{10} in the Great Lakes Basin:

steel mills, including coke batteries, blast furnaces, sinter plants, steel furnaces, coke byproduct plants, and slag handling;
industrial open dust sources, including unpaved roads, paved roads, and storage piles;
iron and aluminum foundries;
asphalt and asphaltic concrete plants;
portland cement plants;
lime plants;
construction materials plants, particular conveyors, quarrying, and other materials handling;
construction and demolition;
grain terminals, including loading and unloading, particularly ship loading and terminal loading;
landfills;
brick kilns;
boilers; and
surface mining.

Analysis of ambient particles (aerosols) collected in Chicago in 1971 indicated that crustal dust (18 percent), coal (6.4 percent), steel processing (3.9 percent), limestone (3.2 percent), motor vehicles (2.8 percent), and residual oil (1.4 percent), as well as sulfates and nitrates from unspecified sources (16.8 percent), accounted for significant portions of observed particulate matter pollution.[14]

Pollution of the ambient air by particulate matter is generally concentrated in areas in the local vicinity of sources. Therefore, particulate matter pollution problems in the Great Lakes Basin are likely to be caused by anthropogenic and natural emissions in the Basin. According to EPA's Aerometric Information Retrieval System (AIRS), stationary sources of particulate matter emissions in the Great Lakes Basin are concentrated in the following areas:

Milwaukee county, Wisconsin;
Cook county, Illinois (Chicago);
Lake county, Indiana (East Chicago, Gary);
Wayne county, Michigan (Detroit);
numerous other counties in Wisconsin (i.e., Waukesha, Brown, Winnebago, Sheboygan, Outagamie,

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[14] Gatz (1975) cited in Controlling Airborne Particles (National Research Council, Committee on Particulate Control Technology, Washington, D.C., 1980).

Dodge, Manitowoc) and Indiana (i.e., Allen, Elkhart, St. Joseph, La Porte).

Exhibit V-1 illustrates the geographic distribution of monitoring sites for particulate emissions in the Basin counties. Exhibit V-2 shows the geographic distribution of estimated particular emissions by Basin county. AIRS reports 1,698 stationary sources of particulate matter emissions in 146 of the 213 Great Lake Basin counties. Great Lake Basin counties with the greatest quantities of particulate matter emissions from stationary sources include the following:

Lake, Porter, and Allen counties in Indiana (62,000 tons/yr);
Cook and Lake counties in Illinois (33,000 tons/yr);
St. Louis and Itasca counties in Minnesota (31,000 tons/yr);
Wayne and Presque Isle counties in Michigan (23,000 tons/yr); and
Monroe, Oswego, Erie, St. Lawrence, and Niagara counties in New York (37,000 tons/yr).

Data from AIRS indicates that approximately 253,500 tons of particulate matter are emitted annually from stationary sources in the Great Lakes Basin. (The 14 counties listed above account for 73 percent of the particulate matter emissions in the Great Lakes Basin.)

Human Health Risk

Toxicity Assessment

Particulate matter less than 10 microns in diameter causes a number of respiratory problems. These small particles may be toxic in themselves or may transport toxic elements and compounds such as lead, cadmium, and other heavy metals. As summarized in a 1980 National Research Council report on particulate matter pollution:

> the potential risk posed by particulate matter depends on the mass of particulate matter to which people are exposed and the size and chemical characteristics of the particles;
>
> only particles less than 10 microns reach the lower respiratory tract during normal nasal breathing and only particles less than 2 to 3 microns in diameter reach the alveoli (where gases are exchanged with the circulatory system); and
>
> particles pose risks by dissolving and releasing contaminants to the digestive or lymphatic system or by physically carrying contaminants (e.g., lead, cadmium) directly to the alveoli where they can enter the circulatory system.[15]

Respiratory effects caused by exposure to particulate matter include increased incidence of respiratory disease, especially in children; aggravation of existing respiratory diseases, particularly bronchitis; reduced resistance to infection; increased respiratory symptoms; and reductions in lung function. Epidemiological studies demonstrate that airborne particulate matter can cause premature mortality, particularly in elderly and ill persons. Particulate matter also causes various lesser effects such as irritation of the eyes and throat.

Primary National Ambient Air Quality Standards (NAAQS) were established to define levels of air quality that are necessary to protect public health with an adequate margin of safety. The NAAQS for PM_{10} are a 24-hour average

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[15] National Research Council, Controlling Airborne Particles, Committee on Particulate Control Technology, Washington, D.C., 1980.

Exhibit V-1

Particulate Emissons Monitoring Sites

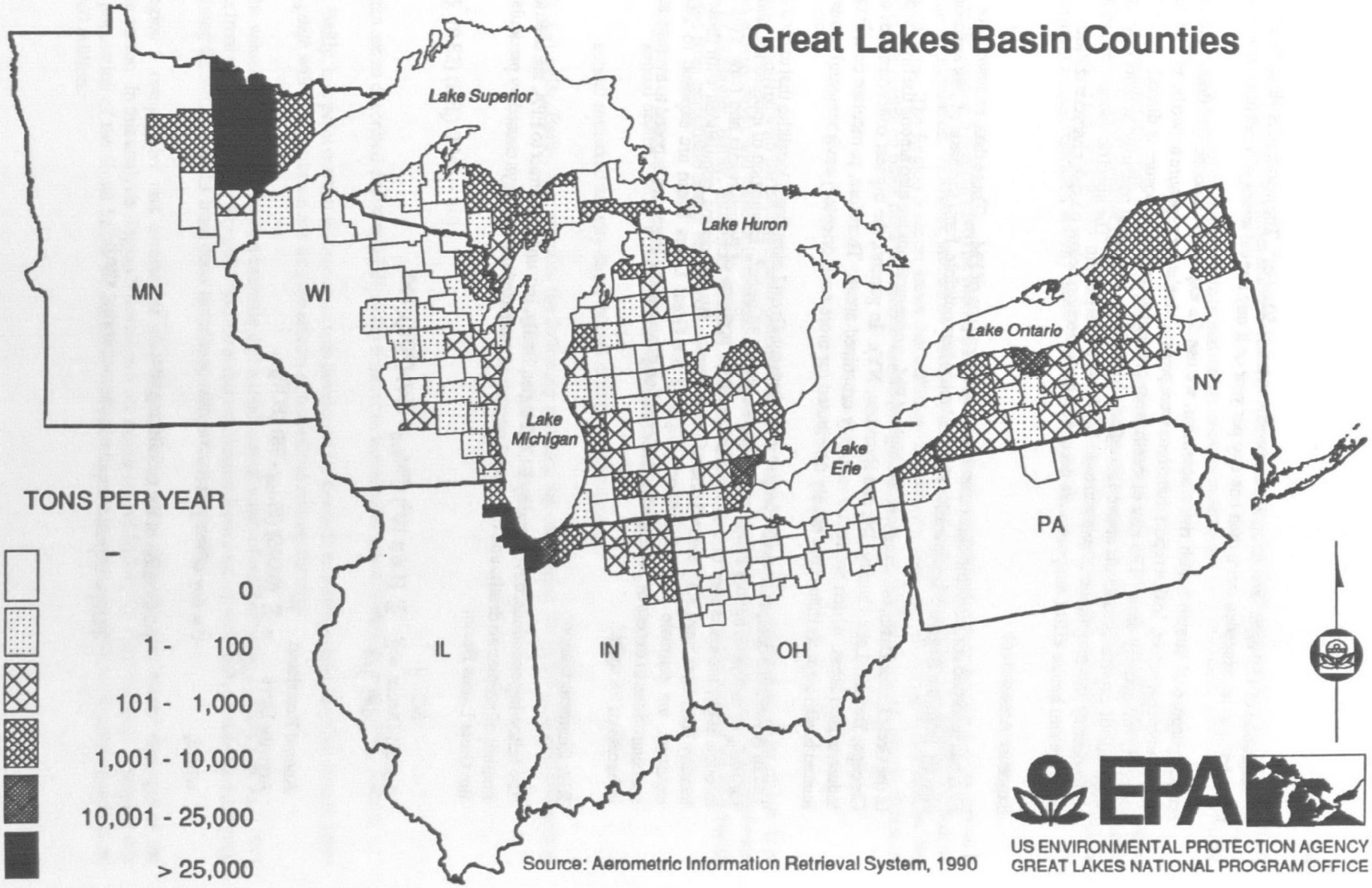
Great Lakes Basin Counties

US ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

Exhibit V-2

Estimated Particulate Emissions

Great Lakes Basin Counties



Source: Aerometric Information Retrieval System, 1990

US ENVIRONMENTAL PROTECTION AGENCY
GREAT LAKES NATIONAL PROGRAM OFFICE

concentration of 150 ug/m^3 and an annual arithmetic mean of 50 ug/m^3. The standard is violated if the 24-hour standard is expected to be exceeded more than one day per year or if any annual average concentrations exceed that standard.

For the purpose of human health risk assessment, we use the exposure-response functions outlined in the Region 5 comparative risk report. In that report, functions were presented relating exposure to two human health endpoints: death and restricted activity days. The risk of death from particulate matter exposure is directly related to frequency and magnitude of exposures to levels above 150 ug/m^3. In addition, the risk of restricted activity days is directly related to the frequency and magnitude of exposures to levels above 38 ug/m^3. The specific quantitative relationships between exposure and health effect endpoints are described in the section below on risk characterization.

Exposure Assessment

EPA has recorded considerable data on ambient concentrations of PM_{10}. These data, retrieved from AIRS and derived directly from the Region 5 comparative risk analysis when possible, form the basis of this exposure assessment.

In the Great Lakes Basin, the areas with the highest PM_{10} concentrations are also among the highest populated areas (i.e., Chicago; Detroit; Lake County, IN; and Syracuse, NY). In general, the highest concentrations are found in heavily industrialized areas, which are found in highly urbanized areas. Therefore, particulate matter causes more adverse human health impacts than more evenly distributed (or more rural-oriented) environmental contaminants.

The EPA Region 5 comparative risk project identified nine Great Lakes Basin localities that exceed the 24-hour standard for PM_{10} or that have annual PM_{10} concentrations above 38 ug/m^3. Evaluation of monitoring data for the years 1985 through 1989, indicates that in the Great Lakes Basin portions of Pennsylvania and New York only one additional locality (i.e., Syracuse, NY) exceed one of these levels. By associating populations with these areas of high PM_{10} exposure, we estimate that 2.5 million people in the Great Lakes Basin are exposed to 24-hour average PM_{10} concentrations in excess of 150 ug/m^3 and 2.7 million people in the Basin are exposed to average annual concentrations in excess of 38 ug/m^3.

Risk Characterization

The following equations, developed by RCG/Hagler, Bailly, Inc. under contract to EPA, are used to calculate the annual number of premature deaths and the annual number of restricted activity days caused by particulate matter pollution in the Great Lakes Basin.

$$\text{Annual Deaths} = \sum_{d=1}^{365} \sum_{j=1}^{j} (1.6 \times 10^{-6}) (PM_{10dj} - 150) (POP_j); \text{ and}$$

$$\text{Annual Restricted Activity Days} = \sum_{j=1}^{j} (0.046) (PM_{10j} - 38) (POP_j)$$

where, d = day of the year;

j = location of the monitoring site;

POP_j = exposed population at monitoring site j;

PM_{10dj} = measured particulate concentration (ug/m^3) on day d at location j, provided it exceeds 150;

PM_{10j} = measured annual average particulate concentration (ug/m^3) at location j, provided it exceeds 38.

Using the Region 5 comparative risk assessment results to characterize risks in the Region 5 portion of the Great Lakes Basin and 1987 through 1989 monitoring data along with 1980 census data to characterize the additional risk in Pennsylvania and New York, we estimate that exposure to PM_{10} in the Great Lakes Basin results in 24 annual deaths and over 1.9 million annual restricted activity days.

Ecological Impacts

As explained in the Region 5 comparative risk report, particulate matter has similar effects on animal populations as it does on the human population. However, studies on wildlife cannot readily be performed through epidemiological or laboratory approaches. The Region 5 report states that sufficient information could not be found to characterize the effects of particulate matter on other flora and fauna. Consequently, we do not characterize the ecological effects of particulate matter.

Welfare Impacts

Welfare effects associated with particulate matter pollution include value of lives prematurely lost, value of lost days (i.e., restricted activity days), and value of household soiling damage. The methods used to estimate these costs were developed by RCG/Hagler, Bailly, Inc. under contract to EPA. Their approach applies unit costs for the two health effects predicted from particulate matter exposure:

annual deaths, valued at $77,300 per death in 1988 dollars; and

annual restricted activity days, valued at $39 in 1988 dollars.

In addition, RCG/Hagler, Bailly, Inc. provides the following equation for calculating the value of household soiling damage:

$$\text{Household Soiling} = \sum_{j=1}^{j} (0.82)\,(HH_j)\,(PM_{10j} - 10)$$

where the terms are as described above and HH_j is the number of households associated with monitoring point j.

RCG/Hagler, Bailly, Inc. point out that this equation was developed for use with total suspended particles data and that use with PM_{10} data will underestimate the welfare effects of household soiling damage.

Calculating the values described above, we estimate that a total annual value of welfare effects of $112 million. $75 million results from restricted activity days, $35 million of this total results from costs associated with household soiling, and the remaining $2 million results from costs associated with premature deaths.

The EPA Region 5 comparative risk assessment also calculates the value of particulate matter damages in the manufacturing sector. In this analysis Region 5 develops a per capita cost of $15.46 (in 1988 dollars). Applying this factor to the population of the Great Lakes Basin, 30,050,000, we determine that the value of these damages is an additional $460 million.

W. UNDERGROUND STORAGE TANKS

Problem Area Definition

There are three types of storage tanks that can potentially affect human health and the environment: underground storage tanks (USTs), ground level or on ground storage tanks, and above ground storage tanks. The risks to human health and the environment from these tanks appear to result primarily from the routine or continuous release of petroleum products or regulated substances to the soils, surface water, ground water, and air. In a national survey of release incidents from USTs, 68 percent of releases were to soil; 45 percent to ground water; 22 percent to surface water; and 15 percent to air.[16]

The stored substances that are of concern include gasoline, diesel fuel, motor oils, heating oils, solvents, lubricants, and inorganic acids and bases. The toxic constituents of these substances include benzene, toluene, xylene, ethylbenzene, chlorinated solvents, petroleum hydrocarbons, and heavy metals.

There are an estimated 313,346[17] registered USTs containing petroleum products or regulated substances in the Great Lakes Basin (Great Lakes Basin). The estimated universe of releases is approximated at 10 to 30 percent of the total registered tanks.[18] This would give an actual count of 31,335 to 94,004 releases.

Although there are three basic types of storage tanks (i.e., USTs, ground level, and above ground) that can potentially leak and thus threaten human health and the environment, this problem area focuses only on USTs. The reason for this is two fold. First, there is little pertinent or available data on other types of tanks. Second, USTs are the most common of the three storage tanks.

Even within this narrower focus on USTs, several assumptions were made in order to complete the analysis. They include the following:

(1) the majority of USTs in the Great Lakes Basin contain petroleum products, particularly gasoline;[19]
(2) the majority of leaks from USTs are gasoline;[20]
(3) USTs are primarily used by retailers (e.g., gas stations); and
(4) there is a high correlation between population density and the concentration of USTs.

The following types of facilities are not analyzed here:

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[16] EPA, Analysis of the National Data Base of Underground Storage Tank Release Incidents, Office of Solid Waste, June 13, 1986.

[17] The number of registered USTs was obtained from each state's Notification Database which lists the number of USTs within that state. The total number of USTs in each state was multiplied by the percentage of that state's population falling within the GLB, and then summed across the eight GLB states. This is based on the Region 5 observation that there is a high correlation between the presence of USTs and population density.

[18] Range stated by the Region 5 comparative risk analysis to be derived from a survey of technical and regulatory literature.

[19] George Halloran, EPA, Region 5, Office of UST/LUST, memorandum to Lorna Jereza dated June 18, 1990. Information current through May 31, 1990.

[20] EPA, 1986, op cit.

Tanks used to store hazardous waste. These facilities are covered in the active hazardous waste facility problem area.

Acute accidents or releases from storage tanks, including tank collapses or explosions (estimated in Region 5 to result in 3 to 4 deaths per year). These incidents are covered in Problem Area D, Spills and Other Accidental Releases.

