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UNITED STATES GREAT LAKES TRIBUTARY LOADINGS

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by

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DISCLAIMER

TABLE OF CONTENTS

	PAGE NO.
LIST OF FIGURES	vii
LIST OF TABLES	ix
SUMMARY	1
CONCLUSIONS	3
INTRODUCTION	7
METHODOLOGY	9
PARAMETERS	9
TOTAL RIVER MOUTH LOAD CALCULATIONS	10
Data Sources	10
Base Years	11
Watershed Areas	11
Correcting Loads to the River Mouth	15
Method of Calculating Loadings	15
POINT SOURCE LOADS	22
Data Sources	22
Location of Point Sources	24
Base Years	24
Estimation of Point Source Loads	25
Municipal Point Sources	25
Industrial Point Sources	27
DIFFUSE LOADS	28
Monitored Areas	28
Unmonitored Areas	29
RESULTS	31
DISCUSSION	71
ACCURACY OF TRIBUTARY LOADING ESTIMATES	71
IJC Surveillence versus U.S. Task D Total Phosphorus Loads	72
EVALUATION OF U.S. TRIBUTARY LOAD ESTIMATES	74
Flow	74
Great Lakes Load Summary	80
Lake Superior	82
River Basin Group 1.1	82
River Basin Group 1.2	84

TABLE OF CONTENTS (continued)

	PAGE NO.
Lake Michigan	85
River Basin Group 2.1	85
River Basin Group 2.2	87
River Basin Group 2.3	87
River Basin Group 2.4	89
Lake Huron	90
River Basin Group 3.1	90
River Basin Group 3.2	91
Lake Erie	91
River Basin Group 4.1	92
River Basin Group 4.2	92
River Basin Group 4.3	92
River Basin Group 4.4	93
Lake Ontario	93
River Basin Group 5.1	93
River Basin Group 5.2	94
River Basin Group 5.3	95
DIFFUSE LOADS	95
Transmission of Point Sources	96
Diffuse Unit Area Loads	97
Types of Diffuse Sources	99
Control of Diffuse Sources	100
POINT SOURCE LOADS	100
Municipal Versus Industrial Point Sources	100
Effect of Small Point Sources	104
Effect of Reducing Municipal Loads	105
FLOW/CONCENTRATION RELATIONSHIPS	107
Variability of Flow	107
Variability of Concentration	110
Variability of Loads	112
Tributary Response Variations	112
Example of Stable Response Tributary - Grand River	117
Example of Event Response Tributary - Nemadji River	118
Watershed Characteristics Versus Tributary Response	121
Recommended Sampling Strategy for Stable Response vs. Event Response Streams	124
Critical Erosion Period	126
REFERENCES	129
APPENDIX A - Individual Tributary River Mouth Loading Data	133
APPENDIX B - Maps Showing Regional Differences in the Total Phosphorus and Suspended Solids Diffuse Unit Area Loading Rates	157

L I S T O F F I G U R E S

NUMBER		PAGE NO.
1	YEARLY FLUCTUATIONS IN FLOW	108
2	MONTHLY FLUCTUATIONS IN FLOW	109
3	MONTHLY CHANGES IN TOTAL P CONCENTRATIONS	111
4	MAUMEE RIVER - FLOW VS TOTAL P CONCENTRATION	116
5	SOIL TEXTURE RIVER BASIN GROUP 1.1	122
6	SOIL TEXTURE RIVER BASIN GROUP 2.3	123

