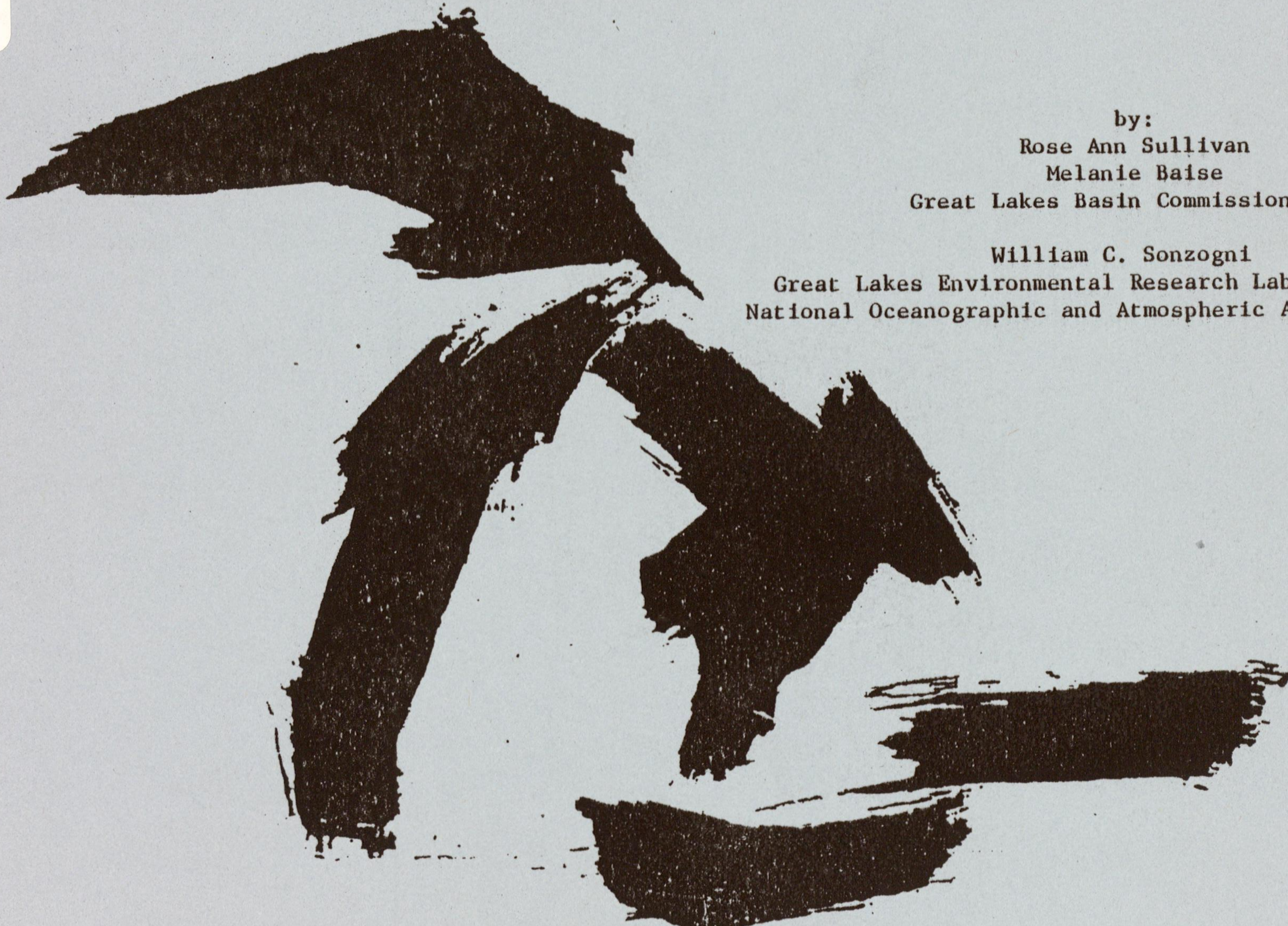
ENVIRONMENTAL QUALITY MAPS FOR THE U.S. GREAT LAKES BASIN



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Great Lakes Environmental Planning Study (GLEPS)
Great Lakes Basin Commission, Ann Arbor, Michigan
Contribution No. 41
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ACKNOWLEDGEMENTS

The authors wish to acknowledge Sandra Gregerman-Rossi, Martha Deline, and Timothy J. Monteith, of the Great Lakes Basin Commission staff, and Karen Wuestenfeld and Boguslaw Piekarski, formerly of the Basin Commission staff, for their assistance with this report. We would also like to thank Dr. Martin Auer at the Department of Civil Engineering, Michigan Technological University and all of the other scientists who participated in the *Cladophora* mapping effort. The secretarial support and graphics assistance contributed by Kelsie Raycroft and the secretarial support of Sue Leemon are much appreciated as well.

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INTRODUCTION

In 1978 the Great Lakes Environmental Planning Study (GLEPS) was initiated as a 3-year special study in support of the Great Lakes Basin Plan. The major objective of the study has been to provide insight into the cumulative long-range impacts on the Great Lakes that may result from different planning and management strategies. To accomplish this objective, studies were conducted on topics such as existing and expected future inputs of phosphorus and heavy metals to the lakes from certain sources, the potential impact of changes in water quality on fisheries, and the impacts of water conservation on the overall water quality of the lakes. By the time the study is concluded, over 50 reports will have been completed by members of different organizations to support the GLEPS work effort.

The intent of this report is to present an overview of results obtained from the Great Lakes Environmental Planning Study in a relatively simple, non-technical manner to facilitate understanding of the reasons for changes in the environmental quality of the lakes and the differences which exist between various sectors of the lakes. To accomplish this task, a great deal of information has been visually depicted in a series of environmental quality maps, located at the end of this report. The text which accompanies these maps provides a general overview of their subject matter and highlights many of the significant conclusions of previous GLEPS reports. Sources of information used in developing the maps are listed in Appendix 1.

While the focus of this effort is on the Great Lakes Environmental Planning Study, some information obtained from other studies has been included to give the reader a more comprehensive picture of Great Lakes concerns.

U.S. GREAT LAKES RIVER BASIN GROUPS AND HYDROLOGIC AREAS

Map No. 1 displays the 15 river basin groups (RBG's) and 72 hydrologic areas in the U.S. Great Lakes basin as delineated by the Basin Commission for planning purposes. Reference will be made to these subdivisions throughout this report. A complete listing of U.S. river basin groups with their hydrologic areas is included as Table 1.

GREAT LAKES POLLUTANTS

PHOSPHORUS

Of all the pollutants delivered to the Great Lakes, phosphorus has been the most intensively studied and was also the focus of GLEPS. This is because of the link between phosphorus and eutrophication. Eutrophication refers to the process of adding nutrients to water bodies and the effects of these additional nutrients (mainly increased aquatic plant productivity and oxygen depletion). Human activity is a major contributor to the excessive loading of aquatic plant nutrients to water, commonly through sewage, detergents, and agricultural fertilizers.

Cladophora

These nutrients can produce nuisance growths of algae, such as *Cladophora* (see Maps No.'s 2 to 6, Distribution of Cladophora in the U.S. Nearshore Areas of the Great Lakes) and other aquatic plants which may cause water quality problems. *Cladophora* grows attached to rocks and other suitable substrates in the nearshore waters of each of the Great Lakes. When *Cladophora* breaks off its substrate (such as after a storm) it often washes up on shore in huge masses, fouling the beaches. Unlike many recent changes in the Great Lakes environment whose relation to pollution is not always clear, growths of Cladophora can often be directly linked with pollution, particularly phosphorus enrichment.

In Lakes Erie and Ontario, the phosphorus level is generally high enough to support luxuriant growths wherever there is proper light and substrate. Cladophora is widely distributed in the disturbed nearshore areas of Lake Michigan and phosphorus concentrations in the offshore waters are approaching levels which may support growth on a lakewide basis. In Lakes Huron and Superior, where phosphorus levels are generally low, Cladophora is more of a local problem. Most heavy Cladophora growths can be attributed to a nearby source of pollution. The source may be a municipal treatment plant, an industrial discharge, drainage from an urban area, or runoff from farmers' fields. Nutrient inputs from these sources may be quite small relative to the lake as a whole, but they can influence Cladophora growth depending on where the discharge enters the lake and how quickly it is dispersed.

Biological Availability

As discussed in GLEPS Contribution No. 40, not all of the phosphorus which enters the lakes is in a form which is biologically available to sustain plant growth. Basically, the phosphorus load delivered to a lake is in two forms - soluble phosphorus and particulate phosphorus. The soluble form, as its name denotes, is dissolved in water and is essentially 100 percent available for uptake by algae and other plants. Phosphorus in the effluents from sewage treatment plants is generally in this form.

Particulate phosphorus is a solid form either attached to eroded soil particles or existing as part of organic detritus. Although this form may exceed the soluble phosphorus content by ten times or more, it is largely unavailable for biological use. Whether or not the particulate phosphorus becomes biologically available depends on a host of factors. Hence, defining the impacts that phosphorus loads from different sources have had on the lakes and their biota is a complicated problem.

TOXIC CONTAMINANTS

GLEPS also investigated toxic inputs to the lakes, particularly inputs of heavy metals. The Great Lakes appear to be especially susceptible to toxic contamination. Their susceptibility results not only from the lakes' proximity to 20 percent of the total U.S. population and 50 percent of Canada's population, but also from the limnological characteristics of the lakes, such as their long hydraulic residence times. The Great Lakes Basin Commission's Committee on Research and Development, composed of Great Lakes scientists, has labeled toxic substance contamination the current major environmental problem facing both the research and management communities.

Probably the most well known aspect of toxic contamination in the Great Lakes is the accumulation in fish of certain persistent toxic chemicals such as the class of industrial chemical, polychlorinated biphenyl (PCB), and the pesticide Mirex. Health warnings have been issued on consuming certain Great Lakes fish, and in some localities the fishery has actually been closed.

The distribution of toxic substances in Great Lakes waters is not readily mapped, since most of the contaminants of concern are found in lake water in extremely small concentrations. It is possible, however, to map the distribution of toxic contaminants in lake sediments. Lake sediments tend to be a major sink for toxic substances in the Great Lakes. Many toxic chemical contaminants associate with particulate material and are carried to the lake bottom as the particulates settle. GLEPS Contribution No. 45 investigated the geochemical character of bottom sediments in Lake Michigan. Map No. 7, Mercury Distribution in the Upper 3 Cm of Lake Michigan Sediments, is derived from one of a series of maps developed from the results of this study.

Toxic contaminants in surficial sediments may move from one area to another. For example, in the shallow waters of Lake St. Clair and western Lake Erie, bottom sediments are continually resuspended (due to wind-induced mixing) and transported down the system. Thus, the deep water areas tend to accumulate most of the sediment-associated contaminants over the long term. The deep hole deposition areas of the Great Lakes are depicted in Map No. 8.

Map No. 9 shows certain "hot spots" of toxic contamination associated with the lakes. In most cases, areas of contaminant discharges to the lakes rather than problem areas in the lakes themselves are shown. Some important contaminated harbors, such as Waukegan Harbor which contains high levels of PCBs, are depicted however.

Because the focus of this report is the work completed in GLEPS, reference in the subsequent discussions will primarily be made to the pollutants studied in GLEPS, phosphorus and heavy metals.

NONPOINT SOURCE POLLUTION IN THE U.S. GREAT LAKES BASIN

Nonpoint source pollution has become a primary concern in the Great Lakes region. Substances such as phosphorus, mercury, PCB's and other industrial organic compounds, pesticides, and sediment create water quality problems, and a large part of their input is derived from diffuse sources. The diffuse load of pollutants consists of inputs such as rural runoff, urban runoff, and combined sewer overflows. In other words, the diffuse load consists of the pollutant load not attributable to identified point sources, such as industrial or municipal sewage treatment plant discharges.

FACTORS INFLUENCING THE MAGNITUDE OF POLLUTANT LOADING TO THE LAKES

A variety of factors influence the magnitude of the land-derived pollutant load to the lakes. Three broad categories can be identified: (1) the naturally occurring physical characteristics of the land; (2) man's land use activities; and (3) meteorological conditions.

Physical Characteristics of the Land

There are a number of factors related to the natural physical characteristics of an area that affect the magnitude of the diffuse load derived from it. The most important of these is soil texture. Generally, fine-textured soils (those with a high percentage of clay) yield greater amounts of sediment and sediment-related pollutants (such as phosphorus) than do coarse (sandy) or medium-textured soils (loam). There are a number of reasons for this. Percolation and infiltration rates are generally lower in clay soils, thereby promoting higher runoff rates. Also, clay particles are more easily suspended and transported and they do not settle out as rapidly as larger soil particles. Clays also have a relatively high capacity to adsorb certain pollutants and thus serve as a significant transport mechanism. Map No.'s 10 through 14 illustrate the predominate soil textures in each of the U.S. lake basins.

Numerous other physical characteristics influence diffuse loading of pollutants. These include slope, physiography, chemical composition of the soil, drainage network, and depth to and quality of groundwater.

Land Use and Management

Land use and management are two additional factors affecting the diffuse loading of phosphorus and other pollutants contributed by an area. Agricultural and urbanizing areas, for example, generally contribute a greater pollutant load than undisturbed forests or wetlands[1] because the soil is more exposed to wind and water erosion. Agricultural practices, such as improper or excessive application of chemical fertilizers, manure, and pesticides, can increase pollutant loading. Urban areas, with their large amount of impervious pavement and stormsewer systems may contribute high levels of runoff. The deposition and washoff of vehicular exhausts, industrial emissions and animal wastes are some of the sources of pollutants from urbanized areas.

An inventory of 10 major classes of land cover in the U.S. portion of the basin was prepared for the Great Lakes Basin Commission utilizing Landsat satellite imagery. Due to prohibitive costs it was not possible to include a composite of this imagery in this report. However, Appendix 2 defines the land classes and Table 3 presents the percentage of total land area in each class (excluding inland water) by lake basin. As can be seen, over half of the U.S. basin's area is forested land, with the Lake Michigan drainage basin accounting for over one-third of this acreage. Plowed field and brushland each account for nearly 15 percent of the total basin land cover area. The largest acreage of plowed field is found in the Lake Erie basin. The Lake Michigan basin contains the greatest acreage of brushland. Grassland covers a little over 10 percent of the U.S. basin with the majority of the acreage in the Lake Michigan basin. Wetlands, barren land and high density residential and commercial land each account for a very small percentage of the U.S. total land cover acreage.

[1]Wetlands may actually reduce pollutant loadings to a waterbody by "trapping" sediments and nutrients from upland sources. See GLEPS No. 27.

Meteorological Conditions

Overlying the physical characteristics of the land and land use is the variety of meteorological conditions which exist around the Great Lakes basin. The annual precipitation, intensity and duration of rainfall events, and timing of the spring thaw all influence the level of pollutant loading.

For example, the relationship between the diffuse phosphorus load and the amount of streamflow to the lakes can be illustrated by the Saint Louis River in the Lake Superior basin. In 1977, a very low total phosphorus load of 70 metric tons per year (mt/yr) was calculated for the river, corresponding to a low flow of 996 cubic feet per second (cfs) for that water year. The marked increase in load (to 310 mt/yr) exhibited during water year 1978 corresponds to a greatly increased flow of 3,755 cfs.

Precipitation: Stable, Event and Variable Response Tributaries. There are also significant differences in the way a tributary responds to runoff caused by precipitation, as discussed in GLEPS Contribution No. 46. In turn, a relationship exists between the tributary type and the concentrations of pollutants, such as suspended solids and total phosphorus, which it carries at different levels of flow.

TABLE 3

U.S. LAND COVER DATA BY LAKE BASIN[1]

	Total Land Area (km^2)	% Wetland	% Forest	%[2] Brushland	% Grassland	% Barren	% Plowed Field	% High Density Residential	% Commercial
Lake Superior Basin	44,000	6.1	85.3	4.4	2.6	0.8	0.6	0.2	0.0
Lake Michigan Basin	117,410	5.5	49.8	17.5	11.0	0.3	12.4	3.2	0.2
Lake Huron Basin	41,920	3.9	48.4	18.5	9.2	0.1	16.5	3.3	1.4
Lake Erie Basin	55,590	1.3	18.1	18.3	15.9	0.4	34.6	10.0	0.1
Lake Ontario Basin	45,770	1.5	64.3	10.2	11.5	0.1	8.9	3.4	0.1
U.S. Basin Total:	304,690	4.0	51.1	14.8	10.5	0,3	14.8	4.0	0.5

[1]Excludes inland water. Definitions of the land cover classes presented appear in Appendix a.

[2]Includes both deciduous and coniferous forests

Source: Monteith and Jarecki, 1978.

Three classes of tributaries have been identified to represent three different responses to runoff. A number of U. S. tributaries to the lakes, classified by their response to runoff are displayed on Maps No's 15 through 19, Major Stable, Event and Variable Response U. S. Tributaries in the Great Lakes Basin. In stable response tributaries the flows do not tend to vary greatly over the short term. The concentrations of pollutants such as suspended solids and total phosphorus do not vary greatly with changes in flow.

Unlike stable response tributaries, event response streams are greatly influenced by runoff. The flow in these streams is much more variable over the short term. The concentrations of pollutants, such as suspended solids and total phosphorus, tend to increase with flow, with the bulk transported by sediment.

A significant number of streams do not clearly fall into the stable response or event response groups. Such tributaries have been classified as "variable response," because they exhibit characteristics of both categories.

There are many factors influencing whether a stream exhibits a stable response, event response or variable response. However, the texture of the soil in the watershed appears to be the primary determinant. Streams draining sandy soils have more stable flows than those draining clay soils. Generally, soils with a high amount of fine clay-sized particles contribute higher loads of suspended solids and phosphorus than coarse-grained, sandy soils. Therefore, water quality of the rivers draining sandy soils is often much better than that of the rivers draining clay.

The importance of soil texture can be seen in the way the three classes of streams cluster in certain areas of the basin. For example, there is a high incidence of event response tributaries in the western Lake Erie and western Lake Superior basins, which have soils with a high clay content. Many stable response tributaries are located in the Michigan portion of the Lake Michigan basin, where sandy soils are prevalent.

CONTRIBUTORS TO NONPOINT SOURCE POLLUTION

Urban and Rural Runoff

GLEPS examined present and future land-derived inputs of pollutants to the lakes and also evaluated the relative cost-effectiveness of a variety of remedial programs to control nonpoint sources. For example, projections of total phosphorus loadings to the Great Lakes from U.S. sources (GLEPS No. 11) indicate that of the more than 27,000 metric tons of phosphorus entering the lakes in the mid-1970's from tributaries, 30 percent were attributable to runoff from rural areas (e.g., plowed fields, grassland, wetland, brushland, forests). Urban land drainage (e.g., commercial, high density residential) accounted for 20 percent of the pollutant load. The remaining 50 percent was contributed by municipal point sources. The same report indicated that very little change is expected in the total phosphorus load to the lakes from rural or urban land drainage over the next 20 years (assuming no additional runoff control measures are implemented).

Maps No.'s 20 through 24 display yearly diffuse loadings of total phosphorus in the late 1970's. Four years of data are presented for each of the lakes, except Lake Erie, for which only three years of information was available. As can be seen, Lake Erie receives the largest diffuse load.

The combined influence of soil texture, land use and tributary type on the diffuse phosphorus load is evidenced in comparing the Grand River in Michigan and the Maumee River in Ohio. These watersheds are similar in size and general climate, but differ markedly in dominant soil texture, intensity of agricultural activity, and tributary type.

The Maumee watershed is largely devoted to agriculture and contains extensive areas of clay. The Maumee River is an event response tributary, exhibiting a correlation between pollutant load concentrations and changes in flow. As can be seen on Map No. 23, these factors combine to result in excessively high diffuse phosphorus loads for water years 1975 to 1977.

In comparison, the surface soil texture of the Grand River watershed is predominantly sand and loam. Agriculture is less intensive and more land is devoted to residential use. The Grand River is a stable response tributary showing little or no correlation between pollutant load concentrations and flow. The levels of diffuse loadings of total phosphorus for water years 1975 to 1977 (as seen on Map No. 21) are less than those of the Maumee River by a factor of ten.

Another GLEPS report (GLEPS No. 12) investigated the relative inputs of heavy metals from urban and rural land drainage. The study found that of the three U.S. sources of pollutants considered (rural runoff, urban runoff, and municipal point sources), rural runoff contributes the highest metals input to Lakes Superior, Michigan, Huron, and Ontario. Urban runoff accounts for the greatest load to Lake Erie.

Shoreline Erosion

Shoreline erosion contributes a significant amount of sediment and associated pollutants to the Great Lakes each year. This is illustrated in Maps No.'s 25 through 29, Average Volume of Material Eroded from Counties along the U.S. Great Lakes Shorelines, and Maps No.'s 53 through 57, Major Inputs of Total Phosphorus to the Great Lakes from the U. S.

Shoreline erosion is a naturally occurring process resulting from the dynamic forces acting upon the coastal zone. The primary cause of shore erosion is the action of waves and currents during severe wind storms. Shore material above and below the still water level is loosened by waves and removed by currents. This process is intensified when there is a temporary rise in the water level of the lake, submerging the beach and enabling the waves to reach higher land. In recent years, high lake levels have accelerated shoreline erosion.

In addition to the combined action of lake levels and waves, the composition of the shoreline is a primary factor in determining the rate at which a shoreline erodes. Unconsolidated glacial tills, sands, silts and clays are the most erodible materials found in the basin. Lake Michigan has the largest number of miles of this shore type and thus its shoreline is the most susceptible to erosion. Another area of large sediment loads is western Lake Superior (see Map No. 25). This corresponds to an area of red clay soil found in Douglas and Bayfield Counties. This soil is easily dislodged and transported and has a high capacity to adsorb and transport pollutants such as phosphorus.

To shoreline property owners, coastal erosion is a costly and potentially hazardous process. Eroded material can also have an important impact on the coastal waters and water quality of the entire Great Lakes system. The particulate material eroded from the shoreline increases the turbidity of the water. Besides having a negative aesthetic impact, this creates economically significant problems at water supply intakes. Excess sedimentation and turbidity may also adversely affect fish and other aquatic organisms in nearshore areas.

Because of the large volume of material contributed to the Great Lakes by shoreline erosion, the loading of total phosphorus associated with the shoreline material is high. However, studies have indicated that a high percentage of this is biologically unavailable phosphorus. This does not mean that the potential impact of shoreline erosion should be minimized, however. If current phosphorus loads are reduced through improved wastewater treatment and better land management practices, the relative importance of shoreline erosion will increase. In addition, since the shoreline erosion input is not evenly distributed, localized shoreline phosphorus inputs may be relatively important, especially where the amounts contributed by other sources are small. Such is the case in Lake Superior where the available phosphorus from U.S. shore erosion is estimated to be about equal to the available phosphorus from U.S. and Canadian tributaries.

Atmospheric Pollution

Efforts to improve the quality of the Great Lakes involve not only controlling substances carried by watercourses, but also require reducing the level of airborne pollutants, a more difficult and complicated problem. There is increasing indication that atmospheric deposition may be a major contributor of trace elements such as PCB's (GLEPS No. 46).

The Great Lakes have the largest surface area of any body of fresh water in the world. Thus, it is not surprising that atmospheric inputs may contribute a large part of the total pollutant load to the lakes. Additionally, the lakes are both near and downwind of major pollution sources and meteorological patterns are conducive to distribution of emitted pollutants over the basin.

Acid Precipitation. As a result of the combustion of tremendous quantities of fossil fuels such as coal and oil, millions of tons of sulfur dioxide and oxides of nitrogen are discharged into the atmosphere each year. Once airborne, these compounds may react with water vapor to form substances such as sulfuric acid and nitric acid, which return to the earth as components of either rain or snow. This is known as acid precipitation.

Sulfur oxides are primarily emitted from stationary sources such as electrical utilities and industrial boilers burning coal as a fuel. In Canada, the smelting of sulfur-rich ores is a major contributor to emissions of sulfur oxides. Nitrogen oxides are emitted from both stationary and transportation-related sources such as cars and trucks.

Maps No.'s 31 to 35 show the location of operating fossil fuel power plants in the U.S. portion of the basin. Efforts to minimize local air pollution associated with power plants by increasing the height of smoke stacks have not alleviated the acid precipitation problem, they have merely transported it. These tall stacks emit the gases higher into the prevailing winds, allowing them to travel some distance before falling with the rain or snow. For example, the cause of the acidification of lakes in the Adirondack Mountains of New York has been traced to the sulfates emitted from industrial centers in Ohio, Indiana and Michigan.

As can be seen from Map No. 36, Areas in the U. S. Great Lakes Basin Subjected to Increased Acidity in Precipitation and Areas Particularly Susceptible to the Effects of Acid Precipitation, the increase in the acidity of precipitation across the Great Lakes basin is variable. However, all parts of the Great Lakes watershed are receiving precipitation which contains 5 to 40 times more acid than precipitation under natural conditions. Generally, higher levels of acidity are found in the eastern half of the basin, reflecting the concentration of pollutant-producing activities and the direction of the prevailing winds.

Map No. 36 also indicates areas highly susceptible to the negative effects of acid precipitation based upon bedrock geology. The Canadian Shield, a geologic formation which extends through upstate New York, the western portion of Michigan's Upper Peninsula, northern Wisconsin and northeastern Minnesota, is a particularly sensitive area. Its bedrock lacks sufficient calcareous material to buffer acidic inputs over extended periods.

Studies have indicated that the pH in the open waters of the Great Lakes themselves is not expected to be lowered significantly by acid precipitation because of the large volume of the lakes. However, localized increases in acidity in northern Lake Huron and Georgian Bay as well as numerous inland lakes have been observed.

As part of the Great Lakes Environmental Planning Study, the potential impact of changes in Great Lakes water quality on fisheries was investigated (GLEPS No. 26). The study noted that increased acidity adversely affects fish in a number of ways. In some species, adult fish may become stunted or deformed under acid stress. A failure of females to spawn has also been noted. A sudden drop in a water body's pH, as can occur during major periods of snowmelt, can cause severe physiological stress and death in fish populations.

Increased acidity may also result in the release of toxic heavy metals from lake bottom sediments and promote the leaching of metals from surrounding soils. Metals may also be entering watercourses directly via precipitation as a result of emissions from the same sources of airborne acidity.

In addition to effects on water quality and aquatic life, acid precipitation may adversely affect cropland and forest productivity, drinking water supplies and increase corrosive damage to cars and buildings.

We do not yet have a complete picture of the consequences of acid precipitation and the rate at which acidification is occurring in most portions of the basin. We do know that unless emissions are strictly controlled, the output of sulfur and nitrogen oxides which cause acid precipitation will increase over the coming years with the increased burning of coal to produce energy. As a result, localized water quality problems and damage to aquatic life will continue in many areas of the basin.

NONPOINT SOURCE CONTROL PROJECTS

There are a number of water quality studies and programs in the basin which are developing detailed information on the causes and control of nonpoint source pollution. Map No. 37 displays the major ongoing and completed nonpoint source control projects in the U. S. portion of the basin. A brief description of each project follows in Table 4.

GLEPS Contributions No.'s 11 and 12 revealed that while low cost, voluntary land management practices (e.g. good land stewardship) to control rural runoff are desirable for such things as soil conservation, they are not likely to significantly reduce either phosphorus or metals loadings to the lakes in comparison to municipal point source control. Urban runoff controls (while expensive) were judged to have the potential for significantly reducing heavy metal inputs, but did not appear to be a cost-effective option for reducing total phosphorus inputs. Exceptions to these scenarios were recognized, however, given the variability in the range of factors influencing the movement of materials to the lakes (e.g. soil texture, tillage practices).

GLEPS Contribution No. 20 took a detailed look at the impacts associated with controlling cropland runoff by changing from conventional to conservation tillage practices. The study revealed that as much as a 55 percent reduction in total phosphorus loading to Great Lakes tributaries from cropland runoff could be achieved if no-till farming was implemented on all soils that would support it and chisel plowing was adopted on all remaining cropland. The report concluded that conservation tillage also provides some monetary benefit to the farmer since it reduces his energy and equipment costs and labor. However, concerns such as increased usage of insecticides and herbicides and problems with fertilizer utilization and movement were also noted.

POINT SOURCE POLLUTION IN THE U.S. GREAT LAKES BASIN

MUNICIPAL TREATMENT FACILITIES

Phosphorus Inputs

A primary component of the point source pollution input to the Great Lakes is municipal wastewater. Reduction of phosphorus loading from municipal treatment plants is especially important because nearly all of the phosphorus input is in a form available for biological uptake. Efforts to reduce the phosphorus content of sewage effluent discharged to surface waters in the basin began in the late 1960's and early 1970's with the upgrading of sewage treatment plants. In GLEPS the impact that improved wastewater treatment would have on the total phosphorus load from U.S. municipal point sources in the basin (GLEPS No. 11) was investigated as well as technologies presently in use for controlling phosphorus at municipal plants (GLEPS No. 14) and the implications for phosphorus control using land application of wastewater (GLEPS No. 19). The effect of a detergent phosphorus ban on municipal wastewater treatment facilities' operations within the basin was also investigated (GLEPS No. 23) in addition to the beneficial effects associated with water conservation (GLEPS No. 31).

Maps No.'s 38 to 42 Present and Future Total Phosphorus Loadings to the Great Lakes from U.S. Municipal Treatment Facilities by River Basin Group show that dramatic reductions in loading are expected in the next several years.

By the mid-1970's, approximately 13,000 mt/yr of total phosphorus were entering the lakes from U.S. sewage treatment plants. Sixty percent of this load (7,900 mt/yr) was entering Lake Erie. Lake Ontario received the second largest load (2,570 mt/yr). Lake Michigan received 1,800 metric tons, Lake Huron - 480 metric tons, and Lake Superior - 180 metric tons. Almost 90 percent of the Lake Huron load was discharged to Saginaw Bay.

Projections indicate that by the year 1990 the total phosphorus load to the lakes from U.S. municipal point sources will be less than half of the mid-1970's load. A reduction of approximately 7,500 mt/yr is expected. Lake Erie should experience the greatest decrease (4,700 mt/yr). As the maps indicate, a gradual increase

(550 mt/yr) in loading is expected between the years 1990 and 2000. This increase is attributable to population growth (see Map No.'s 43 to 47, Present and Future Populations Serviced by U. S. Municipal Treatment Facilities).

The large reduction in phosphorus loading from sewage treatment plants reflects expected implementation of a 1.0 mg/L total phosphorus effluent standard at plants handling average wastewater flows of 1 million gallons per day (MGD) or greater. GLEPS Contribution No. 11 concluded that "full implementation of total phosphorus effluent limitations at municipal sewage treatment plants represents the single most critical step in cost-effectively reducing phosphorus inputs to the Great Lakes."

The 285 sewage treatment plants in the U.S. portion of the basin with average flows of at least 1 MGD contribute a total wastewater flow of approximately 3,300 MGD. The many smaller plants account for a total flow of only 165 MGD. Thus, it is easy to see why implementation of the 1.0 mg/L standard at the larger plants will have such a dramatic effect on phosphorus loading to the lakes. (Maps No.'s 48 through 52 pinpoint the location of the larger U.S. sewage treatment plants handling flows greater than 10 MGD).

GLEPS Contribution No. 14 determined that each of the eight Great Lakes states currently requires plants discharging 1 MGD or greater to surface waters in the basin to limit their total phosphorus effluent concentration to 1.0 mg/L or less. By the late 1970's, about 35 percent of these plants were in compliance with the 1.0 mg/L limitation.

The aforementioned reports also investigated the impact of implementation of a more stringent standard for total phosphorus in the effluent. The studies indicated that a 0.5 mg/L concentration requirement would only reduce loading to the lakes by an additional 2,200 mt/yr., and involve considerable more expense.

Land Application. Land application is the oldest method of treating and disposing of wastes. In this process a series of natural physical, chemical, and biological actions remove pollutants from wastewaters. Acting as a filtering mechanism, the soil removes suspended solids. Bacteria and dissolved materials are broken down biologically or adsorbed by the soil. Vegetation removes water and nutrients.

GLEPS found that under appropriate conditions certain types of land application methods are cost-effective means for treating municipal wastewater and achieving high levels of phosphorus removal (GLEPS No. 19). The major drawback, however, is the sizeable land requirement for this type of treatment system.

Phosphorus Detergent Bans. As indicated in Table 5, five state legislatures in the Great Lakes basin have acted to limit the content of phosphorus in household detergents. In GLEPS Contribution No. 23, the effects of a detergent phosphate ban on total phosphorus loadings to the lakes were investigated as well as the effects on chemical treatment costs at sewage treatment plants.

At plants where phosphorus control is not practiced, a detergent phosphorus ban would result in large reductions in the total phosphorus load discharged. At plants where phosphorus removal is practiced, the phosphorus effluent load may be unaffected. However, because a phosphorus detergent ban can substantially reduce incoming phosphorus concentrations, costs to achieve a given effluent limitation (e.g. 1.0 mg/L) are lessened. It should also be noted that a ban results in phosphorus load reductions from other

TABLE 5

STATUS OF LEGISLATION IN THE GREAT LAKES BASIN* REGARDING PHOSPHORUS LIMITATION IN DETERGENTS

Jurisdiction	Phosphorus Limitation in Detergents, (% by weight as elemental phosphorus)	Effective Date	Comments
New York	0.5	July 1973	
Indiana	0.5	Jan. 1973	
Michigan	0.5	Oct. 1977	
Minnesota	0.5	Jan. 1977	Minnesota Pollution Control Agency was enjoined from enforcing the ban by court injunction, so legally the limit went into effect late although voluntary compliance was very good.
Ohio	None	-	Under consideration in State Legislature. Still no ban.
City of Akron	0.5	-	
Pennsylvania	None	-	
Wisconsin	0.5	July 1979	Legislation passed 1978. Became effective July 1979.
Illinois	None		Because of the phosphate ban in Chicago, other communities in the Illinois portion of the Great Lakes basin receive little, if any, phosphorus detergents. Still no statewide ban.
Chicago	0.5	July 1972	

* As of March 31, 1978, from IJC (1978); updated to July 1979 by GLBC staff.

sources such as combined sewer overflows and septic tank drainage, both of which have been linked to localized water quality problems in the basin.

Water Conservation. GLEPS Contribution No. 31 determined that water conservation would result in reduced phosphorus loads in treated wastewater discharged to the Great Lakes, especially with a 1.0 mg/L phosphorus effluent limitation. This is because the phosphorus load from a treatment plant is equal to the product of the effluent phosphorus concentration multiplied by the flow leaving a plant. Therefore, if the flow is reduced while the concentration remains the same, the loading is reduced. Given the 1.0 mg/L requirement, the largest reductions would be expected for Lakes Michigan and Erie.

Heavy Metals

As previously mentioned, GLEPS investigated the magnitude of current and future metals loading to the lakes from U.S. sources (GLEPS No.'s 12 and 16). The analysis indicated that point source inputs of metals are generally lower than the amounts contributed by either rural or urban runoff.

GLEPS Contribution No. 12 determined that municipal point source inputs of the four metals studied (lead, zinc, copper, and cadmium) should exhibit a significant decrease over the next twenty years. This reduction will be largely the result of implementation of phosphorus controls at sewage treatment plants. Increased metal removal efficiencies are anticipated at these plants. Additionally, further reductions in municipal loadings should result from implementation of national industrial pretreatment requirements, whereby industry treats its effluent before it is discharged to the municipal treatment plant. Because of the large volume of municipal wastewater generated in its basin, Lake Erie should experience the largest decrease in loading.

INDUSTRIAL POINT SOURCES

Phosphorus

Because only certain types of industrial operations discharge phosphorus in significant quantities, loading from this source is quite small compared to that from sewage treatment plants. Because of this fact, GLEPS did not attempt to quantify present or future phosphorus inputs from industrial sources.

Heavy Metals

GLEPS Contribution No. 16 investigated the relative significance of U.S. industrial heavy metal loads to the lakes. Based on information obtained from Michigan and Wisconsin industries, it was determined that industrial inputs of metals are actually relatively small when compared with inputs from other sources. It should be noted, however, that because they are point sources of pollution, both industrial and municipal metals inputs may still cause significant localized water quality problems.