Human Health Risk Assessment

Toxicity Assessment

U.S. EPA examined possible cancer risk from exposure to gasoline in the 1987 Document "Evaluation of the Carcinogenicity of Unleaded Gasoline." This document reviewed several animal studies including two lifetime inhalation bioassays of unleaded gasoline in rats and mice which demonstrated statistically significant increases in renal carcinomas and hepatocellular carcinomas in male rats and female mice respectively. On the basis of these results, U.S. EPA concluded the evidence is sufficient to establish that gasoline is carcinogenic in animals. Carcinogenic potency estimates from these experiments were similar: .0021 $(mg/kg/day)^{-1}$ from the mouse data and .0035 $(mg/kg/day)^{-1}$ from the rat data. In accordance with EPA's Guidelines on Carcinogen Assessment, the more conservative value from the rat study is the recommended cancer potency factor. The presence of benzene (EPA Group A, known human carcinogen) in unleaded gasoline could contribute to the carcinogenic response, but the magnitude of this potential contribution is unknown. It should be pointed out that the types of tumors observed in the rat and mice studies on gasoline are not the types associated with benzene exposure.

The epidemiological literature is replete with studies suggesting a relationship between exposure to gasoline or its constituents, principally benzene, and the incidence of certain types of cancer. Yet to date, only benzene has been causally linked to cancer in humans. Fifty-five epidemiologic studies were reviewed by U.S. EPA and were found to provide inadequate evidence of carcinogenicity in humans. Based on sufficient evidence of carcinogenicity in animals and inadequate evidence in humans, unleaded gasoline is classified as an EPA B2 carcinogen (probable human carcinogen). NESCAUM's (Northeast States for Coordinated Air Use Management) recent study[21] evaluating the health effects from exposure to gasoline offers the following summary of findings from the literature:

> Based on an assessment of the available literature, gasoline is presumed to be carcinogenic to human beings. This finding is based largely on the fact that benzene, a volatile component of gasoline, is an established human carcinogen. Any exposure to gasoline would also involve exposure to benzene.
>
> The epidemiological evidence regarding benzene carcinogenicity is widely accepted. The evidence regarding the human carcinogenicity of the gasoline mixture, however, is subject to significant uncertainties. These uncertainties stem from the limited sensitivity of epidemiological studies to identify carcinogens (particularly weak carcinogens), the complexity of the chemical exposures associated with the petroleum industry, and the lack of any clearly defined target organ which gasoline may specifically affect.

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[21] Northeast States for Coordinated Air Use Management (NESCAUM), Evaluation of the Health Effects from Exposure to Gasoline Vapors, Final Report, August 1989.

Use of the cancer slope factor of .0035 $(mg/kg/day)^{-1}$ from the previously mentioned EPA document, and the Agency verified cancer slope factor for benzene obtained from the Integrated Risk Information System, combined with projected exposures to gasoline due to underground storage tanks, allows quantification of potential carcinogenic risk incurred by exposed populations. Use of the cancer potency factor for gasoline[22] results in a more conservative estimate than the value for benzene since gasoline concentrations in the drinking water are projected to be substantially higher than benzene concentrations.

A multitude of noncancer health effects have been attributed to ingestion, inhalation, or dermal exposure to gasoline or its constituents. As there is currently no EPA reference dose for either gasoline or benzene, NESCAUM values will be used as a default. According to NESCAUM, the most sensitive endpoint for gasoline is kidney toxicity. The most sensitive endpoints for principal constituents of concern include hematotoxicity associated with benzene exposure and neurobehavioral, hematological, and immunological effects associated with toluene exposure. Reproductive and fetotoxic effects have been associated with exposure to xylene. To protect against these endpoints, reference doses and subchronic reference doses were established by U.S. EPA and NESCAUM. A reference dose is an estimate of a lifetime dose which is likely to be without significant risk to human populations. A subchronic reference dose is an estimate of a dose which is likely to be without significant risk to human populations for an exposure period of up to seven years.

Subchronic reference dose values were used where available because it is considered unlikely that someone would be exposed to ground water contamination for a period of more than seven years over a 70-year average lifetime. The EPA[23] subchronic reference dose values are 2.0 (mg/kg/day) for toluene and 4.0 (mg/kg/day) for xylene. EPA subchronic reference dose values are not available for benzene or gasoline so NESCAUM values of 0.1 (mg/kg/day) for benzene and 0.1 (mg/kg/day) for gasoline were used.

Exposure Assessment

The primary exposure pathways of concern in regard to leaking storage tanks are via contaminated ground water and soil. Human health exposure may occur through ingestion of contaminated water, inhalation of vapors and dermal exposure from contaminated water during household use, or through inhalation of vapors penetrating the basement or foundation walls. (In unusual cases, vapor concentrations may reach levels conducive to fire or explosion.) Vapor inhalation may also occur outdoors in areas adjacent to a leaking tank, but this is generally viewed as a less significant exposure pathway. The intake estimates used in this study for gasoline and benzene, however, are based on ingestion of two liters of water per day only, and are shown in Exhibit W-1.

The population potentially at risk in the Great Lakes Basin is defined for this problem area as those whose primary source of drinking water is ground water that is not routinely monitored and treated for volatile organic compounds (VOCs). Routine monitoring and treatment, it is assumed, would prevent ingestion of petroleum-contaminated water and eliminate any risk. There are two types of systems that fall into this unmonitored and untreated category: (1) ground water-based public water systems serving populations of 3,300 or less, and (2) private well water systems.

The population potentially at risk constitutes approximately 24 percent of the total Great Lakes Basin population. This figure was extrapolated in part from the Region 5 comparative risk assessment. It is the percentage of the Region 5 population who use ground-water systems serving 3,300 people or less (20 percent), plus the percentage of the population who use private wells (10 percent), times an "urban correction factor" of 0.8 to account for the higher population density in the Great Lakes Basin as compared to Region 5. The higher density in the Great Lakes Basin is

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[22] These factors for gasoline are based on inhalation data.

[23] U.S. EPA, Environmental Criteria and Assessment Office (ORD) and listed in the Health Effects Assessment Summary Table.

assumed to result in fewer users of small ground-water systems and private wells than in Region 5, and therefore in a smaller percentage of the population at risk. The correction factor was obtained by dividing the population density of Region 5 (140 people/mi^2) by the density of the Great Lakes Basin (180 people/mi^2). The percent population at risk (i.e., 24 percent) was multiplied by the total population in the Great Lakes Basin (20,672,600)[24] , then multiplied by the fraction of tanks estimated to be leaking (0.2), and then multiplied by the fraction of leaking tanks that are known to or have the potential to contaminate drinking water (0.33), in order to determine the population exposed. See Exhibit W-1 for the population exposure data and additional details on how they were obtained.

Risk calculations were preformed using drinking water concentrations of gasoline, benzene, toluene and xylene just below the taste and odor threshold, based on NESCAUM's study.

Exhibit W-1

EXPOSURE DATA

	Concentration in Water[a] (mg/l)	Estimated Mean Exposure[b] (mg/kg/day)
Gasoline	5.7	0.17
Benzene	0.46	0.014
Toluene	0.27	0.008
Xylene	0.29	0.009
	Population at Risk[c]	**Population Exposed[d]**
Great Lakes Basin	4,960,000	327,500

[a] Data taken from the NESCAUM study of health effects. The data is based on ingestion only and on concentrations that are just below the taste and odor threshold.

[b] Estimated mean exposure is based on 2 L/day ingestion by a 70-kg adult.

[c] Population at risk = 20,672,600 (the population of the Great Lakes Basin; estimated by multiplying the population of those counties lying within the Great Lakes Basin by the percentage of that county's land that lies within the Great Lakes Basin) x 0.3 (the fraction of the population who use private wells or public wells serving less than 3,300 people in Region 5; see text) x 0.8 (the population density of Region 5 divided by the density of the Great Lakes Basin -- this factor was included because it is assumed that there are fewer private and small public well users in more densely populated areas).

[d] Population exposed = 4,960,000 (population at risk) x 0.2 (midpoint of the fraction of tanks nationally estimated to be leaking) x 0.33 (fraction of leaking tanks that are known to, or have the potential to contaminate drinking water -- otherwise known as high priority leaking tanks; this number was determined by Region 5 using best professional judgment).

Human Health Risk Characterization

The toxicity and exposure information have been used to derive estimated annual cancer cases and noncancer hazard

[24] Here, the population of the Great Lakes Basin is estimated by multiplying the population of those counties lying within the Basin by the percentage of that county's land that lies within the Basin.

indices for the population at risk in the Great Lakes Basin (see Exhibits W-2 and W-3). Potential cancer cases are estimated at 20 over a 70-year period, or 0.28 per year. The estimated hazard index for systemic toxicity is 1.7 or slightly above the reference dose. This hazard index was obtained using a reference dose which is not verified by U.S. EPA. A hazard index above one raises concern about the possibility of non cancer health effects in some members of the population at risk, but since there is perhaps an order of magnitude uncertainty in non-cancer evaluations, it is difficult to quantify the number of individuals who may be effected.

Exhibit W-2

CANCER RISK ASSESSMENT

	Estimated Mean Exposure[a] (mg/kg/day)	Cancer slope factor $(mg/kg/day)^{-1}$	Estimated Individual Lifetime Cancer Risk[b]
Gasoline	0.017	0.0035	6×10^{-5}
Benzene	0.001	0.029	4×10^{-5}
	Population Exposed	**Estimated Cancer Cases[c] (70-yr life)**	**Estimated Annual Cancer Cases[d]**
Great Lakes Basin	327,500	20	0.28

[a] Estimated mean exposure from Table 1 has been multiplied by 0.1 to average the subchronic exposure over a lifetime (7 years/70 years).

[b] Individual cancer risk = (mean exposure) (subchronic cancer slope factor). As the data indicates, although the cancer slope factor for benzene is higher than for gasoline, the estimated individual cancer risk is lower due to less exposure. The gasoline risk value, therefore, is used to estimate cancer deaths since it is more conservative.

[c] Estimated cancer cases = (estimated individual cancer risk from gasoline) (population exposed).

[d] Estimated annual cancer cases = estimated cancer cases (70-yr life)/70 yrs.

Exhibit W-3

NONCANCER RISK ASSESSMENT

	Exposure (mg/kg/day)	Subchronic Reference Dose (mg/kg/day)	Hazard Index Exp/RfD	Population Exposed
Gasoline	0.17	0.1	1.70	327,454
Benzene	0.014	0.1	0.14	327,454
Toluene	0.008	2.0	0.004	327,454
Xylene	0.009	4.0	0.002	327,454

Two recent activities may tend to decrease risks from USTs. First, effective January 1, 1991 all systems serving 25

people or more are required to sample each water supply source, initially on a quarterly basis to determine the presence and extent of VOC contamination.[25] Assuming regulations are being observed by smaller systems and effectively enforced by the Agency, this requirement will reduce the estimated population at risk (those who are exposed to the contaminated ground water) by up to two-thirds (two-thirds being the fraction of the population at risk who use public water systems serving populations of 3,300 or less[26]). Second, in conjunction with this new law, extensive federal and state leak prevention efforts, such as new containment and leak detection systems, will lower the incidence of releases and therefore the risk to human health.

Ecological Risk Assessment

The locations of USTs in the Great Lakes Basin were not readily available for this analysis. Therefore, this analysis does not involve site-specific information.

Toxicity Assessment

In the event of a release of gasoline or other petroleum product from an UST, a number of scenarios may result. Depending on the extent of release and proximity to sensitive receptors, a release could result in potentially significant adverse ecological effects. The extent of damage to an ecosystem would depend on a number of factors including the nature of the released material, type of habitat, ecosystem stability, and affected species.

Exposure Assessment

The Great Lakes Basin obviously has a significant amount of surface water. Because of the long water retention times of the individual Great Lakes, most noticeable in Lake Superior and Lake Michigan, pollutants are not quickly flushed from the system. Leaking USTs, particularly into surface waters, can therefore levy a significant toll on the aquatic environment. The factors that influence the incidence of surface water contamination from these leaking USTs include: proximity of tank to body of water; materials leaking from tank; amount of released material; ground water flow; and local soils and geology. While available data concentrates on effects on human health rather than on the environment, it is clear that pollutants, specifically petroleum from leaking USTs, can easily find their way into the aquatic food chain.

Historically, leaks from USTs do not appear to have had an overwhelming impact on surface water, probably due to the fact that soil and ground water between the leak and the surface water body acts as an attenuator. If such conditions do exist, however, to allow the flow of released material to surface water, the negative ecological impacts can be extensive. A national survey of tank releases[27] indicates that 22 percent of releases are to surface water. If this information is applied to the estimated number of releases, 62,700 (estimated by multiplying the number of USTs by the fraction of releases, or 313,346 times 0.2), then approximately 13,800 releases in the Great Lakes Basin are estimated to

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[25] EPA, "National Primary Drinking Water Regulations; Synthetic Organic Chemicals; Monitoring for Unregulated Contaminants," Final Rule, 52 Federal Register 25690, July 8, 1987.

[26] Previously, only primary water supply systems serving 3,300 customers or less were required to test for VOC's.

[27] EPA, 1986, op cit.

contaminate surface water. These releases are expected to be small, however.[28]

Leaking USTs can also affect ecosystems via soil contamination and by releasing to ground water, both of which can ultimately contaminate aquifers and surface water. Soil contamination may adversely affect terrestrial organisms at the lowest level of the food chain. This may expose higher-order organisms to adverse health consequences due to ingestion of contaminated food sources. Ground-water contamination may result in adverse health effects upon plant and animal life at the surface through the consumption of contaminated water from springs or wetland areas.

Ecological Risk Characterization

Severity

Ecological damage resulting from UST releases generally can be considered low in severity. Water quality data used for the Region 5 comparative risk study indicates some contamination, but none specifically linked to benzene (a constituent of gasoline) or to USTs.

Reversibility of Damage

It is difficult to determine the time frame in which the affected ecosystems will recover from contamination due to leaking USTs. Oil and gas spills to surface water evaporate quickly (depending on the extent of the release). If sediments are contaminated the period of recovery will be extended accordingly. Because the Great Lakes are relatively clear the natural burial of contaminated sediment is slow. Since this is the primary method of sediment removal from the system, the ecosystem recovery period could be long. Water temperature and turbidity will also affect the rate of recovery. Ground-water contamination is more complex, and it is difficult to determine the rate of recovery. If contaminated, ground water may affect the whole water supply, significant and irreversible damage to plant and animal life could result. Overall, the reversibility of damage from USTs is believed to be medium.

Welfare Damage Assessment

Health Care Costs

In order to estimate health care costs (HCC), the annual cancer cases estimated in the human health risk characterization section were multiplied by the direct medical cost and foregone earnings per cancer case used in the Region 5 comparative risk assessment. Cancer costs were based the Hartunian et al., lower-bound estimate, ($80,000, 1988 $) and the American Cancer Society, upper-bound estimate ($137,000, 1988 $) discussed in previous sections.

Lower-Bound Estimate:

HCC = (0.28) ($80,000) = $22,400 annually

Upper-Bound Estimate:

HCC = (0.28) ($137,000) = $38,400 annually

Environmental Costs

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[28] EPA, OSWER Comparative Risk Study: Ecological Risk Characterization Methodology, OSW, April 1988.

Remediation Costs

Remediation costs associated with leaking USTs were estimated using the following methodology taken from the Region 5 comparative risk study, which assumes a remediation cost of $150,000 per corrective action. The number of corrective actions was determined by multiplying 313,346 (the total number of tanks) by 0.2 (midpoint of the fraction of tanks nationally estimated to be leaking) and by 0.33 (fraction of leaking tanks that are known to, or have the potential to contaminate drinking water). The result is approximately $3 billion.

Slightly different assumptions were used in the Region 5 comparative risk assessment to determine the remediation costs associated with leaking USTs; these assumptions resulted in a lower estimate of costs. The following formula was used to apply the Region 5 methodology to the Great Lakes Basin: cumulative cost of corrective actions = 313,346 (number of tanks in the Great Lakes Basin) x 0.026 (fraction of tanks in Region 5 with confirmed releases) x $150,000. The total cost comes to approximately $1.2 billion.

Replacement Of Contaminated Drinking Water Supplies

Although the analysis of remediation costs should, in effect, account for well replacements and water supply hook ups, the Region 5 comparative risk assessment places these activities in a separate category. We have used this same distinction and applied the Region 5 methodology to the Great Lakes Basin.

Given the number of private well replacements and public water supply hook ups associated with leaking USTs, the cost of replacing contaminated drinking water supplies can be estimated following the method used in the Region 5 risk assessment. This method assumes that the capital costs are $3,500 for replacing a private well by digging a new well, and $300,000 for replacing a public supply well by extending a hook up from another public supply well. These were upper-bound cost estimates, yet they do not include the annual operating costs for these private and public systems.