LIST OF TABLES

NUMBER		PAGE NO.
1	DRAINAGE AREA MEASUREMENT (HYDROLOGIC)	12
2	EXAMPLE OF LOAD CALCULATION USING THE RATION ESTIMATOR PROGRAM	16
3	EXAMPLE OF RATIO ESTIMATOR RIVER MOUTH LOAD CALCULATION USING STRATA	19
4	MEAN EFFLUENT CONCENTRATION FOR GREAT LAKES MUNICIPAL TREATMENT PLANTS	26
5	MUNICIPAL PLANT EFFLUENT CONCETNRATIONS	27
6	U.S. GREAT LAKES TRIBUTARY LOADINGS	32
7	HYDROLOGIC AREA LOADS	35
8	COMPARISON OF SURVEILLANCE SUBCOMMITTEE AND U.S. TASK D 1976 TOTAL PHOSPHORUS TRIBUTARY LOADS	73
9	ESTIMATED TOTAL ANNUAL MEAN DAILY TRIBUTARY FLOW TO THE GREAT LAKES	74
10	TOTAL ANNUAL DAILY FLOW PER UNIT AREA OF WATERSHED	75
11	INDIVIDUAL ANNUAL MEAN FLOW FROM U.S. GREAT LAKES TRIBUTARIES	76
12	RATIO OF SPRING (MARCH + APRIL + MAY) FLOWS FOR SEVERAL GREAT LAKES TRIBUTARIES	79
13	RATIOS OF CHLORIDE LOAD AND ANNUAL FLOW BETWEEN WATER YEARS 1975 and 1976	81
14	TOTAL PHOSPHORUS DIFFUSE LOADS ASSUMING 50 and 100 PERCENT DELIVERY OF UPSTREAM POINT SOURCES 1975	96
15	EXAMPLE COMPUTER PRINTOUT OF UPSTREAM AND DOWNSTREAM POINT SOURCE LOADS	98
16	1975 AND 1976 TOTAL TRIBUTARY POINT SOURCE LOADS (MT/YR) FROM MUNICIPAL AND INDUSTRIAL PLANTS	102
17	COMPARISON OF POINT SOURCE PHOSPHORUS INPUTS TO LAKE ERIE TRIBUTARIES COMPILED BY THE LAKE ERIE WASTEWATER MANAGEMENT STUDY AND GLBC (THIS STUDY)	105
18	U.S. TRIBUTARY TOTAL PHOSPHORUS LOADS ASSUMING DIFFERENT MUNICIPAL EFFLUENT PHOSPHORUS CONCENTRATIONS	106
19	MANITOWOC RIVER (WISCONSIN) SUSPENDED SOLIDS LOADING DATA	113
20	LINEAR REGRESSION OF FLOW (cfs) VS CONCENTRATION (mg/ℓ)	114
21	GRAND RIVER TOTAL PHOSPHORUS AND SUSPENDED SOLIDS LOADS CALCULATED BASED ON DAILY AND A MONTHLY SUBLET OF THESE SAMPLES (DURING WATER YEAR 1976)	118
22	AVERAGE ANNUAL TOTAL PHOSPHORUS AND SUSPENDED SOLIDS CONCENTRATION MEASURED NEAR THE MOUTH OF THE GRAND RIVER SINCE 1963	119
23	NEMADJI RIVER (WISCONSIN) SUSPENDED SOLIDS DATA	120
24	LAKE HURON SOIL DATA	125

SUMMARY

Annual loads to the Great Lakes from U. S. tributaries were estimated for total phosphorus, soluble ortho phosphorus, suspended solids, total nitrogen, nitrate nitrogen, ammonia nitrogen, and chloride. Loads were calculated for water years 1975 and 1976 using all available data. All loads for monitored tributaries were calculated using the ratio-estimator calculation method except for Lake Erie tributary loads which were obtained from the Lake Erie Wastewater Management Study. In order to provide complete coverage of the basin, loads from unmonitored watersheds were estimated from unit area loads determined from similar and usually adjacent monitored watersheds.

Lake Erie received the highest phosphorus and suspended solids tributary loads during water year 1975, and Lake Superior the smallest. Tributary loads of most parameters were higher during the 1976 water year than the 1975 water year for all Lakes except Lake Superior. Differences in loads generally corresponded with trends in flow. Tributary flows during water years 1975 and 1976 were higher than the long-term average flows, with the exception of Lake Superior tributaries.

Municipal and industrial point sources discharging to U. S. Great Lakes tributaries were inventoried and their loading contribution estimated. Emphasis was placed on phosphorus and suspended solids loads, with the most complete information being available for municipal sources. When 100 percent transmission to the river mouth was assumed, identified point sources accounted for a relatively small percent of the total tributary load. Significantly reducing the assumed delivery of identified point source loads generally resulted in only a slight increase in the proportion coming from non-point sources. The non-point or diffuse unit area loading rate varied widely from year-to-year as would be expected due to annual variations in total tributary loads.

Two broad categories of Great Lakes tributaries were noted. Loads from "event response" tributaries were greatly influenced by runoff events. However, loads from "stable response" tributaries were not as greatly influenced by runoff events, since concentrations did not usually vary greatly with flow, and variations in flow with time tended to be more moderate. Event response tributaries (such as many of the Lake Erie tributaries) had high annual diffuse unit area loading rates for phosphorus and suspended solids, while stable response tributaries (such as many found in the eastern basin of Lake Michigan) had relatively small annual diffuse unit area loading rates for these parameters. Although many factors probably influence tributary response, the texture of surface soils in the watershed

is thought to be very important. Event response tributaries tend to drain watersheds whose soils have a high proportion of fine grained, clay particles, while stable response tributaries have watersheds with relatively coarse-grained, sandy soils.

Importantly, while the estimated loads are believed to be based on the best available information, they are naturally subject to the limitations of the data and must be interpreted with these limitations in mind. A major source of error for the estimated loads of some tributaries is the lack of representative data over different flow regimes during the annual cycle. However, if the data are carefully interpreted with the limitations of specific situations in mind, much useful information can be obtained. Moreover, the loading information presented should serve as a foundation for expanding and improving load estimates as more extensive and long-term data become available.

CONCLUSIONS

1. Annual loads from U. S. Great Lakes tributaries were estimates for total phosphorus, soluble ortho phosphorus, suspended solids, total nitrogen, nitrate nitrogen, ammonia nitrogen, and chloride. Loads for all parameters were calculated (except for Lake Erie loads, which were taken directly from the Lake Erie Wastewater Management Study), using the ratio estimator method, which was found to be a useful method for estimating loads on a comparable basins. Individual loads were calculated for 43 to 110 (depending on the year and parameter) U. S. tributaries. Loads from monitored tributaries account for about 55 to 80 percent of the U. S. Great Lakes drainage basin.