SUMMARY OF MAJOR INPUTS OF TOTAL PHOSPHORUS TO THE LAKES

The maps numbered 53 through 57, Major Inputs of Total Phosphorus to the Great Lakes from U.S. Sources in the Mid to Late 1970's, include estimates of the inputs from shoreline erosion, tributaries, and sewage treatment plants. As can be seen, the relative magnitude of the total phosphorus load contributed by each of the three sources varies from one area of the basin to another.

As previously mentioned, the total

phosphorus load contributed by shoreline erosion is most significant in the Lake Superior basin where the contributions from other sources are small. There are few municipal treatment facilities discharging to surface waters in this basin and diffuse loading of total phosphorus is low. Thus, because only a small amount of available phosphorus is entering this lake, eutrophication is not yet a problem. Indeed, Lake Superior is commonly referred to as the "cleanest" of the Great Lakes.

The eutrophication problems experienced at Green Bay, Wisconsin are not surprising considering the nature of its phosphorus inputs (see Map No. 54). The Fox River transports a sizeable phosphorus load (which includes inputs from sewage treatment plants) to the bay and direct municipal inputs are also significant. As a result, a considerable amount of the total phosphorus input is biologically available. A similar situation exists at Saginaw Bay where the Saginaw River transports a very large total phosphorus load to Lake Huron (see Map No. 55).

As can be seen on Map No. 56, Lake Erie receives the largest loading of total phosphorus of any of the Great Lakes. Numerous sewage treatment plants contribute large amounts of available phosphorus to the lake. In 1978, Detroit's sewage treatment plant alone discharged about 2,300 metric tons of total phosphorus annually. Diffuse loadings are also high. The tonnage contributed annually by the Maumee River basin to western Lake Erie is particularly significant.

Municipal point source inputs and diffuse loadings of total phosphorus are also large in the Lake Ontario watershed. Both the Oswego and Genessee Rivers contribute sizeable pollutant loads to the lake. Shoreline erosion is a relatively insignificant source of phosphorus.

PROBLEMS RELATED TO GREAT LAKES NAVIGATION

Without question, the Great Lakes form a vital national and international transportation system. Navigation of the Great Lakes is however, affected by certain fundamental constraints. These include the depths of harbors and connecting channels of the lakes, overall levels of lakes and the ability to continue navigation on a year-round basis. These issues are controversial ones with a diversity of interests holding different opinions. How these issues are resolved directly affects the environmental quality of the lakes.

DREDGING

The size of vessels carrying goods through the lakes has increased significantly in the past several decades. Accommodation of these ships and barges requires continual maintenance and, at times, enlargement of harbors and navigation channels by dredging. The traditional method of disposing of the dredged lake sediments has been dumping in open lake water. This greatly accentuates sedimentation problems, affecting both aquatic organisms and their habitat.

Increasing pollution of channel sediments prompted the U.S. Army Corps of Engineers in 1966 to study the effects of, and alternatives to open water disposal. It was argued that open-water disposal of polluted dredged material would facilitate the release of harmful organic contaminants and heavy metals into the water. One alternative to open water disposal which has been pursued is the construction of diked disposal areas (see Map No. 58, U. S. Commercial Ports on the Great Lakes and Diked Disposal Areas). These are confined areas which separate the dredged sediment from the lake. By 1980 the Corps of Engineers had completed 19 diked disposal areas in the Great Lakes region. However, controversy still exists surrounding the need for such facilities. Dredged materials are determined to be "polluted," requiring diked disposal, based upon their total chemical composition. This approach assumes that all contaminants are available to the environment, which may not be the case. Additionally, there is evidence that due to problems with design and management, this method of disposal may have greater adverse environmental impact than originally perceived.

In managing dredge wastes, constructive uses have been found which utilize the positive attributes of the material. Dredge material which is nontoxic and high in nitrates and phosphates can be applied to farmland as fertilizer. Dredge material has been used for beach nourishment, shore protection and breakwater construction. One of the secondary benefits attributed to disposal areas is the creation of new land for port and residential development, as well as for recreational purposes such as the Point Mouillee State Game Area on Lake Erie which is managed for waterfowl nesting and fishing.

LAKE LEVELS

Navigation interests in the basin are vitally concerned with changes in the levels of the Great Lakes. Fluctuating lake levels have a number of causes, including precipitation, evaporation, storm winds and human activities such as domestic water supply uses, power production and agriculture. High lake levels are related to long periods of heavy rain and snow. Low lake levels are caused by long periods of drought, high temperatures that increase evaporation, and human uses that consume water.

Lake levels are artificially regulated by changing the amount of water flowing through locks, dams and power facilities located in the rivers between the Great Lakes. It is a complicated process requiring that a balance be struck between the wide variety of interests in all the lakes.

As previously mentioned, shoreline property owners want moderate lakes levels at all times. Fluctuating lake levels is the primary cause of shoreline erosion (with accompanying sedimentation and pollutant loading) and flood damage. However, navigation interests benefit from higher lake levels, which enable vessels to be loaded to their full capacity. Power companies prefer a fairly wide range of water levels in order to have enough storage to operate their turbines. Lakes levels are also vitally important to wildlife interests. Changes of habitat, especially in marshland areas, occur with fluctuating lake levels.

WINTER NAVIGATION

Navigation on the Great Lakes is most clearly affected by climatic conditions during the winter months. Under natural conditions the official shipping season extends from April 1st through December 15th, with thick ice during the winter months preventing navigation. However, from 1974 until 1980, ice breakers and other devices were used to keep the locks and channels open year-round.

Winter navigation benefits the Great Lakes shippers of iron ore, coal, grain and other cargo more than any other group because year-round navigation allows for more efficient use of ships. Benefits also extend to the region as a result of increased industrial productivity and stable employment levels in the shipping industry.

Much of the controversy about winter navigation centers around potential environmental effects on the Great Lakes ecosystem. The main area of concern is the effect on aquatic organisms, fish and wildlife. For example, the migration patterns of deer, moose and wolves might be disrupted by a break-up of the ice. Additionally, shore property owners are concerned about shoreline erosion and property damage from ship induced waves and the turbulence created by ice movement.

The issues of Great Lakes harbor and channel dredging, regulation of lake levels and winter navigation are indeed complex and there are obviously many interests to balance. Given the importance of navigation to the region, these will undoubtedly remain controversial issues.

VESSEL-RELATED SPILLS

Of related concern is the fact that some cargo carried on the lakes could be hazardous or toxic if it was spilled into the water. While the likelihood of such an event is small, GLEPS did investigate sites where spillage would most likely occur and the types and amounts of pollutants that could enter the lakes in order to evaluate possible effects on the Great Lakes ecosystem (GLEPS No. 24). The report concluded that harbors and connecting channels are the sites with greatest potential for a spill of vessel-transported toxic substances. The report also revealed that most past spills on the lakes have involved petroleum products.

EFFECTS OF POLLUTION ON FISHERIES

Water quality deterioration has created problems for fish populations in the Great Lakes, especially in nearshore areas, harbors and embayments. Together with the invasion and successful establishment of the sea lamprey and alewife and overexploitation of certain species of fish, it is a major factor contributing to the present instability of the fishery.

As previously mentioned, increased loadings of nutrients (especially from sewage treatment plants) have stimulated growth of phytoplankton such as Cladophora (see Maps No.'s 2 to 6). In turn, more vegetative material decomposing and settling into bottom waters has increased the rate of oxygen depletion, impairing the habitat of fish and other aquatic organisms. Additionally, heavy growths of algae now cover many rock and sandy areas formerly used for fish spawning.

Sedimentation of watercourses may also adversely affect fish populations. For example, excess sedimentation may clog the gills and filtering apparatus of fish, or it may fill in gravel beds, prohibiting salmonid species from depositing their eggs in this preferred substrate. Excessive amounts of suspended sediment reduce the efficiency of food capture by sight-feeding fish such as walleye.

Toxic substance contamination poses a significant problem to the Great Lakes fishery. Mercury contamination closed the western Lake Erie walleye fishery in 1970. Other persistent contaminants which have been identified in Great Lakes fish include DDT, DDE, PCB's, and Mirex (Mirex in Lake Ontario only). Studies have demonstrated both reductions in spawning and retardation of growth in some fish species following exposure to certain levels of contaminants. As previously discussed, acid precipitation may either directly or indirectly affect fish populations in nearshore areas of the lakes and inland waters.

GLEPS provided an outlook for the response of the Great Lakes fishery to current pollution control initiatives (GLEPS No. 26). Generally, it is expected that improvement in desirable fish populations will be most notable in the nearshore zone, harbors and embayments.

With a decrease in phosphorus loading to the lakes algal production should decrease and the habitat should improve for desirable fish species and the bottom dwelling organisms on which they feed.

Localized reductions in erosion and sedimentation are also expected as nonpoint source controls gain acceptance. Generally, a decrease in siltation and turbidity would have a beneficial impact on fish populations. Since sediments act as a transport mechanism for other pollutants, (e.g., phosphorus), decreased sediment loads would also reduce inputs of these materials to the lakes. Alternatively, since particulate materials tend to sorb and carry to the lake bottom certain forms of contaminants, decreased sediment loading could cause an increase in the presence of toxic substances and increased accumulation in fish.

Concentrations of some hazardous materials, such as PCB's, appear to be on the decline. At the same time, however, new toxic substances are being developed and identified in the lakes. Much remains to be learned about the present and future effects of new and existing contaminants on Great Lakes fish.

The deleterious effects of acid precipitation are expected to be confined to the nearshore zone of the Great Lakes and certain inland waters in the northern portion of the basin. Severe effects associated with acid precipitation have already been documented in certain fish populations (i.e., in the Adirondack lakes of New York State).

Information on the spawning grounds and seasonal distribution of desirable fish species is largely unavailable at the present time. Thus, environmental quality maps for fisheries have not been included in this report. However, three studies were found which have made an initial attempt at gathering and mapping this data.

The University of Wisconsin Sea Grant Institute has published "Fish Spawning Grounds in Wisconsin Waters of the Great Lakes." Based on interviews with commercial fishermen, this document pinpoints spawning areas of a number of fish on detailed maps.

A survey of the reefs and shoals of Lake Michigan and the Apostle Islands was conducted during 1979 by a research group at the Marine Studies Center of the University of Wisconsin at Madison. Major spawning grounds utilized by several species of fish were described.

Finally, the University of Michigan Sea Grant Institute is developing a report on factors influencing the distribution of eight commercial fish in Lake Michigan. A series of maps will be included in this document which should be completed this summer.

COASTAL ZONE AREAS OF PARTICULAR CONCERN

The Federal Coastal Zone Management program provided funding to help states develop plans for managing their coastlines. These plans follow general federal guidelines which are flexible enough to allow each state to address their individual needs. Michigan, Pennsylvania, and Wisconsin are the only Great Lakes states with approved coastal management programs. The other five states (Indiana, Illinois, Minnesota, New York, and Ohio) all participated in the program in the past, but have since withdrawn.

In developing their coastal programs, each state was required to designate areas of particular concern (APCs). These APCs are areas of special significance for their fragility, uniqueness, economic potential or other reasons. State agencies and the general public worked together in nominating and designating these areas. APCs may either be generic (for example, all wetlands areas) or specific (a historic lighthouse, for example).

The criteria used by each state in designating APCs varies, but are consistent in that an APC must be a unique resource area requiring protection or enhancement. Also, the approach that different states use to manage APCs varies with each state's legislative authorities and the nature of the resource itself.

There are hundreds of APCs designated by Michigan, Pennsylvania, and Wisconsin. Many more APCs were nominated by the remaining five Great Lakes states which withdrew from the program. While it was not possible to map all of these APCs at the scale chosen, the ecological significance of many of these areas should be recognized. For example, Wisconsin includes 12 fish management areas as APCs, one of which is an important northern pike spawning area. In Ohio, areas proposed included coastal wetlands, which are of particular value for fish and wildlife habitat.

SUMMARY

It is evident that the Great Lakes are a complicated resource to manage, given the diverse soils, land use patterns, and other factors affecting pollution inputs. This underscores the need for a water quality management strategy which can be tailored to suit local conditions and needs. Because water pollution abatement has received considerable attention in the basin (perhaps more so than anywhere else in the U.S.) Great Lakes managers are fortunate to have a broad research base to draw from as they determine cost-effective control measures.

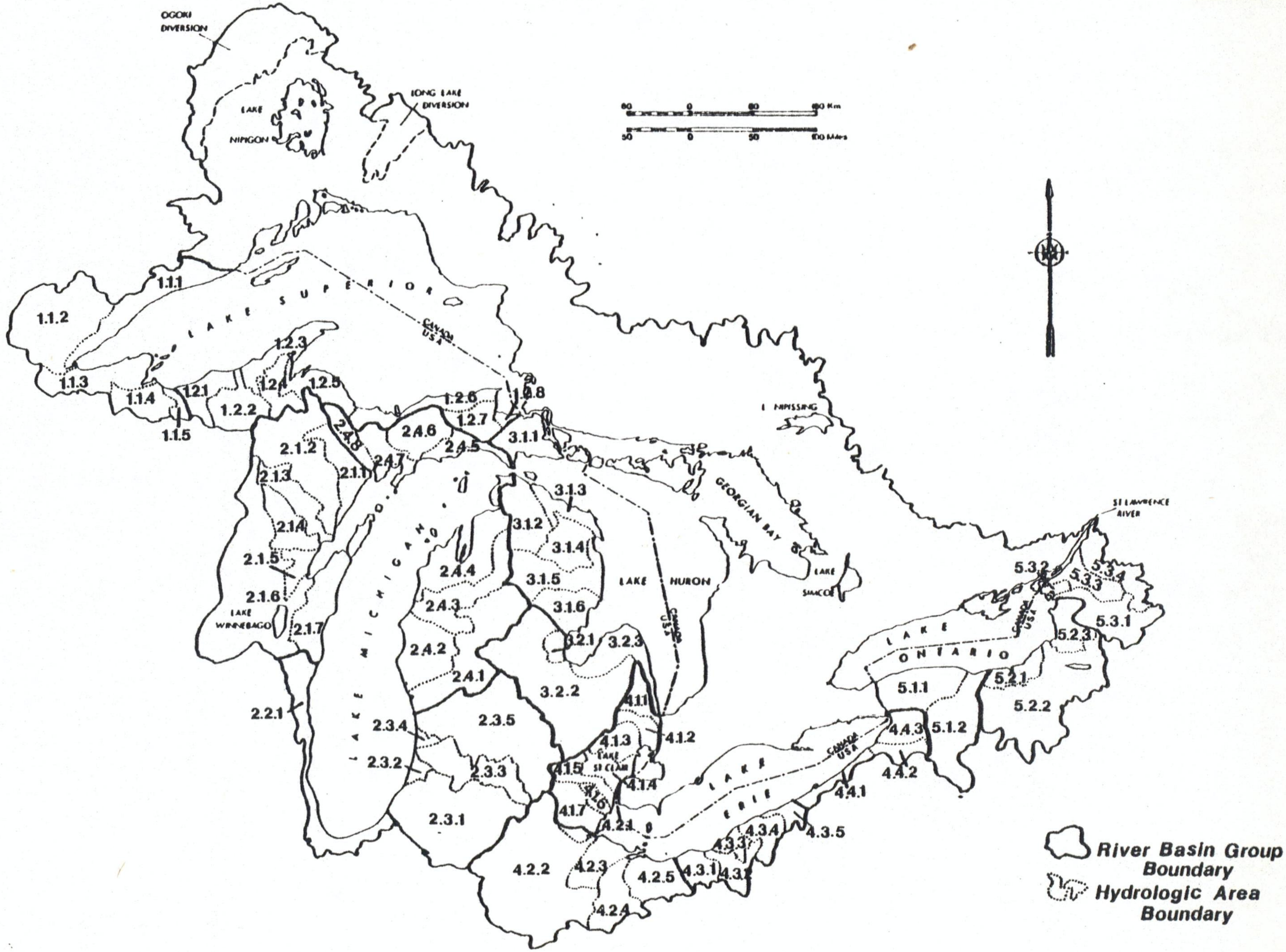
It is also evident that we cannot afford to treat pollutants and pollutant sources one at a time. We need to employ a mix of both point and nonpoint control measures aimed at not only reducing phosphorus loading to the lakes, but toxic materials and other pollutants as well. Our water quality management strategy must address the whole system.

Finally, it will always be difficult to accommodate each of the groups with a special interest in the management of the lakes: the power companies, shoreline property owners, fishermen, and others. However, it is vital that all interests be weighed and that intangible values always be included in any evaluation of management alternatives.

MAPS

U.S. Great Lakes River Basin Groups and Hydrologic Areas

1



*See Table 1 for identification of hydrologic areas associated with numbers

TABLE 1

U.S. RIVER BASIN GROUPS AND HYDROLOGIC AREAS

River Basin Group 1.1
Hydrologic Areas:

1.1.1 Superior Slope Complex
1.1.2 Saint Louis River
1.1.3 Apostle Island Complex
1.1.4 Bad River
1.1.5 Montreal River Complex

River Basin Group 1.2
Hydrologic Areas:

1.2.1 Porcupine Mountains Complex
1.2.2 Ontonagon River
1.2.3 Keweenaw Peninsula Complex
1.2.4 Sturgeon River
1.2.5 Huron Mountain Complex
1.2.6 Grand Marais Complex
1.2.7 Tahquamenon River
1.2.8 Sault Complex

River Basin Group 2.1
Hydrologic Areas:

2.1.1 Menominee Complex
2.1.2 Menominee River
2.1.3 Peshtigo River
2.1.4 Oconto River
2.1.5 Suamico Complex
2.1.6 Fox River
2.1.7 Green Bay Complex

River Basin Group 2.2
Hydrologic Areas:

2.2.1 Chicago-Milwaukee Complex

River Basin Group 2.3
Hydrologic Areas:

2.3.1 Saint Joseph River
2.3.2 Black River (S.Haven) Complex
2.3.3 Kalamazoo River
2.3.4 Black River (Ottawa Co.) Comp.
2.3.5 Grand River

River Basin 2.4
Hydrologic Areas:

2.4.1 Muskegon River
2.4.2 Sable Complex
2.4.3 Manistee River
2.4.4 Traverse Complex
2.4.5 Seul Choix-Groscap Complex
2.4.6 Manistique River
2.4.7 Bay De Noc Complex
2.4.8 Escanaba River

River Basin 3.1
Hydrologic Areas:

3.1.1 Les Cheneaux Complex
3.1.2 Cheboygan River
3.1.3 Presque Isle Complex
3.1.4 Thunder Bay River
3.1.5 Au Sable and Alcona Complex
3.1.6 Rifle-Au Gres Complex

River Basin 3.2
Hydrologic Areas:

3.2.1 Kawkawline Complex
3.2.2 Saginaw River
3.2.3 Thumb Complex

River Basin 4.1
Hydrologic Areas:

4.1.1 Black River
4.1.2 St. Clair Complex
4.1.3 Clinton River
4.1.4 Rouge Complex
4.1.5 Huron River
4.1.6 Swan Creek Complex
4.1.7 Raisin River

River Basin 4.2
Hydrologic Areas:

4.2.1 Ottawa River
4.2.2 Maumee River
4.2.3 Toussaint-Portage Complex
4.2.4 Sandusky River
4.2.5 Huron-Vermilion Complex

River Basin 4.3
Hydrologic Areas:

4.3.1 Black-Rocky Complex
4.3.2 Cuyahoga River
4.3.3 Chagrin Complex
4.3.4 Grand River
4.3.5 Ashtabula-Conneaut Complex

River Basin 4.4
Hydrologic Areas:

4.4.1 Erie-Chautauqua Complex
4.4.2 Cattaraugus Creek
4.4.3 Tonawanda Complex

River Basin 5.1
Hydrologic Areas:

5.1.1 Niagara-Orleans Complex
5.1.2 Genesee River

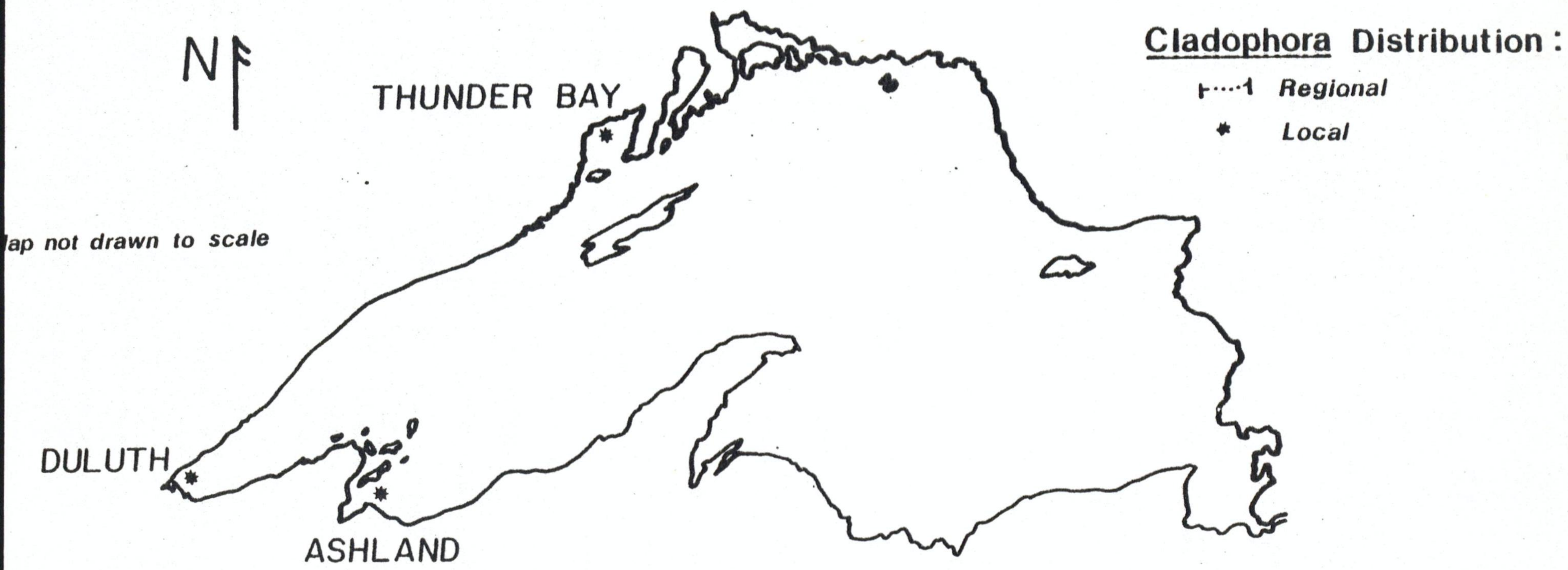
River Basin 5.2
Hydrologic Areas:

5.2.1 Wayne-Cayuga Complex
5.2.2 Oswego River
5.2.3 Salmon Complex

River Basin 5.3
Hydrologic Areas:

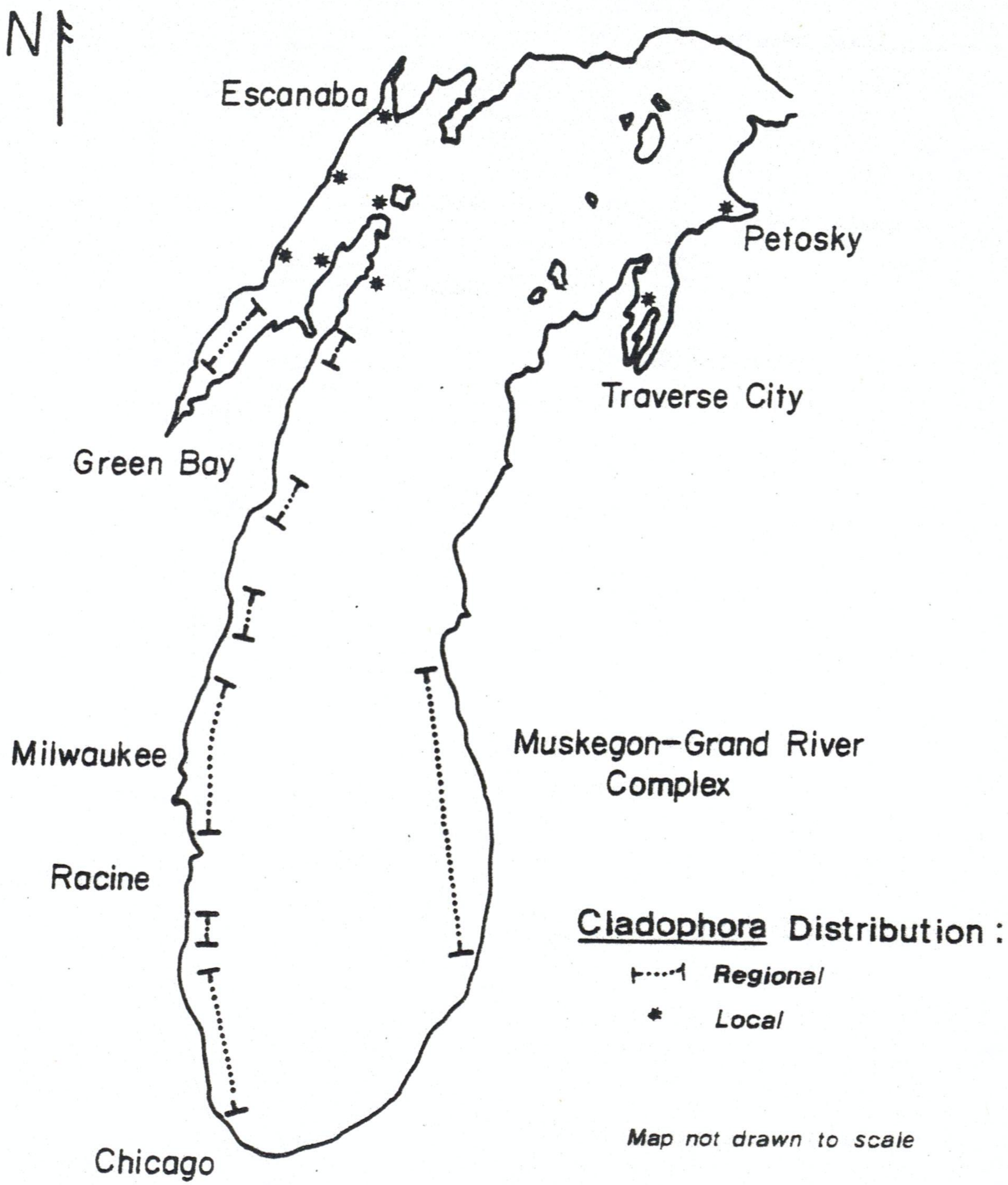
5.3.1 Black River
5.3.2 Perch Complex
5.3.3 Oswagatchie River
5.3.4 Grass-Raquette-St. Regis Comp.

2

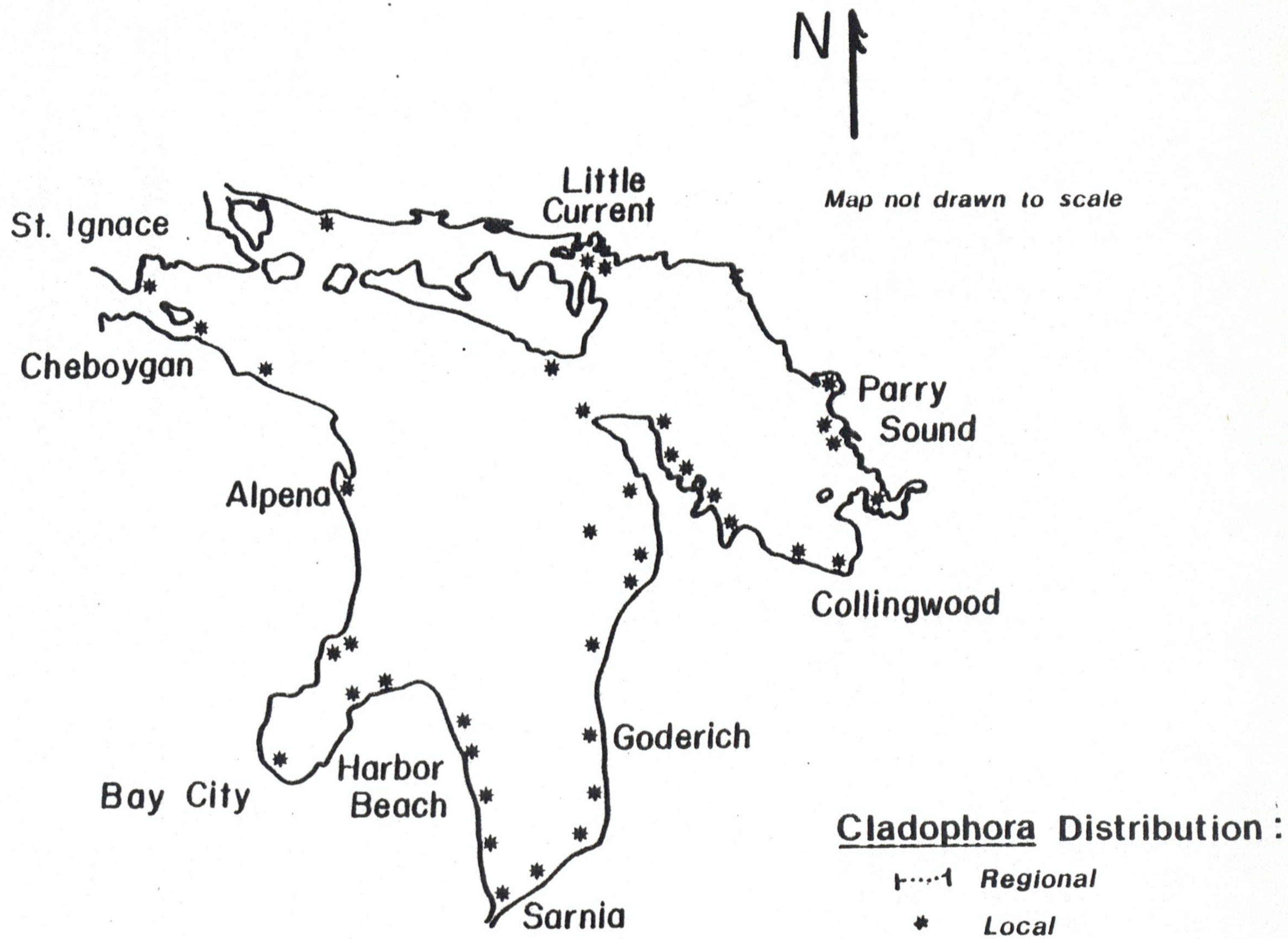


Cladophora in the Nearshore Areas of L. Superior

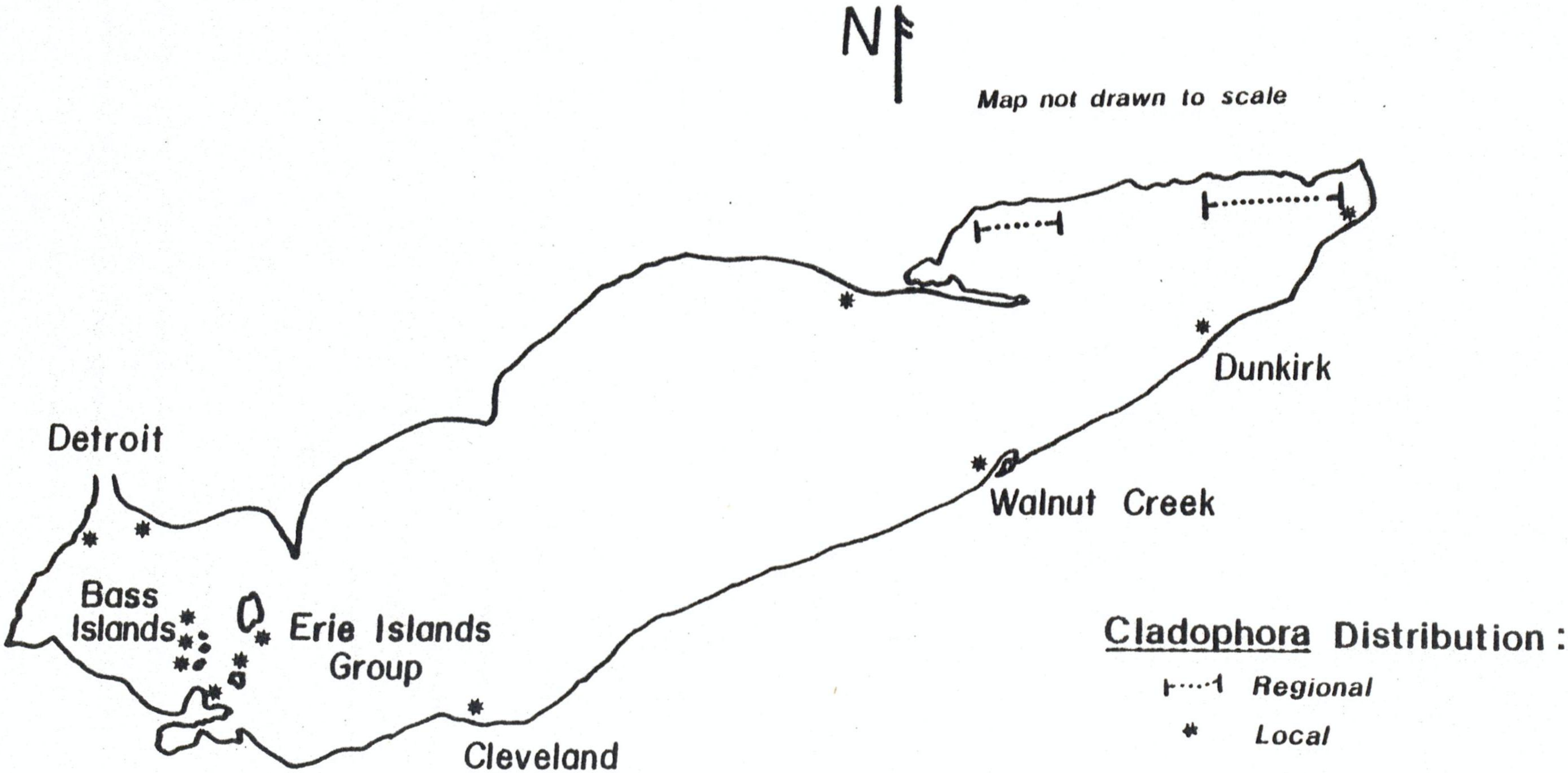
3



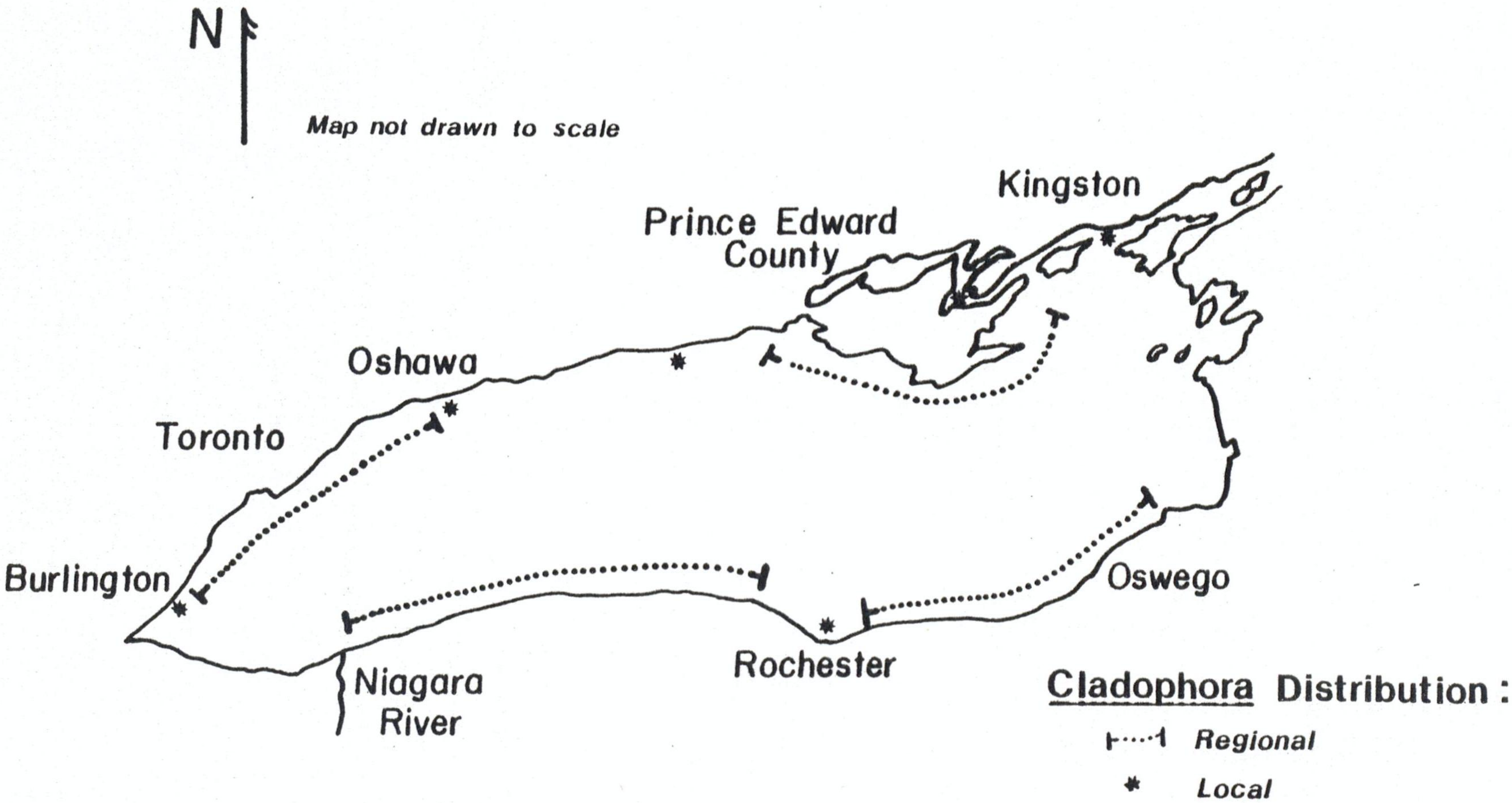
Cladophora in the Nearshore Areas of L. Michigan