Because data describing the number of private well replacements and public water supply hook ups were not available, best estimates were used. It was assumed that 10 percent of releases to ground water (assuming 20 percent of tanks leak, and 33 percent of these potentially contaminate drinking water) would result in private well replacements, and 2 percent of releases would result in public well replacements. The reason there are fewer replacements for public wells is due to the larger size of the aquifer, and the more comprehensive treatment and monitoring that is associated with a public water supply system as opposed to a private one. The cumulative costs associated with these replacements are $7.2 million and $124 million, respectively, for a total of $131.4 million. This does not correspond closely with an estimate of ground-water valuation (using replacement costs as a proxy) derived from an OSWER comparative risk study.[29] That study estimated an average of $10,700 would be spent for every UST, and when multiplied by the number of USTs in the Great Lakes Basin, 313,346, the total cost is approximately $3.4 billion. One of the remediation cost estimates above (i.e., $3 billion) is much closer to this amount.

[29] ICF Incorporated, OSWER Comparative Risk Project: Ground-Water Valuation Task Force Report (Draft), prepared for EPA, Office of Underground Storage Tanks, February 4, 1988.

X. PESTICIDES: HUMAN HEALTH

Human Health Impacts

The magnitude of the Pesticides problem is characterized above, under Problem Area L, Pesticides Discharges and Environmental Risk. To characterize the human health impacts posed by pesticide applications in the Great Lakes Basin, we have adopted the analytical methodology presented in the Pesticides section of the Region 5 comparative risk study.

Pesticide risks to human health occur through various pathways, including

direct contact;
inhalation of short and long range drift;
runoff into surface water sources including drinking water sources;
leaching into ground-water drinking water supplies; and
residues on food and bioaccumulation.

A number of subgroups of the people residing in the Basin are at risk from pesticide exposure. The population most at risk is pesticide applicators, particularly farm workers who mix, load, and apply pesticides. People residing in agricultural areas are at risk through pesticide contaminated drinking water as well as short range drift. Employees at pesticide manufacturing and storage facilities are at risk from direct contact with pesticides through accidents and spills as well as short range drift. Likewise, persons residing near such facilities are also at risk. Finally, the general public is also at risk from exposure particularly through pesticide residues on food.

Toxicity Characterization

Each pesticide was examined for evidence of human toxicity, cancer and noncancer, and for ecological effects. For cancer risk, both risks from food residues and to applicators were evaluated according to the 1987 "Unfinished Business" Report. For noncancer risk from pesticide residues in food, data did not permit a separate analysis. Where no carcinogen category has been assigned, the Reference Dose for noncancer health effects was used to analyze risk for applicators, along with available exposure assessments from EPA documents, such as Special Review Position Documents, and Registration Standards (now called Reregistration Documents).

Exhibit X-1 presents the toxicity factors available for 7 pesticides used in the Basin. With over 600 active ingredients registered by the U.S. EPA, it was not possible to analyze all pesticides for the Great Lakes Basin. Toxicity factors are given for those pesticides which had appropriate information available.

Exposure Characterization

As discussed earlier, humans are exposed to pesticides through a variety of pathways, including during application-related tasks, through drift, runoff, leaching into ground-water supplies, residues in food, and other exposure routes. To estimate the risk from each route of exposure, we must first determine the population exposed.

Since 12 percent of the U.S. population (30 million people) resides in the Great Lakes Basin, this is the number assumed to be exposed to pesticide residues in food. The level of exposure is assumed to be minimal since most residues are negligible in foods consumed after preparation (washing, peeling, and cooking).

The next major population group exposed to risks from pesticides that is considered here is certified applicators. Certified applicators include (1) private applicators, primarily farmers, and (2) commercial applicators, which are

categorized by agricultural pests, ornamental and turf pests, structural pests, forest pests, and rights-of-way maintenance, among others. There are approximately 100,500 and 29,200 private and commercial pesticide applicators in the Great Lakes Basin in 1989. These figures were derived from the number of certified applicators in Region 5 using the proportion of people in the Basin to the number of people residing in Region 5 (65 percent).

The population in the Basin estimated to be exposed to widely used chemicals, such as homeowner use of lawn care and garden pesticides, will be the total number of people residing in the Basin (30 million people).

Risk Characterization

To analyze human health risk from consumption of pesticide residues in food and from pesticide use in the Great Lakes Basin, the highest volume pesticides were examined for evidence of cancer and noncancer effects in animal testing, as described in the Toxicity Assessment above.

Exhibit X-1

Toxicity Factors for Selected
Pesticides Used in the Great Lakes Basin

Pesticide	Reference Dose (ppm/day)
Atrazine	0.005
Alachlor	0.01
Metolachlor	0.15
Cyanazine	0.002
Trifluralin	0.003
Carbofuran	0.005
2,4-D	0.01

Pesticide Residues in Food: Cancer Risk

The "Unfinished Business: Report (1987) considered 7 oncogenic pesticides and determined the number of cancer cases in the U.S. population making several assumptions. For the purposes of estimating cancer risk in the Basin, a proportion of the national cancers was taken using the percentage of the U.S. population residing in the Basin (12 percent). The Office of Pesticide Programs (OPP) estimated that the total annual population risk from dietary exposure to oncogenic pesticides was 6000 people/year. This means that for the Great Lakes Basin there would be an estimated population risk of 720 people/year.

Another issue of concern is the consumption of fish contaminated with such suspended and canceled pesticides as aldrin, dieldrin, chlordane, heptachlor, DDT, and mirex. Several studies of fish consumption have been undertaken in the Basin. For example, a recent study by the Michigan Department of Health found that average fish consumption is 16.1 grams per day for a sample of 2600 holders of sport fishing licenses. Of the 16.1 grams per day consumed, 56 percent or 9 grams per day represents commercially purchased fish and 44 percent or 7 grams per day represents locally caught sport

fish. The population eating sportfish in Michigan was estimated to be about 2.5 million people.

Pesticide Residues in Food: Noncancer Risk

Available data did not permit separate analysis of the noncancer risk in the Basin from residues in food. The assessment in "Unfinished Business" and that provided by OPPE on July 26, 1990, analyzed dietary risk using only pesticides with oncogenic risk numbers.

Risks to Pesticide Applicators: Cancer Risk

As stated above, the "Unfinished Business" Report used extrapolations from long term animal studies to estimate human risk on a nationwide basis. Since oncogenicity studies are based on lifetime daily oral exposure, several adjustment were made, as follows:

> Yearly exposure is used for risk calculation and average daily exposure is calculated by dividing yearly exposure by 365.
>
> Workers are exposed for 40 years of a lifetime of 70 years.
>
> Dermal and inhalation absorption versus oral absorption, if known, was factored in.

OPP estimated the average lifetime population risk to be 35 persons per lifetime per chemical. The yearly risk per chemical would then be 0.5 persons per year per chemical (35/70 years in a lifetime). Since approximately 200 pesticides were estimated to be oncogens, the yearly risk was estimated to be 0.5 X 200 or 100 persons per year.

To determine the number of certified applicators in the Basin we used the proportion of the Basin population to the Region 5 population (30,050,000/46,428,000 or 65 percent) multiplied by the number of certified applicators in Region 5 (200,000) to arrive at an estimated 130,000 applicators in the Basin (200,000 X 0.65). We estimated the number of applicators in the Basin at risk by multiplying the population risk of 100 persons per year for the nation by the percent of national applicators that practice in the Basin (130,000/1,249,000 or 10 percent) to arrive at 10 Basin applicators at risk per year (100 X 0.10).

Risk to Pesticide Applicators: Noncancer risk

The reference dose was used to calculate risk to applicators for pesticides without quantitative cancer risk assessments. We used available EPA documents, which included Special Review Position Documents, and Reregistration Documents (formerly called Registration Standards) to obtain exposure assessments for pesticides used in the Basin. Exposure populations were estimated from numbers of certified applicators in categories known to use particular pesticides and other available information. Using methods prescribed by the Comparative Risk Technical Steering Committee for Region 5, final risk evaluations were made. The two pesticides used in the Basin were in the medium to low category, as follows:

Pesticide	Final Risk Score
Cyanazine	Medium-Low
2,4-D	Medium-Low

Other pesticides were not included because either they did not appear to be used in the Basin as evidenced by their failure to appear in the RFF data base, or because applicator exposure information was not available. Most risks were medium-low using this method of analysis. The analysis assumes that protective clothing is worn during application and applicators exercise appropriate precautions when applying pesticides.

OPPE provided a summary of non-dietary risks from pesticide use in their July 26, 1990 report. Six pesticides were used to calculate noncancer risks to applicators and farm workers. The Temple, Barker, and Sloane report was used to obtain rough estimates of the population of farm workers and applicators for Region 5 which were then scaled down using a Basin percentage figure. These estimates are as follows:

Total farm workers: 1.3 million (includes unpaid workers, hired workers, farm operators, and ground applicators; migrant workers were not added).

Total off-site workers: 350,000 (includes all hired workers and commercial ground applicators).

With higher numbers of people exposed, the overall risk ranking for this category in Region 5 was medium-high. Given the lower numbers of people exposed in the Basin as compared to Region 5, we assume the overall ranking to be medium to medium-high.

Other Impacts on Human Health from Pesticides in the Basin

Several other potential impacts to human health exist in the Basin from such sources as the use of pesticides in the lawn care, turf, and golf course industries, the use of insect repellents such as DEET due to the concern about the spread of the Deer tick and Lyme disease within the Basin, the impacts of having approximately 2600 pesticide producing and custom blending establishments in the Basin, and non-occupational exposure to pesticides. These analyses are qualitative and are described below.

Lawn Care and Turf Industries

Use of pesticides in the lawn care and turf industries, has been estimated by EPA to be 67 million pounds of active ingredient per year. Using a population proportion for the Basin, this amount scales down to approximately 8 million pounds of active ingredient per year applied to lawns by professional lawn care operators and homeowners in the Basin. Using a population proportion for the Basin again, there are approximately 11,200 certified applicators in the turf/ornamental category in the Basin who apply pesticides for about 3-4 hours per day during the late Spring to early Fall season. Estimates by industry technical representatives indicate the solutions applied are rather dilute, with less than 1 percent active ingredient with 6-7 percent fertilizer. The major pesticides used in the industry are 2,4-D, MCPP, pendimethalin, diazinon, chlorpyrifos, dicamba, and isofenphos. The RFF data base shows use of some but not all of these pesticides in the Basin. One company in Region 5 indicated that no pesticides requiring respirators were used in their operations. In addition, the company requires protective clothing to be worn when hauling concentrated material and when filling tanks. During application, boots and clean uniforms are worn and gloves are encouraged. Over the next few years, as the Agency looks into the lawn care industry and evaluates the risks from this use of pesticides, more information on exposure will become available and this can be used to make a quantitative evaluation of risk.

Golf Courses

Extrapolating from Region 5 data, there are approximately 2.4 million acres of golf courses in the Basin and are treated

with 2.2 million pounds of pesticides annually.[30] In late 1986, EPA called for the withdrawal of diazinon on golf courses and sod farms because of cases of severe allergic reactions to some golfers and impacts to birds. Approximately 399,900 pounds of diazinon were applied in the Basin in one year in the mid 1980s. Starting with the 1990 season, Wisconsin is requiring that all commercial applicators keep records of all pesticides used, including restricted use and general use pesticides. Most golf course superintendents are interested in gathering information which reflects the true practices in their industry. In the future, more information will develop to use in the quantitative evaluation of risks from the use of pesticides on golf courses.

Insect Repellents/DEET

Use of insect repellents including the active ingredient DEET has increased greatly over the last few years. USA Today found that sales of "OFF" insect repellent had increased by 50 percent during the summer of 1989. With the high degree of outdoor recreational opportunities in the Basin, it can be reasonably estimated that most of the Basin population at one time or another has used insect repellents. With increasing concern over Lyme disease and the spread of the Deer Tick, we expect the use of repellents will most likely increase. In Michigan, the Centers for Disease Control reported an incident rate for Lyme disease of 41 cases per 100,000 people between 1987 and 1988. DEET, an especially effective active ingredient in repellents, is currently under reassessment, and when more information is known on the toxicity and exposure associated with its use, the Agency will provide this information to States and the general public in order to reduce the risks even further. In the interim, EPA recommends using repellents with no higher than 15 percent DEET for children and infants, and to apply such products sparingly to the outside of clothing.

Pesticide Producing and Custom Blending Facilities

Extrapolating from Region 5 data, there are approximately 2600 pesticide producing and custom blending facilities located in the Great Lakes Basin. In preparing the Region 5 comparative risk report on pesticides, an attempt was made to look at the activities associated with the synthesis of pesticides, the combination of active ingredients with inert ingredients and the risks associated with these activities. A FIFRA/TSCA Tracking System report was obtained with pesticide producing establishments and products made at each location. The Toxic Release Inventory System was also accessed to look for use of toxic chemicals at locations where pesticides are synthesized and formulated. About 25-30 locations in the Region were found to have reported threshold quantities of toxic chemicals and to be associated with the production of agricultural chemicals, as determined by Standard Industrial Codes. The search provided only a general idea of association between these activities and exposure of risks and no quantitative risk assessment was possible. In the future, as reporting becomes more sophisticated, such an assessment may become more possible.

Non-Agricultural Pesticide Use

The Non-Occupational Pesticide Exposure Study (NOPES) considered the human exposure to 32 household pesticides. The objective of the NOPES was to estimate the levels of non-occupational exposure to selected household pesticides, primarily through indoor air, but also through food, drinking water, and dermal contact. The study was conducted in two locations, (1) Jacksonville, Florida, and (2) Springfield and Chicopee, Massachusetts in order to consider areas of, respectively, high and low to moderate non-agricultural pesticide use. The Basin could be considered in the low to moderate non-agricultural pesticide use category.

Results of the NOPES study showed a number of pesticides, some already canceled, were detected at least once in minute quantities in the majority of households including chlordane, heptachlor, chlorpyrifos, orthophenylphenol, and

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[30] Water Quality Board, International Joint Commission. 1987. "1987 Report on Great Lakes Water Quality," p. 183.

propoxur. Other pesticides detected include aldrin and diazinon.

Other conclusions of the NOPES include:

diet was a more important source than air for exposures to 14 of the 32 household pesticides;

airborne concentrations of pesticide residues were higher indoors than outdoors;

there were seasonal variations in ambient residue levels;

short term variations in residue levels were influenced by recent pesticide applications, indoor ventilation, and ambient temperatures;

usage categories did not correlate with airborne residue concentrations; and

residue levels could be reduced if labels are read closely and followed, and with improved guidance on how to safely dispose of unused pesticides.

EPA concluded that the concern for human health risk from exposure to pesticides found in this study is low to negligible.

APPENDICES

APPENDIX A: DATA SOURCES, UNCERTAINTIES AND GAPS
APPENDIX B: BIBLIOGRAPHY
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APPENDIX A: DATA SOURCES, UNCERTAINTIES AND GAPS

Physical Degradation of Water Habitat and Wetlands

Sources:The primary sources of information drawn upon include the 1990 water quality reports prepared by each of the Great Lakes states, and Natural Heritage Inventory data for the Basin counties which was supplied by the midwest regional office of The Nature Conservancy.

Uncertainties and Gaps:There is no hard data that can be used to accurately quantify the physical degradation of open water and wetlands habitat. Data provided by the Nature Conservancy only identifies the examples of wetlands that are biotically diverse, sensitive, or that hold a rare or endangered plant or animal species.

No data could be used to calculate risks posed to water and wetlands habitats. More specifically, no quantitative data was found addressing the residual risks posed to human health due to wetlands loss, the environmental hazards and toxicity of pollutants found in wetlands, or human and monetary losses due to flooding.

Physical Degradation of Terrestrial Ecosystems

Sources:This section employed tracking data of biologically significant sites in Basin counties from the National Heritage Program, and information from the Region 5 Problem Area Paper "Physical Degradation of Terrestrial Ecosystems."

Uncertainties and Gaps: The Heritage data only identifies examples of biotically diverse or sensitive areas, or those that hold rare or endangered species. It does not address more common ecosystems, or the degree of impact on those ecosystems from anthropogenic stressors. Quantitative data on these impacts is unavailable.

Exotic Species Introduction to the Great Lakes

Sources: The primary sources of data were articles from academic journals, agency reports, and conversations with agency experts. The U.S. Fish and Wildlife Service supplied a bibliography documenting journal articles on a number of different exotic species. The Great Lakes Fishery Commission supplied articles and reports on the sea lamprey and alewife as well as other exotic species. The Great Lakes Commission supplied newspaper articles and reports on the zebra mussel. The U.S. Fish and Wildlife Service provided summary information on Ruffe. Taken together, these sources provide a general characterization of the problems in the Great Lakes due to the presence of exotic species.

Uncertainties and Gaps: Data is largely anecdotal. Quantitative data is unavailable on the problems or their impacts. Population figures for the exotic species are estimates whose statistical validity is not known.

Welfare impacts are gross estimates. They have been provided to give a range of costs that officials have ascribed to the problem.

Data on the ecological and welfare impacts of the spiny water flea, asian clam, alewife and the smelt were unavailable for this draft.

Spills and Other Accidental Releases

Sources: 1989 ERNS data on Basin counties was used as well as United States and Canadian Coast Guard reports and data. The Canadian Coast Guard commissioned a report entitled *Counter Measures for Marine Spills of Hazardous Materials* that looked at the amount of hazardous materials that travel on the Great Lakes, and calculates the probability of spills in specific areas of the Great Lakes. This section draws heavily on data from that report.

Uncertainties and Gaps: There are several nuclear power plants within the Great Lakes Basin. These risks are of low probability but high catastrophic impact. Due to time constraints, risks of accidental releases from these sources were not included.

No information was available on exposures to accidental releases. No information was used on ecological impacts in the Basin. US Fish and Wildlife as well as State natural resource trustees have identified ecologically sensitive areas and information that could be used. Some data on general ecological effects could also be extrapolated to identify some risk to ecological impact. A correlation might be made between the areas of greatest ecological sensitivity and the possibility of a spill in those areas.

Differing jurisdictions and inconsistencies in the data reported mean inaccurate information on spills in the Great Lakes. There is no precise spill inventory for the Great Lakes Basin.

Global Climate Change

Sources: The information presented in this section is primarily based on the EPA Office of Policy, Planning, and Evaluation's report entitled "The Potential Effects of Global Climate Change on the United States." In this study, regional outputs, including one for the Great Lakes Basin, were used from three General Circulation Models. All three estimate climate change caused by a doubling of carbon dioxide in the atmosphere. Expert judgment by the report's authors regarding potential effects was used to supplement the scenarios. The results were not predictions, but rather indications of the impacts that could occur as a result of anthropogenic climate change. The analytic approaches described above were used as tools to determine the potential sensitivities and vulnerabilities of systems such as the Great Lakes to climate change.

Uncertainties and Gaps: The precise impact of global climate change in the Great Lakes Basin is impossible to determine due to the vast uncertainties involved in this emerging area of investigation. The information presented above represents the current best professional judgment concerning likely impacts of such change in the Basin. As modeling resolution and data indicating the trends improve, these estimates will be refined.

Changing Lake Levels

Sources: This problem area used information from the IJC's 1985 report, "Living with the Lakes: Challenges and Opportunities," and the Great Lakes Commission 1986 report, "Water Level Changes, Factors influencing the Great Lakes."

Uncertainties and Gaps: This analysis is primarily qualitative in nature, as sufficient data are not yet available to quantify specific impacts. Where available, data are presented to assess overall losses in terms of recreational and infrastructure impacts. Quantifiable data for the changing lake levels problem area was unavailable for:

- the extent of property damage from severe weather and flooding,
- the economic losses incurred due to property damage,

- the extent of wetland damage from severe weather including drought and flooding,
- human health impacts and costs.

Industrial Point Source Discharges to Surface Waters

Sources : The characteristics of the industrial dischargers in the Great Lakes Basin counties were drawn from EPA Permit Compliance System (PCS) data[1]. Ambient surface water quality information for the Basin was taken from the 1989 305(b) Reports reported by the Great Lakes States. This ambient surface water information and toxic constituent concentrations in fish tissue were supplemented by the 1987 and 1989 IJC Water Quality Board Reports[2] and the Upper Great Lakes Connecting Channels Study.[3] Fish consumption data and exposure information were taken from U.S. Department of Agriculture studies and EPA guidance.[4]

Uncertainties and Gaps: The level of toxic or conventional pollutant loading to the Basin from industrial point sources can only be estimated. The apportionment of load to industrial point sources in this study was made based on limited data from two of the Connecting Channels in the Basin. As those data demonstrate, the relative importance of industrial, municipal, and nonpoint source load varies considerably across the Basin.

PCS data does not include data on the many minor dischargers in the Basin.

Precise data on fish consumption and human exposure to contaminants in Basin fish is currently unavailable.

Municipal Point Source Discharges to Surface Waters

Sources and Uncertainties: See Industrial Point Source Discharges to Surface Waters.

Nonpoint Source Loading to Surface Water

Sources: The major data sources investigated for this analysis included 1989 Section 319 State Nonpoint Source Assessment Reports, Conservation Tillage Information Center data, the Upper Great Lakes Connecting Channels Study, and the 1989 IJC Report on Great Lakes Water Quality. Studies conducted at Heidelberg College, Ohio, were also reviewed for information on nonpoint source pollution in the Lake Erie basin.[5]

Uncertainties and Gaps: There is a great deal of uncertainty concerning the total load of nonpoint source contaminants to the Great Lakes Basin. Unlike point sources, which can be measured at the end of the pipe, nonpoint source load can only be estimated based on land use practices and observed contaminant levels in the surface water environment. As a result, this analysis relied on the apportionment of contaminant source load

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[1] Note: PCS does not track all minor dischargers in the Basin.

[2] Great Lakes Water Quality Board. 1987. "1987 Report on Great Lakes Water Quality," Report to the International Joint Commission; Great Lakes Water Quality Board. 1989. "1989 Report on Great Lakes Water Quality," Report to the International Joint Commission.

[3] U.S. EPA, et. al. 1988. "Upper Great Lakes Connecting Channels Study."

[4] U.S. Department of Agriculture. 1989. "Consumption and Family Living," Agricultural Statistics; U.S. EPA/OWRS. 1989. "Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish: A Guidance Manual," EPA-503/8-89-002.

[5] Baker, D.B., "Overview of Rural Nonpoint Pollution in the Lake Erie Basin," Logan, Terry J., et al., eds., Effects of Conservation Tillage on Groundwater Quality: Nitrates and Pesticides, chapter 4, Lewis Publishers, Inc., Chelsea, MI, 1987.

described in Industrial Point Source Discharges to Surface Waters. Additional data to better characterize the true nature of nonpoint source load in the Basin would improve the risk assessment.

Atmospheric Loading to Surface Water

Sources: Sources of data for this section include: The Great Lakes Atmospheric Deposition Network, 1982 and 1983, GLNPO, EPA; IJC's 1987 "Summary Report of the Workshop on Great Lakes Atmospheric Deposition;" and the IJC's 1989 Report on Great Lakes Water Quality.

Uncertainties and Gaps: Evaluation of this problem area involves a number of assumptions necessary to overcome the high uncertainties associated with the available data and the simplified analytical methodology applied here. Major sources of uncertainty include:

- the relative role of atmospheric deposition to levels of all of the contaminants of concern in each of the Great Lakes,
- the geographic distribution of fish contamination,
- the effect of fishing advisories on human health risks from fish consumption,
- the effect of water treatment on human health risks from drinking water,
- the severity of ecological effects attributable to atmospheric deposition of toxic contaminants into the Lakes, and
- the degree to which the Lakes are sources of PCBs to the atmosphere.

Toxic Sediments

At this time there are major data gaps over the amounts, pathways, and risks from contaminated sediments. The U.S. EPA's Great Lakes National Program Office (GLNPO) is responsible for a multi-agency program entitled Assessment and Remediation of Contaminated Sediments (ARCS), scheduled for completion in 1992. While the results of the ARCS Program should provide clarification as to the extent of the contaminated sediment problem, not much data is currently available. Therefore, the sediment analysis summarizes the problem qualitatively utilizing information available from sources such as the IJC Reports on Great Lakes Water Quality, GLNPO, New York State 305(b) report, Great Lakes: Great Legacy? and others.

Pesticides Discharges

Sources: All data on amounts and rates of active ingredients applied to agricultural lands in the Basin were obtained from Resources for the Future (RFF). RFF data are presented in two separate data bases:

- RFF published data for 21 pesticides used in the Basin for a typical year in the mid 1980s. These data are digitized and are available by county for 181 counties in the Basin.

- RFF is also currently updating its National Pesticide Usage Data Base which includes data on application rates and total agricultural acres treated with 35 active ingredients for a typical year in the late 1980s. These data are also automated and are available by county for 213 counties in the Basin.

This discussion uses these more recent data for the 7 active ingredients applied in the Basin that are also in the earlier, Basin-exclusive data base. RFF has not updated the more recent data base for the 21 active ingredients used in the Basin.

This section also uses data from the 1988 U.S. EPA, GLNPO Report on Agricultural Tillage Practices in the Basin, and the 1990 Region 5 comparative risk project. Finally, this section incorporated summary data from the IJC's 1987 Report on Great Lakes Water Quality.

Uncertainties and Gaps: There are several caveats to the use estimates of the RFF pesticide data. These caveats are:

- Not all pesticides used in the Basin were included;
- Non-cropland uses of pesticides were not included;
- Two different data sets were used, as noted, and are for a typical year. It is not known to what extent these estimates reflect current use patterns;
- The estimates assume uniformity for all counties within states for the same pesticide/crop use.
- It is not known to what extent the actual use pattern varies within each state.
- The accuracy of state-level use estimates cannot be assessed. Many of the use estimates represent the opinions of weed scientists and other extension personnel. There is no independent set of estimates to verify these estimates; and
- The older and more recent data sets are taken for 181 and 213 counties, respectively, in the Basin. This difference will result in differences in the total amount of pesticides applied. Any conclusion based on this data will have to be carefully drawn.

Risk estimates were made by extrapolating data generated from Region 5. It is not known to what extent these derived risk estimates are statistically valid.

Sulfur and Nitrogen Oxide Emissions

Sources: For this section, the AIRS Facility Subsystem (1990 retrieval) provided data for the Basin counties on total, permitted, and fugitive emissions as well as data for ambient levels.

Uncertainties and Gaps: The Region 5 comparative risk study applied the same method to estimate health impacts from sulfur and nitrogen oxide pollution as was used in this study. The Region 5 paper points out three important limitations of this approach. First, the quantitative relationship between estimated health effects and sulfate exposure is based on epidemiological study results that demonstrate association but not causation. Therefore, Region 5 points out that some uncertainty exists regarding the magnitude, and in some cases even the existence, of the presumed causal relationship presented between the pollutants and human health.

Second, although sulfate aerosols are the best available indicator for acid aerosol exposure, acidic sulfate aerosols would be a preferred, and more valid indicator.

Finally, estimates of the number of people exposed to various levels of sulfate are quite uncertain. Problems associated with determining the exposed population include Basing judgments on limited monitoring data, estimating the area that each monitor represents, and estimating the number of people in this area who are actually exposed to the pollutant.

Uncertainties related to the ecological impacts section are most significant with regard to terrestrial effects. The National Acid Precipitation Assessment Program study of lake acidification provides a good lower bound estimate of the acreage of acidified lakes. Studies of fish populations in acidified and non-acidified lakes in the Adirondacks provide information on the impacts of lake acidification. Consequently, there is a low degree of uncertainty in the effects of acid deposition on aquatic ecosystems.

In contrast, the terrestrial impacts of acid deposition must be considered to be hypothetical. There is a high degree of uncertainty regarding effects of acid deposition on terrestrial ecosystems.

Hazardous/Toxic Air Pollutants

Sources: This section and the airborne lead problem rely on the Region 5 comparative risk study. Data to estimate cancer risks was taken from EPA Office of Air Quality, Planning and Standards report: "Cancer Risk from Outdoor Exposure to Air Toxics," September, 1990. National data from the EPA Air Toxic Exposure and Risk Information System data base was apportioned to the Great Lake Basin by population.

Uncertainties and Gaps: The cancer risk values used in this study are based on many assumptions and are therefore somewhat uncertain. Further, the fraction of the total risk attributable to pollutants and source categories not covered in the study is unknown. Nevertheless, the OAQPS study is valuable as a reasonable indication of the magnitude of potential cancer risk caused by this specific group of pollutants and is therefore, in general, considered to be moderately to highly certain.

For noncancer risk, data was insufficient to predict ambient concentrations of most air pollutants. In addition, data pertaining to various noncancer endpoints for many pollutants was minimal. Further, inhalation studies are scarce. The degree of certainty associated with this study is considered to be low to moderate.

It should be noted that the monitoring network for lead is somewhat limited. It is likely that we underestimated the number of people potentially at risk from exposure to airborne lead. In addition, the current NAAQS for lead was promulgated in 1978 to protect children from blood levels of 30 micrograms per deciliter (ug/dl). Since that time, new information has become available which has prompted the Clean Air Scientific Advisory Committee to set the new maximum safe blood lead level at 10 ug/dl. Because of this, using the present NAAQS as the only basis for evaluating health impacts is likely to result in significant underestimation of risk.

The analysis of health cost for cancer cases assumes that economic damages associated with cancer cases can be adequately described without taking into account the pain and suffering caused by these cancers. This assumption leads to an underestimate of the actual economic damages.

Active RCRA Hazardous Waste Management Facilities

Sources: The Hazardous Waste Data Management System (HWDMS), September 1990, was used to obtain the number of operating land disposal units (LDUs), storage and treatment units (STUs), and incinerators in the Great Lakes Basin. Information from the Database on Marketers and Burners of Hazardous Waste Fuel and from the Corrective Action Reporting System was also used.

Uncertainties and Gaps: No Basin data was available on accidents resulting in injuries or death at RCRA sites, risks from recycling units, ecological risks associated with facilities, potential toxic loadings from RCRA sites to the Great Lakes, air exposures to emissions from operating units other than incinerators and burners, or size distribution of corrective action sites.

Abandoned Hazardous Waste Sites

Sources: This problem area used data from a 1990 CERCLIS retrieval for the Basin counties.

Uncertainties and Gaps: The health risk analysis was believed to be a reasonable estimate of the risks from abandoned waste sites. However, some significant uncertainties remain:

First, the risks presented in the endangerment assessments for the NPL sites used in the Region 5 Comparative Risk Project are the risks at the sites without any remedial actions. Presumably, a significant number of the sites that pose a significant risk to human health, if not all of these sites, will be undergoing some degree of cleanup either by the federal government, the state, or private parties.

Second, Region 5's data on populations exposed were highly uncertain. Only a few endangerment assessments had detailed exposure data, and many had no population data at all. Estimates were made based on the exposure route and the site characteristics, but the available information was often crude at best.

The quantitative analysis conducted in this study was hampered by the lack of information on ecological effects. Many sites had little or no ecological assessment, and those that did varied considerably in the type, depth, and quality of data collected. Also, projecting results from the 51 sites within Region 5 to all sites within the Basin creates a high level of uncertainty. Direct extrapolation of ecological risk from the Regional analysis to the Great Lakes Basin might underestimate Great Lakes ecological risk.

An underestimation of ecological risks is also possible because sites requiring no further action were not included in this assessment, and because their status of "no further action" was determined primarily based on human health effects.

Another important source of uncertainty in this type of analysis is associated with projecting risks to populations and ecosystems from impacts observed in individuals.

Municipal Solid Waste Facilities

Data Sources: Actual information on the contributions of municipal solid waste sites to the degradation of the Great Lakes Basin is limited. For this assessment, data were compiled from "Draft Regulatory Impact Analysis of Proposed Revisions to Subtitle D Criteria for Municipal Solid Waste Landfills," a document prepared for EPA's Office of Solid Waste Economic Analysis Staff. Unless otherwise noted, most data were compiled on the national level and weighted by population and land size of the Great Lakes Basin. Nearly all other data were obtained from state listing of solid waste facilities obtained from EPA's Region 5 office and the environmental agencies in the states of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin.

Uncertainties and Gaps: Major uncertainties exist when weighting national data by population for the Basin.

Due to time constraints, state listings for solid waste sites in the New York and Pennsylvania portions of the Basin were not available for this report.

Data was unavailable for releases of contaminants from operating municipal landfills, potential exposures resulting from releases, data on the 1910 closed municipal solid waste landfills in Region 5, contributions of incinerators to pollutant loadings to the Great Lakes, or ecological impacts of MSW landfills.

Industrial Solid Waste Facilities

Sources: Two data sources were used for this problem area. The first is a 1988 EPA Office of Solid Waste report entitled "Screening Survey of Industrial Subtitle D Establishments" (Screening Survey). This study's goals were:

- To develop a list of establishments that manage Subtitle D wastes in landfills, surface impoundments, land application units and waste piles that are not regulated as hazardous;

- To develop national and industry specific estimates of the number of establishments that manage industrial Subtitle D waste on site; the number of establishments that manage Subtitle D wastes on site in landfills, surface impoundments, land application units and waste piles; the number of landfills, surface impoundments, land application units, and waste piles used to manage Subtitle D waste; and the amount of Subtitle D waste managed on site through the four types of land based waste management units;

- To collect basic data on each type of waste management unit;

- To identify which establishments managed industrial Subtitle D wastes using methods other than the four land-based waste management units.

The second source is a 1988 EPA report entitled "Industrial Subtitle D Risk Screening Analysis" (Screening Analysis). The objective of this study was to identify industrial waste management scenarios that may pose significant human health and environmental risks. This study was also conducted on a national basis, so the national data was weighted in terms of Great Lakes Basin population. Most of these results will appear in the human health risk section of this problem area.