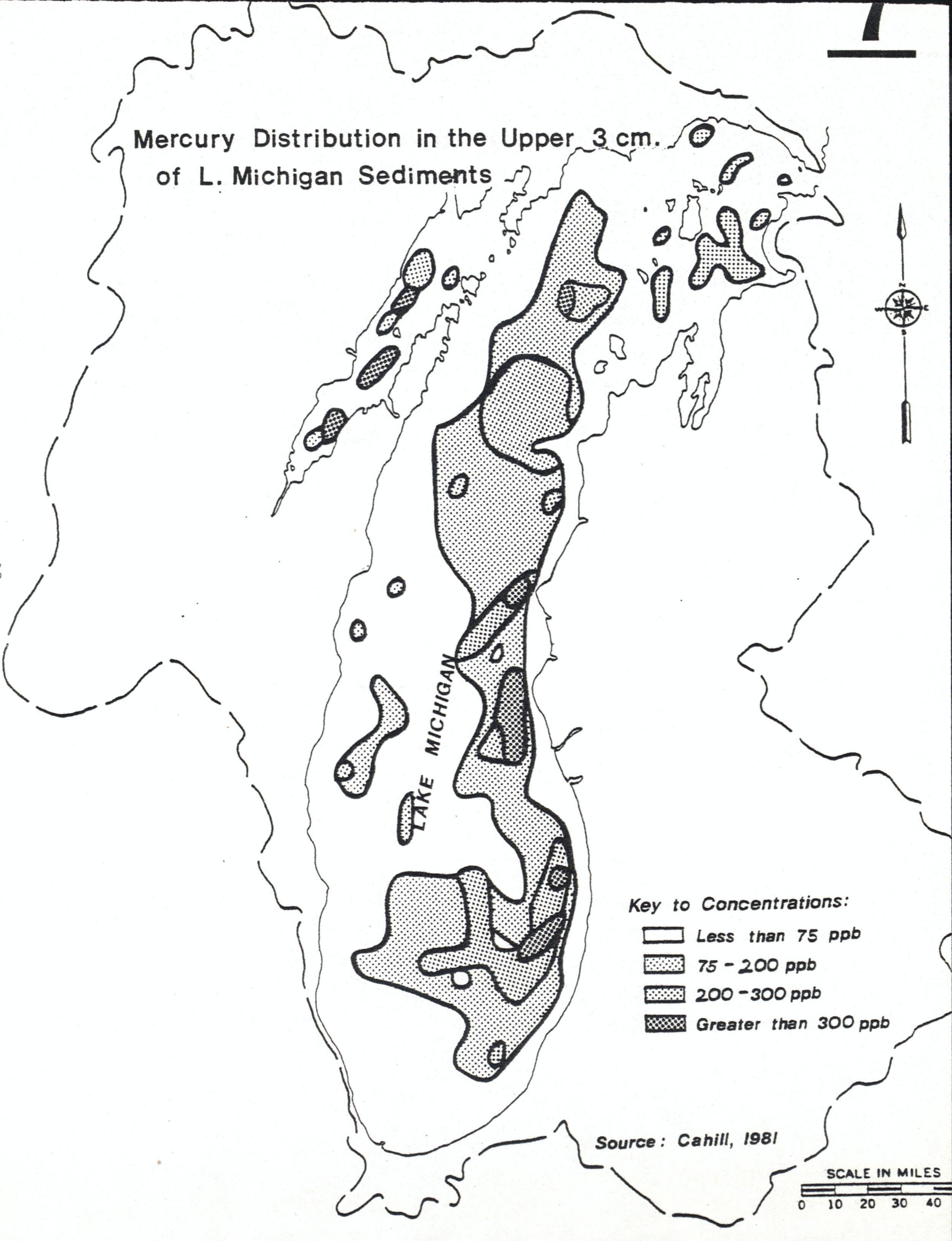
Cladophora in the Nearshore Areas of L. Huron



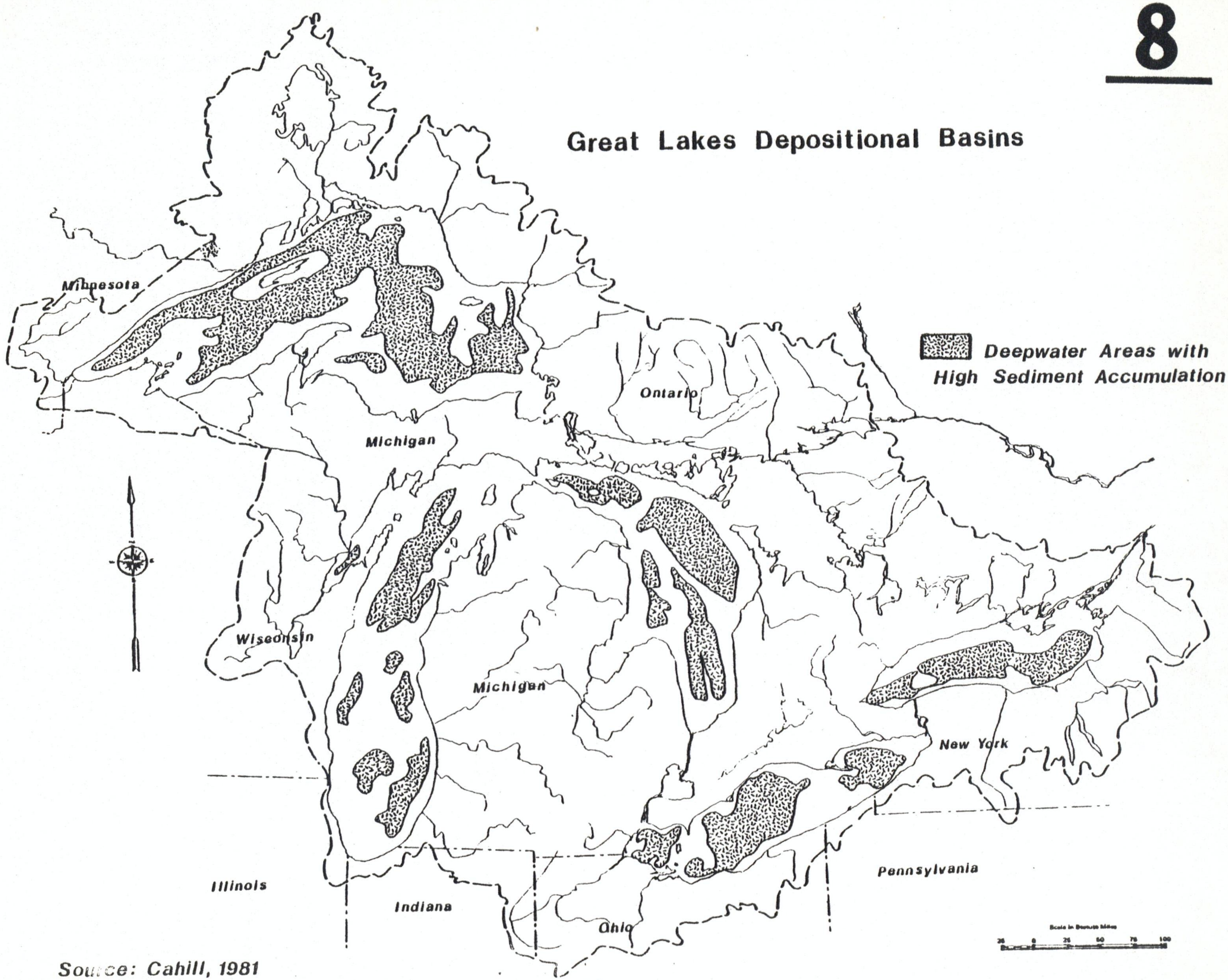
Cladophora in the Nearshore Areas of L. Erie



Cladophora in the Nearshore Areas of L. Ontario


Mercury Distribution in the Upper 3 cm.
of L. Michigan Sediments
LAKE MICHIGAN
Key to Concentrations:
Less than 75 ppb
75 - 200 ppb
200 - 300 ppb
Greater than 300 ppb
Source: Cahill, 1981
SCALE IN MILES
0 10 20 30 40

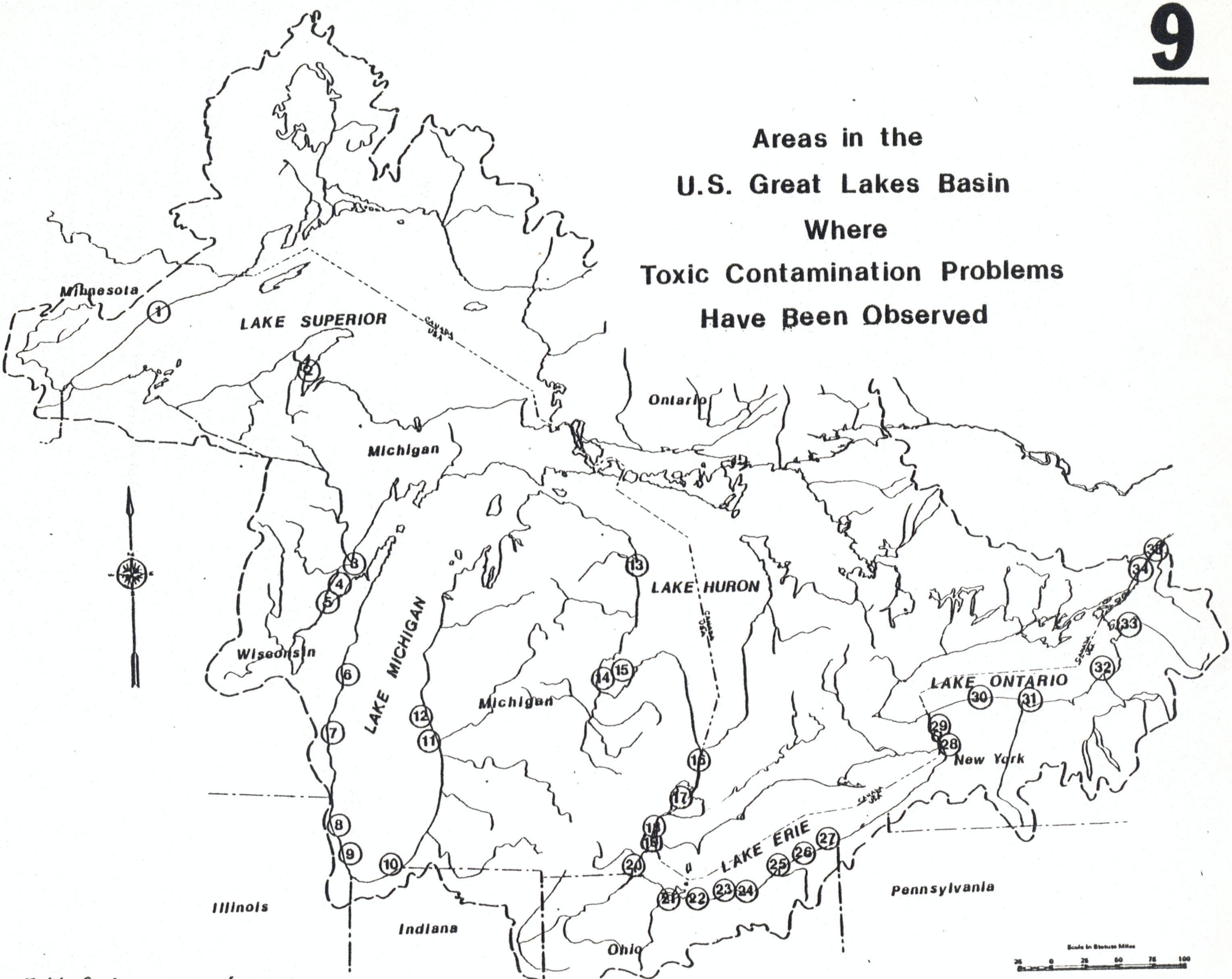
8



Source: Cahill, 1981

9

Areas in the U.S. Great Lakes Basin Where Toxic Contamination Problems Have Been Observed

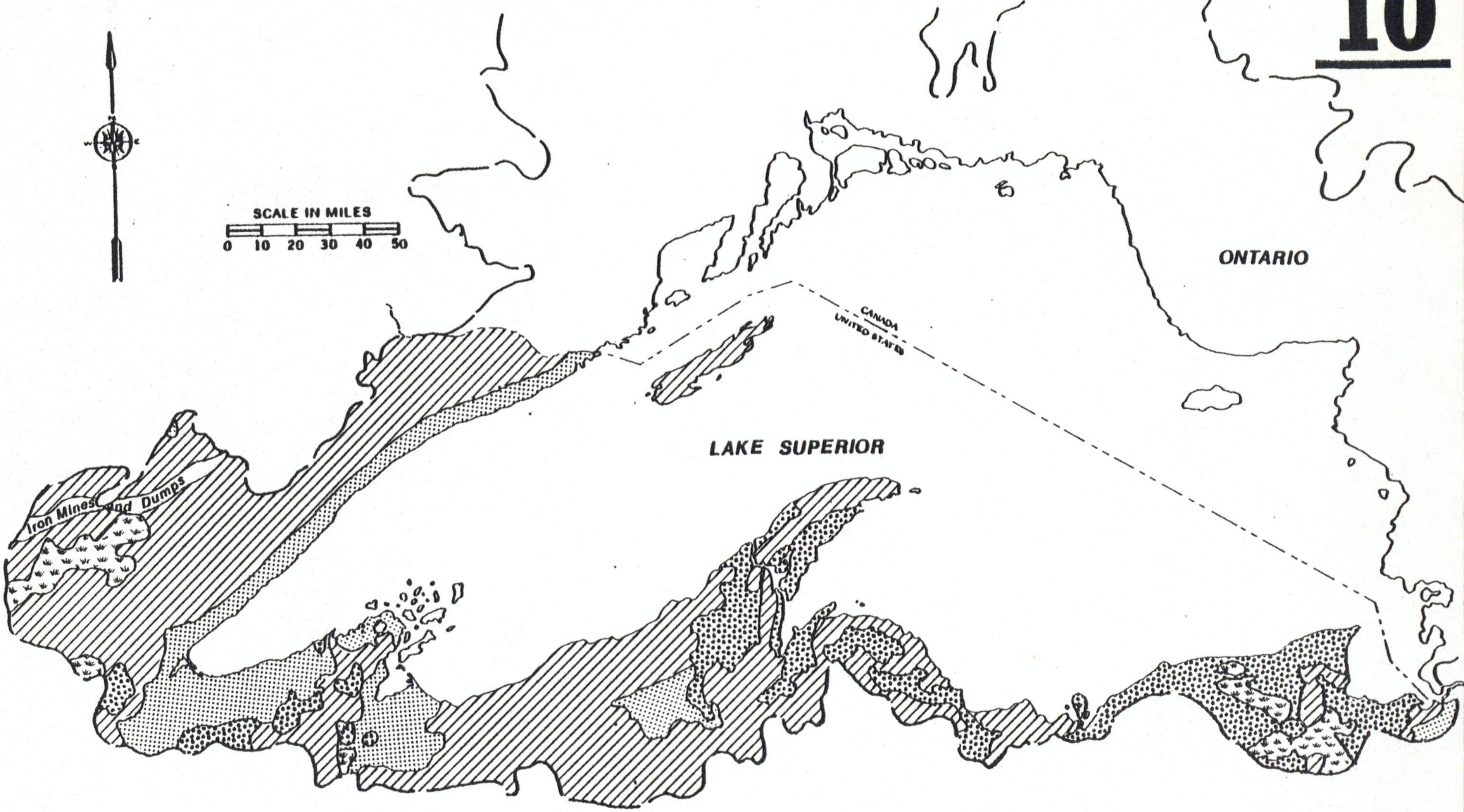


* See Table 2 for names of areas

TABLE 2

TOXIC CONTAMINATION PROBLEM AREAS IN THE U.S.
GREAT LAKES BASIN

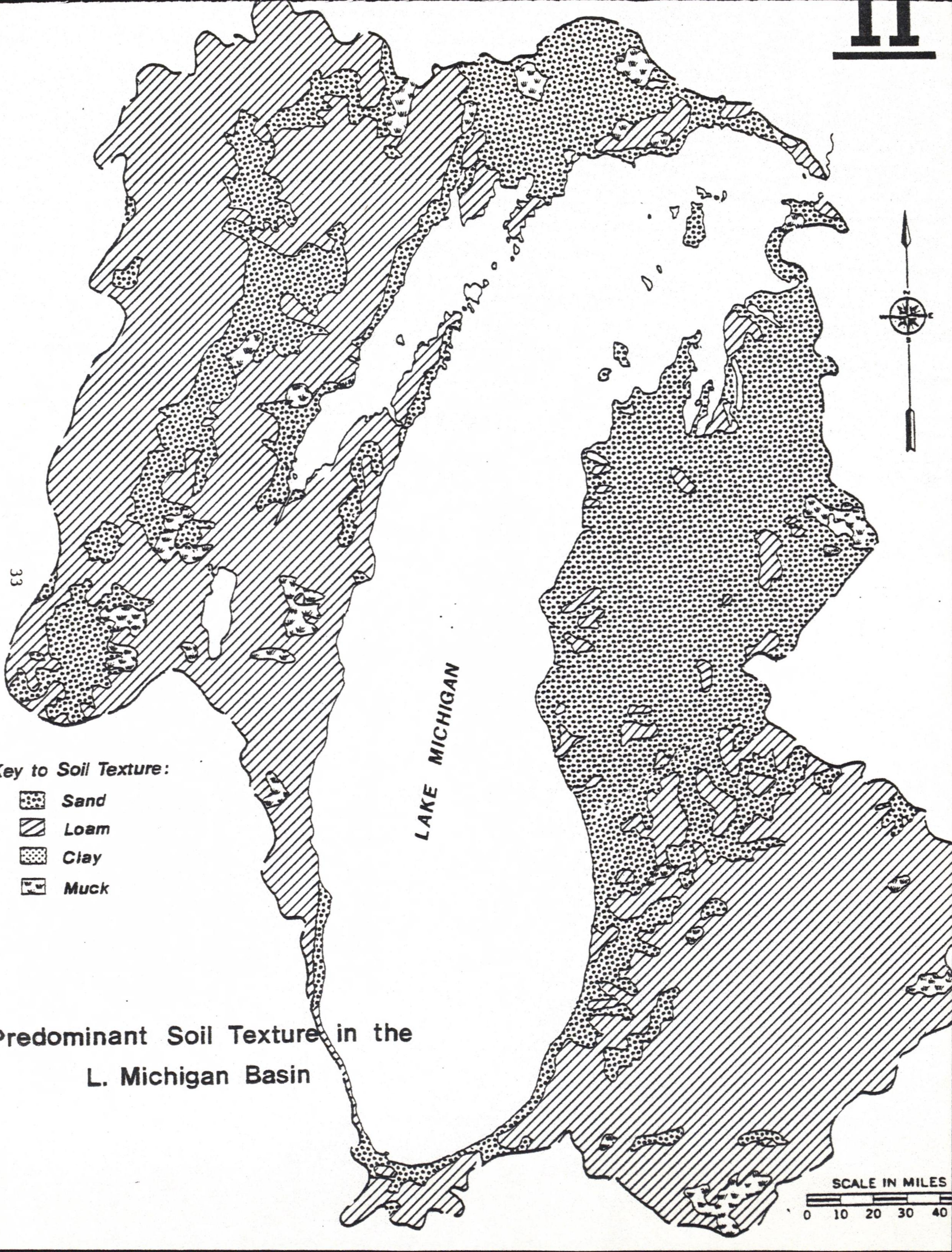
Map No.	Area	Contaminant(s) of Concern
1	Silver Bay	Asbestiform fibers
2	Upper Portage Entry	Copper and zinc in mine tailings
3	Menominee/Marinette	Arsenic
4	Green Bay	PCBs and mercury
5	Fox River	PCBs and PAHs
6	Sheboygan River	PCBs
7	Milwaukee Harbor	PCBs, PAHs, and heavy metals
8	Waukegan Harbor	PCBs
9	Great Lakes Naval Training Center	Heavy metals
10	Indiana Harbor	PCBs, PAHs, mercury, lead, phenols, zinc, arsenic
11	Muskegon/Big Black Creek	PCBs, DDT
12	White Lake	Chlorinated organics
13	Alpena	Aldrin
14	Pine, Tittabawassee, Saginaw Rivers	PCBs, PBBs, dioxin
15	Saginaw Bay	PCBs, DDT
16	St. Clair River	PCBs, heavy metals, chlorinated organics
17	Lake St. Clair	Mercury
18	Detroit River	PAHs, iron, phenols
19	Wyandotte	Chlorinated organics
20	Monroe	PCBs and heavy metals
21	Sandusky River	Copper
22	Huron River	Arsenic and manganese
23	Black River	Phenols, heavy metals
24	Cleveland	Phenols, heavy metals
25	Grand River	Phenols
26	Ashtabula River	Iron, zinc, copper, lead, HCB, HCBD, PAHs
27	Conneaut	Iron and zinc
28	Buffalo River	Phenols, mirex, PAHs
29	Niagara River	Mirex, PCBs, PAHs, phenols
30	Olcott	PCBs, DDT, mirex
31	Rochester Harbor	Phenols, heavy metals
32	Oswego Harbor	Mirex
33	Sackets Harbor	Mercury
34	Massena	DDT and PCBs
35	Grass River	PCBs



Predominate Soil Texture in the U.S. L. Superior Basin

Key to Soil Texture:
- Sand
- Loam
- Clay
- Muck

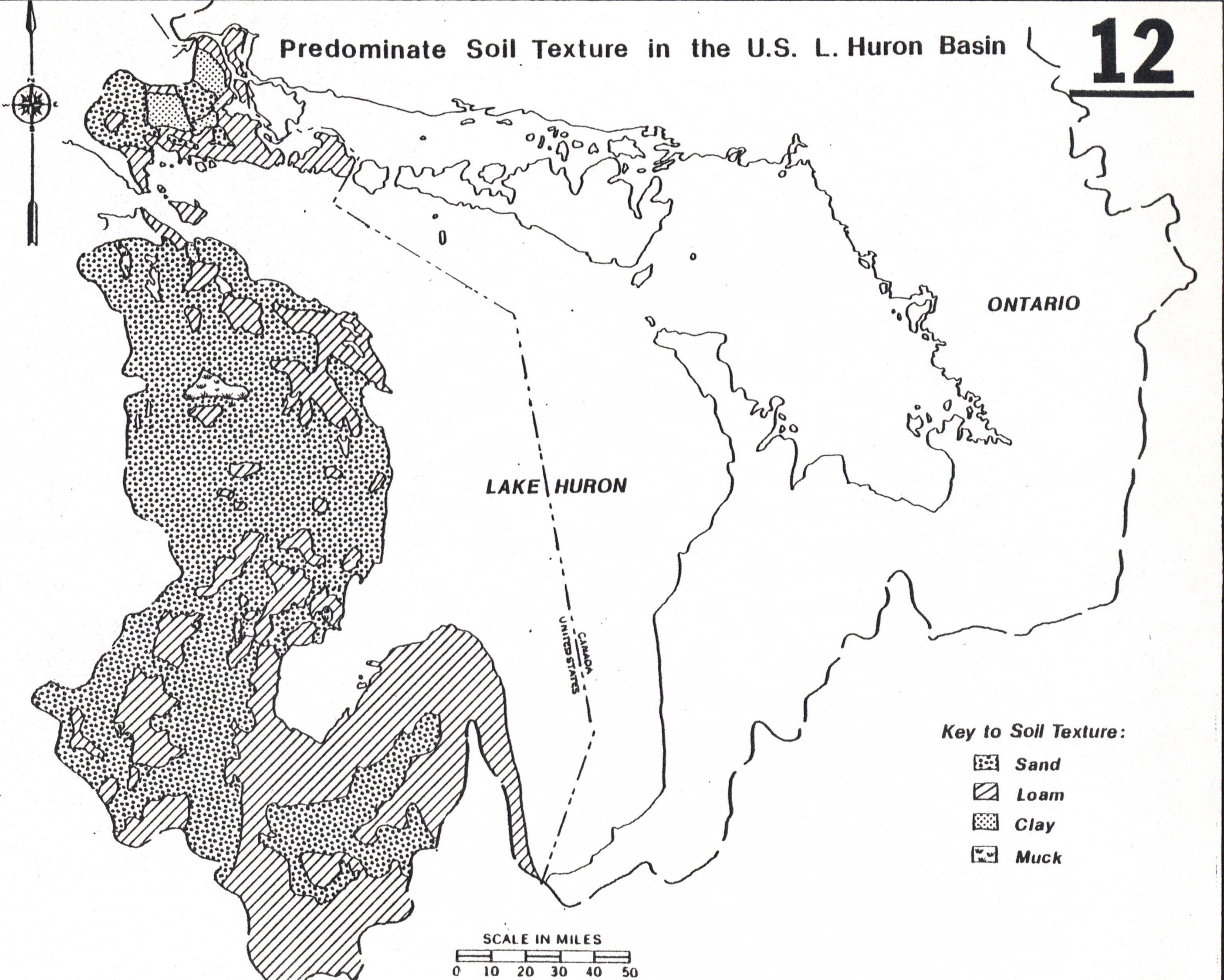
II



Predominant Soil Texture in the L. Michigan Basin

12

Predominate Soil Texture in the U.S. L. Huron Basin



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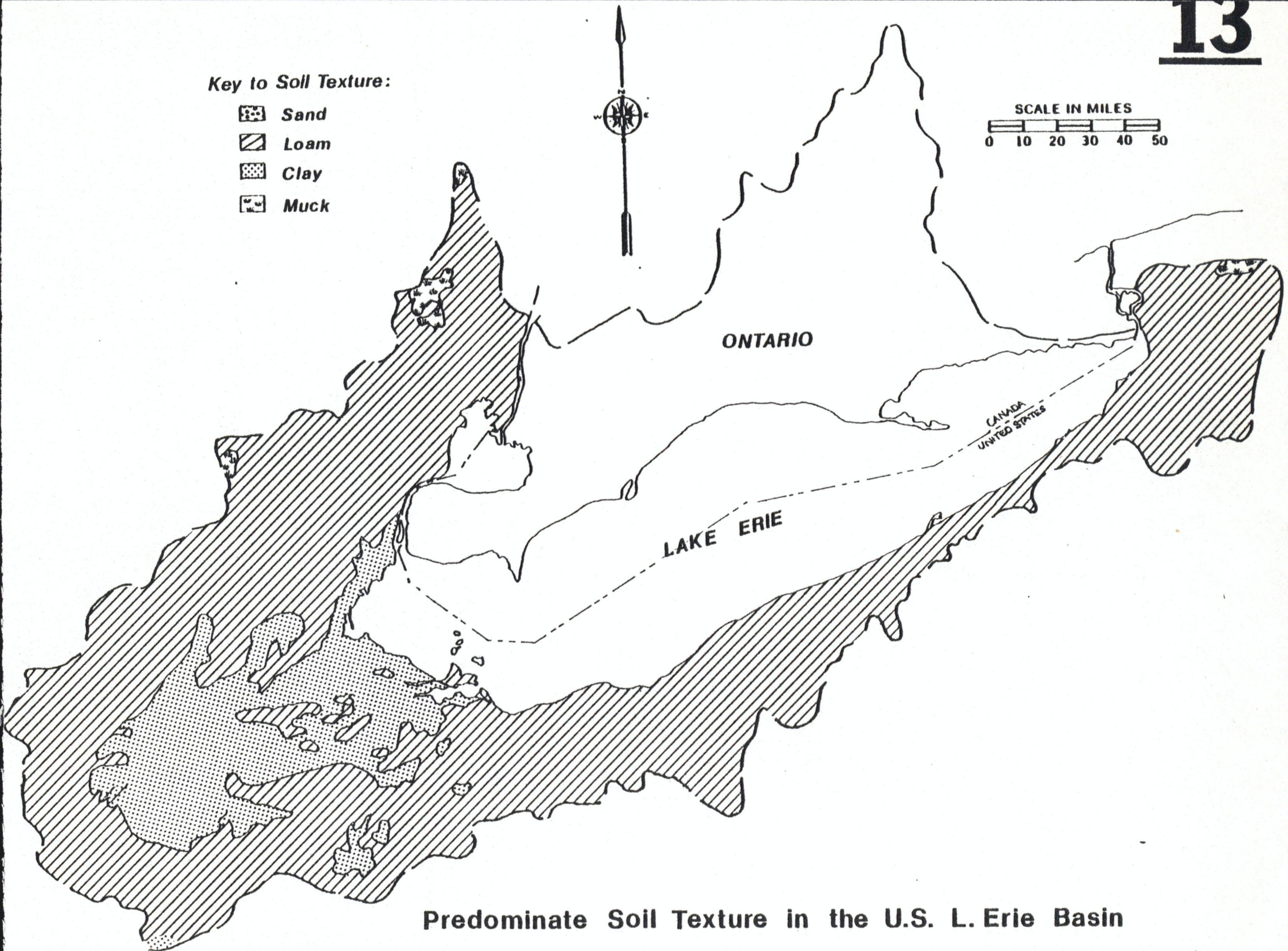
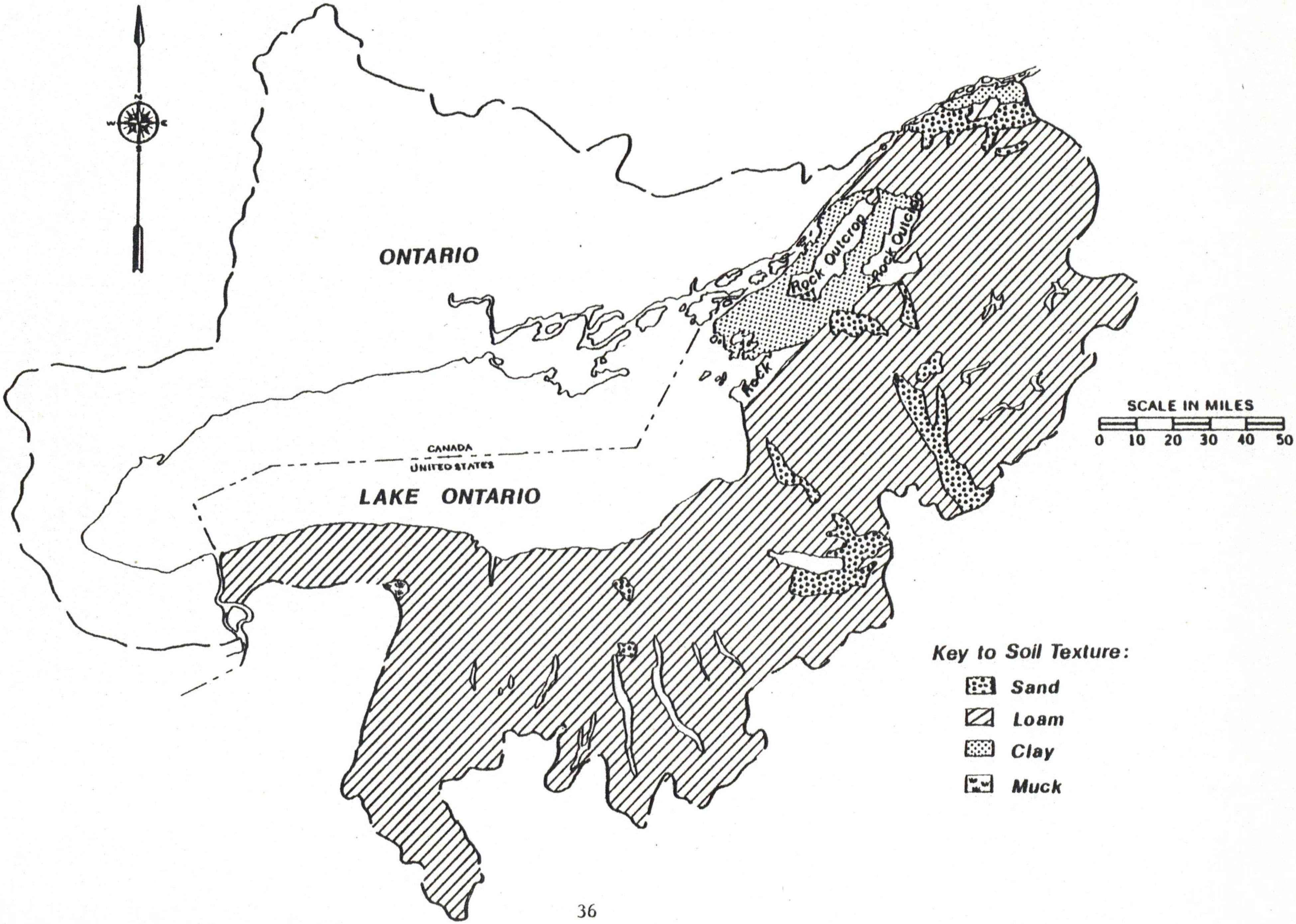
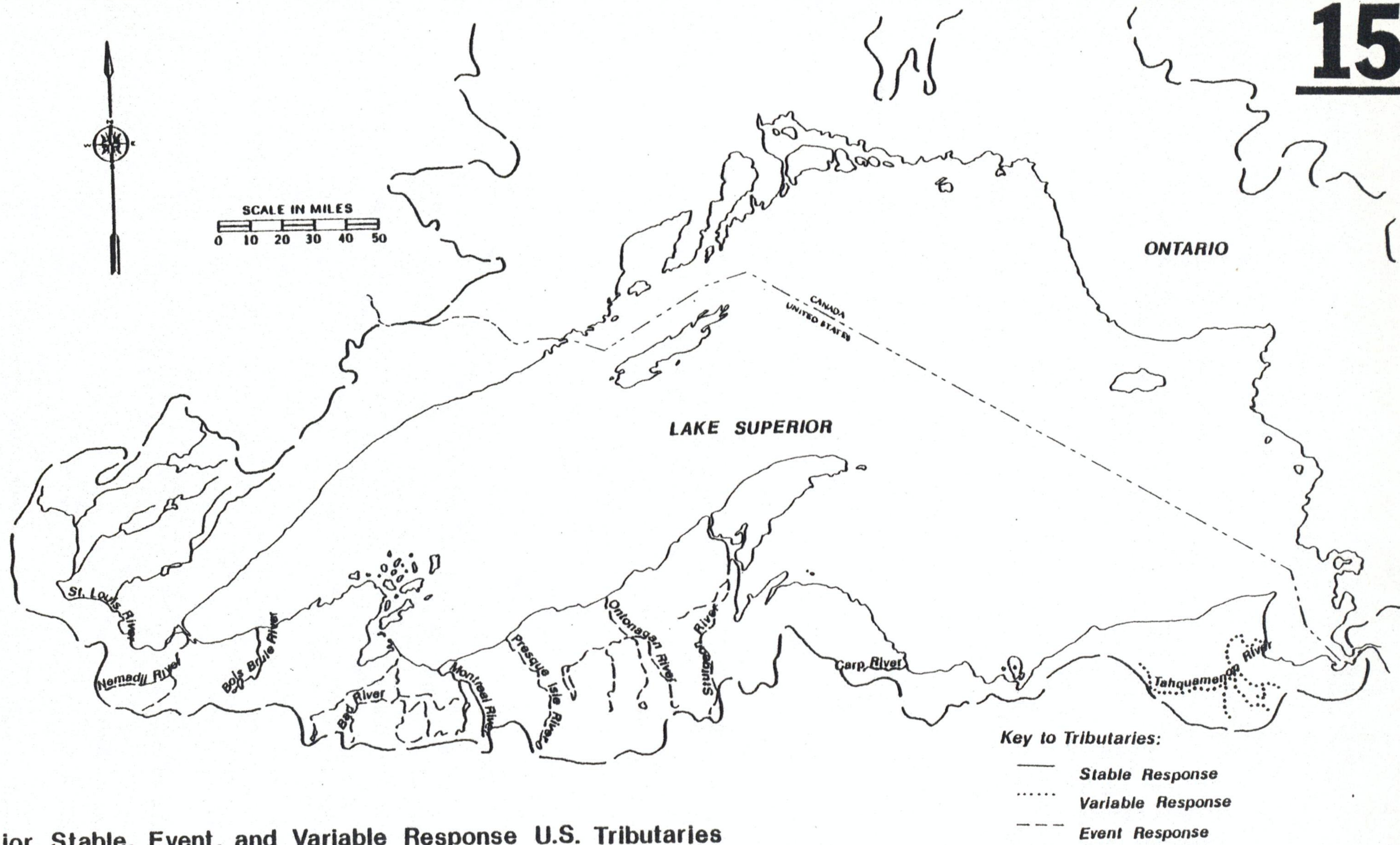