Uncertainties and Gaps: For this study, the national data were weighted in terms of Basin population. The figures obtained may not accurately represent the actual industrial solid waste data for the Basin due to the following reasons:

- The Great Lakes Basin contains a substantial amount of industry. Consequently, weighting of the national data may not be representative of the Basin since it may underestimate the proportion of industry.

- The data from the Screening Survey was collected in 1985. During the past five years, the Basin has had a significant population decline. The affect of this change further adds to uncertainty in the analysis. Additionally, 1985 industrial solid waste site data was weighted against the 1988 population data, rather than the 1985 population data. This would distort the human risk analysis because the population at risk would appear to be lower.

Readily available data on the population of industrial solid waste facilities are limited, and, when available, are often aggregated at the national level. While states are in a better position to generate data on specific facilities, this information is not easily accessible.

Although the toxic constituents in various types of industrial wastes are known and can be evaluated, the data needed to translate known potential health effects of these toxic constituents into risks posed to populations or ecological systems are currently unavailable. Basic data needs include the concentrations of toxic constituents in the solid wastes managed at industrial facilities, estimates of the potential for uncontrolled releases of contaminants from these facilities, and information on the potentially exposed populations residing near these facilities.

Aggregated Drinking Water

Sources: 1990 FRDS data for public water systems, their sources, the number of public systems with at least one MCL violation, the specific contaminants associated with the violations by Basin county, and the populations affected was collected and analyzed for this problem area.[6]

Uncertainties and Gaps: Because we followed the general approach used in the Region 5 comparative risk study, many of the uncertainties realized in the Region 5 study were implicit in this analysis. The most important of these is the use of the FRDS database as the primary data source. First, there is great potential for inaccurate data in the system, particularly with regard to populations and chemical concentrations. Second, because FRDS only contains violations and associated concentrations, these concentrations may represent worst-case exposures instead of average exposures. Third, because FRDS classifies all systems that receive unfinished water from both ground and surface waters as surface-water based systems, a tally of the number of ground-water based systems can potentially be grossly underestimated; conversely, a tally of the number of surface-water based systems may be an overestimate.

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[6] Further analysis of FRDS retrieval will be incorporated into subsequent drafts.

Aggregated Ground Water

Sources: As described in Aggregated Drinking Water, EPA planned to select representative drinking water contaminants by reviewing quantitative information from its 1990 FRDS data base for public drinking water supplies within the Great Lakes Basin. Ideally, contaminants of concern for this analysis would depend upon those constituents for which MCL violations in ground-water based public water supply systems were noted in the FRDS retrieval. This analysis was based largely on the Region 5 comparative risk study.[7]

Uncertainties and Gaps: As for the drinking water risk analysis, we relied on the Region 5 comparative risk study for much of our analysis of risk posed to ground water within the Basin; therefore, the uncertainties associated with the use of the FRDS data base apply also to this analysis. Of particular note is recognition that the total population served by ground water may be underestimated because FRDS classifies all systems that receive unfinished water from both ground and surface waters as surface-water based systems; thus, a percentage of the population that relies of ground water may go unnoticed when data from FRDS are utilized.

No data was available on ground water impacts on ecosystems, or on percentages of runoff versus ground water contributions to baseflow for streams and lakes.

Ozone and Carbon Monoxide

Sources: The AIRS Facility subsystem (1990 retrieval) provided data for Basin counties on total, permitted, and fugitive emissions, and for ambient levels.

Uncertainties and Gaps: It is highly certain that some people in the Great Lakes Basin are experiencing adverse health effects due to the significant ozone pollution problem. It is also highly certain that people in various areas of the Basin are experiencing adverse health effects due to exposure to CO. However, only a moderate degree of certainty can be associated with the exact number of people experiencing the specific health effects that are presented above. The greatest difficulty in determining exact figures arises in assessing the population exposed.

First, it is not certain that all exceedances of NAAQS were monitored and thereby factored into the estimates presented above. In particular, we are confident that there are numerous areas in the Basin that are not monitored and that have ambient ozone concentrations exceeding the cut-off of 0.12 ppm. Since only monitoring data were used, the figures presented above are likely to underestimate the risk.

Second, the area that each monitor represents must be determined. Finally, the number of people in this area who are actually exposed to the pollutant must be determined. For ozone we made the assumption that an exceedance at a monitoring location in any given county indicates exposure to the entire Great Lakes Basin population in that county, even if exceedances were not predicted for all monitors in the county. This process leads to a moderate degree of uncertainty.

As indicated by the qualitative nature of the discussion of the ecological impacts of ozone and CO pollution, there is a high degree of uncertainty in the severity of the effect of the these pollutants. It is generally accepted that ozone adversely impacts vegetation, but its severity in the Great Lakes Basin is not known.

Likewise, the estimated welfare impacts of ozone and CO pollution are highly uncertain. First, the analysis of these impacts did not consider any impacts of CO. Second, the estimated impacts caused by ozone are quite uncertain. Health care cost estimates are based on moderately uncertain health effects estimates and average health care unit

[7] FRDS analysis will be included in a later draft.

costs that may introduce additional uncertainty. Estimates of agricultural damage from ozone are highly uncertain because they are based on Region 5 exposure-response levels that may be uncertain and may not be accurate for the Great Lakes Basin. In addition, we assumed the same yield per acre as was used for Region 5, which may not be correct. Material damage costs are similarly uncertain because they rely on average costs.

Particulate Emissions

Sources: The AIRS Facility Subsystem (1990 retrieval) provided Basin county data on total, permitted, and fugitive emissions, and on ambient levels.

Uncertainties and Gaps: The are considerable uncertainties in this evaluation of the risks posed by particulate matter. First, monitoring for PM_{10} does not encompass the entire areal extent of the Basin and high levels of particulate matter outside the monitored areas have not been incorporated into the estimated effects. Second, the population exposed to levels of concern is not known with certainty. Therefore, this analysis uses best professional judgment to estimate the exposed population.

In addition, ecological effects associated with particulate matter pollution are not known with any certainty. No data was available concerning the effects of PM_{10} on flora and fauna.

Finally, the welfare effects are limited by their use of relatively uncertain human health effects estimates and the application of a model developed for use with total suspended particles data while only PM_{10} data are available.

Underground Storage Tanks

Sources: Summary State UST data was obtained from State notification databases, and the National Database of UST Release Incidences was employed in this section.

Uncertainties and Gaps: Due to limitations inherent in the data on which these estimates are based, conservative (but not worst-case) assumptions have been introduced whenever necessary to fill primary data gaps or inadequacies. Thus, the resulting estimates could tend to overstate real-world risk levels to some extent. Data was unavailable for other than petroleum products, and for vapor release from ground water or soil.

This analysis is confined to cancer and noncancer risks associated with daily ingestion of two liters of drinking water contaminated by low levels of petroleum or its by-products. Higher exposure levels are assumed to trigger a taste or odor response which effectively serves to limit subsequent exposure. It is further assumed that few, if any, would be subjected to a lifetime of exposure. Available evidence points to much shorter exposure periods. The subchronic level of seven years provides a suitably conservative assumption for purposes of this analysis.

A potentially significant problem with this analysis, one that suggests the results are underestimated, is that it does not incorporate risk calculations for inhalation and dermal exposure. The exposure figures are solely based on ingestion of ground water. While dermal exposure appears to result in the least exposure, there is much controversy over the relative importance of inhalation vs. ingestion. Estimates of the relative magnitude of inhalation compared to ingestion exposure of VOCs range from approximately 1 to 6 times.[8]

Pesticides - Health See Pesticide Discharges.

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[8] Thomas E. McKone, "Human Exposure to Volatile Organic Compounds in Household Tap Water: The Indoor Inhalation Pathway," Table VII, Environmental Science and Technology, December 1987.

APPENDIX B: BIBLIOGRAPHY

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APPENDIX C: ACRONYM LIST

ACRONYMS	LISTING
(AIRS)	Aerometric Information Retrieval System
(AOC)	Areas of Concern
(ARC)	Assessment and Remediation of Contaminated Sediments
(AWQC)	Ambient Water Quality Criteria
(BAT)	Best Available Technologies
(BEST)	Best Extraction Sludge Technology
(CDF)	Confined Disposal Facilities
(CERCLA)	Comprehensive Environmental Response, Compensation, and Liability Act
(CERCLIS)	Comprehensive Environmental Response, Compensation and Liability Information System
(CF)	Critical Fluids
(CFR)	Code of Federal Regulation
(CSO)	Combined Sewer Overflow
(CTIC)	Conservation Technology Information Center
(EPA)	Environmental Protection Agency
(ERNS)	Emergency Response Notification System
(FRDS)	Federal Reporting Data System
(GLAD)	Great Lakes Atmospheric Deposition
(GLFC)	Great Lakes Fishery Commission
(GLNPO)	Great Lakes National Program Office
(HCC)	Health Care Costs
(HDWMS)	Hazardous Waste Data Management System
(HEAST)	Health Effects Assessment Summary Tables
(HI)	Hazard Index
(HRS)	Hazard Ranking System
(IJC)	International Joint Commission
(IRIS)	Integrated Risk Information System
(LAMP)	Lakewide Action Management Plan
(LDU)	Land Disposal Unit
(LEL)	Lower Explosive Limit
(LOAEL)	Lowest Observed Adverse Effect Level
(MCL)	Maximum Contaminant Level
(MCLG)	Maximum Contaminant Level Goals
(MEPAS)	Multimedia Environmental Pollutant Assessment System
(MP)	Migration Potential
(NAAQS)	National Ambient Air Quality Standards
(NAPAP)	National Acid Precipitation Assessment Program
(NAPL)	Non-aqueous phase liquids
(NESCAUM)	Northeast States for Coordinated Air Use Management
(NOAEL)	No Observed Adverse Effect Levels
(NOPES)	Non-Occupational Pesticide Exposure Study
(NPDES)	National Pollutant Discharge Elimination System
(NPL)	National Priority List
(OAQPS)	Office of Air Quality, Planning and Standards
(ODW)	Office of Drinking Water
(OPP)	Office of Pesticide Programs
(OPPE)	Office of Policy, Planning and Evaluation

(OSWER)	Office of Solid Waste and Emergency Response
(OTA)	Office of Technology Assessment
(OWD)	Office of Drinking Water
(PCS)	Permit Compliance System
(PWS)	Public Water System
(RAP)	Remedial Action Plan
(RCRA)	Resource Conservation and Recovery Act
(RFF)	Resources for the Future
(SDWA)	Safe Drinking Water Act
(STU)	Storage and Treatment Unit
(TMP)	Toxic Management Plan
(TRI)	Toxic Chemical Release Inventory
(TSDF)	Treatment, Storage, and Disposal Facility
(USCG)	United States Coast Guard
(US)	United States
(UST)	Underground Storage Tank

ACRONYMS **CHEMICAL/MEASUREMENT LISTING**

(AAC)	Acute acceptable concentrations
(ANC)	Acid neutralizing capacity
(AOX)	Adsorbable organic halogen
(BCF)	Bioconcentration factor
(BHC)	Benzenhexachloride
(BOD)	Biochemical oxygen demand
(CAC)	Chronic acceptable concentrations
(CFC)	Chlorofluorocarbons
(CO)	Carbon monoxide
(COD)	Chemical oxidation
(CPF)	Cancer Potency Factor
(DDE)	Dichlorodiphenyl dichloriethylene
(DDT)	Dichlorodiphenyltrichloroethane
(HCB)	Hexachlorobenzene
(kg)	kilogram
(km)	kilometer
(KPEG)	Potassium-polyethylene
(mg)	milligram
(mg/L)	milligram per liter - part per million
(NO_x)	Nitrogen oxide
(OSC)	Octachlorostyrene
(PCB)	Polychlorinated Biphenyls
(PCE)	Tetrachloroethylene
(PAH)	Polycyclic aromatic hydrocarbon
(ppb)	parts per billion
(ppm)	parts per million
(RfD)	Reference Dose
(RIA)	Regulatory Impact Analysis
(SO_2)	Sulfur dioxide
(TCA)	Trichloroethane
(TCE)	Trichloroethylene
(TCDD)	Tetrachlorodibenzo-p-dioxin

(TCDF)	Tetrachlorodibenzofuran
(THM)	Trihalomethane
(TOC)	Total organic chlorine
(TSS)	Total suspended solids
(TTO)	Total toxic organics
(ug/L)	microgram per litre
(VOC)	Volatile organic compound

APPENDIX D

PRELIMINARY

ANNEX 1 LIST OF GREAT LAKES SUBSTANCES

CHEMICAL	CAS No.	LISTING TRIGGER	SYNONYM
Acenaphthene	83-32-9	1	
Alachlor	15972-60-8	5	
Aldrin	309-00-2	5	
Antimony	7440-36-0	5	
Arsenic	7440-38-2	8	
Atrazine	1912-24-9	5	
Barium	7440-39-3	5	
Benzene	71-43-2	8	
Benz(a)anthracene	56-55-3	8	
Benzo(a)pyrene	50-32-8	8	3,4-benzopyrene
Benzo(b)fluoranthene	205-99-2	8	
Benzo(k)fluoranthene	207-08-9	8	11,12-benzofluoroanthene
Benzo(g,h,i)perylene	191-24-2	11	
Beryllium	7440-41-7	1	
Bis(2-ethylhexyl)phthalate	117-81-7	8	
Bromodichloromethane	75-27-4	8	
Butylate	2008-41-5	5	
Butylbenzylphthalate	85-68-7	4	
Cadmium	7440-43-9	1	
Carbofuran	1563-66-2	5	
Carbon disulfide	75-15-0	7	
Carbon tetrachloride	56-23-5	8	
Chlordane	54-74-9	5	
cis-chlordane	5103-71-9	*	alpha-chlordane
trans-chlordane	5103-74-2	*	beta-chlordane
oxychlordane	27304-13-8	*	
Chlorobenzene	108-90-7	5	
Chlorodibromomethane	124-48-1	8	
Chloroform	67-66-3	8	
Chloromethane	74-87-3	8	
1-Chloronaphthalene	90-13-1	4	
Chlorpyrifos	2921-88-2	5	
Chromium	7440-47-3	1	
Cobalt	7440-48-4	5	
Copper	7440-50-8	1	
Cyanazine	21725-46-2	5	bladex
Cyanide (an ion)	57-12-5	1	
DDT and metabolites	NA	8	
o,p'-DDT	789-02-6	8	
p,p'-DDT	50-29-3	8	
o,p'-DDD	53-19-0	8	
p,p'-DDD	74-54-8	8	
o,p'-DDE	3424-82-6	8	
p,p'-DDE	72-55-9	8	
p,p'-DDMU	1022-22-6	8	
Dehydroabietic Acid	1740-19-8	1	
Diazinon	333-41-5	1	

Dibenzo(a,h)anthracene	53-70-3	8	
Di-n-butylphthalate	84-74-2	1	
Dicamba	1918-00-9	5	
Dichloromethane	75-09-2	8	
1,2-Dichlorobenzene	95-50-1	5	
1,4-Dichlorobenzene	106-46-7	8	
1,1-Dichloroethane	75-34-3	8	
1,2-Dichloroethane	107-06-2	8	
1,2-Dichloropropane	78-87-5	8	
2,4-Dichlorophenoxy-acetic acid	94-75-7	5	2,4-D
Dieldrin	60-57-1	8	
N,N-Dimethylaniline	121-69-7	5	
Dimethyldisulfide	624-92-0	1	methyldisulfide
Di-n-octylphthalate	117-84-0	1	
2,6-Di-t-butyl-p-cresol (BHT)	128-37-0	10	
Endosulfan	115-29-7	5	
alpha-Endosulfan	959-98-8	*	
beta-Endosulfan	33213-65-9	*	
Endosulfan sulfate	1031-07-8	*	
Endrin	72-20-8	5	
Ethion	563-12-2	5	
Ethylbenzene	100-41-4	1	
S-Ethyl dipropylthiocarbamate	759-94-4	5	EPTC
Fonophos	944-22-9	5	
Furan	110-00-9	5	furfuran; divinylene oxide
Heptachlor	76-44-8	5	
Heptachlor epoxide	1024-57-3	8	
Heptachlorinated dibenzo-p-dioxins	38871-00-4	8	
Heptachlorinated dibenzofurans	38998-75-3	8	
Hexachlorinated dibenzo-p-dioxins	34465-46-8	8	
Hexachlorinated dibenzofurans	55684-94-1	8	
Hexachlorobenzene	118-74-1	8	
Hexachloro-1,3-butadiene	87-68-3	5	
Hexachlorocyclopentadiene	77-47-4	1	
Hexachloroethane	67-72-1	5	
Indeno(1,2,3-cd)pyrene	193-39-5	11	
Lead	7439-92-1	8	
Lindane (gamma-HCH)	58-89-9	8	gamma-hexachlorocyclohexane
Hexachlorocyclohexane	608-73-1	*	
alpha-Hexachlorocyclohexane	319-84-6	8	alpha-HCH
beta-Hexachlorocyclohexane	319-85-7	*	
Linuron	330-55-2	5	
Malathion	121-75-5	5	
Mercury	7439-97-6	1	
p,p-Methoxychlor	72-43-5	1	
2-Methyl-4-chlorophenoxy-acetic acid	94-74-6	5	MCPA
2-(2-Methyl-4-chlorophenoxy)-propionic acid	7085-19-0	5	MCPP; mecoprop

Metolachlor	51218-45-2	5	
Metribuzin	21087-64-9	5	
Mirex	2385-85-5	5	
10-monoH-mirex	NA	*	
2,8-diH-mirex	NA	*	
photomirex	39801-14-4	*	
Naphthalene	91-20-3	5	
Nickel	7440-02-0	8	
n-Nitrosodiphenylamine	86-30-6	8	
Octachlordibenzo-p-dioxins	3268-87-9	8	
Octachlorodibenzofurans	39001-02-0	8	
Octachlorostyrene	29082-74-4	11	
Pendimethalin	40487-42-1	5	penoxalin; prowl
Pentachlorobenzene	608-93-5	11	
Pentachlorodibenzo-p-dioxins	36088-22-9	8	
Pentachlorodibenzofurans	30402-15-4	8	
Pentachlorophenol	87-86-5	5	
Perylene	198-55-0	10	
Phenanthrene	85-01-8	1	
Phenol	108-95-2	9	
Polychlorinated biphenyls	NA	8	
Aroclor-1232	11141-16-5	8	
Aroclor-1242	53469-21-9	8	
Aroclor-1248	12672-29-6	8	
Aroclor-1254	11097-69-1	8	
Aroclor-1260	11096-82-5	8	
Aroclor-1262	37324-23-5	8	
2,2',3,4,5,5',6-heptachloro-1,1'-biphenyl	52712-05-7	8	
hexachloro-1,1'-biphenyls	26601-64-9	8	
2,2',3,3',4,4'-hexachloro-1,1'-biphenyl	38380-07-3	8	
2,2',3,4,4',5'-hexachloro-1,1'-biphenyl	35065-28-2	8	
2,2',3,4,5,5'-hexachloro-1,1'-biphenyl	52712-04-6	8	
2,2',4,4',5,5'-hexachloro-1,1'-biphenyl	35065-27-1	8	
2,2',4,4',6,6'-hexachloro-1,1'-biphenyl	33979-03-2	8	
pentachloro-1,1'-biphenyls	25429-29-2	8	
2,2',3,4,5'-pentachloro-1,1'-biphenyl	38380-02-8	8	
2,2',3,5',6-pentachloro-1,1'-biphenyl	38379-99-6	8	
2,2',4,5,5'-pentachloro-1,1'-biphenyl	37680-73-2	8	
2,3',4,4',5-pentachloro-1,1'-biphenyl	31508-00-6	8	
2,2',3,3',4,4',5,5'-octa-			

chloro-1,1'-biphenyl	35694-08-7	8	
Tetrachloro-1,1'-biphenyls	26914-33-0	8	
2,2',3,5'-tetrachloro-1,1'-biphenyl	41464-39-5	8	
2,2',4,5'-tetrachloro-1,1'-biphenyl	41464-40-8	8	
2,2',6,6'-tetrachloro-1,1'-biphenyl	15968-05-5	8	
2,3',4,4'-tetrachloro-1,1'-biphenyl	32598-10-0	8	
2,3,4,5-tetrachloro-1,1'-biphenyl	33284-53-6	8	
2,3',4',5-tetrachloro-1,1'-biphenyl	32598-11-1	8	
2',3,4-trichloro-1,1'-biphenyl	38444-86-9	8	
Pyridine	110-86-1	5	
Selenium	7782-49-2	1	
Silver	7440-22-4	5	
Silvex (2,4,5-TP)	93-72-1	5	fenoprop; 2,4,5-TP
Styrene	100-42-5	8	
1,2,3,4-Tetrachlorobenzene	634-66-2	1	
1,2,3,5-Tetrachlorobenzene	634-90-2	1	
1,2,4,5-Tetrachlorobenzene	95-94-3	5	
Tetrachlorodibenzo-p-dioxins	41903-57-5	8	
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6	8	2378-TCDD, "dioxin"
Tetrachlorodibenzofurans	55722-27-5	8	
1,1,2,2,-Tetrachloroethane	79-34-5	8	
Tetrachloroethylene	127-18-4	8	
Thallium	7440-28-0	4	
Toluene	108-88-3	7	
Toxaphene	8001-35-2	8	
Tribromomethane	75-25-2	5	bromoform
1,2,3-Trichlorobenzene	87-61-6	1	
1,1,1-Trichloroethane	71-55-6	8	
1,1,2-Trichloroethane	79-00-5	8	
Trichloroethylene	79-01-6	8	
2,4,5-Trichlorophenol	95-95-4	1	
2,4,6-Trichlorophenol	88-06-2	8	
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)	93-76-5	5	2,4,5-T
2,4,5-Trichlorotoluene	6639-30-1	1	
Trifluralin	1582-09-8	5	
Uranium	7440-61-1	5	
Xylenes	1330-20-7	9	
o-Xylene	95-47-6	9	
m-Xylene	108-38-3	9	
p-Xylene	106-42-3	9	

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GREAT LAKES WATER QUALITY AGREEMENT ANNEX 1 LIST NO. 1; 1989 ISSUE
KEY TO SYMBOLS

NA = Not Available

LISTING TRIGGER: This refers to the category within the Standard Methods which resulted in the chemical being placed on List No.1. A chemical may be eligible for placement due to one or more triggers; the one listed is not necessarily the most important toxicological effect of the chemical. See the Standard Methods (draft 11/30/89) for the toxicity trigger level associated with each of the below categories:

1. Acute aquatic toxicity
2. Acute mammalian toxicity
3. Chronic aquatic toxicity
4. Chronic plant toxicity
5. Chronic mammalian toxicity
6. Chronic terrestrial non-mammalian toxicity
7. Teratogenicity
8. Carcinogenicity
9. Adverse reproductive effects
10. Mutagenicity
11. Bioaccumulation

* Placed on the List based upon parent chemical toxicity, for the purposes of grouping

APPENDIX E: DESCRIPTIONS OF U.S. GREAT LAKES AREAS OF CONCERN[9]

Lake Superior

(1) **St. Louis River.** The St. Louis River is 171 miles long, with its headwaters in Minnesota, emptying into Lake Superior, forming the boundary between Wisconsin and Minnesota for the lower 23 miles. The AOC includes the near-shore waters of southwestern Lake Superior, all of the Duluth-Superior Harbor, and upstream past the City of Cloquet. Land use is residential, recreational, and industrial, including shipping and pulp and paper mills.

The following contaminants are found in bottom sediments and have impaired fish consumption, as well as swimming and other water contact sports:

Problems:	Sources:
■ Organic Chemicals	■ Past and present industrial discharges
■ Heavy Metals	■ Municipal combined sewer overflows
■ Cyanide	■ Municipal treatment plant waste water
	■ Stormwater and agricultural runoff
	■ Contaminated ground water, surface water, and sediments
	■ Atmospheric deposition

(2) **Torch Lake.** Torch Lake is located on the southern shore of Lake Superior in the State of Michigan's upper peninsula. The entire lake is the AOC, including the shoreline. The land around the AOC is primarily forested now, and copper mining and processing were prevalent in the area until 1968.

Lake sediments are contaminated with the following contaminants, resulting in impaired fish consumption and degraded benthic organisms.

Problems:	Sources:
■ Heavy metals	■ Tailings Copper mine tailings deposited in the lake
■ Organic chemicals	

(3) **Deer Lake, Carp Creek, Carp River.** Located in the upper peninsula of Michigan northwest of Ishpeming, Deer Lake is near the shore of Lake Superior. The lake is connected to Lake Superior by Carp River, and fed by Carp Creek. The AOC includes Deer Lake, the Carp River and Carp Creek. Land use around the area is primarily forestry, however, iron ore and gold mining activities took place in the past. Sediments in the surface water are contaminated, impairing fish consumption, water, and aquatic wildlife.

Problems:	Sources:
■ Heavy metals	■ Past mining industry
	■ Ishpeming wastewater treatment plants

[9] Information presented in this section was drawn from the 1989 IJC Report on Great Lakes Water Quality: Appendix A, and from Great Lakes Areas of Concern Fact Sheets prepared by the Center for the Great Lakes.

Lake Huron

(1) **Saginaw Bay, Saginaw River.** On the western shore of Lake Huron, Saginaw River is 52 miles long and between 13-26 miles wide. Saginaw River accounts for about 75% of the water which drains into Saginaw Bay. The AOC includes the entire River and Bay. Over half the region's land use is agricultural. The constituents below have contaminated sediments, and increased the level of nutrients which leads to a growth in undesirable algae, a threat to fish consumption, and adverse effects on wildlife and their habitat.

Problems:

- PCBs
- Nutrients

Sources:

- Contaminated sediments
- Agricultural runoff
- Combined sewer overflows
- Urban runoff
- Atmospheric deposition
- Past industrial discharges
- Municipal wastewater treatment plants
- Industrial discharges

Lake Michigan

(1) **Manistique River.** The Manistique River is located in Upper Peninsula Michigan, and flows northeast into Lake Michigan at the City of Manistique. The AOC includes 1.7 miles of the river from the dam in Manistique to the harbor. Land use within the AOC is primarily residential and industrial.

The following contaminants have contaminated sediment and ground water and surface runoff into the river, impairing fish consumption.

Problems:

- Heavy metals
- PCBs

Sources:

- Paper products manufacturing

(2) **Menominee River.** The Menominee River borders Upper Peninsula Michigan and northeastern Wisconsin. The main portion flows between the cities of Menominee and Marionette and into Green Bay. The AOC includes the lower three miles of the river up to the second Scott Paper Company dam, the cities of Marionette and Menominee, and the nearshore area of Green Bay extending three miles from the river mouth. Land use is primarily industrial and residential.

The contaminants below have been found in sediments and ground water beneath the AOC, causing adverse affects on fish consumption, navigation, aesthetics, and water recreational activities.

Problems:

- PCBs
- Arsenic and other heavy metals
- Oil and grease

Sources:

- Combined sewer overflows and sewage bypassing
- Industrial discharge such as chemical companies

- Urban runoff
- Coal and salt pile runoff
- Contaminated ground water

(3) **Fox River/Southern Green Bay.** The Fox River is located in northeastern Wisconsin at the southern end of Green Bay. The AOC covers approximately 20 square miles and includes: the City of Green Bay, the lower 7 miles of the Fox River, and the southern end of Green Bay extending north to Long Tail Point and Point au Sable. Land use is highly industrial and agricultural, with the largest concentration of pulp and paper mills in the world.

A significant number of contaminants have been found in sediments, surface water, and ground water, causing adverse affects on wetlands and other critical habitats; water and terrestrial wildlife; underwater plants; shore and water use; water recreational activities; and navigation. In addition, these contaminants have caused an imbalance in the food chain around the AOC.

Problems:

- PCBs and other organic compounds
- Pesticides
- Heavy metals
- Phosphorus

Sources:

- Pulp and paper mills and other industrial discharges
- Municipal sewage
- Agricultural and urban runoff
- Contaminated sediments

(4) **Sheboygan River.** The Sheboygan River feeds into Lake Michigan at the City of Sheboygan, Wisconsin. The AOC consists of the lower 14 miles of the river from the Sheboygan Falls and includes Sheboygan Harbor. Land use is industrial and residential, but the headwaters and tributaries of the Sheboygan River flow from agricultural areas west of the city.

The following contaminants have contaminated wildlife, sediments, ground water and surface water, impairing fish consumption, water recreational activities, and wildlife habitat.

Problems:

- PCBs
- Heavy metals
- Phosphorus and organic compounds
- Fecal coliform

Sources:

- Industrial discharge
- Agricultural and urban runoff
- Contaminated sediment

(5) **Milwaukee Estuary.** The Milwaukee Estuary AOC, also referred to as the Milwaukee Harbor AOC, is located near Milwaukee, Wisconsin. The AOC includes the lower 3.2 miles of the river, the lower 2.5 miles of the Menominee River, and the lower 2.5 miles of the Kinnickinnic River. Land use is primarily industrial, and contains large shipping and port facilities. Other uses include residential and commercial districts along the river. Sediment and water quality problems have been identified in the AOC, as a result of the following contaminants. These contaminants have impaired fish and wildlife consumption, recreational activities, navigation, and aesthetics.

Problems:

- PCBs
- Heavy metals

Sources:

- Industrial discharge
- Municipal wastewater

- Phosphorus and organic compounds
- Contaminated sediments
- Low levels of oxygen
- Bacteria
- Nutrients
- treatment plants
- Combined sewer overflows
- Urban and storm sewer runoff
- Impoundment area for dredged sediment

(6) **Waukegan Harbor.** Waukegan Harbor is located approximately 37 miles north of Chicago. The AOC consists of the entire harbor, approximately 37 acres in size. Land use around the harbor is primarily industrial and commercial.

The following contaminants found in soil and harbor sediments have impaired fish consumption and navigation.

Problems:

- PCBs

Sources:

- Outboard Motor Company plant

(7) **Grand Calumet River, Indiana Harbor Canal.** The Grand Calumet River is 13 miles long, and flows through the heavily industrialized cities of Gary, East Chicago, and Hammond in northwest Indiana. The AOC includes the east branch of the river, a small portion of the west branch, and the entire Indiana Harbor Canal. Land use is primarily industrial and residential.

Sediments and water are contaminated with the following contaminants, impairing water recreational activities, industrial water supplies, fish consumption, and navigation.

Problems:

- PCBs and organic compounds
- Heavy metals
- Fecal coliform bacteria

Sources:

- Industrial and municipal wastewater discharge
- Combined sewer overflows
- Contaminated sediment
- Highway and industrial runoff
- Leachate and ground water from waste sites
- Atmospheric deposits
- Illegal dumping

(8). **Kalamazoo River.** The Kalamazoo River is located in southwestern Michigan, and discharges into Lake Michigan near the City of Saugatuck. The AOC includes the lower 28 miles of the river. Land upstream of the AOC is heavily industrialized, including several large paper companies.

Fish, water, and sediment contains the following contaminants, impairing fish consumption.

Problems:

- PCBs

Sources:

- Contaminated sediment
- Impoundment area for dredged sediment

(9). **Muskegon River.** Muskegon Lake is on the eastern shore of Lake Michigan near the City of Muskegon, separated from Lake Michigan by large sand dunes. The entire lake is the AOC. Land use in its watershed is primarily residential and industrial, with chemical companies, and foundries.

Sediment and water contain the following contaminants, impairing fish consumption.

Problems:	Sources:
■ PCBs	■ Contaminated sediments
■ Heavy metals	■ Ground water contamination
	■ Industrial and municipal discharge
	■ Storm sewer drainage

(10). White Lake. White Lake is located near the eastern shore of Lake Michigan just north of the City of Muskegon. The AOC includes the entire lake and a .25 mile-wide zone around the lake. Land use is primarily recreational and agricultural, however, there is some residential and industrial activity.

The primary problem is contaminated ground-water containing the following contaminants. This contamination is impairing fish consumption and drinking water.

Problems:	Sources:
■ PCBs	■ Municipal wastewater treatment discharge
■ Heavy metals	■ Industrial and chemical company discharge
■ Phosphorus	■ Contaminated ground water
■ Organic chemicals	■ Urban runoff and combined sewer overflows
■ Chloroform	■ Contaminated sediment

Lake Erie

(1). Clinton River. The Clinton River is located just north of Detroit, Michigan and flows into Lake St. Clair. The AOC includes a spillway at the mouth and the main branch of the river, downstream of Red Run. Land use within the AOC is entirely urban, and on the north branch is agricultural.

Sediment and water contains the following contaminants, impairing fish and river bottom aquatic wildlife communities.

Problems:	Sources:
■ PCBs	■ Municipal and industrial discharge
■ Heavy metals	■ Urban and agricultural runoff
■ Pesticides	■ Contaminated sediments
■ Phosphorus and organic matter	■ Contaminated ground water

(2). Rouge River. Rouge River flows into the Detroit River at Zug Island in southeastern Michigan. Over 400 lakes and ponds and many tributaries flow into the river's four main branches. The AOC includes the entire river basin. Land use in the river basin is used for housing, commerce, or industry.

Sediment and water contains the following contaminants, impairing fish consumption, water recreational activities, navigation, and industrial and agricultural water supplies.