Predominate Soil Texture in the U.S. L. Erie Basin

Predominate Soil Texture in the U.S. L. Ontario Basin

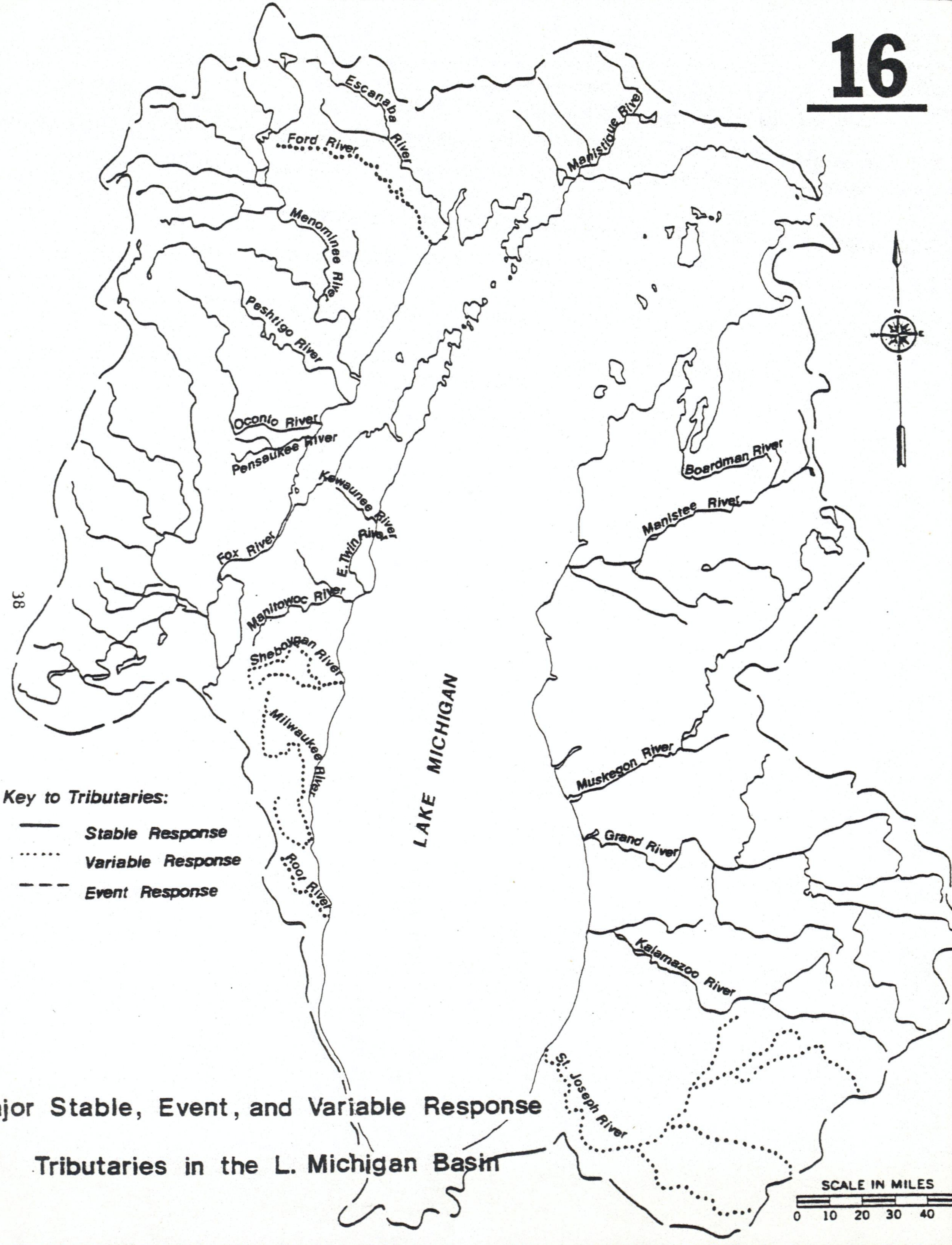


15



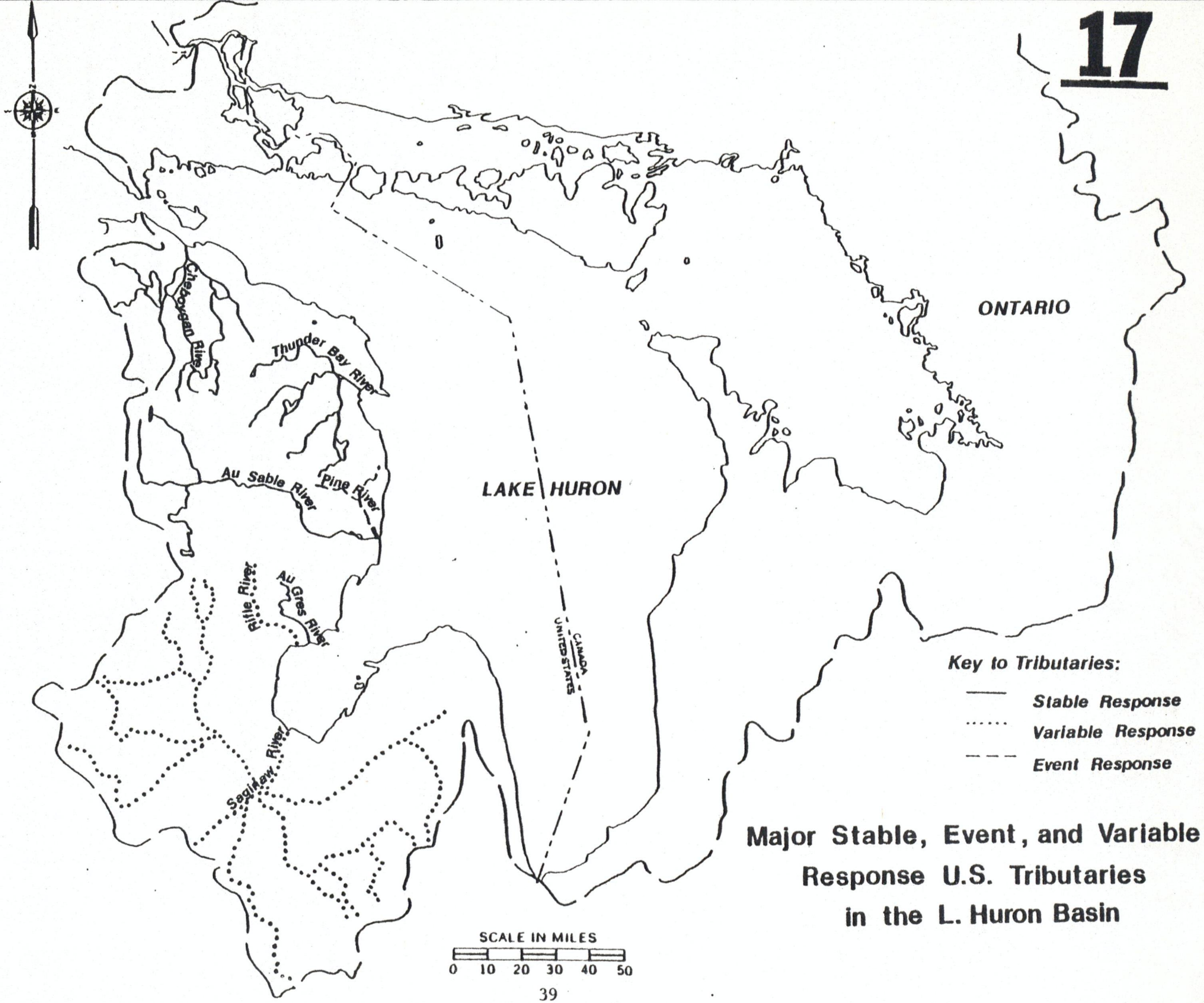
Major Stable, Event, and Variable Response U.S. Tributaries in the L. Superior Basin

16

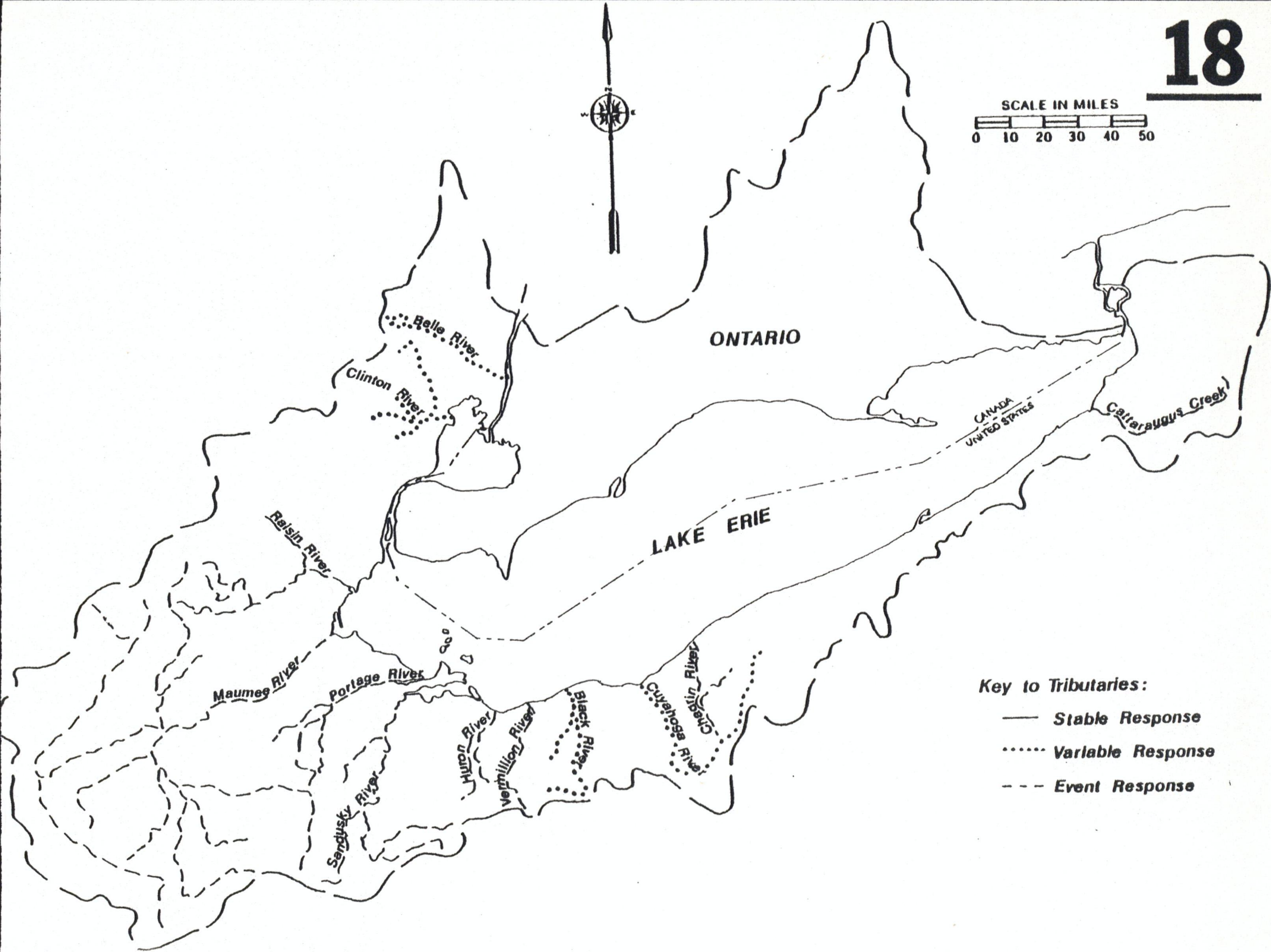


Major Stable, Event, and Variable Response Tributaries in the L. Michigan Basin

17



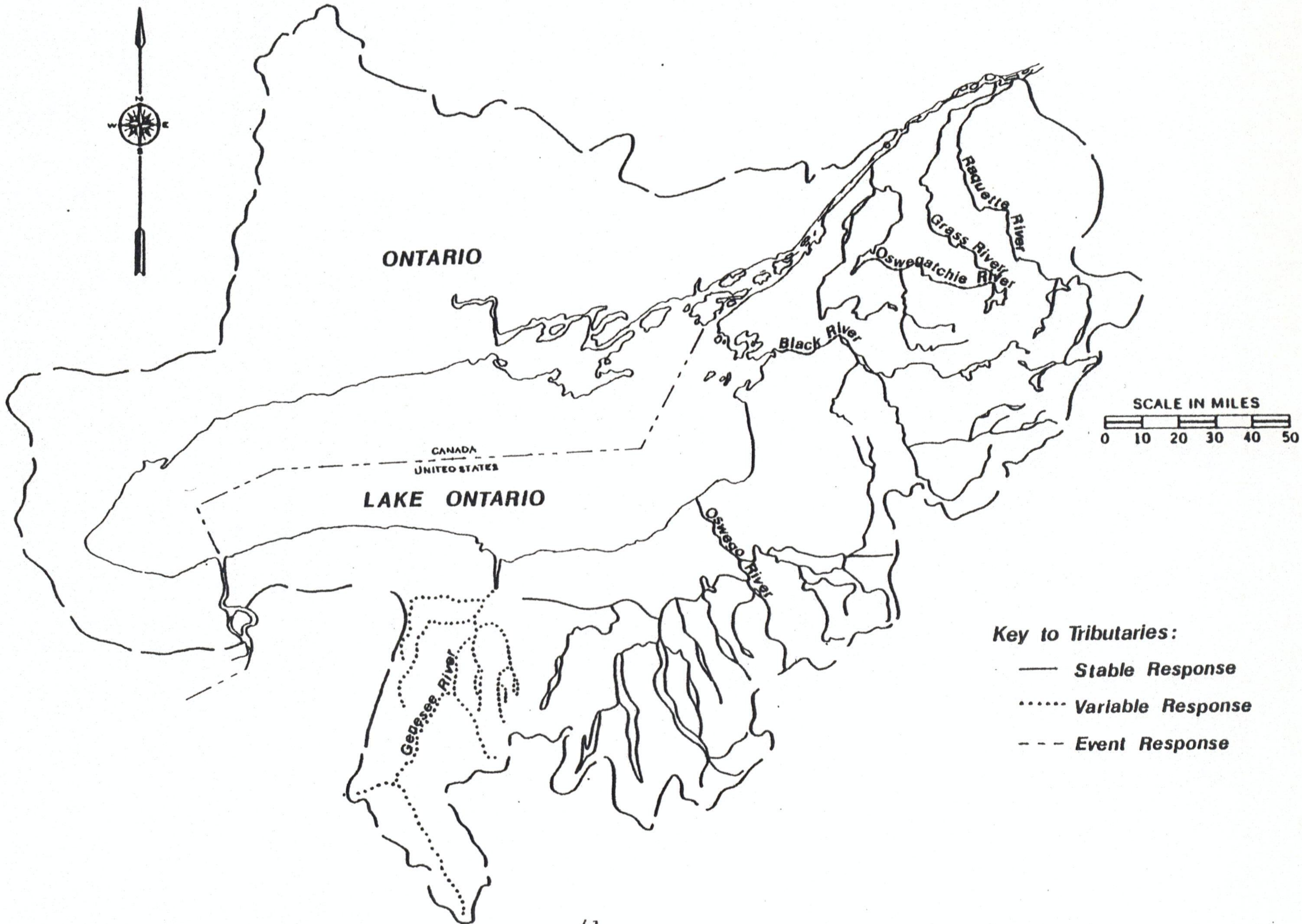
Major Stable, Event, and Variable Response U.S. Tributaries in the L. Huron Basin

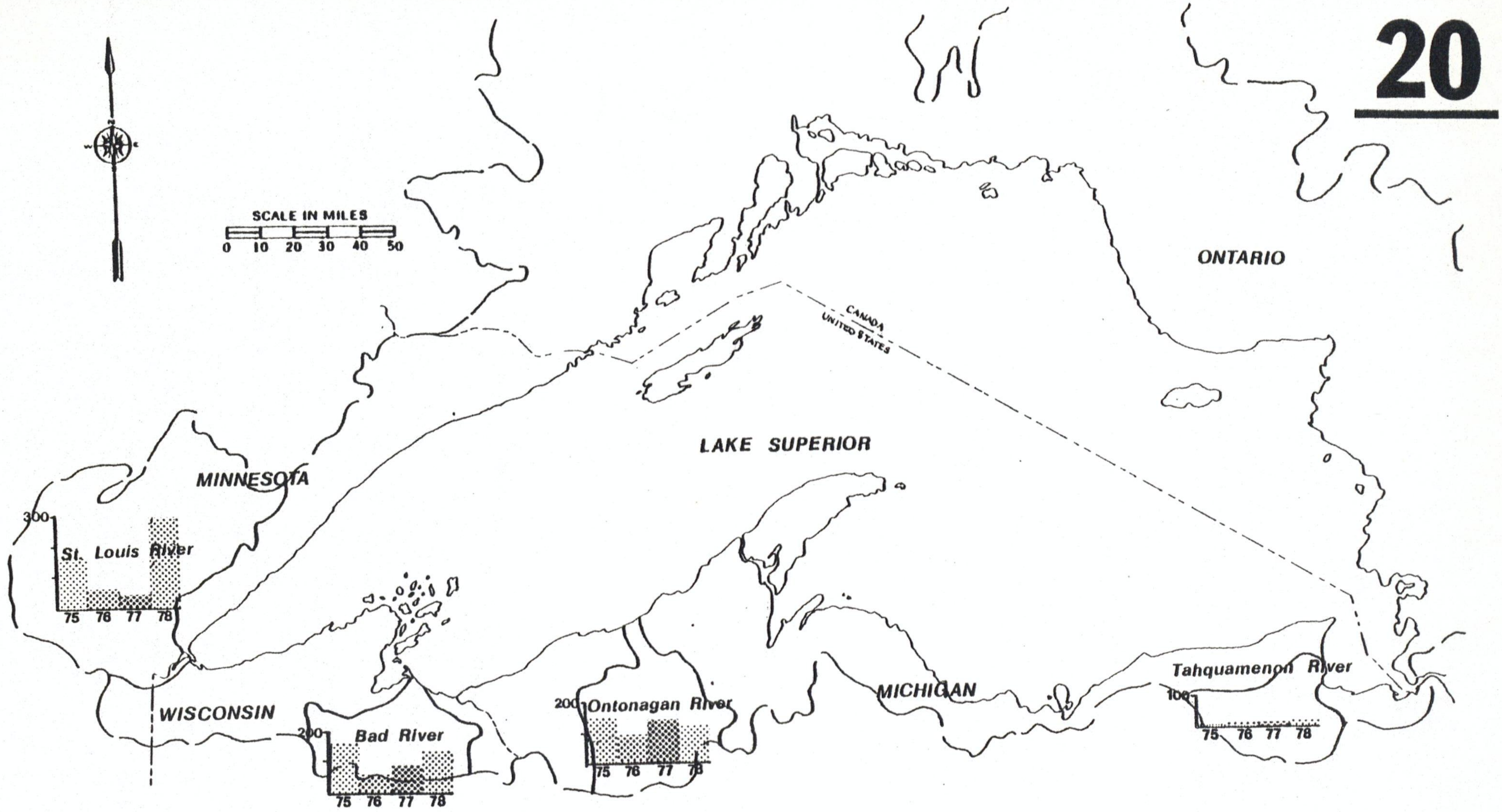


Major Stable, Event, and Variable Response U.S. Tributaries in the L. Erie Basin

19

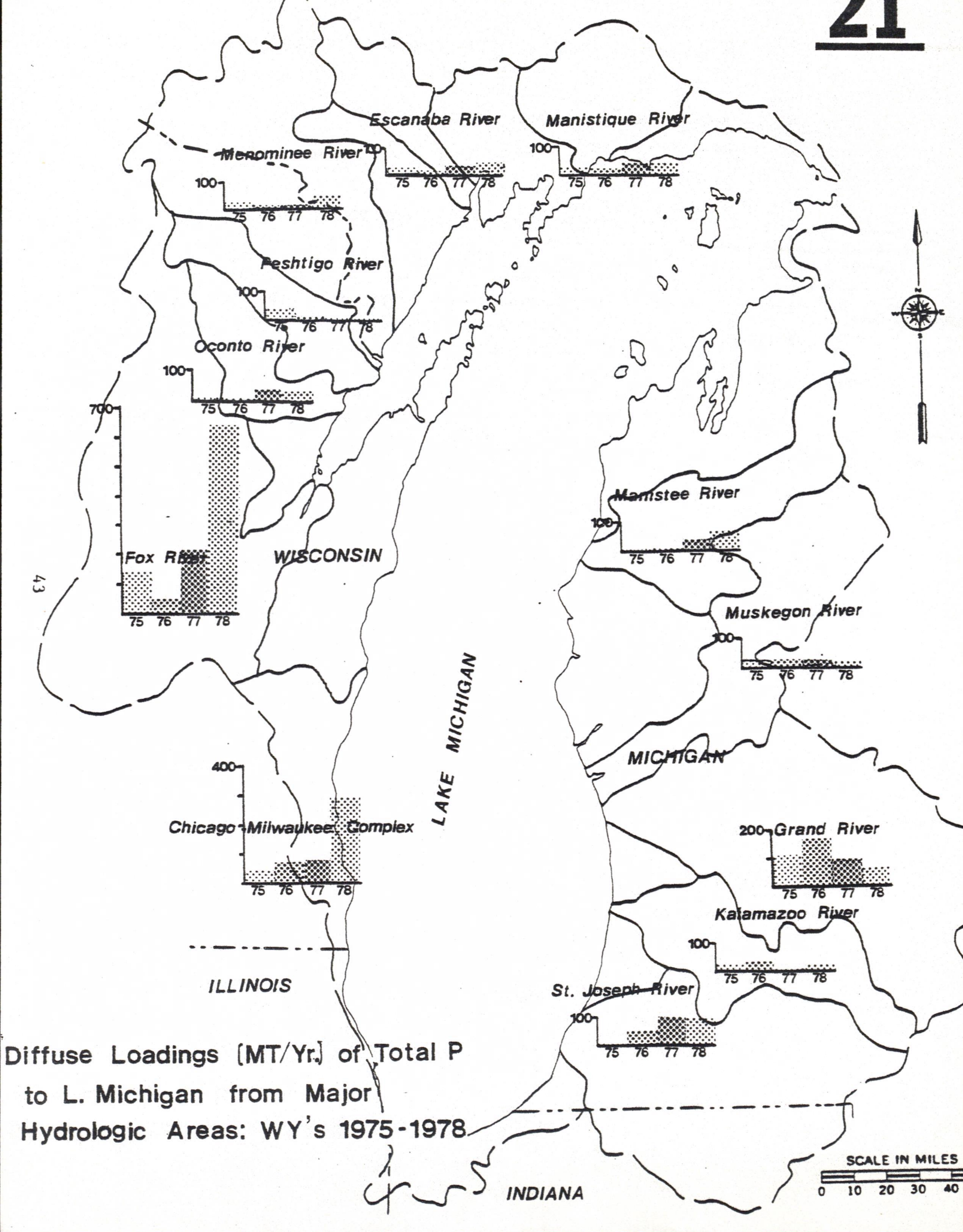
Major Stable, Event, and Variable Response U.S. Tributaries in the L. Ontario Basin





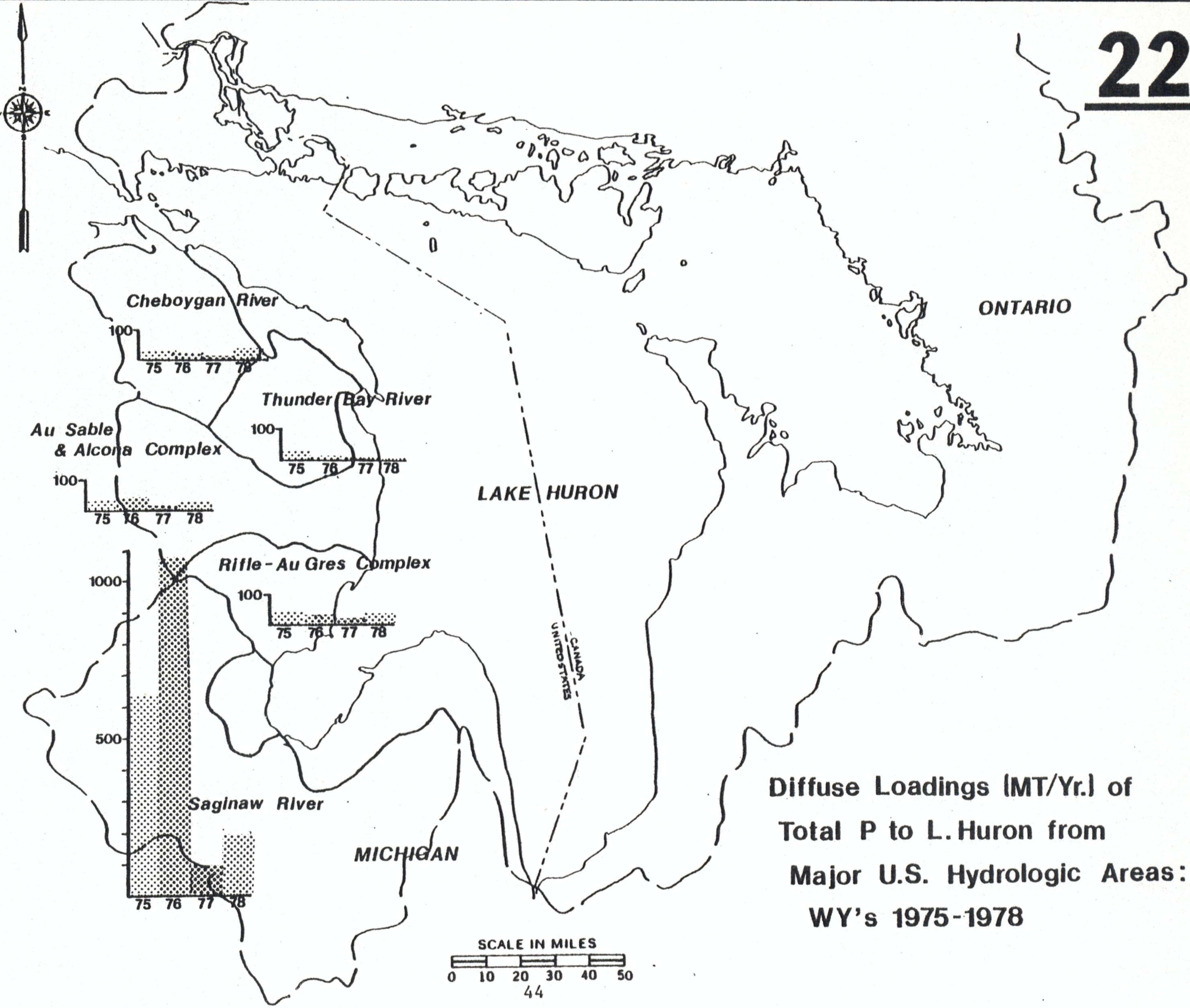
Diffuse Loading (MT/Yr.) of Total P to L. Superior from Major U.S. Hydrologic Areas: WY's 1975-1978

21

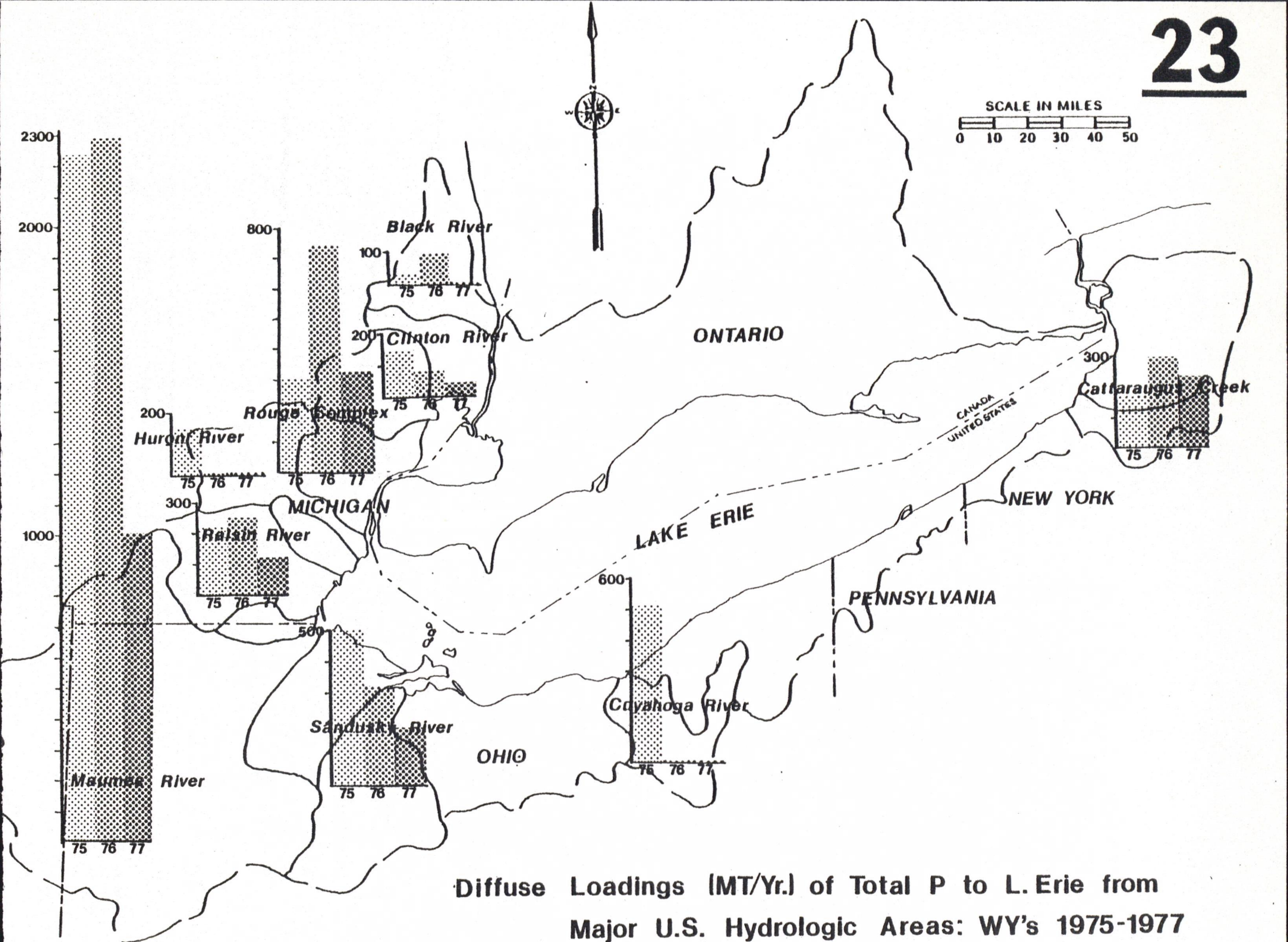


Diffuse Loadings (MT/Yr.) of Total P to L. Michigan from Major Hydrologic Areas: WY's 1975-1978

22



Diffuse Loadings (MT/Yr.) of Total P to L. Huron from Major U.S. Hydrologic Areas: WY's 1975-1978



Diffuse Loadings (MT/Yr.) of Total P to L. Erie from Major U.S. Hydrologic Areas: WY's 1975-1977

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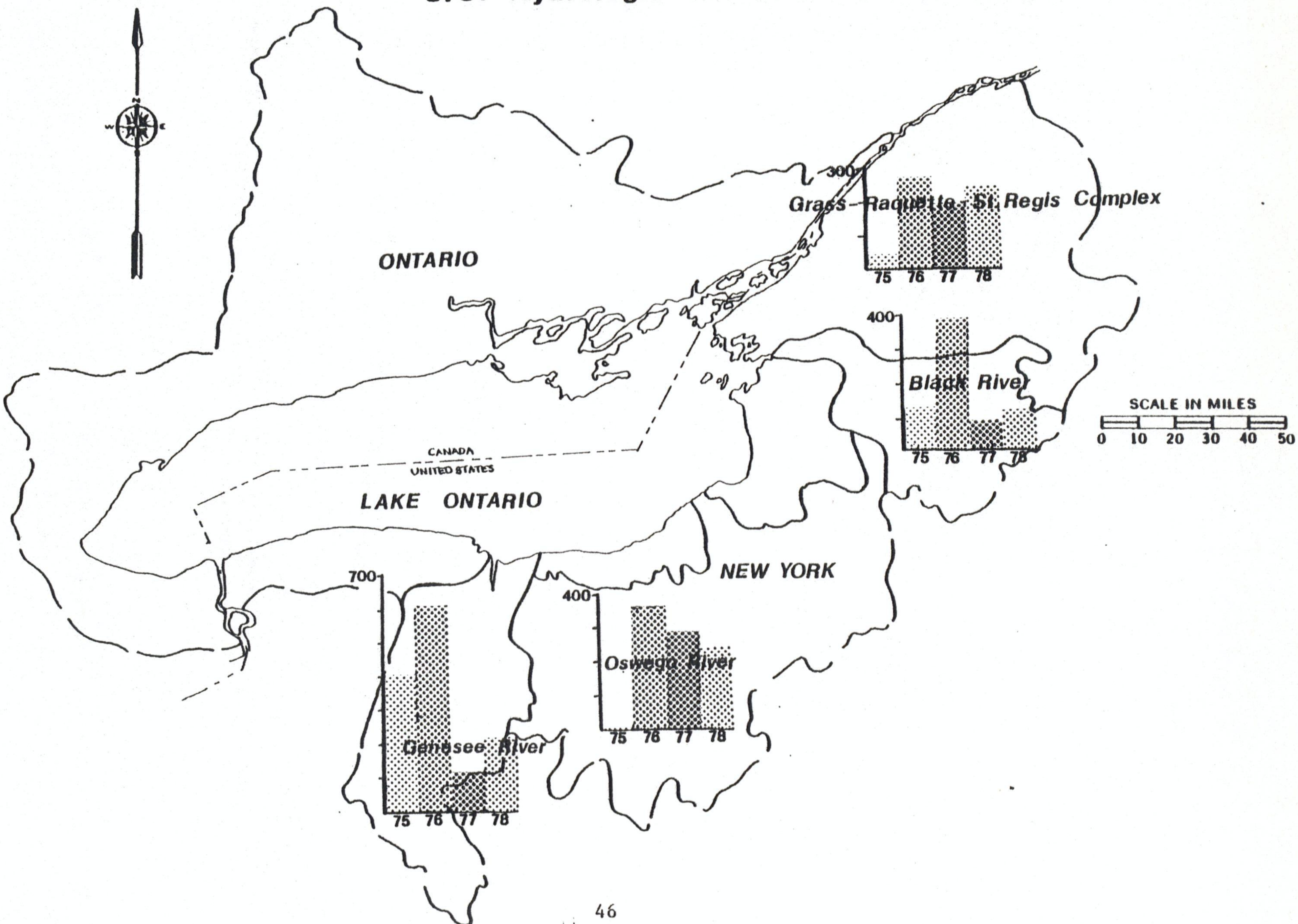
Diffuse Loadings (MT/Yr.) of Total P to L. Ontario from Major U.S. Hydrologic Areas: WY's 1975-1978