Problems:	Sources:
■ PCBs	■ Combined sewer overflows
■ Heavy metals	■ Urban runoff
■ Organic chemicals	■ Hazardous waste sites
■ Bacteria	■ Contaminated sediment
■ Habitat loss	■ Municipal and industrial discharge

(3). **Raisin River.** The Raisin River is located southeastern Michigan, and discharges into Lake Erie at Monroe Harbor. The AOC includes the lower 2.6 miles of the river, from the dam No. 6 through the harbor and one-half mile into Lake Erie, Plum Creek which discharges to Lake Erie through a canal, and from the north end of Sterling State Park to one-half mile south of Dunbar Road on the south bank of Plum Creek. Land use is residential and industrial, including metal, steel, paper, chemical, and food processing industries.

The following contaminants have been found in sediment, water, and fish, impairing fish consumption, drinking water, and navigation.

Problems:	Sources:
■ PCBs	■ Municipal and industrial landfills and waste piles
■ Heavy metals	■ Contaminated ground- and surface-water
■ Oil and grease	■ Contaminated sediment

(4). **Maumee River.** The Maumee River, the largest tributary to Lake Erie, is located in northwestern Ohio. The AOC includes the lower 20.5 miles of the river, Maumee Bay, the area near the shore of Lake Erie southeast of the mouth, and the lower segments of several tributaries to the river and bay. Land use is industrial, agricultural and includes the City of Toledo.

The following contaminants have been found in water and sediment, impairing habitats for fish, plants, and other organisms, navigation, aesthetics, industrial and agricultural supplies, and water recreational activities.

Problems:	Sources:
■ PCBs	■ Contaminated sediments
■ Heavy metals	■ Municipal sewage treatment plants
■ Phosphorus and organic	■ Agricultural and urban runoff
■ Fecal coliform bacteria	■ Combined sewer overflow
	■ Municipal and industrial discharge
	■ Municipal and industrial landfills and impoundments

(5). **Black River.** The Black River flows into Lake Erie between the cities of Cleveland and Sandusky at the City of Lorain. The AOC includes Lorain Harbor and the portion of the river flowing between Lorain Harbor and the city of Elyria, which lies approximately 15.5 miles upstream.

Sediment and water contain the following contaminants, impairing fish consumption, navigation, and water recreation activities.

Problems:

- Heavy metals
- Organic chemicals
- Decreased oxygen levels
- Increased water temperature

Sources:

- Municipal wastewater treatment plants
- Industrial discharge
- Municipal landfills
- Agricultural runoff
- Combined sewer overflow

(6). **Cuyahoga River.** The Cuyahoga River is located in northeastern Ohio. It enters Lake Erie through the Cleveland Harbor. The AOC includes the portion of the river below the Akron Wastewater Treatment Plant, the ship channel and the shore area of Lake Erie inside the Cleveland Harbor breakwater.

The following contaminants have been found in water and sediment, impairing fish consumption, recreational activities, navigation, and aesthetics.

Problems:

- PCBs
- Organic chemicals
- Heavy metals
- Decreased oxygen levels
- Fecal coliform bacteria

Sources:

- Combined sewer overflow
- Municipal wastewater treatment plants
- Industrial discharge
- Dredging of ship canal
- Agricultural and urban runoff
- Erosion
- Contaminated ground water
- Shoreline development

(7). **Ashtabula River.** The Ashtabula River is located in the northeastern corner of Ohio and enters Lake Erie at the City of Ashtabula. The AOC includes the lower 2 miles of the river, Fields Brook which empties into the river approximately 1.5 miles upstream river's mouth, and nearshore Lake Erie.
The following contaminants are in sediment and water, impairing fish consumption, navigation, and water recreational activities.

Problems:

- PCBs
- Heavy metals
- Organic chemicals

Sources:

- Municipal wastewater treatment plants
- Industrial discharge
- Contaminated sediments
- Municipal and private landfills
- Atmospheric deposits
- Combined sewer overflows

(8). **Buffalo River.** In the southern part of the City of Buffalo, New York, Buffalo River empties into eastern Lake Erie. The AOC includes the river and the three major tributaries that feed it: Cayuga, Cazenovia, and Buffalo Creek. Land use was heavily industrial, however, steel production and oil refining stopped in the early 1980s. In addition, sediments were found to contain dyes from chemical and dye industrial dischargers. In the early 1980s, seventeen major industries were then diverted into Buffalo's municipal treatment systems.

The following substances have contaminated sediments, impairing fish consumption; navigation and water recreational activities; causing loss of fish and wildlife habitat; and degrading fish and wildlife populations.

Problems:

- PCBs
- Heavy metals
- Industrial organic chemicals
- Pesticides

Sources:

- Municipal and industrial wastewater discharges
- Combined sewer overflows
- Contaminated sediment
- Inactive hazardous waste sites

Lake Ontario

(1). **Eighteen Mile Creek.** Located in northwestern New York, the AOC is just north of the city of Lockport. The AOC includes the creek, Olcott Harbor, and the waters near the shore of Lake Ontario near Olcott.

Sediment and water has been found to contain the following contaminants, impairing fish consumption and navigation.

Problems:

- PCBs
- Heavy metals
- Organic chemicals
- Pesticides

Sources:

- Municipal wastewater treatment plants
- Industrial discharge

(2). **Rochester Embayment.** Rochester Embayment is located on the southern shore of Lake Ontario near the city of Rochester, New York. The AOC includes nearshore areas of Lake Ontario from the town of Greece to the Nine Mile Point area of the town of Webster, and the Genessee River, which flows into the Rochester Embayment. Land use is primarily industrial and residential.

Sediment and water contains the following contaminants, impairing fish consumption, water recreational activities, and aesthetics.

Problems:

- PCBs
- Heavy metals
- Organic chemicals

Sources:

- Municipal wastewater treatment plants
- Industrial discharge
- Combined sewer overflows
- Agricultural and urban runoff
- Contaminated sediment
- Inactive disposal sites

(3). **Oswego River.** The Oswego River empties into Lake Ontario near the City of Oswego, New York. The AOC includes the harbor within the breakwaters and upstream to the first barrier dam. Land use is urban and residential.

The following contaminants have been found in sediment and water, resulting in impaired fish consumption and degradation of aquatic wildlife and ecosystems.

Problems:

- PCBs
- Heavy metals
- Organic chemicals
- Nutrients

Sources:

- Municipal and industrial discharge
- Municipal wastewater treatment plants
- Combined sewer overflows
- Ground- and surface-water runoff from landfills
- Contaminated sediments

Connecting Channels

The five connecting channels of the Great Lakes are designated as international AOCs.

(1). **St. Mary's River.** The St. Mary's River flows southeast for 68 miles, connecting Lake Superior to Lake Huron. The entire river is within the AOC. Land use along the river is mostly agricultural, forestry, and residential.

Contamination problems are mostly confined to the Canadian shore, causing restrictions on water recreational activities, impairing fish consumption, and aesthetics.

Problems:

- PCBs
- Heavy metals
- Organic chemicals
- Bacterial contamination

Sources:

- Municipal and industrial discharge
- Municipal wastewater treatment plants
- Abandoned waste sites
- Contaminated sediment

(2). **St. Clair River.** The St. Clair River flows south, connecting Lake Huron to Lake St. Clair. The entire river is within the AOC. Land use differs between the Canadian side and the Michigan side. On the Ontario shoreline it is primarily industrial with petrochemical industry and refineries. Along the Michigan shoreline it is primarily agricultural.

The following contaminants are found in sediment, aquatic life, and water, impairing water recreational activities, and fish consumption.

Problems:

- PCBs
- Heavy metals
- Organic chemicals
- Bacterial contaminants
- Oil and grease

Sources:

- Industrial discharge and spills
- Storm sewers
- Industrial landfills and other waste disposal sites
- Municipal sewage treatment plants
- Combined sewer and overflows
- Agricultural and urban runoff
- Inactive deep well disposal areas
- Contaminated sediment

(3). **Detroit River.** The Detroit River is 31 miles long, connecting Lake St. Clair and Lake Erie. The AOC is found between Windmill Point and the Detroit Light. The largest tributary to the Detroit River is Rouge River, which is an AOC itself. Land use is residential, commercial and industrial, with a population of approximately four million people.

Sediment and water have been found to contain the following contaminants, impairing fish and wildlife consumption, water recreational activities, wildlife habitat, and river bottom aquatic life.

Problems:	Sources:
■ Heavy metals	■ Industrial discharge, storage and spills
■ Organic chemicals	■ Industrial and municipal wastewater discharge
■ Bacterial contaminants	■ Waste disposal sites
	■ Agricultural and urban runoff
	■ Sewage treatment plants

(4). **Niagara River.** The Niagara River flows 37 miles from Lake Erie to Lake Ontario. The entire river is within the AOC. Land use is agricultural, residential, and industrial, with textile production, paper product production, and metal fabrication.
The problems identified below have impaired fish consumption. Additional contaminants, sources, and impairments will be determined as a cleanup plan is developed.

Problems:	Sources:
■ PCBs	■ Industrial discharge
■ Heavy metals	■ Municipal wastewater treatment plants
■ Organic chemicals	■ Industrial and municipal landfills
■ Pesticides	■ Urban runoff
■ Cyanide	

(5). **St. Lawrence River.** The St. Lawrence River leads to the St. Lawrence Seaway which extends to the Atlantic Ocean. The AOC centers around Massena, New York, but includes areas on the Ontario shore near Cornwall and Maitland, and includes Lake St. Francis immediately downstream of Cornwall. Land use in the AOC is primarily residential, commercial, and industrial. The following contaminants have been found in sediment and water, impairing fish consumption and water recreational activities.

Problems:	Sources:
■ Heavy metals	■ Industrial discharge
■ Organic chemicals	■ Municipal wastewater treatment plants
	■ Combined sewer overflows
	■ Hazardous waste sites

APPENDIX F: NUCLEAR RELEASES

This discussion focuses on human health and ecological risk posed by the potential for releases from the 15 nuclear power plants in the Great Lakes Basin.[10] Nuclear power plant accidental releases are a high impact, low probability event. These releases can be caused by a single catastrophic event or a combination of several minor events. For example, six core meltdown accident types have been identified for the Zion nuclear power plant by the Nuclear Regulatory Commission (NRC) including:[11]

- Station blackout;
- Loss of coolant accident;
- Component cooling water and service water induced reactor coolant pump seal loss of coolant accident;
- Anticipated transients without scram accident;
- Interfacing system loss of coolant accident and steam generator tube rupture; and,
- Transients other than station blackout.

The most likely event is a malfunction of the cooling system, which accounts for more than 75 percent of the probability of core damage. The extent of damage from a nuclear power plant release is dependent upon:

- The extent and magnitude of the radiation emission;
- The number of people within range of the radiation;
- The vulnerability of the ecosystem affected by radiation; and
- The amount of radiation taken internally by humans, animals,and plants through ingestion of radioactive food and water.

Human Health Risk Assessment

Ionizing radiation refers to radiation that strips electrons from atoms in the medium through which it passes. The adverse effects of exposure to ionizing radiation, and hence of radioactive materials, are carcinogenicity, mutagenicity, and teratogenicity. From the perspective of total societal risk, cancer inducing and genetic mutations are believed to be stochastic effects; i.e., the probability of these effects and the risk of the occurrence increases with dose, but the severity of the effect is independent of the dose. Furthermore, there is no convincing evidence of a threshold of exposure below which the risks are zero. Evidence of the deleterious effects of exposure to ionizing radiation comes from both human epidemiology and animal studies.

The unit used in radiation dose assessment is the rad (radiation absorbed dose). One rad is the dose corresponding to the absorption of 100 ergs per gram of tissue. Since not all forms of ionizing radiation produce the same effect per rad, the rem is used as the unit of dose equivalence. For materials taken into the body, the dose will be delivered over the period that the material remains in the body. Thus, the convention has been established to integrate the dose over the entire period that the material will remain in the body and assign the total dose to the year of exposure, resulting in the committed dose equivalent (rem). Finally, since irradiation of the organs and tissues of the body may

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[10]Nuclear power plant radiation data were not available for this study for the New York and Pennsylvania portions of the Great Lakes Basin. Consequently, actual risk factors as estimated by the Nuclear Regulatory Commission are presented for Indiana, Illinois, Michigan, Minnesota, Ohio, and Wisconsin, while best professional judgment estimates of exposure levels are provided for nuclear power plants in New York and Pennsylvania.

[11]U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research. Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants. Summary Report Volume 1.

not be uniform, the radiation protection community has introduced the concept of the effective dose equivalent (rem EDE). The EDE is calculated by weighting the doses received by the various organs by risk based factors and then summing the weighted organ doses to derive the EDE. The collective population exposure is given in person-rem EDE and is derived by simply summing the exposures of the individuals in the population. In this report, the doses are given in rem or millirem EDE for individuals and person-rem EDE for populations. The quantification of radiation exposures and resulting cancer risks are based on the following estimates:[12]

Lifetime exposure to 3 mrem/year EDE = 1×10^{-3} lifetime fatal cancer risk;

1×10^{5} person-rem/year EDE = 400 fatal cancers/year; and

Total Cancer Incidence/Fatal Cancer Incidence = 2, a 50 percent mortality rate once a cancer has been expressed.

The risk factors used in this report are consistent with those used by the EPA in the recent radionuclide NESHAPS rulemaking.[13] They are based on a linear extrapolation of the dose response exhibited by the Japanese A-bomb survivors (rather than from a nuclear accident) and other epidemiologic data using the relative risk projection model and assuming that there is no risk threshold. The EPA believes that the estimated fatal cancer risk of 400 per 1×10^{5} person-rem EDE represents a best estimate, and that the actual risks likely lie within the range of 120 to 1,200 fatal cancers per 1×10^{5} person-rem EDE. For radiation exposure to the whole body, as is thought to occur in a nuclear accident, the total incidence of cancer does not exceed the incidence of fatal cancer by more than a factor of two. The risk coefficient has been extrapolated from high dose and high dose rates. At the lower doses, the current consensus of scientific opinion is that no zero risk threshold exists.

The EPA's Office of Radiation Programs has estimated the exposures to both nearby individuals and the populations within 80 km of nuclear power plants under likely nuclear contaminant failure scenarios.[14] The estimates that are presented in Table 1 are derived from EPA's estimates and only include exposure to emissions released to air. Exposure to radioactive materials via liquid pathways is not estimated, but is roughly comparable to exposures to radioactive materials released to air from industrial sources. Additionally, these estimates only represent commercial nuclear power plants in the Basin and do not include Department of Energy or Department of Defense facilities which also release radiation or other manmade enhanced sources.

The estimates for exposure of the general population to industrial sources are based on both site-specific assessments and extrapolations from reference facilities. Where reference facilities provide the basis, the site name is marked with an asterisk. For actual facilities, the exposure of the maximally exposed individual reflects either an actual off-site residence, or the fencepost exposure reference facilities where enhanced radiation is used. The maximum exposure is based on an individual assumed at a close location in the predominant wind direction. Where the original assessment used a reference facility, collective populations are estimated using the generic population distributions that were assessed and the number of facilities in the Basin. If the projected population obtained in this manner exceeded the Basin population, the population at risk was constrained to the regional population.

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[12]U.S. Environmental Protection Agency, Environmental Impact Statement--NESHAPS for Radionuclides: Background Information Document Volume I: Risk Assessment Methodology, EPA 520/1-89-005, Office of Radiation Programs, September, 1990.

[13]Ibid.

[14]This estimate is in direct contradiction to the NRC's safety goals which estimate early fatality risk within one mile of the site and latent cancer fatality risk within 10 miles of the site.

TABLE 1

INDUSTRY/ SITE	AVERAGE EXPOSURE in rem/year	POPULATION AT RISK	EXPOSURE in person-rem/ year	FATAL CANCERS PER YEAR	TOTAL CANCERS PER YEAR*
Zion 1	0.0002	5898100	1179.62	4.72	9.44
Zion 2	0.0002	5898100	1179.62	4.72	9.44
Cook 1	0.0002	318200	63.64	0.25	0.51
Cook 2	0.0002	318200	63.64	0.25	0.51
Fermi 2	0.0002	4098200	819.64	3.28	6.56
Palisades	0.00009	329800	29.68	0.12	0.24
Davis-Besse 1	0.00009	579100	52.12	0.21	0.42
Perry 1	0.0002	1928500	385.70	1.54	3.09
Point Beach 1	0.0002	310700	62.14	0.25	0.50
Point Beach 2	0.0002	310700	62.14	0.25	0.50
Big Rock Point	0.0002	91000	18.20	0.07	0.15
**Kewaunee	0.0002	26900	5.38	0.02	0.04
**Fitzpatrick	0.0002	216900	43.38	0.17	0.35
**Nine Mile Point 1	0.0002	216900	43.38	0.17	0.35
**Ginna	0.0002	216900	43.38	0.17	0.35
TOTAL				16.21	32.41

* Does not include occupational exposures for power plant workers.

** Best professional judgment estimates for average exposure at these plants.

Ecological Risk Assessment

The adverse effects associated with low-levels of radioactivity in the environment include cancer, genetic effects and birth defects. Such effects, even if extremely rare or undetectable, are of concern to humans. However, for organisms other than man, the concern is not with individual organisms, but with the viability of the species and the function and structure of the ecosystem as a whole. The following briefly summarizes current research which has demonstrated that low level radiation may be considered inconsequential in terms of its potential ecological effects. However, a short term high level dose may have considerable impact on certain ecosystems.

During the 1960s and 1970s, a vast amount of radiobiological research was performed to assess the impacts of radiation on plant and animal communities. The research included a large number of comprehensive laboratory and field studies motivated primarily by concern over fallout from weapons tests. A literature review was prepared by the Office of Radiation Programs in 1986.[15]

Overall, it appears that prolonged exposures to ecosystems below a few rad per day, results in no detectable adverse ecological impacts. Though the community interactions to prolonged exposures to ionizing radiation are complex and difficult to predict, doses on the order of several hundred rads per year would be needed to cause extinction of a species. Such exposures can occur following a major nuclear accident, but are not associated with the production and use of radioactive materials. Nor are they associated with uncontrolled sites where previous activities have resulted in contamination of the site. It should also be noted that welfare impacts are high for ground-water clean up as well as species preservation, should a mid-level accident occur.

Welfare Assessment

The potential welfare effects associated with radiation exposure can be divided into two broad categories:

- costs associated with effects on human health, and
- costs associated with commercial damage.

The costs associated with health effects include direct medical costs and low productivity due to the inability to conduct normal work activities. The 1988 Cancer Facts and Figures, published by the American Cancer Society, estimates that for 1985 the total economic cost of cancer was $71.5 billion. This includes direct medical costs and indirect costs associated with lost productivity. The American Cancer Society estimates that there were 985,000 new cases of cancer in the United States in 1988. Over the past 30 year period, the per capita age adjusted cancer death rate has increased at a rate of less than one percent per year; therefore, the estimate of 985,000 cancers can be used to estimate the approximate cost per cancer. Escalating the cost by 7.5 percent per year for health care service costs and assuming the cancer incidence remains virtually unchanged, results in an economic cost per cancer case in 1990 dollars of approximately $100,000 on average. The lower bound estimate based on Hartunian, et al is $80,000.00, while the upper bound estimate given by the American Cancer Society is $137,000.00.

Health care costs estimate can be obtained using the following formula:

(Annual Cancer Cases)(Direct Costs and Foregone Earnings) = $Health Costs.

As described above, the total number of cancers in the Basin that result from nuclear power plant operations and likely release scenarios is 32.41. The upper and lower bound costs resulting from these releases are as follows:

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[15]U.S. Environmental Protection Agency, Effects of Radiation on Aquatic Organisms and Radiobiological Methodologies for Effects Assessment, EPA 520/1-85-016, Office of Radiation Programs, Washington, D.C., February, 1986.

The lower bound estimate is:

(32.41)($80,000) = $2,592,800.00

The upper bound estimate is:

(32.41)($137,000) = $4,401,700.00

The costs associated with commercial damage caused directly by radiation are variable. The contamination of facilities and sites where radioactive materials have been or are produced and used, can result in considerable cleanup costs. For commercial facilities, the costs of decontaminating and decommissioning the facilities and the sites are reflected in the costs of the products or services. For sites owned by government agencies, the costs will be borne by the taxpayers. Restoration of the sites operated for the Department of Energy has been intimated. Current estimates place these restoration costs in the hundreds of billions of dollars. Whether or not such costs will actually be incurred is uncertain at this time, and no estimate is made of the costs on a Basinwide basis.

APPENDIX G: MERCURY TRENDS IN THE GREAT LAKES BASIN

This section addresses the trends in mercury concentrations in the Great Lakes Basin and the resulting potential effects of mercury contamination. Historical trends indicate that mercury concentrations have been increasing in fish and sediments from inland lakes in Michigan, Minnesota, and Wisconsin. These increases have been attributed to atmospheric deposition of mercury.

Problem Area Description

Mercury can cause adverse effects on human health and ecological receptors at low concentrations, although the toxicity of mercury is dependent on its chemical state. Exhibit AH-1[16] presents the chemical forms of mercury and their principal characteristics.

EXHIBIT AH-1

CHEMICAL FORMS OF MERCURY

Molecular Form	Chemical and Biochemical Properties
Hg	Elemental mercury. The vapor is highly toxic when inhaled; less toxic via direct ingestion.
Hg^{+}	Mercurous ion. Insoluble as the chloride; low toxicity.
Hg^{2+}	Mercuric ion. Highly toxic via ingestion and inhalation routes; may be converted to methyl mercury.
RHg^{+}	Organomercurials. Extremely toxic, especially CH_3Hg^{+} (methyl mercury); causes irreversible nerve and brain damage; easily transported across biological membranes; stored in fat tissue.
R_2Hg	Diorganomercurials. Moderately toxic but often converted to RHg^{+}.
HgS	Mercuric sulfide. Highly insoluble and nontoxic. Mercury is trapped in soil in this form.

As presented in the exhibit, some forms of mercury may pose lower toxicity because they are insoluble and therefore are not readily absorbed. However, in aquatic environments, the most toxic form of mercury, methyl mercury, if often produced from elemental mercury.[17] For instance, elemental mercury can be oxidized to mercuric ion. Bacteria found in sediments then transform this inorganic mercury into methyl and dimethyl mercury. These compounds are highly toxic and bioconcentrate readily in the aquatic food chain to a greater degree than do their inorganic precursors.

Historically, principal wastewater sources of mercury pollution in the Great Lakes Basin have been paper mills and

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[16] Spiro, T.G. and W.M. Stigliani, 1980. Environmental Science in Perspective, p. 204.

[17] EPA, 1984, Ambient Water Quality Criteria for Mercury. Office of Water Regulations and Standards. EPA440/5-84-026, PB85-227452.

chloralkali plants. The combustion of fossil fuels, particularly coal, is considered to be a primary source of atmospheric mercury.[18] Other atmospheric sources are mining and smelting operations, involving mercury and copper ore, and solid waste incineration.[19] Some analyses have reported that mercury from paint was a major atmospheric source. In 1990 EPA banned the use of mercury in indoor paints, and is phasing out all mercury in outdoor paints. The weathering of rocks containing mercury also provides a background level of mercury in aquatic systems.[20]

Magnitude of the Problem

The existence of high concentrations of mercury poses a number of threats to human health and the environment in the Great Lakes Basin. Among these threats are:[21]

- human nerve and brain damage from exposure to bioconcentrated levels of mercury in fish and other game species;
- restrictions on fish and wildlife consumption;
- restrictions on dredging;
- degradation of fish and wildlife populations;
- deformities and other reproductive problems in birds or animals feeding on fish (bald eagle, osprey, loon, mink and otter)
- lower species diversity.

The typical pathway of exposure to methyl mercury is from mercury deposited to waters, from either atmospheric or point sources, which then settles to sediments where the methylation process described above occurs. The resulting methyl mercury is then bioaccumulated and passed up the food chain in ever increasing concentrations. The bioconcentration factor has been estimated to be about 80,000.[22] As top predators, large game fish and humans are ultimately exposed to the highest mercury concentrations.

Point source discharges of mercury in the Basin are tracked through EPA's Permit Compliance System (PCS). Although the available data do not support a detailed analysis, the lower Great Lakes appear to receive a higher load of mercury releases from municipal sources (See Exhibit H-1). Mercury discharged from municipal sources to Lakes Michigan and Erie represents 95 percent of the mercury discharged to the entire Great Lakes Basin.

A second indicator of current and past mercury loadings is the sediment concentrations of mercury observed in the Basin. STORET 405b data summarizing sediment concentrations were obtained from sampling stations located in 32 harbors throughout the Basin. The average mercury concentration for all locations is 0.63 ppm. The maximum value, 24.0 ppm, was reported in Erie County, New York. Wayne County, Michigan, which includes the Detroit area, recorded several mercury concentration readings of 3.00 ppm to 3.60 ppm. Brown County, Wisconsin, which includes Green Bay, reported concentrations ranging from 0.40 ppm to 3.00 ppm.

As expected, those areas reporting higher point discharges of mercury also exhibit higher sediment concentrations of mercury, with urban areas around Lake Erie and its connecting channels, such as Buffalo, Cleveland and Detroit

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[18] Lindberg, S.E., 1984. Emission and Deposition of Atmospheric Mercury. Oak Ridge National Laboratory. DE95006304.

[19] EPA, 1987. Toxic Air Pollution/Source Crosswalk, EPA 450/4-87-023a.

[20] Gavis, J., Ferguson, J.F. 1972. The Cycling of Mercury Through the Environment, Water Res., 6:986-1008.

[21] Agency for Toxic Substances and Disease Registry, Toxicological Profile for Mercury, Dec., 1989.

[22] Op Cit., EPA, 1984.

exhibiting high sediment concentrations, along with the Green Bay area on Lake Michigan.

The significance of these sediment concentrations can best be assessed by observing the resulting bioaccumulation impacts on Great Lakes Basin fish. Mercury contamination was found in virtually all areas sampled for fish, with levels ranging from 0.1 ppm to over 0.4 ppm.[23] This is not unexpected given the high sediment mercury levels reported in most of the sampled areas. The area with the lowest mercury levels was Isle Royale, located in a remote area of Lake Superior, which had fish samples with mercury levels below 0.1 ppm. In contrast, fish samples taken in the Green Bay area showed higher concentrations with mercury levels greater than 0.4 ppm. These figures generally coincide with the patterns observed in mercury discharge levels from point sources and sediment concentrations.

Most recently, there have been reports suggesting an upward trend for mercury in fish. Studies conducted on fish from lakes in upper Minnesota show mercury concentrations increasing 5% per year since the 1970s.[24] Similarly, sediment concentrations have shown a three fold increase since the early 1800s.[25] The lakes chosen for study have no known point sources of mercury. A survey of 80 lakes revealed mercury concentrations averaging 2.5 ppt mercury.[26] In contrast, fish collected from Minnesota rivers during the 1970s were reported to show a decline, attributed to increased regulation of point sources.[27]

These findings indicate that the atmosphere is a significant source of mercury. Research conducted in northern Wisconsin Lakes has also shown that mercury concentrations are greatest in the uppermost portion of sediment cores.[28] It is not clear if atmospheric input of mercury has been increasing over the past decade. Atmospheric inputs in Minnesota are reported to be in the range of 18-26 ug/m^2 yr.[29] Lakes with highest levels of mercury contamination tend to be those of lower pH (less than 7.0) and lower buffering capacity.[30] A possible relationship with increasing mercury levels in fish and increases in the acidity of rain could exist. Further research, establishing trends in atmospheric loadings and lake chemistry, is needed.

Birds and mammals which consume fish, in particular, bald eagles, loons, ospreys, herons, mergansers, minks and otters, have also been shown to have elevated levels of mercury in Wisconsin.[31] This indicates that mercury is passed upward through the food chain. Research is also being conducted on fish-eating birds from Lakes in Northeastern Minnesota.

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[23] Op. Cit., EPA, 1990.

[24] Swain, E.B. and D.D. Helwig. 1989. Mercury in Fish from Northeastern Minnesota Lakes. Minnesota Pollution Control Agency.

[25] Henning, et al. 1989. Historical and Areal Depisition of Mercury in N.E. Minnesota and Northern Wisconsin Lakes. Report to the Minnesota Pollution Control Agency.

[26] Sorensen, et al. 1989. Airborne Mercury Deposition and Watershed Characteristics in Relationship to Mercury Concentrations in Water, Sediments, Plankton and Fish of Eighty Northern Minnesota Lakes. Report to the Minnesota Pollution control Agency.

[27] Op Cit., Swain and Helwig, 1989.

[28] Beasday, C.D., Personal Letter of Communication to W.K. Reilly, April 27, 1990.

[29] Op. Cit., Henning, et al., 1989.

[30] Op. Cit., Sorensen, et al., 1989.

[31] Op. Cit., Beasday, 1990.

Human Health Impacts

Due to bioaccumulation of mercury in fish, fish consumption is considered the primary threat to human health (i.e., a greater threat than drinking water consumption). The chronic oral Reference Dose for mercury is 0.0003 mg/kg-bw-day.[32] Therefore, adults may have an intake of 21 ug/per day over their lifetime without a significant potential for adverse health impacts. Risk assessments by Great Lakes State health departments have established sportfish consumption advisories from 0.16 to 0.5 ppm to assure adequate protection for heavy fish consumers, pregnant women, and children.[33] The Food and Drug Administration has established an action level of 1.0 ppm mercury for fish entering interstate commerce.[34]

Following extensive surveys of mercury in sportfish from hundreds of lakes, starting in 1989, the States of Michigan, Minnesota, and Wisconsin began expanding the number of lakes under fish consumption advisories for mercury.[35] The May, 1991 advisory for Minnesota, lists 310 (95%) of 327 inland lakes on fish advisories due to mercury. In 1990 Wisconsin placed 170 (29%) of 600 lakes on a fish consumption advisory due to elevated levels of mercury. Three out of four lakes (a total of 170) tested in Michigan were found to have mercury levels exceeding 0.50 ppm in at least one fish species, prompting the State to issue an advisory for women and children not to consume more than one meal per month of fish from all inland lakes.

For an individual consuming 150g/day of fish having 0.5 ppm of mercury, over several days or weeks, the average mercury dosage would be 0.001 mg/kg-bw-day. When compared to 14 day health advisory values of 0.001 mg/kg-bw-day derived from animal studies, no adverse impacts would be expected. For long-term exposures, and those consuming 100 g/day (upper 90% intake for sportfishermen), dosages would be 0.0007 mg/kg-bw-day. When compared to EPA's Reference Dose of 0.0001 mg/kg-bw-day, a Hazard Index of 7.0 results. This indicates increased risk for the heavy consumer of sportfish. For an average sportfishermen in the Great Lakes consuming 19 g of fish per day a Hazard Index of 1.3 results, indicating that the average sportfishermen are not at an adverse risk, as long as they follow fish advisories.

Ecological Impacts

As discussed in the introduction above, mercury contamination can cause serious ecological impacts. These impacts range from reproductive impairment and deformities in offspring to lower species diversity and other adverse ecosystem impacts. Direct aquatic toxicity from mercury appears unlikely in inland lakes as water concentrations of about 1 ppb are required before chronic effects on zooplankton and fish occur.[36] The highest values reported in Minnesota waters was 7 ppt.

However, with biomagnification, low part per trillion levels in water, result in fish concentrations of 0.1 to 1 ppm. Studies on loons and other waterfowl in Minnesota and Wisconsin indicate elevated levels of mercury, with concentrations of 20-80 ppm found in livers of diseased loons.[37] Non-diseased loongs were found to have

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[32] U.S. EPA. 1991. Integrated Risk Information System.

[33] State Fish Advisories for Minnesota, Michigan, Wisconsin, 1989-1991.

[34] Op. Cit., Agency for Toxic Substances and Disease Registry, 1989.

[35] Op. Cit., Fish advisories.

[36] Op. Cit., EPA, 1984.

[37] Personal communication with Karen Larsen of the Minnesota Pollution Control Agency, 4/19/91.

significantly lower concentrations of mercury. Threshold effects for impacts on mink occur at about 1.1 ppm in fish.[38] Hoffman[39] found that for quail, a concentration dose of 0.2 to 8 ppm of mercury in feed, caused eggshell thinning to occur. Therefore, it is clear that fish-eating wildlife are currently exposed to mercury at levels of concern.

The mercury toxicity reference values for aquatic species have been set at:

- EPA Acute Freshwater Ambient Water Quality Criteria (ug/L) = 2.4.
- EPA Chronic Freshwater AWQC (ug/L) = 0.012

(for bioaccumulation in fish and human consumption)

Summary of Human Health and Ecological Impacts

Given the high concentrations of mercury at many locations in the Great Lakes Basin, and the fact that mercury may be increasing due to atmospheric deposition, pervasive mercury levels are a current and future threat to the health of the Great Lakes Basin ecosystem and indigenous wildlife. The extensive State fish advisories for mercury in Minnesota, Michigan, and Wisconsin, affecting over 500 lakes, indicates the magnitude and significance of this emerging problem. Persons consuming large amounts of fish from inland Lakes, in particular those not following State issued fish advisories, are at increased risk of reproductive and neurological impacts. Similarly, fish eating wildlife are also subjected to these adverse health impacts from mercury. Continued research on mercury sources and trends should be considered a high priority.

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[38] Op. Cit., EPA, 1984.

[39] Hoffman, D.J. 1985. Morphological and physiological responses to environmental contaminants in bird embryos and nestlings. November 1985, SETAC Abstracts, U.S. Fish and Wildlife Research Service, Laurel, MD.