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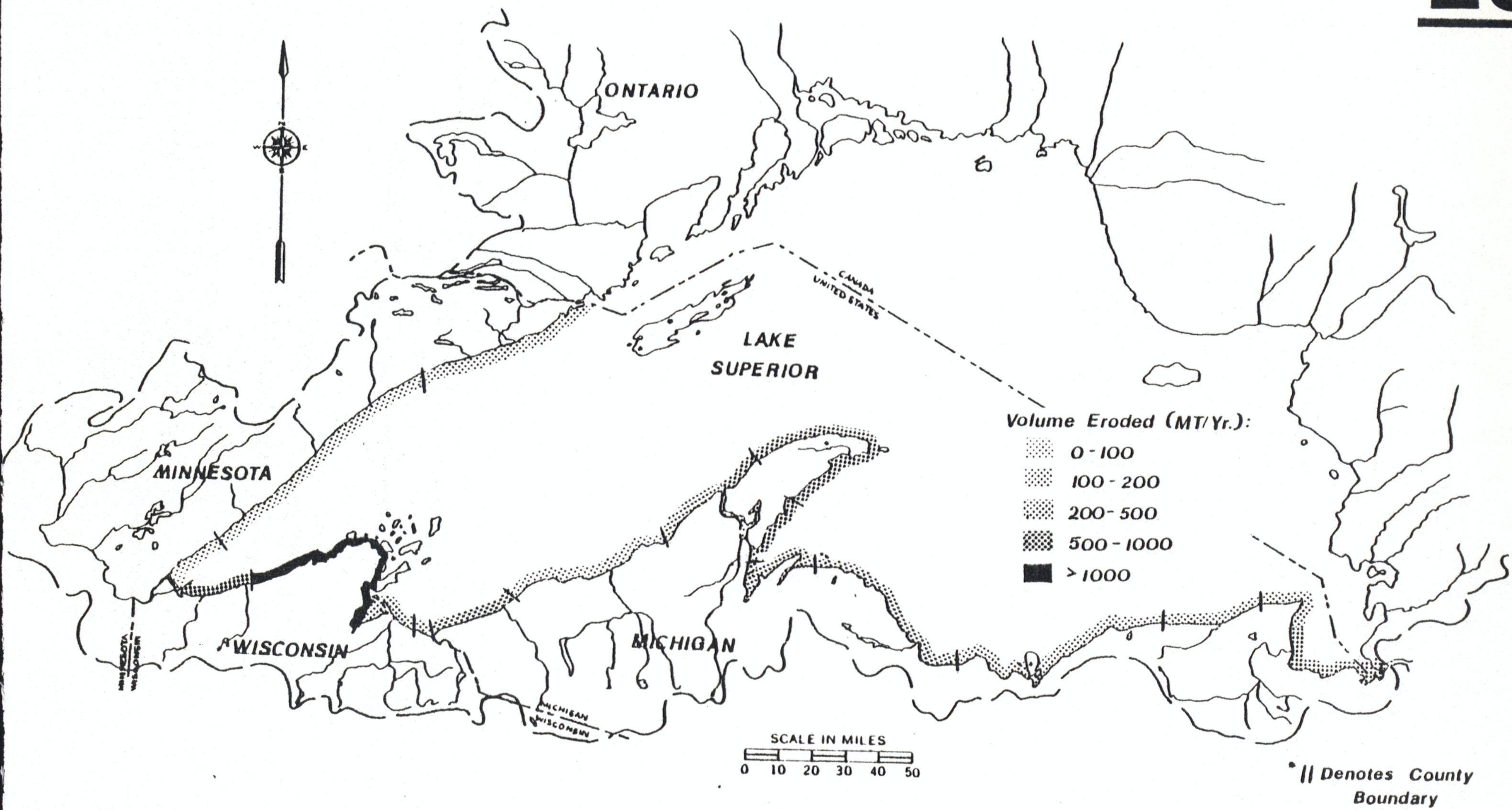
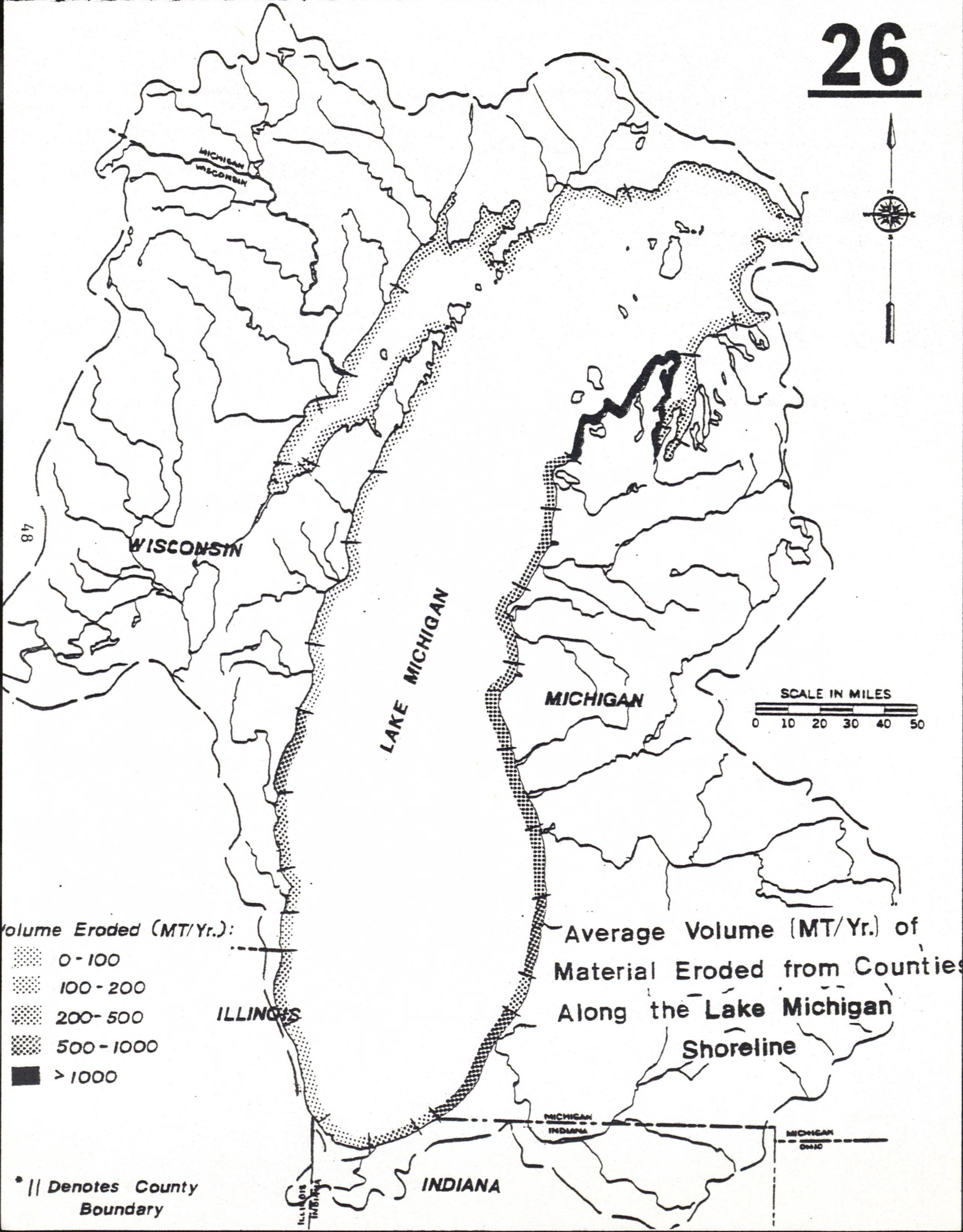


Average Volume (MT/Yr.) of Material Eroded from Counties Along the U.S. Lake Superior Shoreline



Average Volume (MT/Yr.) of Material Eroded from Counties Along the Lake Michigan Shoreline

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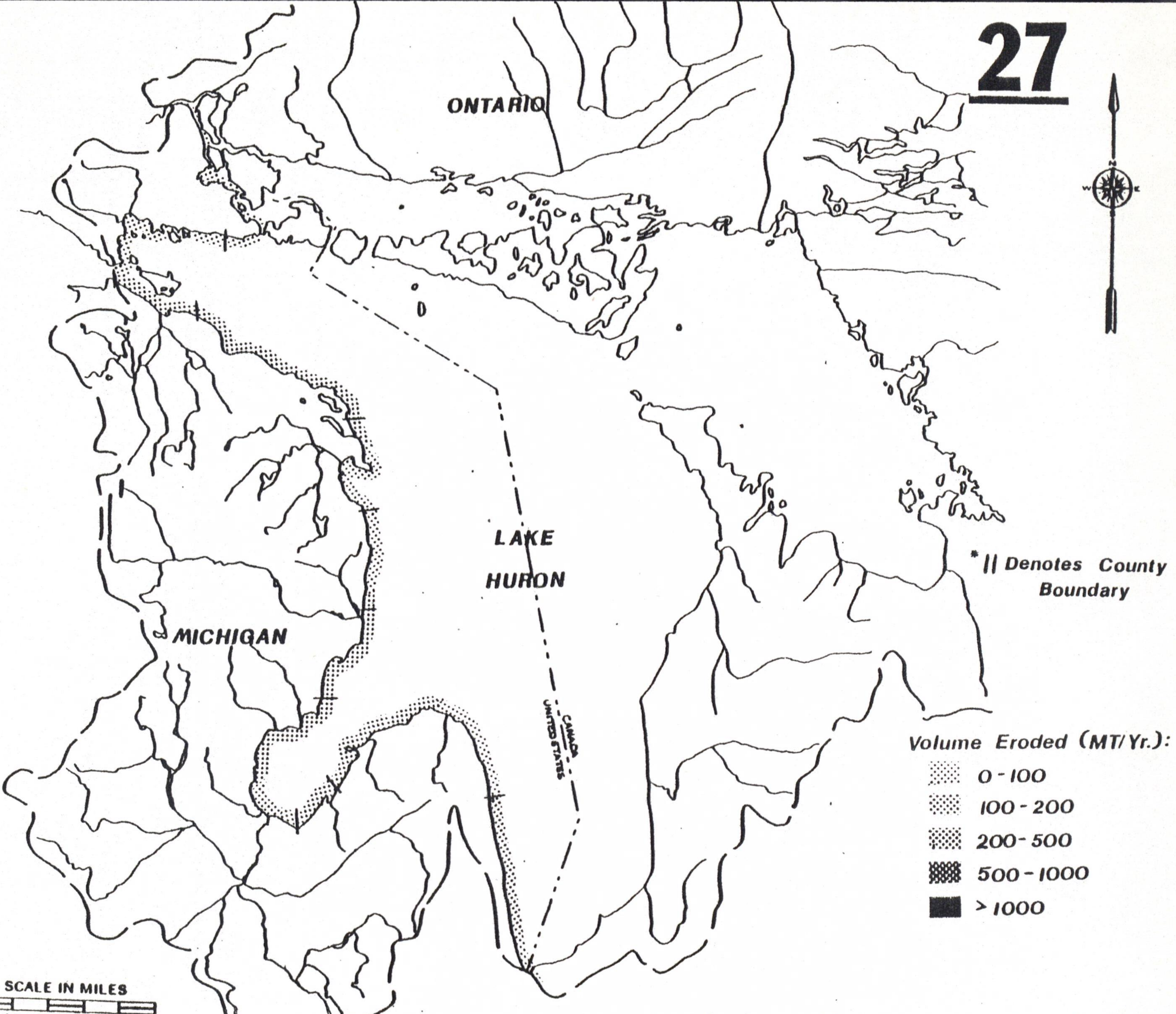

Average Volume (MT/Yr.) of Material Eroded from

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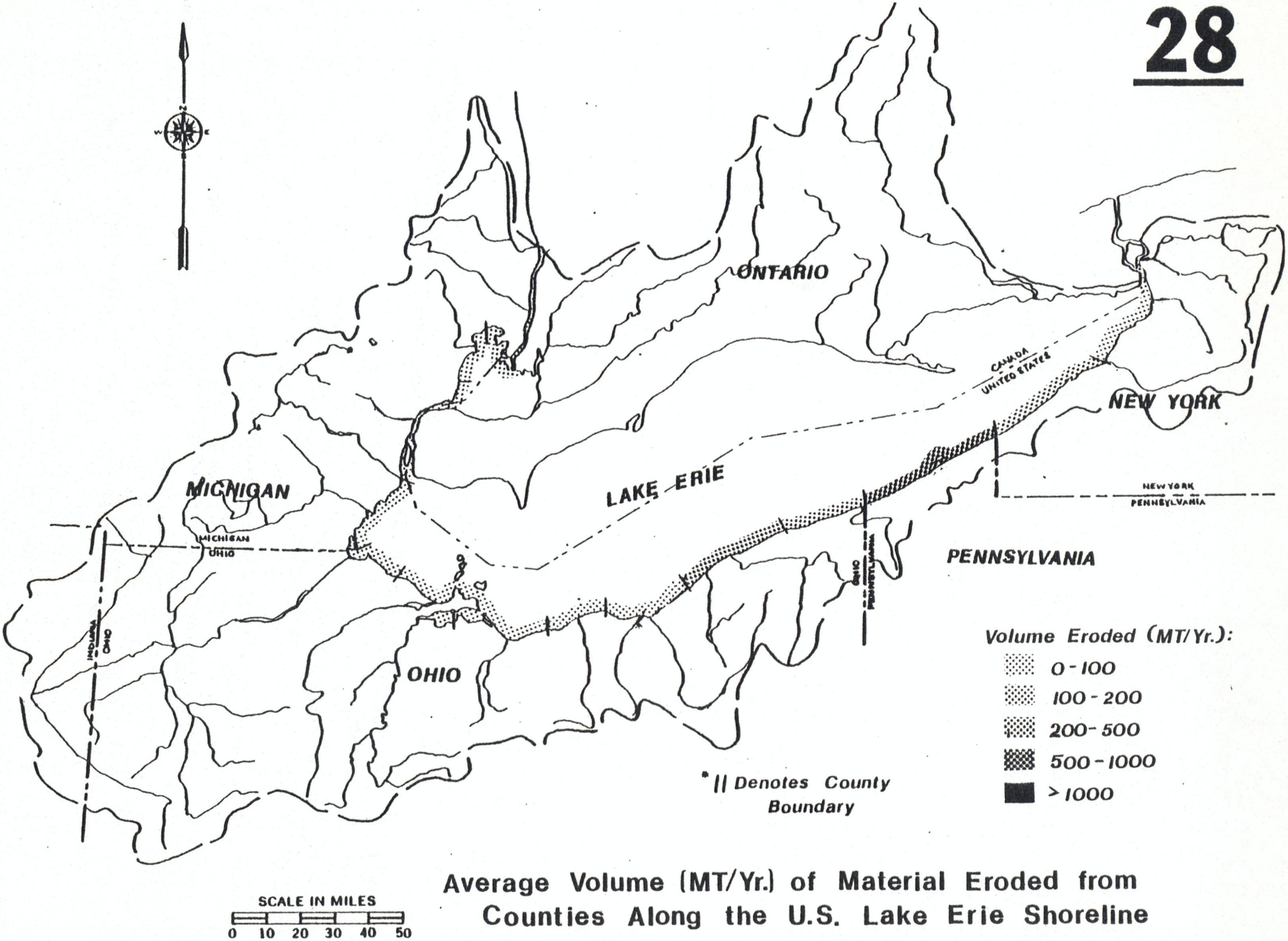
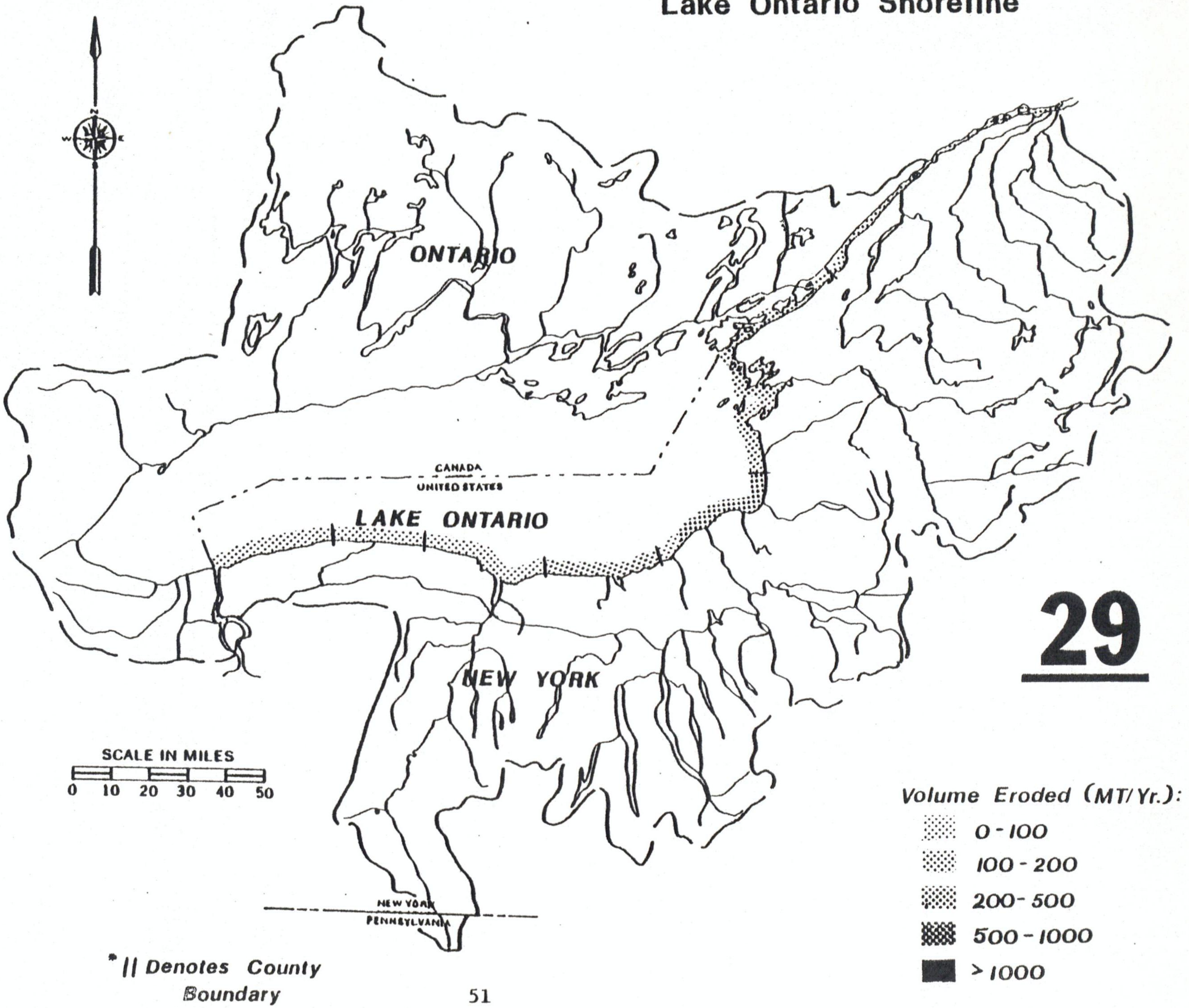


Average Volume (MT/Yr.) of Material Eroded from Counties Along the U.S. Lake Erie Shoreline

Average Volume (MT/Yr.) of Material Eroded from Counties Along the U.S. Lake Ontario Shoreline



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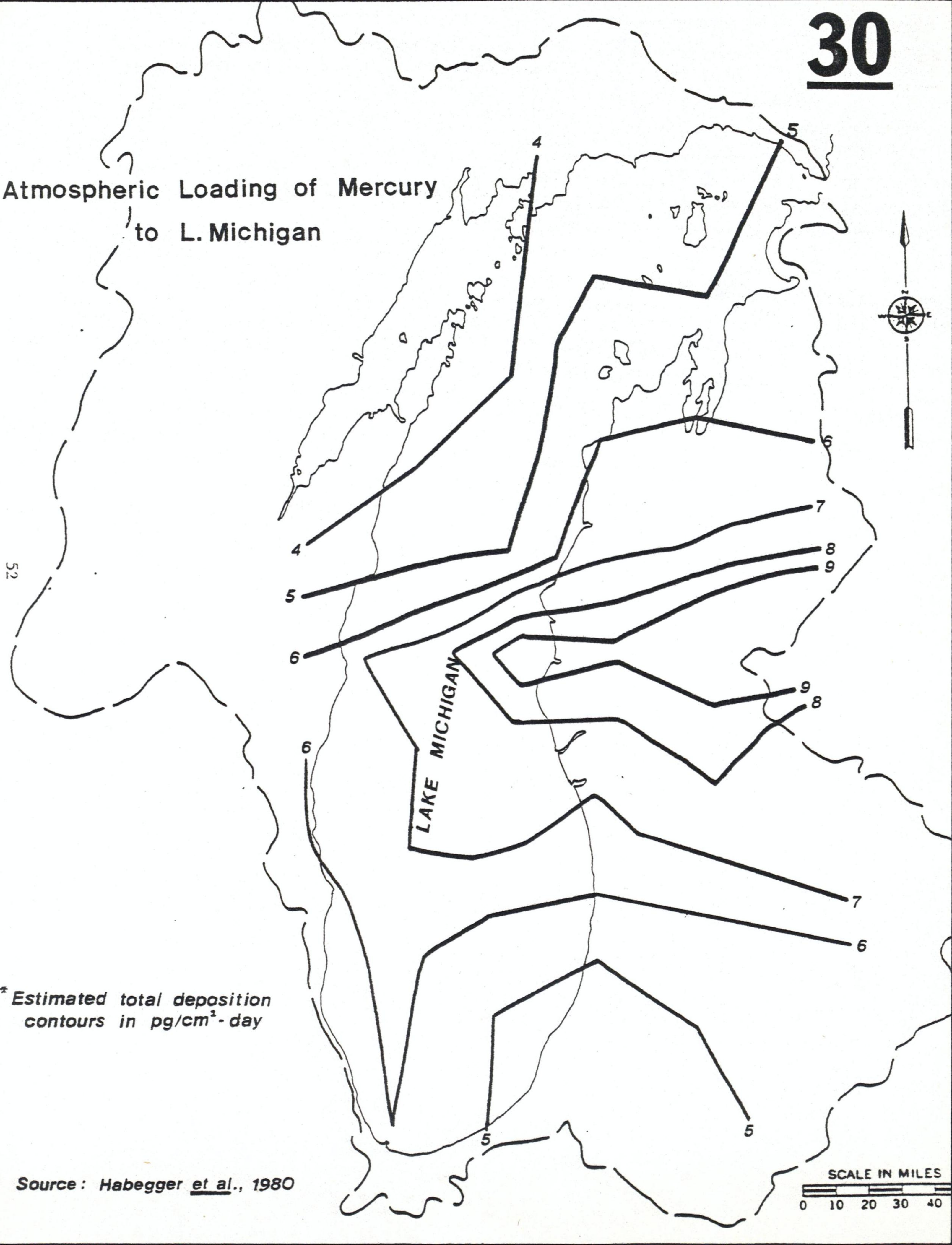
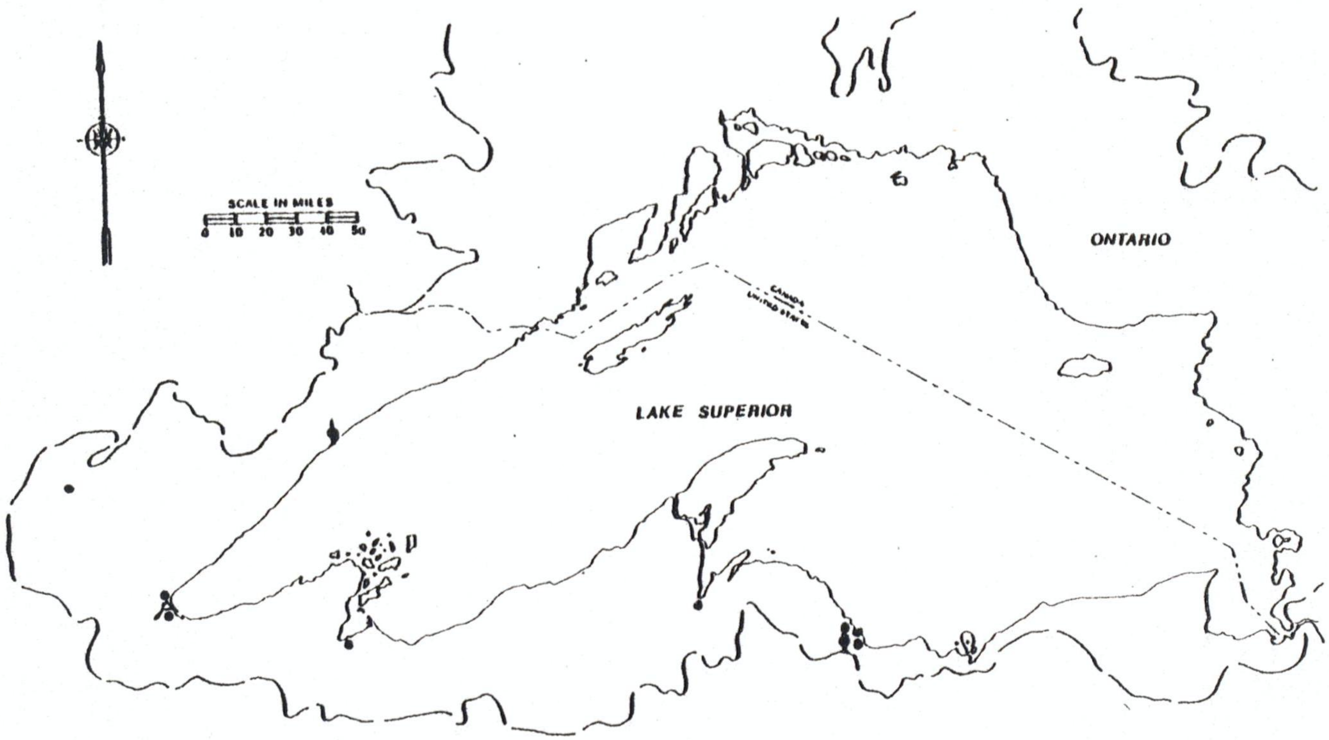
Atmospheric Loading of Mercury to L. Michigan



* Estimated total deposition contours in pg/cm²-day

Source: Habegger <u>et al</u>., 1980

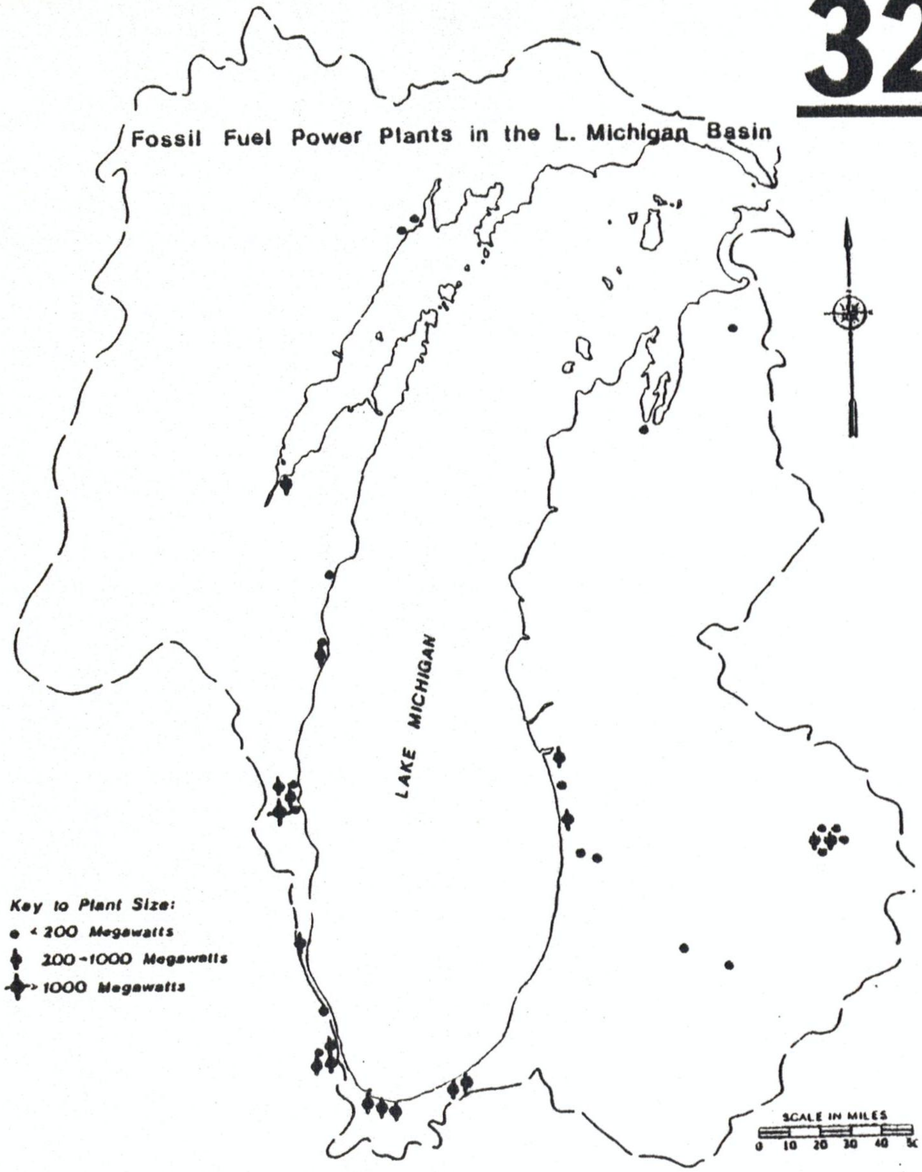
31



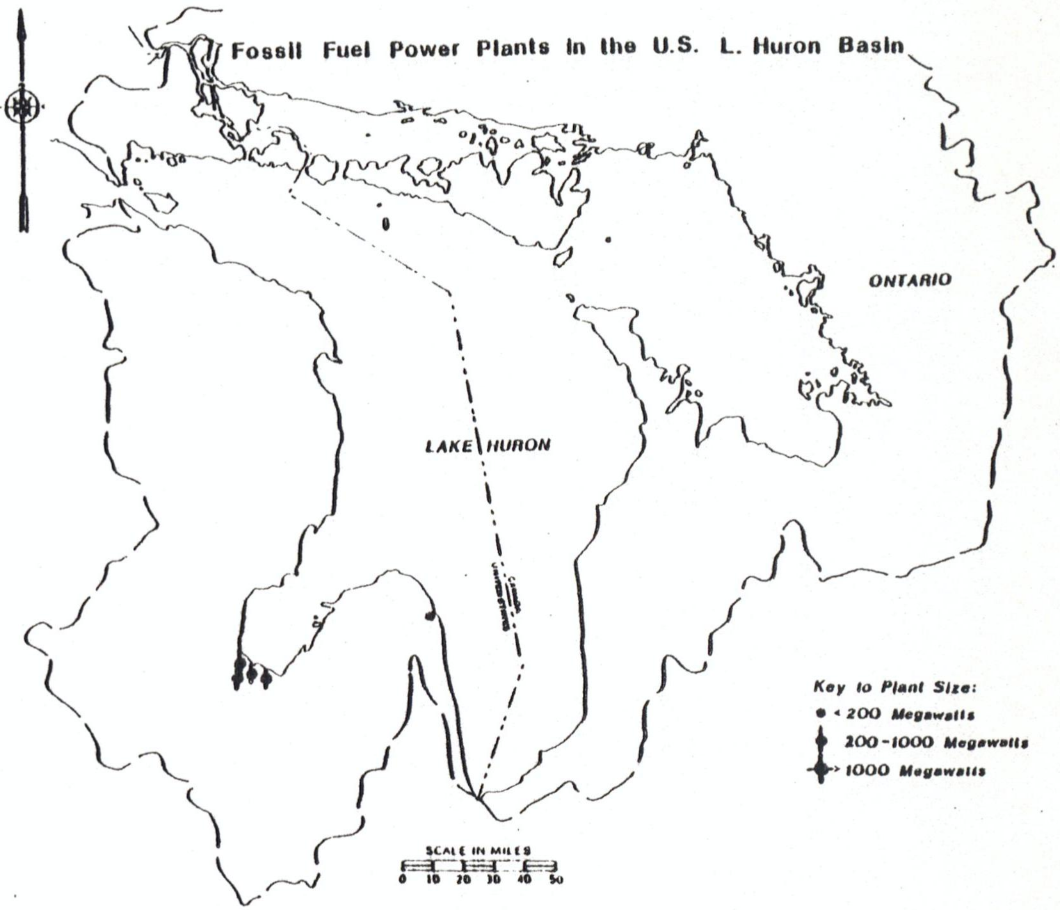
Fossil Fuel Power Plants in the U.S. L. Superior Basin

Key to Plant Size:
- < 200 Megawatts
- 200 - 1000 Megawatts
- > 1000 Megawatts

32


Fossil Fuel Power Plants in the L. Michigan Basin
LAKE MICHIGAN
Key to Plant Size:
< 200 Megawatts
200-1000 Megawatts
> 1000 Megawatts
SCALE IN MILES
0 10 20 30 40 50

33


Fossil Fuel Power Plants in the U.S. L. Huron Basin
ONTARIO
LAKE HURON
Key to Plant Size:
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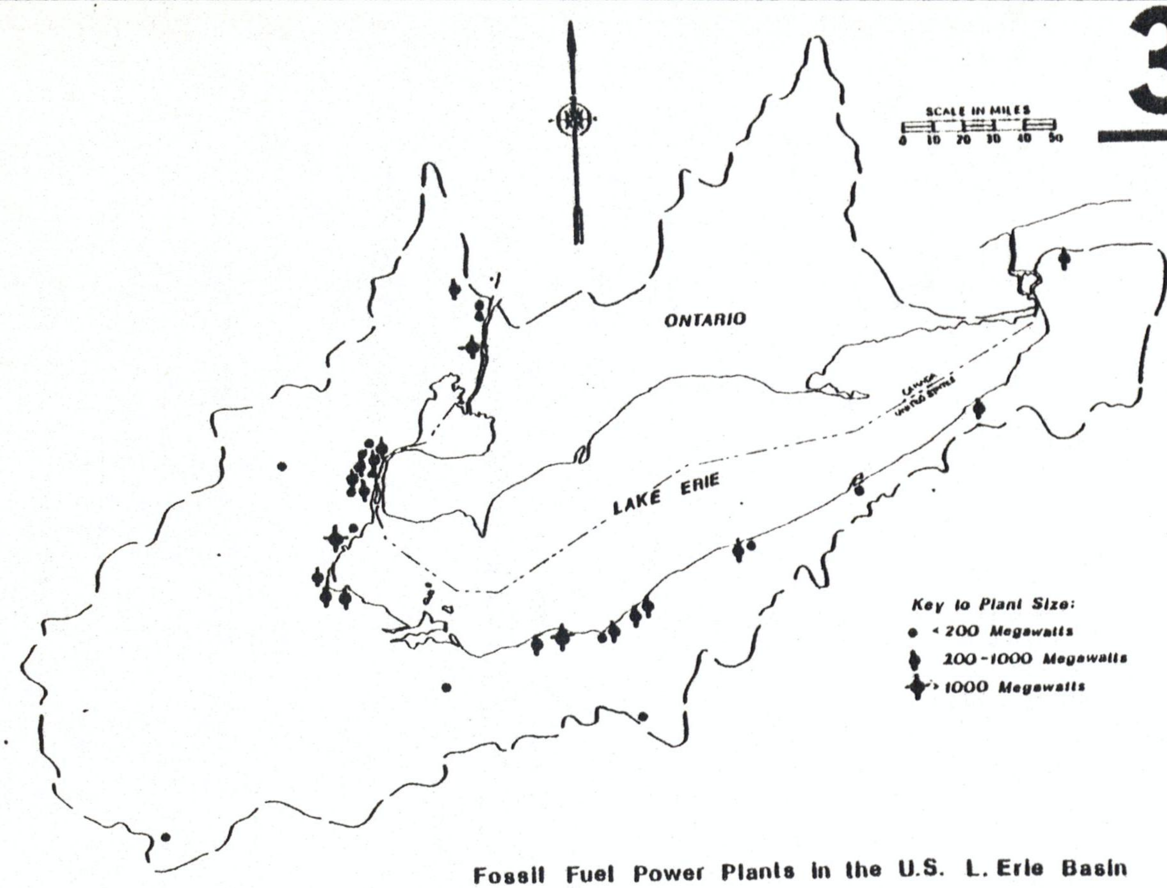
200-1000 Megawatts
> 1000 Megawatts
SCALE IN MILES
0 10 20 30 40 50

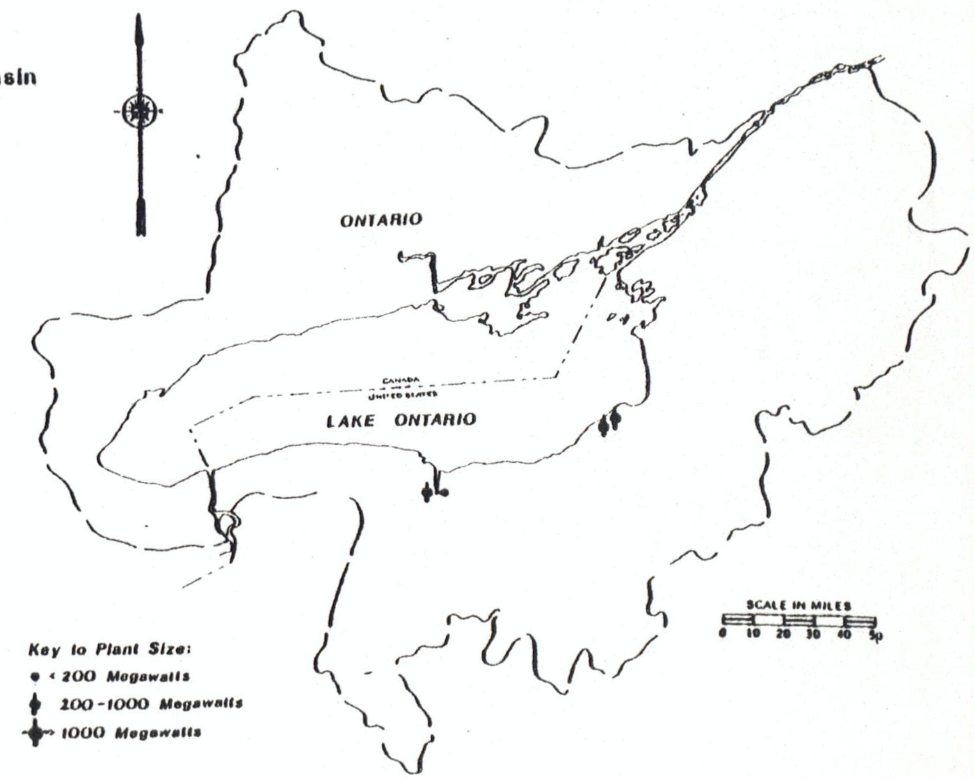
34



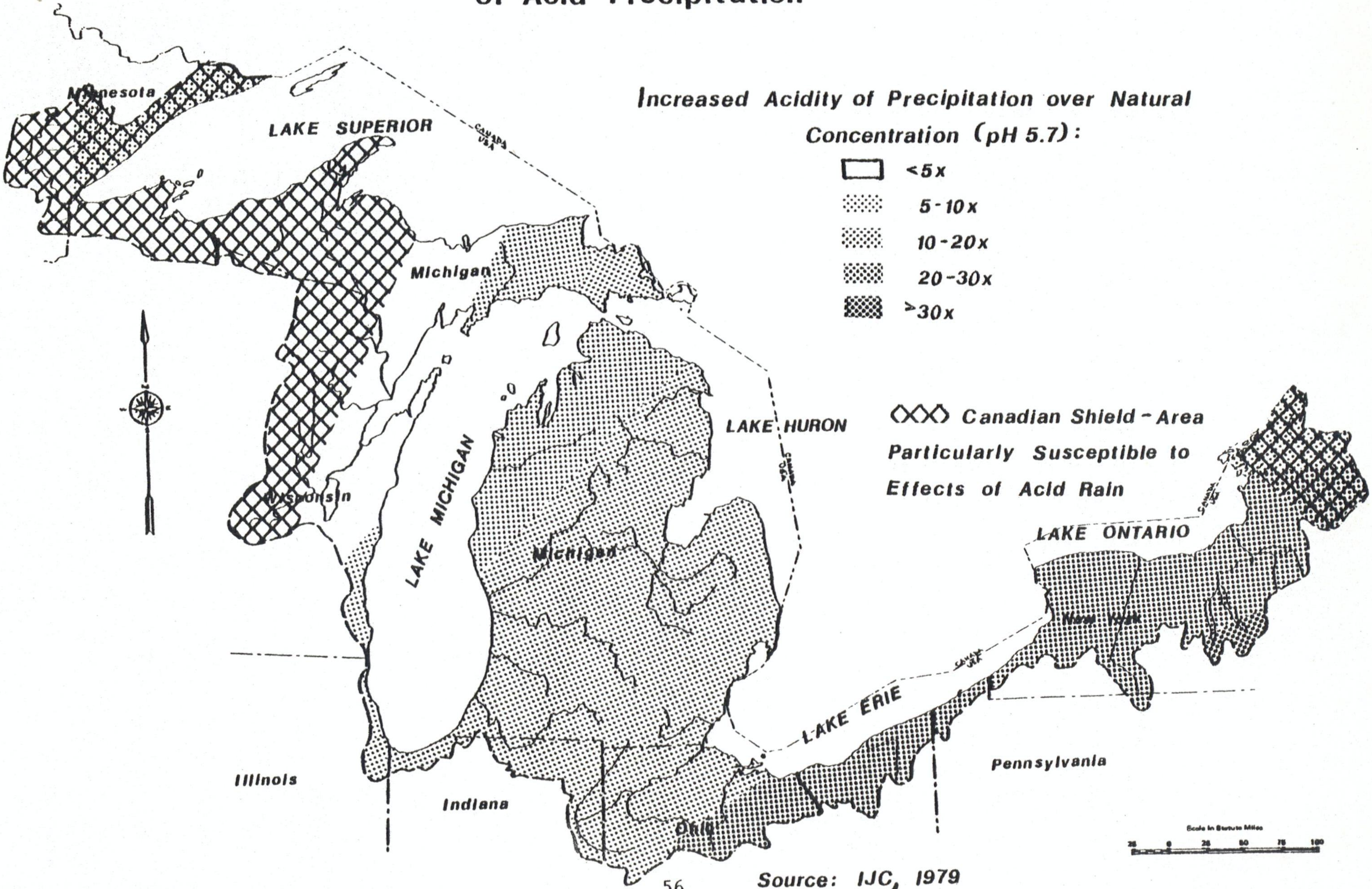
Fossil Fuel Power Plants in the U.S. L. Erie Basin

35

Fossil Fuel Power Plants in the U.S. L. Ontario Basin



Areas in the U.S. Great Lakes Basin Subjected to Increased Acidity in Precipitation & Areas Particularly Susceptible to the Effects of Acid Precipitation



Major Nonpoint Source Control Projects in the U.S. Great Lakes Basin

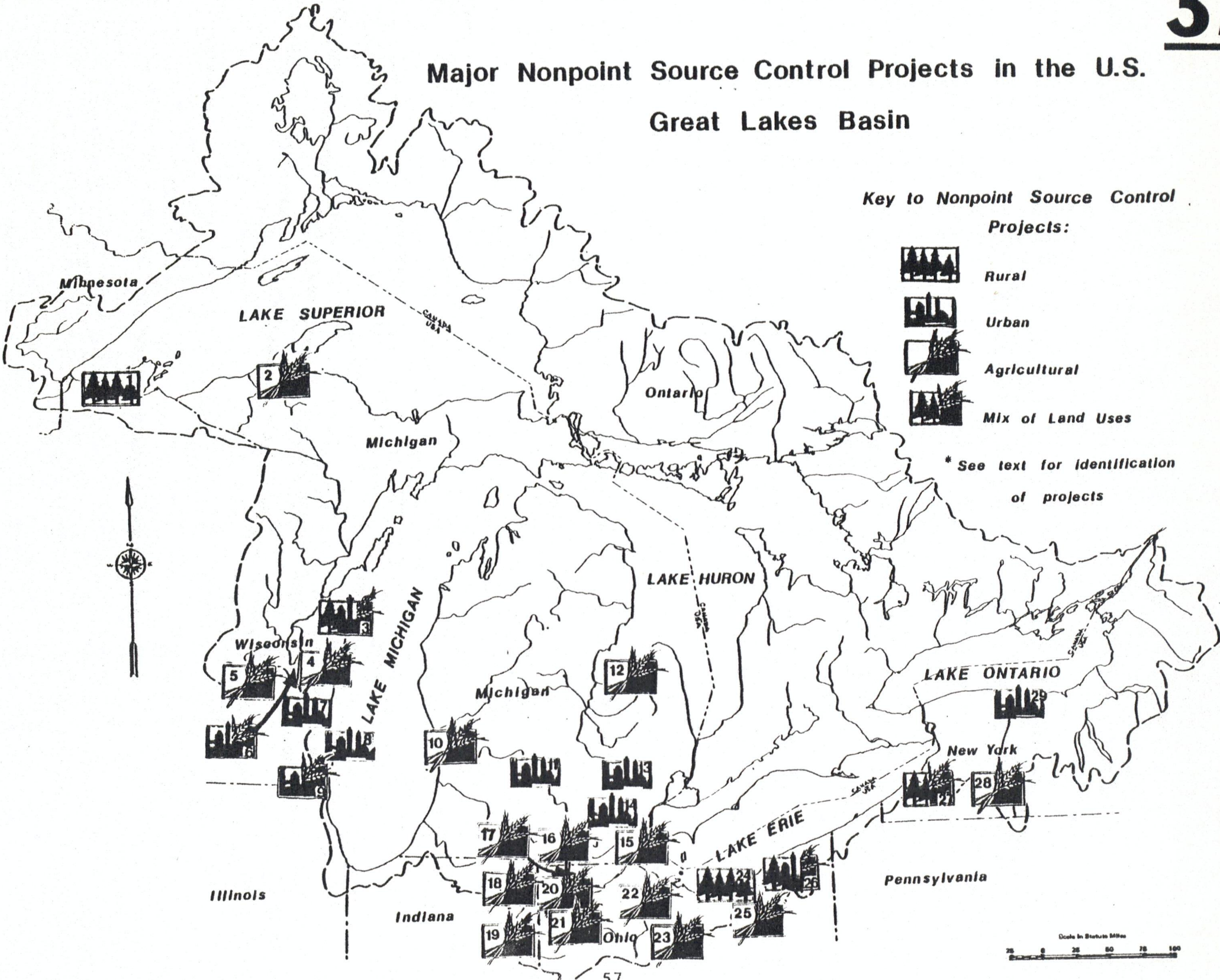
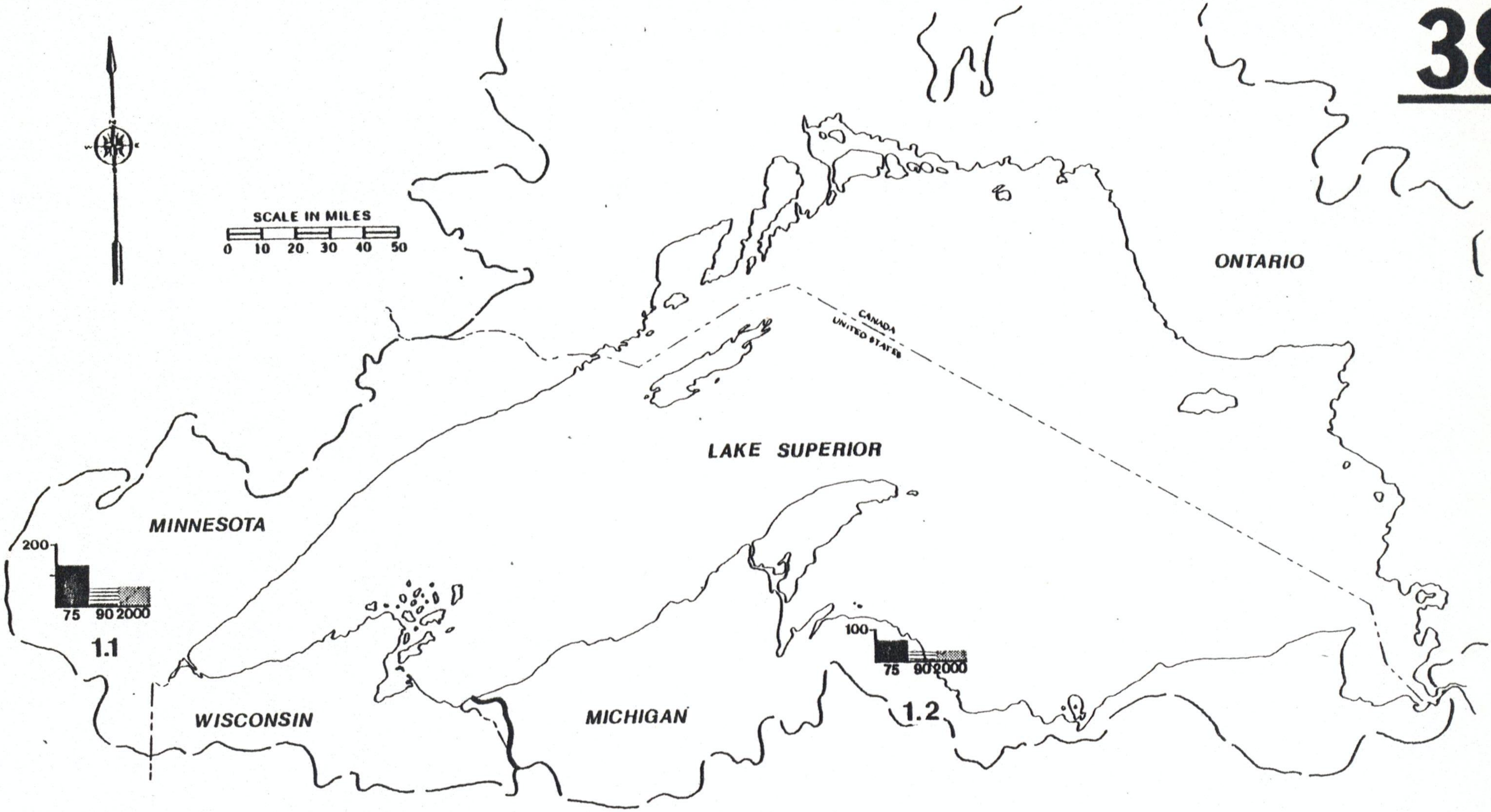


TABLE 4

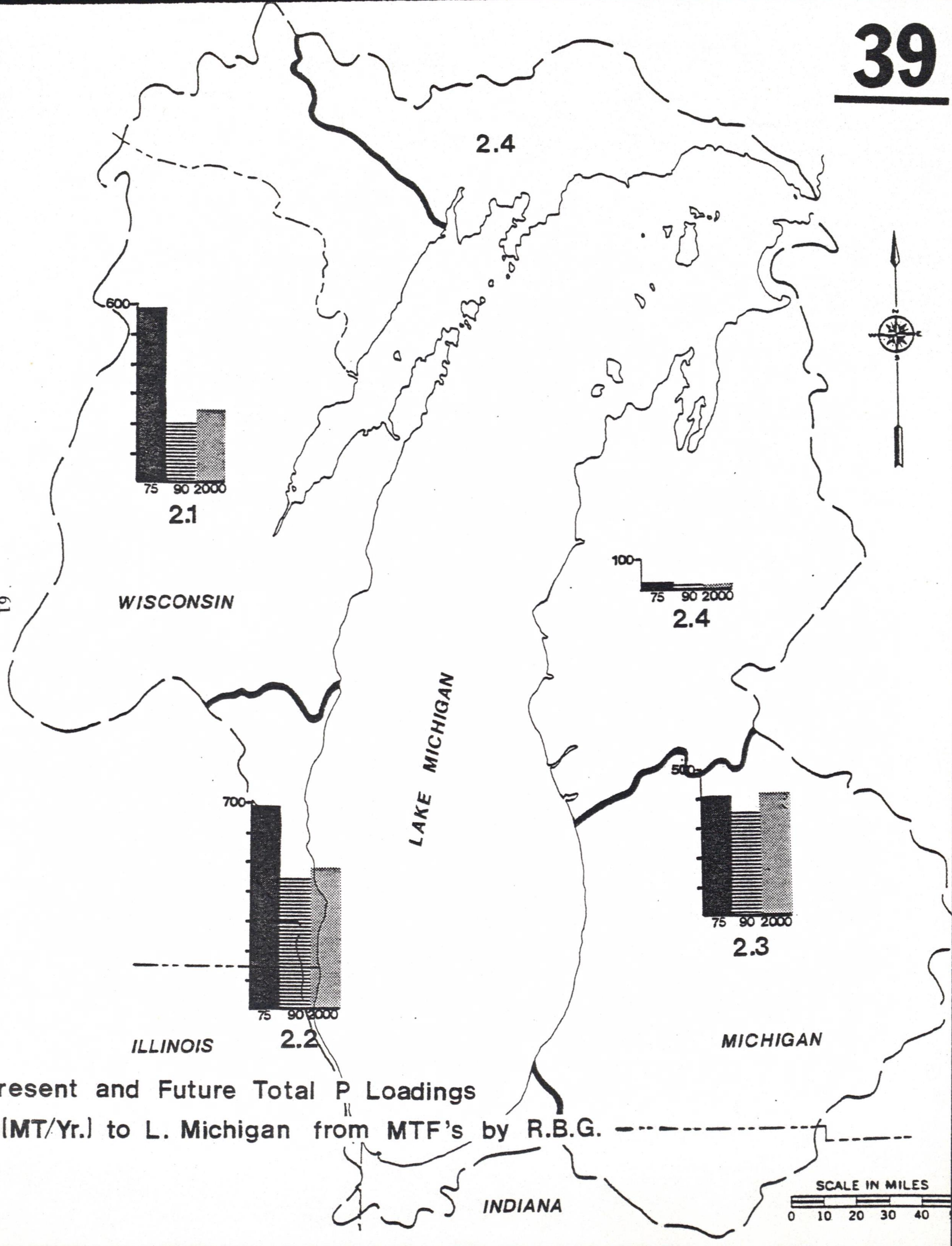
MAJOR NONPOINT SOURCE CONTROL PROJECTS
IN THE U.S. GREAT LAKES BASIN

Project No.	Project Name	Status	Location	Principle Problems Addressed
1	Western Lake Superior Red Clay Erosion Study (Sec. 108(a) Demonstration Project)	Complete	Skunk Creek Watershed Minnesota; Little Balsam, Pine Creek Watershed, Spoon Creek Watershed, Madigan Beach and Indian Cemetery Beach, Wisconsin	Streambank, shoreline and roadside erosion
2	Agricultural Conservation Program (ACP) Small Farmer Project	Ongoing	Baraga & Houghton Counties, Michigan	Soil erosion problems resulting from high soil acidity, which deters establishment of long-term vegetative cover
3	Lower Manitowoc River Watershed Study (Rural Clean Water Program)	Ongoing	Wisconsin	Pollution from manure carried in runoff from barnyards or frozen or saturated fields; erosion from streambanks and agricultural and construction activities; septic system malfunctions, urban runoff
4	Onion River Watershed Study (Wisconsin Fund)	Ongoing	Wisconsin	Pollution from manure carried in runoff from frozen or saturated fields
5	Green Lake Watershed Study (Wisconsin Fund)	Ongoing	Wisconsin	Agricultural nonpoint source pollution
6	Washington County Project (Sec. 108(a) Demonstration Project)	Complete	Wisconsin	Erosion from agricultural and construction activities; pollution from manure carried in runoff from unmanaged barnyards
7	Menomonee River Pilot Watershed Study	Complete	Wisconsin	Nonpoint source pollution associated with urban residential land uses
8	Nationwide Urban Runoff Program (NURP) Prototype Project	Ongoing	Milwaukee County Wisconsin	Water quality effects of a streetsweeping program
9	Root River Watershed Project (Wisconsin Fund)	Ongoing	Wisconsin	Erosion and sedimentation from cropland and construction sites
10	Mill Creek Pilot Watershed Study	Complete	Michigan	Pesticide losses from fruit orchards
11	Nationwide Urban Runoff Program (NURP) Prototype Project	Ongoing	Lansing, Michigan	Evaluation of three BMP's for urban storm drainage improvements
12	Southeast Saginaw Bay Control Drainage Basin Project (Agricultural Conservation Program)	Ongoing	Huron & Tuscola Counties, Michigan	Sediment and nutrient runoff from agricultural lands; wind erosion

13	National Urban Runoff Program (NURP) Prototype Project	Ongoing	Troy, Michigan	Evaluation of BMP's for control of excess runoff and sediment
14	National Urban Runoff Program (NURP) Prototype Project	Ongoing	Ann Arbor, Michigan	Evaluation of three BMP's for reducing or preventing pollutant loading from urban runoff
15	Saline Valley Project (Rural Clean Water Program)	Ongoing	Washtenaw & Monroe Counties, Michigan	Erosion and sedimentation from cropland, streambanks, and roadsides; wind erosion; manure carried in runoff from unmanaged barnyards
16	Bean Creek Watershed Project (Lake Erie Wastewater Management Study)	Ongoing	Michigan	Evaluation of BMPs for control of erosion and sedimentation
17	Ottawa Creek Watershed Project (Lake Erie Wastewater Management Study)	Ongoing	Ohio	Evaluation of BMPs for control of erosion and sedimentation
18	Black Creek Project (Sec. 108(a) Demonstration Project	Complete	Indiana	Erosion and sedimentation from agricultural land
19	Allen County Project (Sec. 108(a) Demonstration Project)	Ongoing	Indiana	Demonstration and evaluation of voluntary conservation tillage systems; demonstration of alternative rural sewage systems
20	Defiance County Project (Sec. 108(a) Demonstration Project	Ongoing	Ohio	Demonstration and evaluation of a subsidized conservation tillage program
21	Maumee River Pilot Watershed Study	Complete	Ohio	Sediment and nutrient losses from agricultural land as affected by seasonal changes and soil characteristics
22	Sandusky River Watershed Project (LEWMS)	Ongoing	Ohio	Evaluation of BMPs for control of erosion and sedimentation
23	Honey Creek Watershed Project (LEWMS)	Ongoing	Ohio	Demonstration and evaluation of conservation tillage systems
24	Loraine Harbor Study	Ongoing	Ohio	Streambank erosion and sedimentation of the Black River
25	West Branch of the Rocky River Watershed Project (LEWMS)	Ongoing	Ohio	Evaluation of BMPs for control of erosion and sedimentation
26	Cuyahoga River	Ongoing	Ohio	Steambank and upland erosion
27	South Branch of the Cattaraugus Watershed Project (LEWMS)	Ongoing	New York	Evaluation of BMPs for control of erosion and sedimentation
28	Genessee River Pilot Watershed Study	Complete	New York	Nonpoint source pollution associated with a mixture of land uses
29	Rochester, New York Sec. 108(a) Demonstration Project	Complete	New York	Pollution from combined sewer overflows and an evaluation of a number of treatment alternatives



Present and Future Total P Loadings (MT/Yr.) to L. Superior from U.S. MTF's by R.B.G.



Present and Future Total P Loadings (MT/Yr.) to L. Michigan from MTF's by R.B.G.

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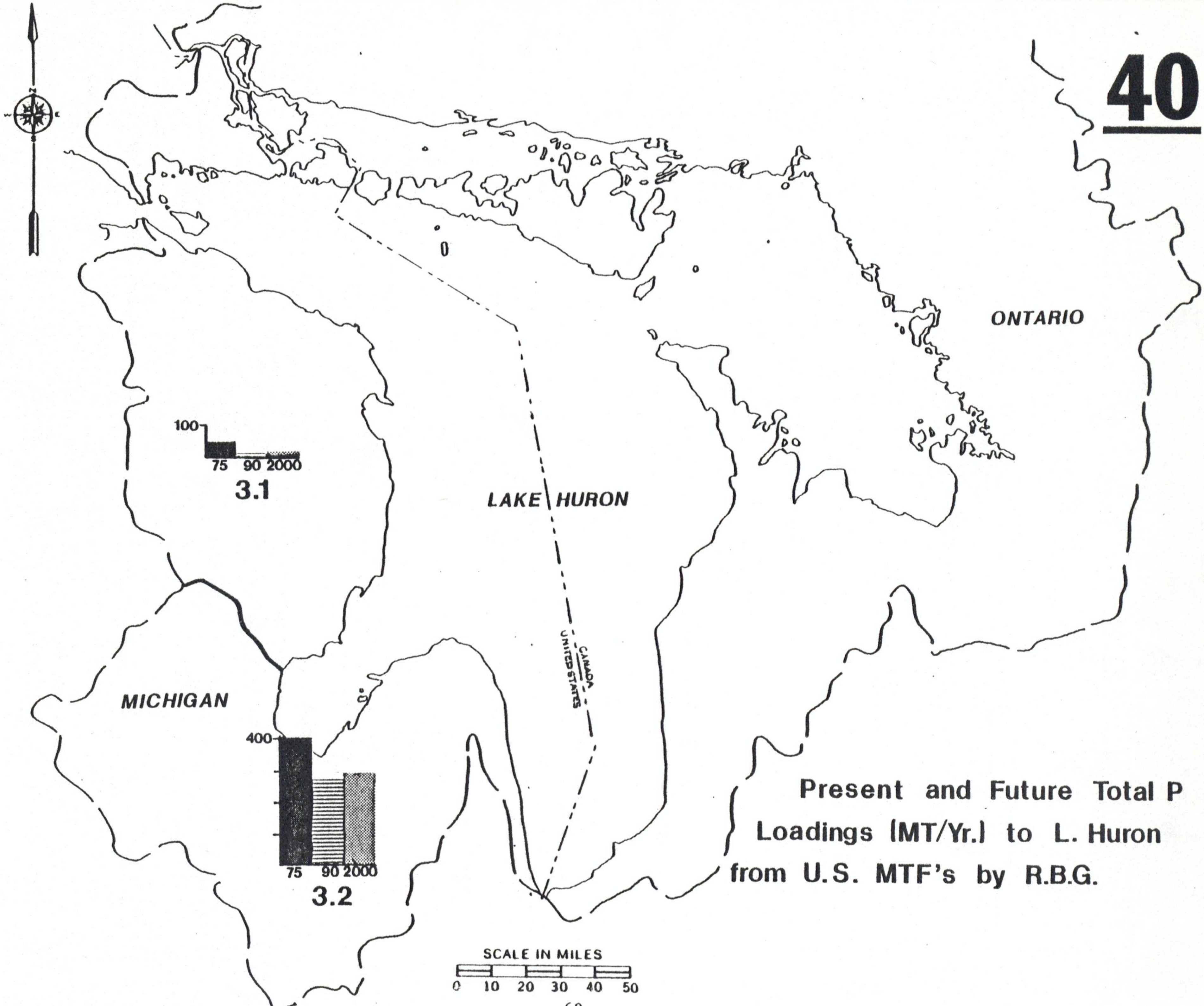
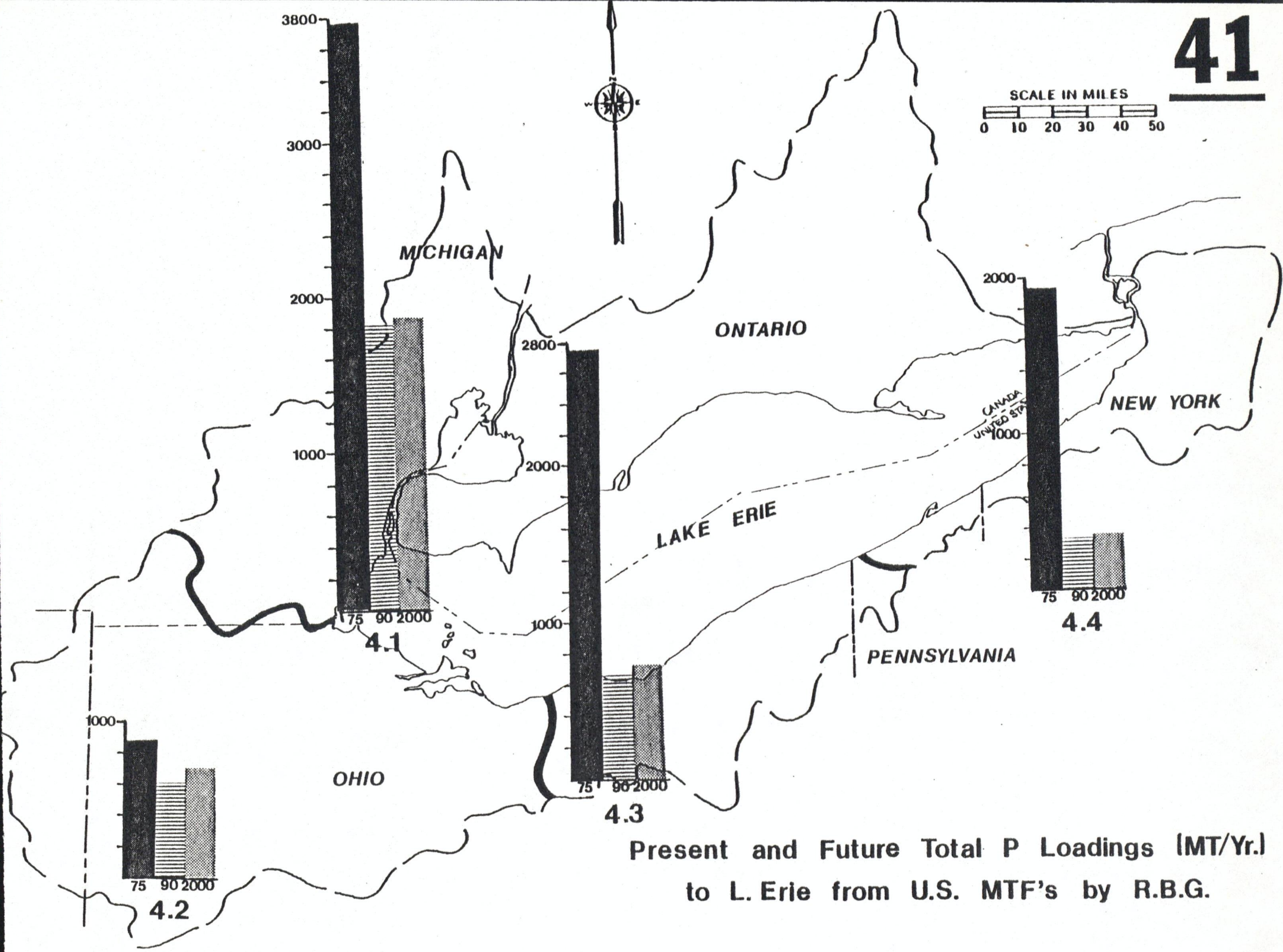
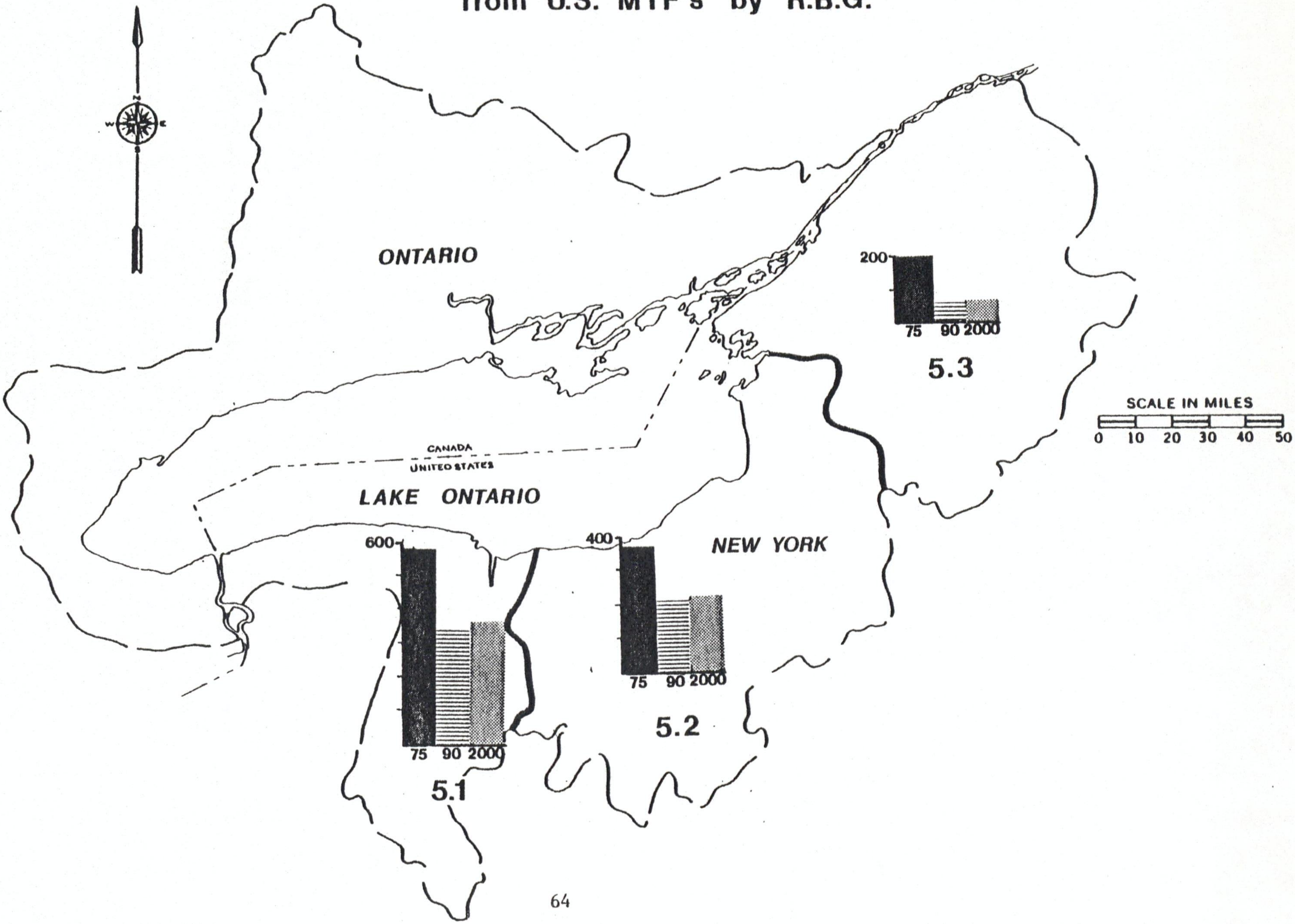


Present and Future Total P Loadings (MT/Yr.) to L. Huron from U.S. MTF's by R.B.G.



Present and Future Total P Loadings (MT/Yr.) to L. Erie from U.S. MTF's by R.B.G.

Present and Future Total P Loadings (MT/Yr.) to L. Ontario from U.S. MTF's by R.B.G.



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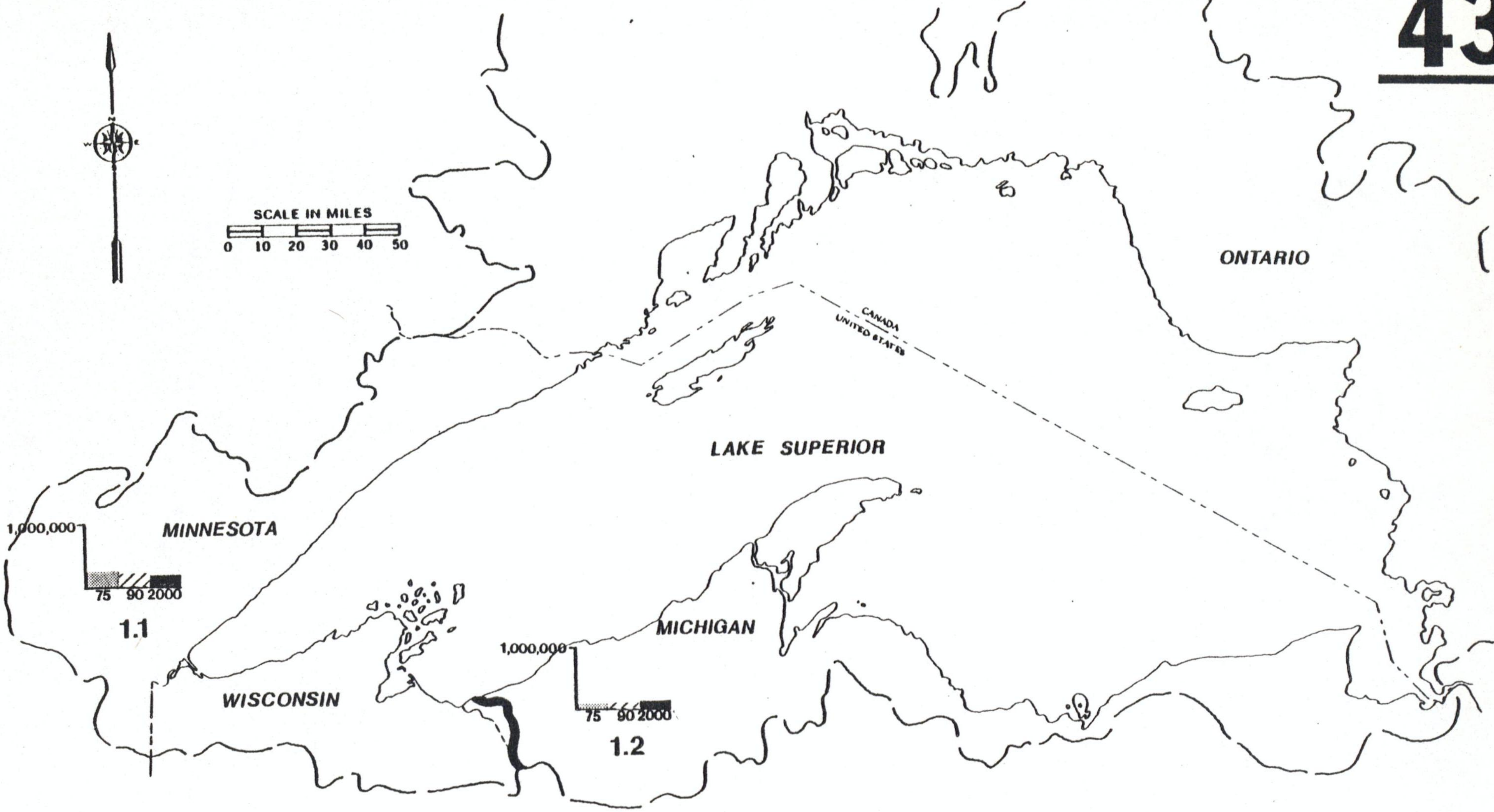
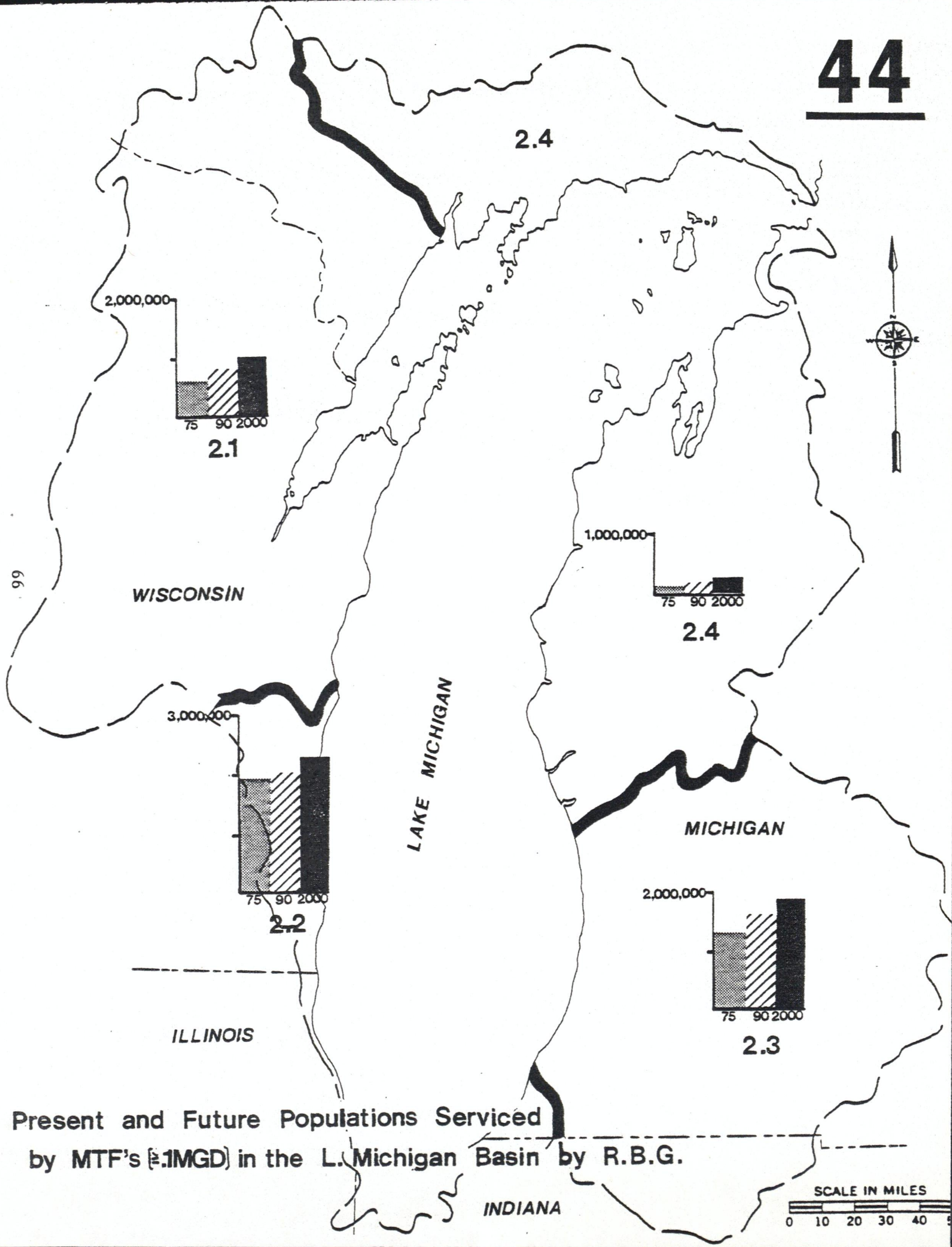


Present and Future Populations Serviced by U.S. MTF's (≥.1MGD) in the L. Superior Basin by R.B.G.



Present and Future Populations Serviced by MTF's (≥.1MGD) in the L. Michigan Basin by R.B.G.

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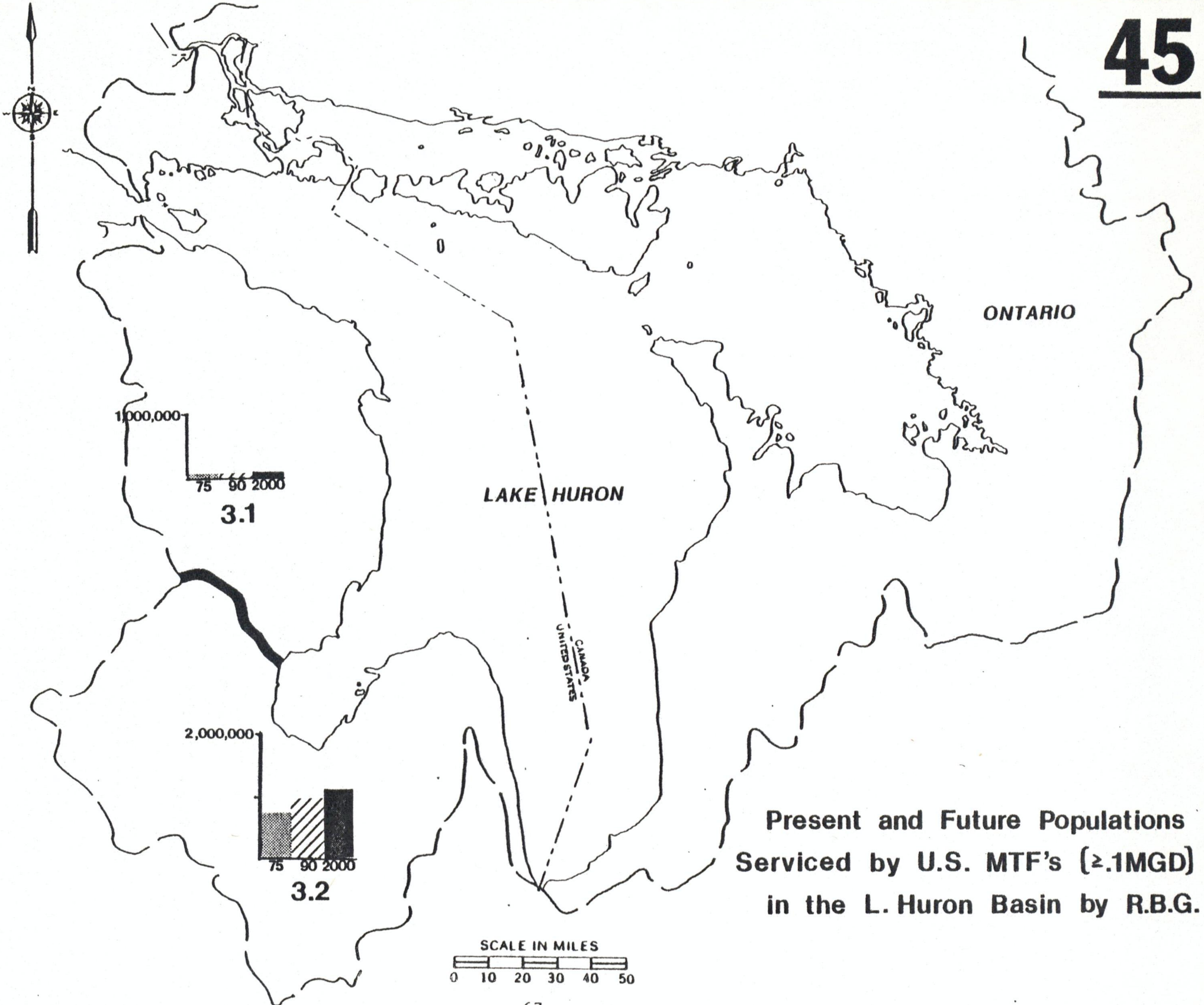

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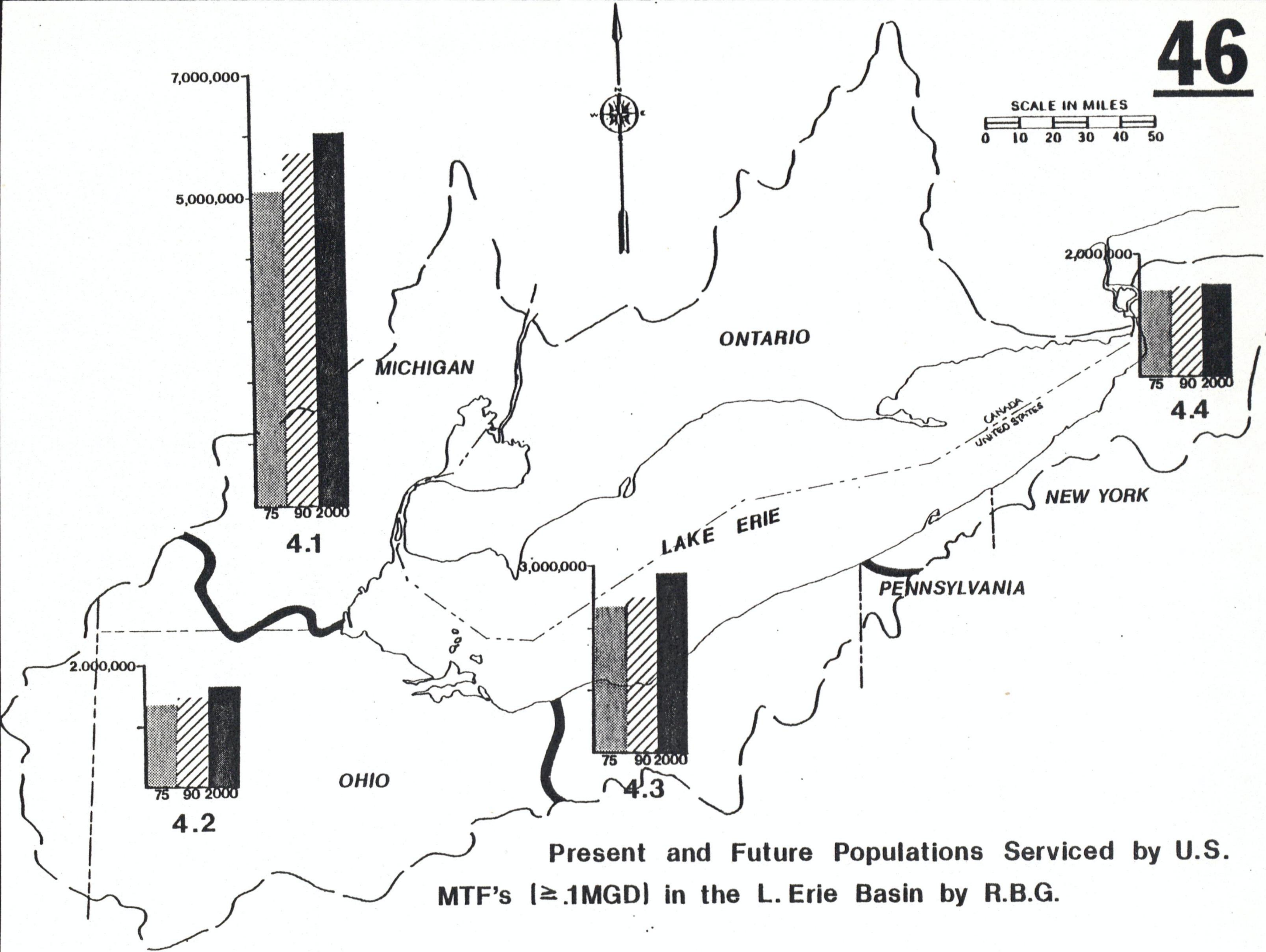

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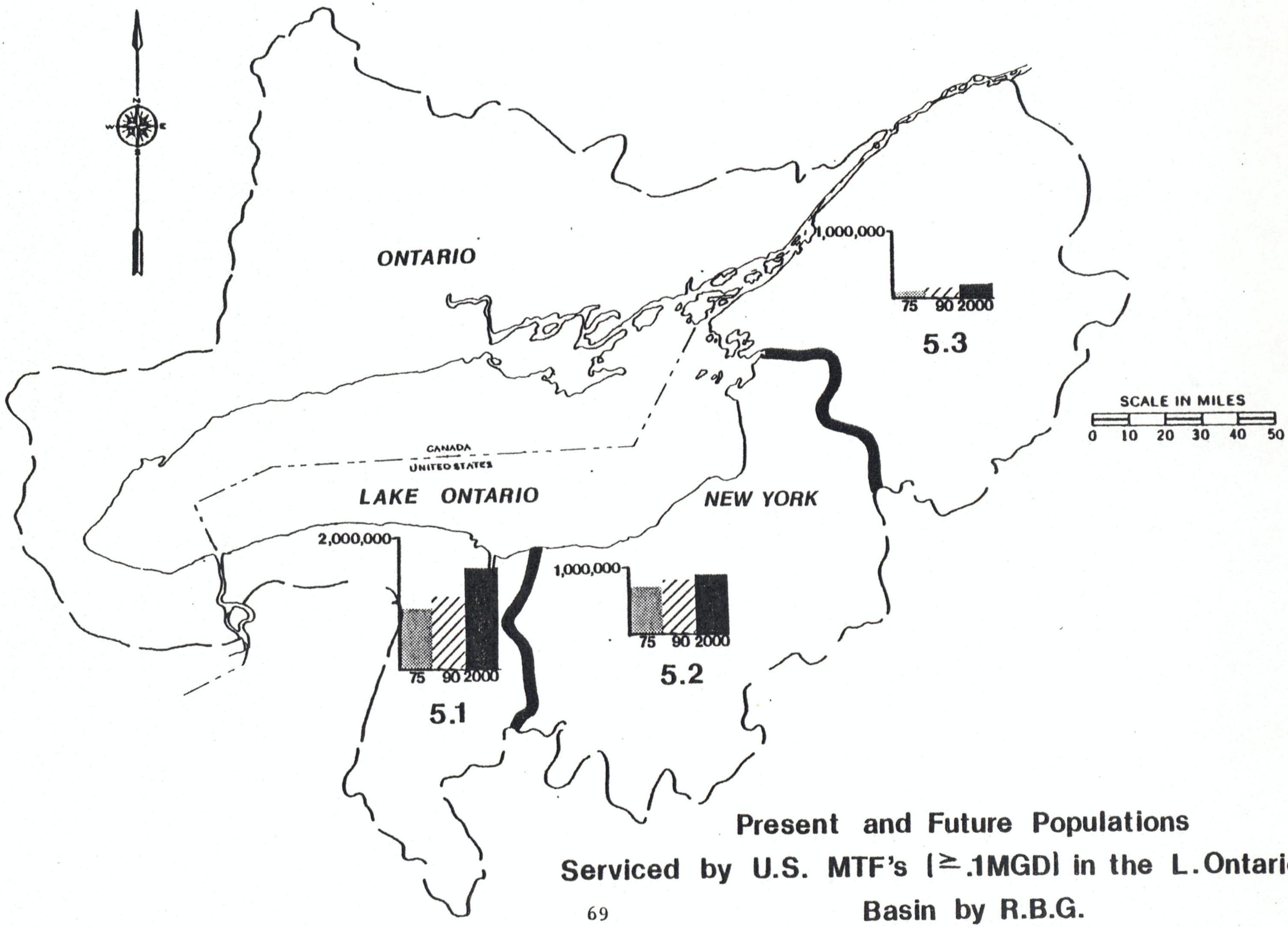
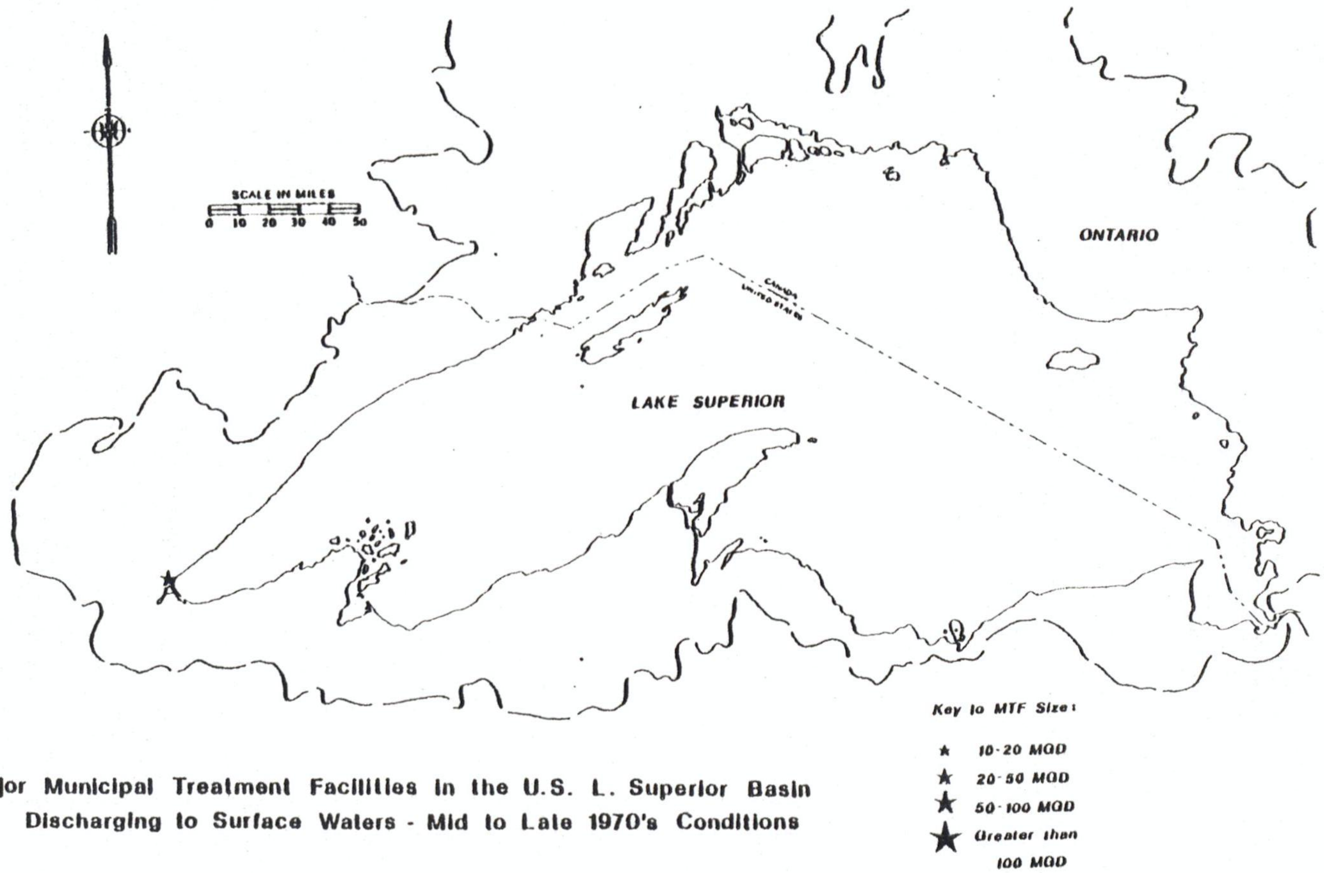


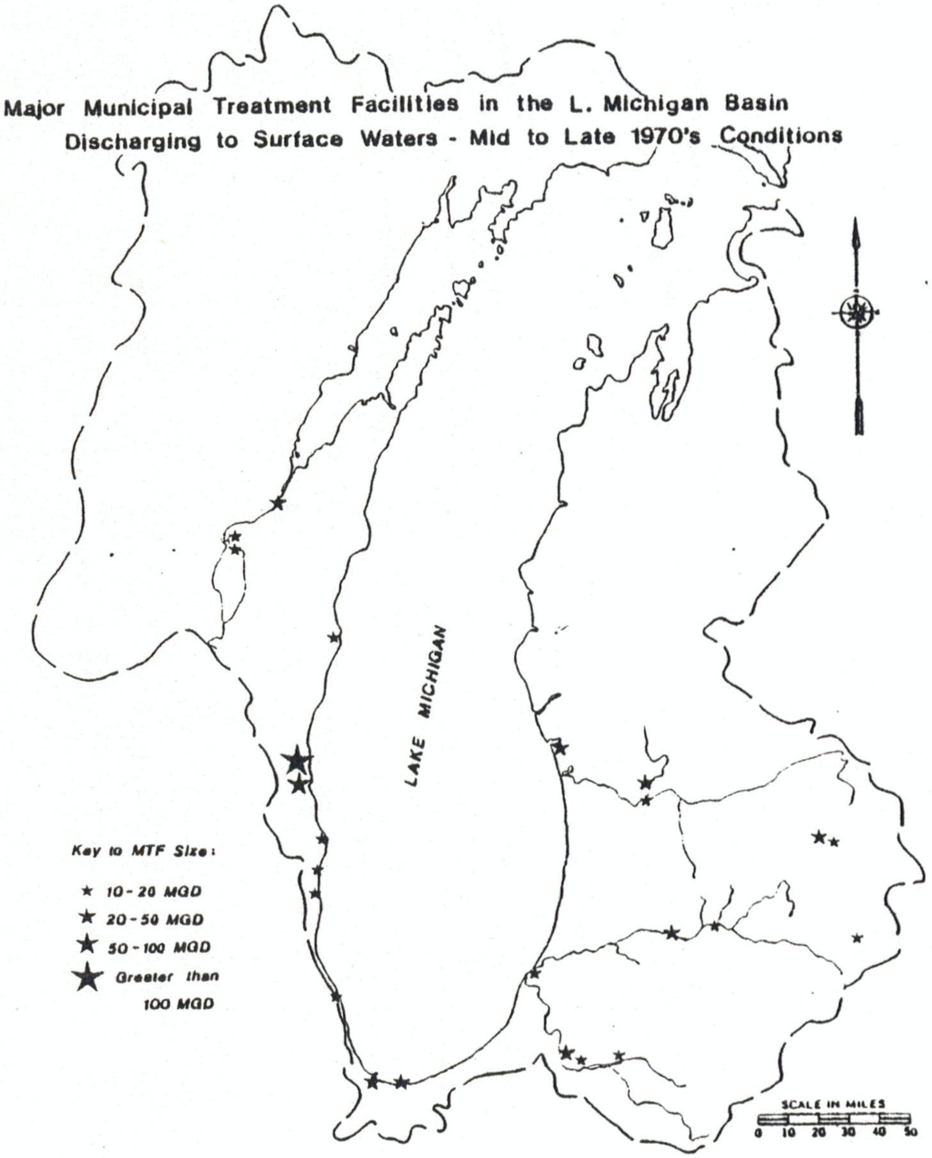
Present and Future Populations
Serviced by U.S. MTF's (≥ .1MGD) in the L. Ontario
Basin by R.B.G.



Major Municipal Treatment Facilities in the U.S. L. Superior Basin Discharging to Surface Waters - Mid to Late 1970's Conditions

49

Major Municipal Treatment Facilities in the L. Michigan Basin Discharging to Surface Waters - Mid to Late 1970's Conditions



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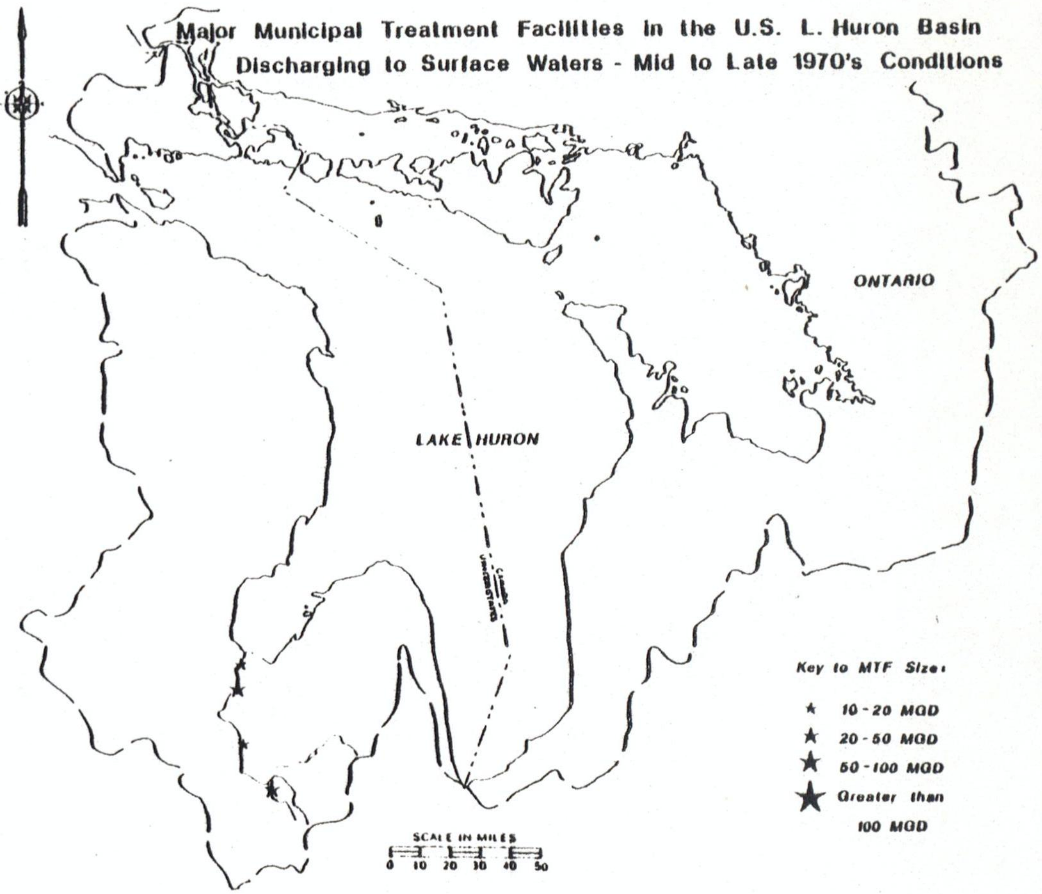
Major Municipal Treatment Facilities in the U.S. L. Huron Basin Discharging to Surface Waters - Mid to Late 1970's Conditions



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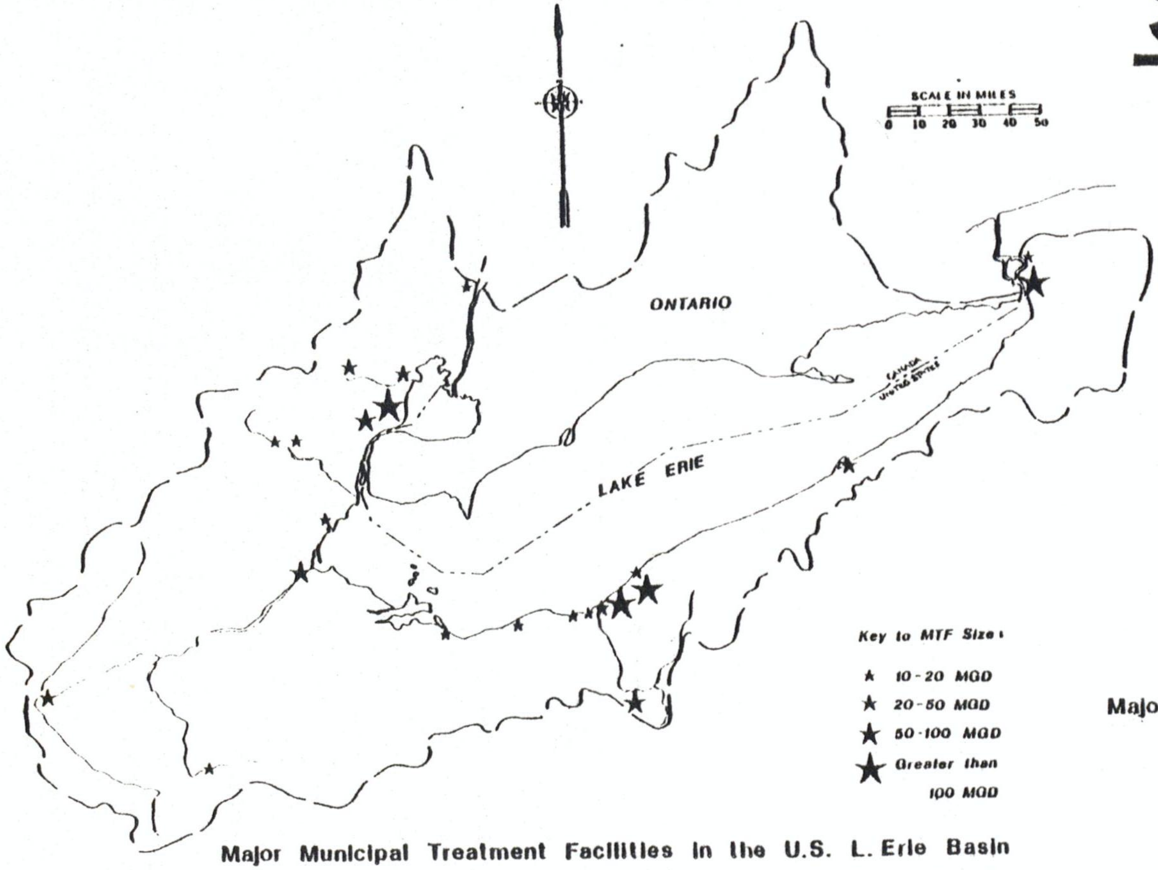

Major Municipal Treatment Facilities in the U.S. L. Erie Basin Discharging to Surface Waters - Mid to Late 1970's Conditions

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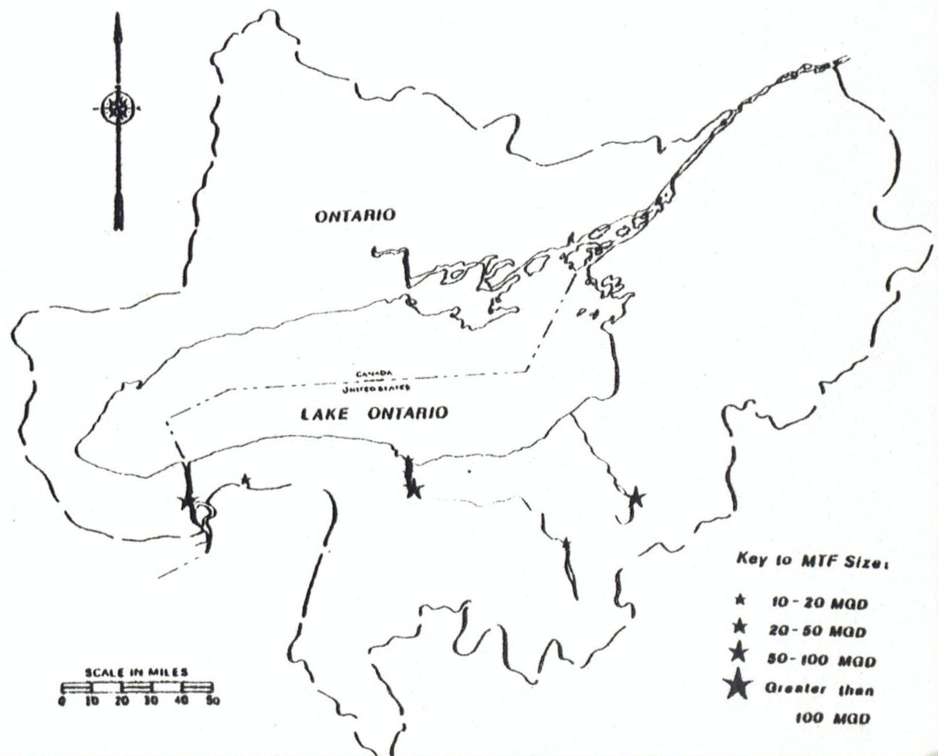
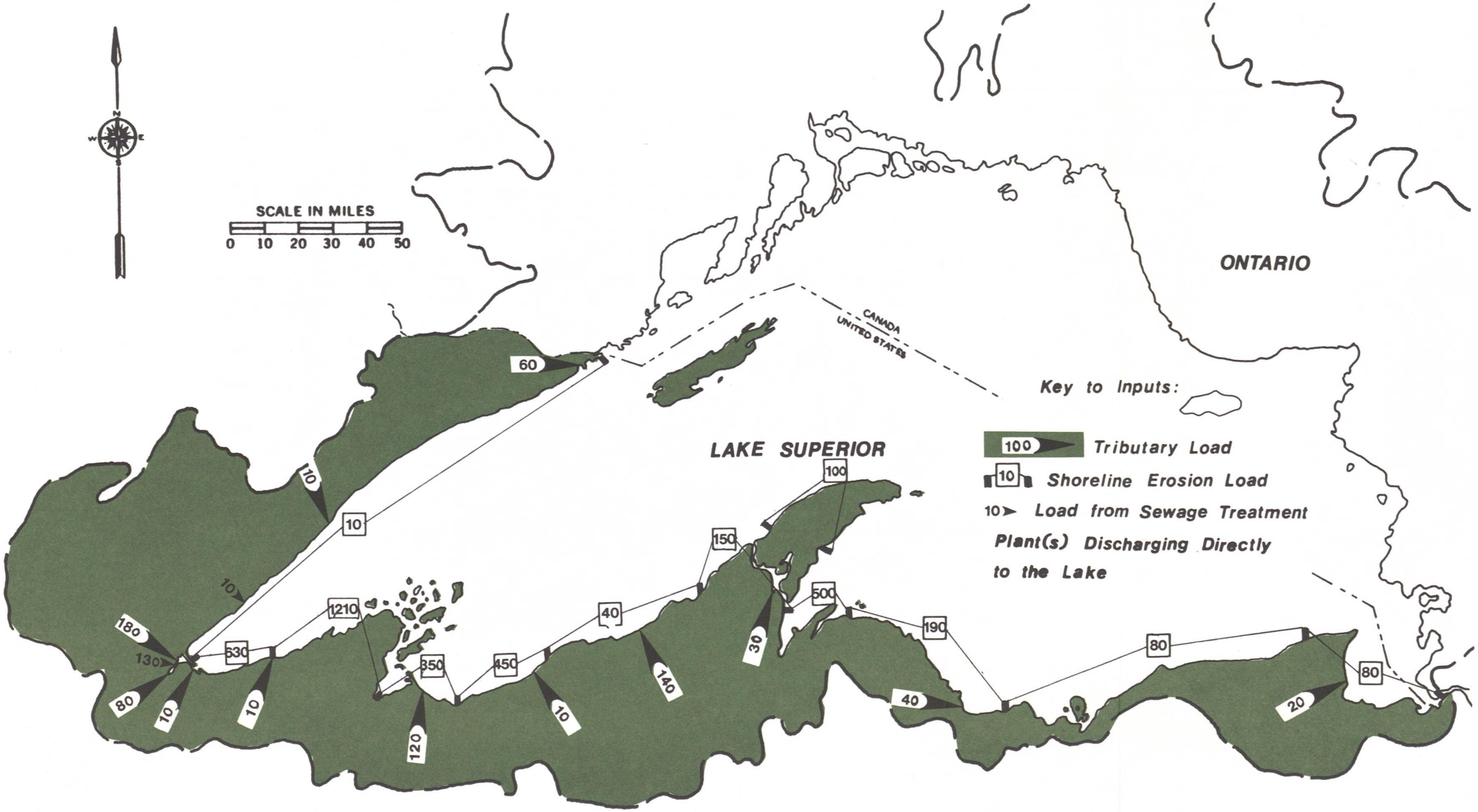
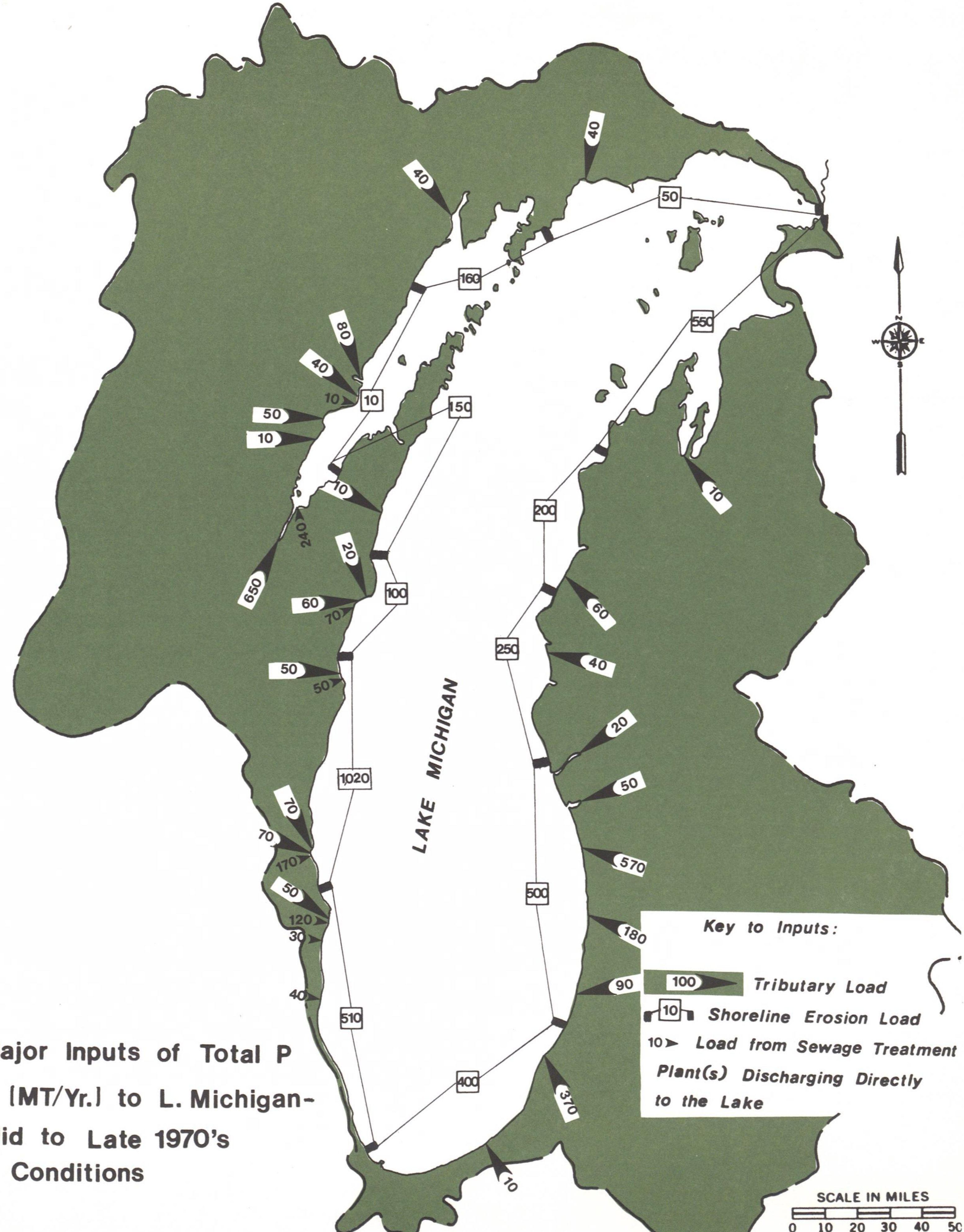
Major Municipal Treatment Facilities in the U.S. L. Ontario Basin Discharging to Surface Waters - Mid to Late 1970's Conditions



MAPS NO'S 53-57

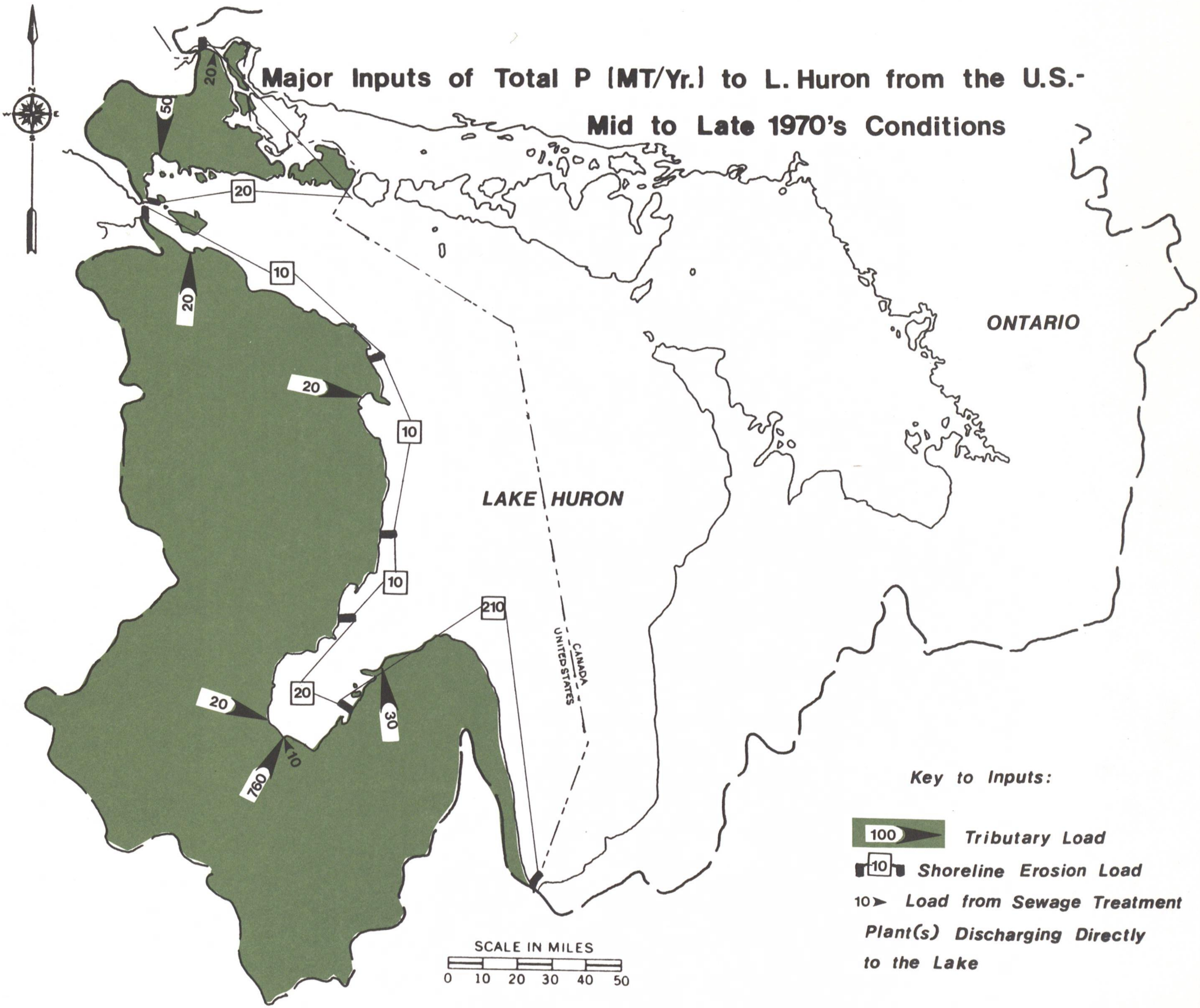


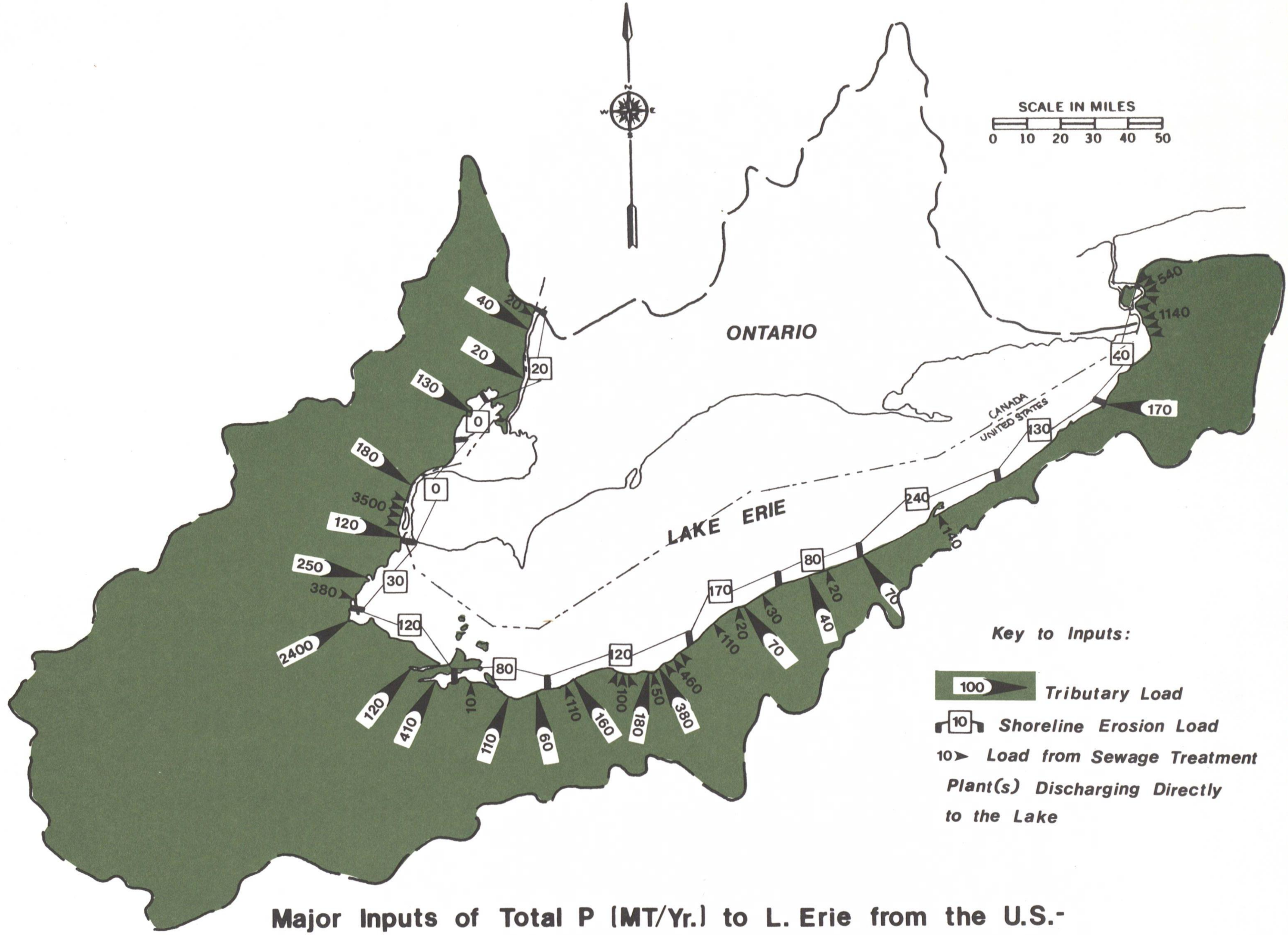
Major Inputs of Total P [MT/Yr.] to L. Superior from the U.S.- Mid to Late 1970's Conditions



Major Inputs of Total P (MT/Yr.) to L. Michigan- Mid to Late 1970's Conditions

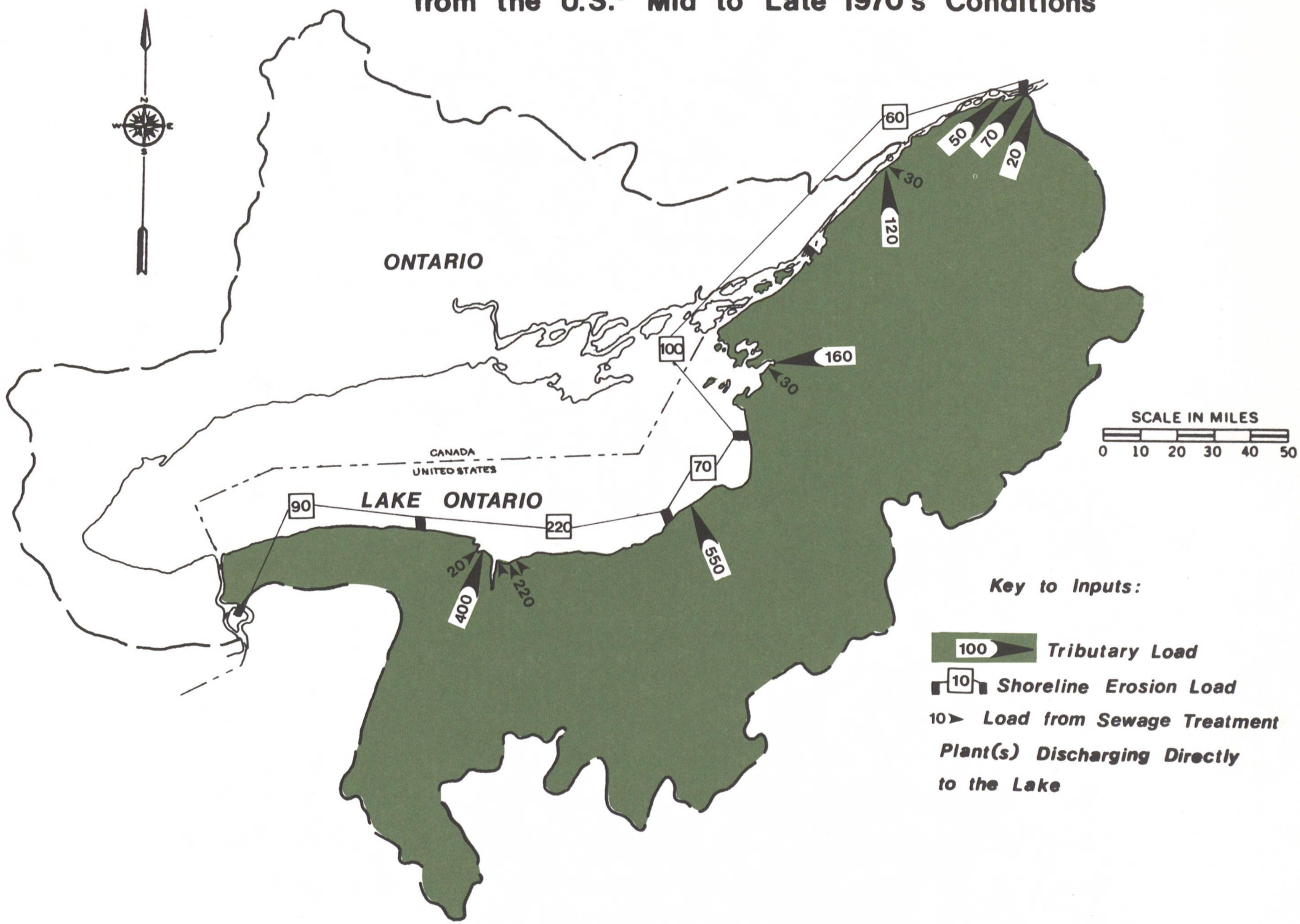
Major Inputs of Total P (MT/Yr.) to L. Huron from the U.S.- Mid to Late 1970's Conditions



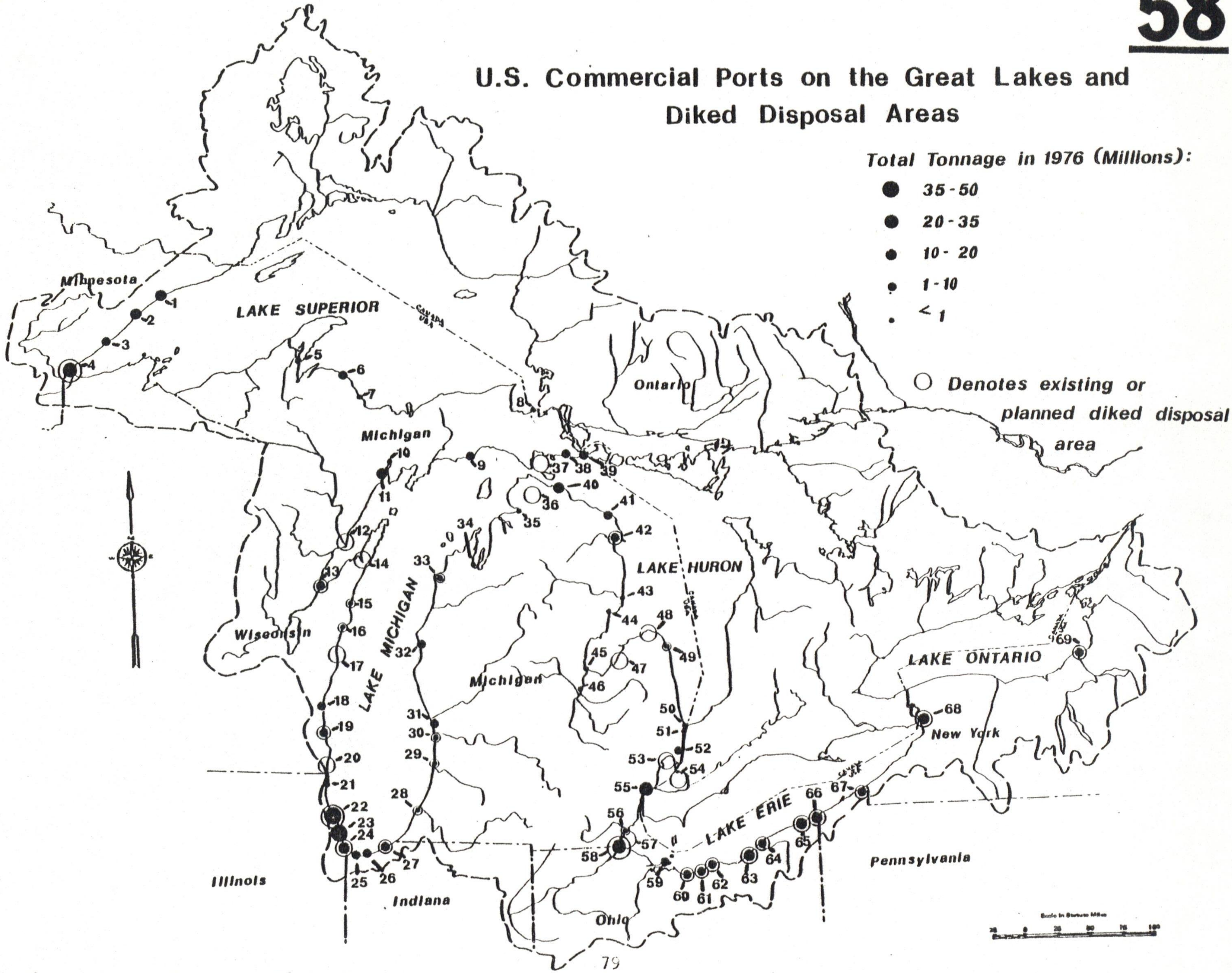


Major Inputs of Total P (MT/Yr.) to L. Erie from the U.S.- Mid to Late 1970's Conditions

Major Inputs of Total P (MT/Yr.) to L. Ontario from the U.S.- Mid to Late 1970's Conditions



U.S. Commercial Ports on the Great Lakes and Diked Disposal Areas



* See Table 6 for names of areas

TABLE 6

List of U.S. Commercial Ports and Existing or Planned Diked Disposal Areas on the Great Lakes

Map No.	Location
1	Taconite
2	Silver Bay
3	Two Harbors
4	Duluth-Superior
5	Haughton
6	Presque Isle
7	Marquette
8	Sault Ste. Marie
9	Port Inland
10	Gladstone
11	Escanaba
12	Menominee
13	Green Bay
14	Sturgeon Bay
15	Kewaunee
16	Manitowoc
17	Sheboygan
18	Port Washington
19	Milwaukee
20	Kenosha
21	Waukegan
22	Chicago
23	Calumet
24	Indiana Harbor
25	Buffington
26	Gary
27	Burns Waterway
28	St. Joseph
29	Holland
30	Grand Haven
31	Muskegon
32	Ludington
33	Frankfort
34	Traverse City
35	Petoskey
36	Inland Route
37	Les Cheneaux Is. Channel
38	Port Dolomite
39	Drummond Island
40	Calcite
41	Stoneport
42	Alpena
43	Port Gypsum
44	Alabaster
45	Bay City
46	Saginaw
47	Sebewaing
48	Port Austin
49	Harbor Beach
50	Port Huron
51	Marysville
52	St. Clair
53	Clinton River
54	Lake St. Clair
55	Detroit
56	Monroe
57	Bolles
58	Toledo
59	Marblehead
60	Sandusky
61	Huron
62	Lorain
63	Cleveland
64	Fairport
65	Ashtabula
66	Conneaut
67	Erie
68	Buffalo
69	Oswego

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(GLEPS) CONTRBUTIONS

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30. "Optimizing Phosphorus Control Strategies for the Great Lakes Basin: A Linear Programming Approach," November, 1980.

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34. "Quantification of the Lake Trophic Typologies of Naumann (Surface Quality) and Thiememann (Oxygen) and with special reference to the Great Lakes," December, 1980.

35. "Least Cost Optimization to Meet Phosphorus Objectives in the Great Lakes."

36. "State of Risk Assessment and Applications to Water Quality Management."

37. "Great Lakes Subregional Models: An Overview of Potential Management Applications," January 1, 1981.

38. "A Review of Water Quality & Related Indices," University of Wisconsin, Water Resources Center, February 1, 1981.

39. "Chloride Budget for the Great Lakes - A Current Assessment," in preparation.

40. "Bioavailability of Phosphorus Inputs to Lakes: Significance to Management," February, 1981.

41. "Environmental Quality Maps for the U.S. Great Lakes Basin," June, 1981.

42. "An Environmental Quality Index for Nearshore Waters of the Great Lakes," March, 1981.

43. "Risk Assessment in Decision Making," February, 1981.

44. "Modeling of Water Quality in Lake Michigan and the Effect of the Anomalous Ice Cover of 1976-1977," February, 1981.

45. "Geochemistry of Recent Lake Michigan Sediments," April, 1981.

46. "Deposition of Atmospheric Pollutants into Lake Michigan," June, 1981.

47. "Variations in U.S. Great Lakes Tributary Flows and Loadings," May, 1981.

48. "Statistical Analysis of Nearshore Water Index," in preparation.

49. "Mapping of Major _Cladophora_ Populations in the Great Lakes," Draft, June, 1981.

APPENDICES

APPENDIX 1

HOW THE MAPS WERE DEVELOPED

Map No.	
1	Hydrologic areas shown were primarily based on the hydrologic areas and flood frequency regions delineated in the U.S. Geological Survey Water Supply Paper No. 1677. Hydrologic areas documented in this paper are delineated on the basis of drainage area and runoff characteristics. Political subdivisions were taken into account in assigning hydrologic areas to river basin groups.
2-6	These maps are taken from GLEPS Contribution No. 49, "Mapping of Major Cladrophora Populations in the Great Lakes," Draft, June, 1981.
7	This map is from GLEPS Contribution No. 45, "Geochemistry of Recent Lake Michigan Sediments".
8	This map is also from GLEPS Contribution No. 45.
9	Information for this map was obtained from the U.S. Environmental Protection Agency's report, "Toxic Substances in the Great Lakes," and from the 1980 report to the International Joint Commission by the Great Lakes Water Quality Board entitled, "1980 Report on Great Lakes Water Quality."
10-14	The soil texture maps are derived from maps included in "Critical Assessment of U.S. Land Derived Pollutant Loadings to the Great Lakes," which was prepared for the International Joint Commission's Pollution From Land Use Activities Reference Group (PLUARG) Study. The graphics in this report were originally developed on the basis of soils data collected by U.S. Task B of PLUARG. In Maps No.'s 10 through 14 the general textural classes: sand, loam, and clay, include the more specific textural classes specified below:

Sand	Sandy Loamy sands Sandy loam Fine sandy loam

	Loam	Very fine sandy loam Loam Silt Loam Silt Clay Loam Sandy Clay Loam Silty Clay Loam
	Clay	Sandy Clay Silty Clay Clay

15 - 19 Information used to develop these maps was obtained from GLEPS Contribution No. 47, "Variations in U.S. Great Lakes Tributary Flows and Loadings."

20 - 24 Information used to develop these maps was obtained from two reports completed by GLBC staff, "United States Great Lakes Tributary Loadings" and "Post-PLUARG Evaluation of Great Lakes Water Quality Management Studies and Programs, Vol. II."

25 - 29 The shoreline erosion maps were prepared from data presented in "United States Great Lakes Shoreline Erosion Loadings," which was prepared by GLBC staff for the Pollution from Land Use Activities Reference Group (PLUARG) of the International Joint Commission.

30 The source of this map is an Argonne report entitled, "Deposition of Atmospheric Pollutants into Lake Michigan," GLEPS No. 46.

31 - 35 Information used to develop these maps was obtained from a listing prepared by Atomic Industrial Forum, Inc., May, 1980.

36 The source of this map is the "Annual Report of the Science Advisory Board, July, 1979," to the International Joint Commission.

37 Information used to develop this map was obtained from "Post-PLUARG Evaluation of Great Lakes Water Quality Management Studies and Programs, Vols. I & II."

38 - 42 Information used to develop these maps was obtained from the data base developed for GLEPS Contribution No. 11, "Future U.S. Phosphorus Loadings to the Great Lakes: An Integration of Water Quality Management Planning Information." The information base for this study was derived primarily from local water quality

management plans prepared under Section 208 of the Federal Water Pollution Control Act Amendments of 1972. A complete description of the data base may be found in the report itself.

43 - 47 Information used to develop these maps was obtained from the same source described above for Map No.'s 36 to 40.

48 - 52 Information used to develop these maps was obtained from the same source described above for Maps No.'s 36 to 40.

53 - 57 Information on the total phosphorus load contributed from erosion of U.S. shoreline was obtained from "United States Great Lakes Shoreline Erosion Loadings." Average values were utilized and grouped by county, according to arbitrary reaches of shoreline. Information on the load contributed from major tributaries was obtained from the two reports described above for Maps No.'s 20 to 24. A flow-weighted average annual load was determined using data from water years 1975 to 1978. Each tributary load estimate includes inputs from both point and nonpoint sources located in the watershed. Because a number of municipal sewage treatment plants discharge directly to the lakes or below tributary gauging stations, the phosphorus loads from these plants were presented separately. These plants and their phosphorus loads were identified from the data base compiled for "United States Great Lakes Tributary Loadings" and the information base compiled for GLEPS Contribution No. 11 (described above). Sewage treatment plants dicharging 10 mt/yr or more of total phosphorus were included. All figures were rounded-off to the nearest "tenth".

58 Sources of information for this map were "Dredging in the Great Lakes - Implication of Dredging Policies to Transportation Planning and Management in the U.S. Coastal Zone," completed by Great Lakes Basin Commission staff, and the U.S. Army Institute for Water Resources 1978 "Map of Great Lakes and St. Lawrence Seaway Region Waterways and Ports."

APPENDIX 2

DEFINITIONS OF LAND COVER CLASSES

Barren - Areas devoid of vegetation, such as sand, beaches and areas of recent construction.

Brushland - Very low density forest, harvested forest, scrub, and neglected farms. Areas which are a mixture of barren and vegetated land are also usually included in this class.

Commercial - Areas within cities which are totally devoid of vegetation and areas which have been discolored by industrial practices.

Forest - self explanatory.

Grassland - This class represents most areas other than forest which are completely and densely covered with lush vegetation. Its main component is pastureland. Also included are open parks, golf course, and any grass crops fully covering the ground when the Landsat photo was taken.

High Density Residential - This class is especially difficult to extract from Landsat imagery due to the wide range of land cover involved. The class is quite good near the large population centers of the basin and in small city centers. In some of the more remote areas containing only small villages, no high density residential class was extracted.

Plowed Field - Areas characterized by bare, recently cultivated soil or crops with a small percent of ground coverage at the date of the Landsat image acquisition. Image dates were primarily in May, so one shortcoming is that any crops, such as winter wheat, which had achieved full ground coverage are omitted. In unpopulated areas, total agricultural land will be the sum of recently plowed fields and grassland classes.

Wetlands - Those land areas where land cover is a mixture of water and vegetation, and those areas inundated with water often enough to restrict vegetation to marsh species. Forested wetlands with nearly complete canopy closure are not included.

APPENDIX 3

GLOSSARY OF TERMS

ALEWIFE: a small fish which is a member of the herring family. Alewives have vastly increased in number in the lakes with the decrease in populations of lake trout and whitefish due to sea lamprey predation. The alewife has a relatively low commercial value.

AREAS OF PARTICULAR CONCERN (APC's): coastal areas recongized by a State as being especially significant for their uniqueness, fragility, or other reasons.

CANADIAN SHIELD: a broad geologic formation extending through the northern portions of the Great Lakes basin.

CHISEL PLOW: conservation tillage system in which the seedbed is prepared without complete inversion of the soil.

CLADOPHORA: type of algae which has proliferated in the lower Great Lakes with increased loading of nutrients such as phosphorus.

COMBINED SEWER OVERFLOWS: discharge of a mixture of raw sewage and surface runoff to a water body, usually occurs during wet weather when the sewage treatment plant is unable to handle the increased flow.

CONSERVATION TILLAGE: the general term referring to tillage practices which involve less soil disturbance and the retention of more plant residue on the surface than conventional methods.

CUBIC FEET PER SECOND (cfs): a common unit used to describe rate of streamflow. It is the volume of water (in cubic feet) flowing past any given stream section per second.

DIFFUSE LOAD: the pollutant load to a waterbody derived from nonpoint sources.

EFFLUENT: the wastewater discharged from point sources.

EFFLUENT STANDARD: the maximum allowable concentration of a substance in the effluent discharged to surface waters from a point source such as a sewage treatment plant.

EUTROPHICATION: the sequence of enrichment of a waterbody by the gradual addition of plant nutrients leading to abundant plant growth and changes in the aquatic environment. This natural aging process is often accelerated by man.

GLACIAL TILL: a mixture of rock fragments deposited directly by glacial ice.

HEAVY METALS: metals such as cadmium, copper, mercury, zinc, chromium, and nickel.

HYDROLOGIC AREA: one of 72 subdivisions of the Great Lakes basin delineated on the basis of runoff characteristics and drainage area. Hydrologic areas in the U.S. portion of the basin are assigned to one of 15 "river basin groups".

LAND APPLICATION: the application of wastewater to land to obtain treatment through a series of physical, chemical and biological actions involving the soil, vegetation, and micro-organisms present.

LANDSAT: earth-orbitting satellite which repetitively scans all portions of the terrestrial surface of the earth to provide natural resources inventory data.

LEACHING: the loss of material in solution from a soil.

METRIC TONS PER YEAR (mt/yr): a common unit used to describe the yearly loading of a pollutant to a watercourse. A metric ton is equal to 2204.6 lbs.

MILLIGRAMS PER LITER (mg/L): a unit of concentration referring to the weight of a substance (in milligrams) in a unit volume (one liter) of water.

MILLION GALLONS PER DAY (mgd): a common unit used to describe the rate of wastewater flow handled by a sewage treatment plant in one day.

NITROGEN OXIDE: a compound containing both nitrogen and oxygen. A common by-product of the burning of fossil fuels.

NO-TILLAGE (No-Till): a crop-planting method which involves no seedbed preparation beyond providing a hole for the seed.

NONPOINT SOURCE POLLUTION: water pollution resulting from surface runoff to receiving waters.

PBB's (Polybrominated Biphenyls): a class of organic compounds used as flame retardants and in other related applications. These compounds do not readily break down; thus, they may persist in the environment for many years.

PCB's (Polychlorinated Biphenyls): toxic organic compounds of the same class as PBB's, used in electrical transformers and capacitors. They also persist in the environment for many years.

pH: numerical value used to describe the degree of acidity or alkalinity of a substance. The scale ranges from 0 to 14 with smaller values indicating acidic conditions, larger values indicating basic conditions, and a pH of 7 being neutral.

PARTS PER BILLION (ppb): a unit of concentration.

PHOSPHORUS: one of the primary substances required for the growth of aquatic vegetation. "Available" phosphorus is that which is in a form readily usable by plants.

PHYTOPLANKTON: minute floating plant life in a body of water (e.g., algae).

POINT SOURCE POLLUTION: water pollution resulting from discharges to surface waters from identifiable "points" such as sewage treatment plants.

PRETREATMENT: wastewater treatment provided by industry prior to discharge to municipal sewers.

RURAL RUNOFF: the rainfall, melted snow and irrigation water which flows across rural land picking up and transporting pollutants to surface waters.

SALMONID: any fish which belongs to the same family as salmon or trout.

SEA LAMPREY: a large, non-native fish which resembles an eel. The sea lamprey undergoes a 12 to 20 month parasitic stage during which it latches onto other fish, draining them of blood and nutrients. The sea lamprey is a primary contributor to the present instability of the Great Lakes fishery.

SOIL TEXTURE: the relative proportions of sand, silt, or clay in a soil.

SULFUR OXIDE: a compound containing both sulfur and oxygen. A common by product of the burning of fossil fuel.

URBAN RUNOFF: the water from rainfall and melted snow which flows across the urban landscape picking up and transporting pollutants to surface waters.

WATER YEAR (WY): a twelve month period which begins October 1st, when streamflows are typically low, and ends September 30th.

TD 365 .G72 no.41 c.1
Sullivan, Rose Ann.
Environmental quality maps
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