2. Loads from monitored U. S. tributaries accounted for about 65 to 80 percent of the total U. S. tributary load on a lake basin basis during the 1975 water year. In some cases, the 1976 U. S. monitored tributary loads for individual tributaries accounted for less than this amount, indicating less extensive field sampling during the 1976 water year.

3. While the estimated loads are believed to be based on the best available information, they are subject to limitations of the data and must be interpreted with these specific limitations in mind. A major source of error in estimating river mouth loads for some (but not all) streams is the lack of a representative temporal and spatial distribution of sample data over the annual cycle.

4. For most parameters, loads were generally higher during the 1976 water year than during the 1975 water year. The one exception was Lake Superior, where the opposite occurred. This pattern corresponds with general trends in flow over the same period. Wide variation in loads from year to year is not uncommon and, as is necessary in estimating representative flows, long-term records are necessary to establish an "average" or "mean" load. Nevertheless, a reasonable judgement on whether or not a load can be considered typical can be reached by comparing historical flow information with current flow conditions.

5. Annual mean daily discharge to each of the Great Lakes was generally higher than the historical average in water years 1975 and 1976, except for Lake Superior, where the 1976 flow was slightly less than the historical average flow. Individual tributaries exhibited wide variations in mean annual flow as compared to their historical averages, implying in certain cases local climatological variations. Many streams had higher spring (March, April and May) flows during 1976 than in 1975.

6. Flow per unit area of watershed was highest for Lake Ontario. Unit area flows for the other four Great Lakes were approximately equivalent.

7. Lake Erie received the largest U. S. tributary total phosphorus and soluble ortho phosphorus loads, while Lake Superior received the smallest. Suspended solids and nitrogen tributary loads were also highest to Lake Erie. It appears that Lake Ontario receives the largest chloride tributary load. Lake Erie again received the largest diffuse loads (total load minus point source loads) per unit area of watershed.

8. Analysis of loadings during water year 1975 indicated that the Maumee River, which drains into Lake Erie, contributes about twice as much total phosphorus to the Great Lakes as the Saginaw River, the next largest tributary contributor. Other Lake Erie tributaries and the Grand River in Michigan were also among the highest total phosphorus contributors. Soluble ortho phosphorus loads followed a similar pattern, with the Grand River (Michigan), Black-Rocky Complex (Lake Erie), and the Saginaw River ranking behind the Maumee River as the largest contributors.

9. During water year 1975 the largest suspended solids load from any tributary was also contributed by the Maumee River. The load from the Maumee was about twice as great as the next largest contributors, which included several other Lake Erie tributaries, the Genesee River (Lake Ontario), and the Ontonagon River (Lake Superior). Excluding Lake Erie tributaries, for which 1976 data were not available, the Genesee River was the largest suspended solids contributor to the Great Lakes in water year 1976.

10. The diffuse load, which is defined as the total tributary load minus the identified point source inputs, includes contributors from both surface runoff and base flow. Diffuse sources accounted for a large percentage of the total load for most parameters, assuming 100 percent transmission of identified point source inputs. During 1975 about 70 percent of the total phosphorus load and about 60 percent of the soluble ortho phosphorus tributary load to the Great Lakes was classified as attributable to diffuse sources. The 1975 water year suspended solids load to the Great Lakes was attributable almost entirely to diffuse sources. Ammonia nitrogen loads to the Great Lakes were least affected by diffuse sources, as less than 50 percent were considered to be derived from diffuse sources. With the exception of Lake Superior, the total phosphorus diffuse load contributed to each of the Great Lakes was higher in water year 1976 than in water year 1975, reflecting the general increase in total tributary loads. No comparison can be made for Lake Erie due to the lack of 1976 data.

11. Since assuming 100 percent delivery of point sources may overestimate the tributary point source load to the Lakes (at least on a short-term basis), loading estimates were also derived assuming 50 percent delivery of upstream point sources and 100 percent delivery of downstream point sources. Generally, the assumption of 50 percent upstream point source transmission increased the diffuse load by only a small percentage when compared to the diffuse load derived under the assumption of 100 percent delivery of both upstream and

downstream sources. However, in some cases, the effect was significant, increasing the diffuse load by as much as 20 percent. Loading data had been categorized in a format which facilitates the calculation of the total diffuse load under a variety of delivery assumptions.

12. As might be expected, diffuse unit area loads calculated for different watersheds varied widely from basin-to-basin and from year-to-year. Phosphorus and suspended solids unit area loads varied somewhat analgously, with estimates highest for the Lake Erie basin, the thumb area of the Lake Huron basin, and parts of the Lake Ontario basin. A relatively low unit area load was derived for a major portion of the eastern Lake Michigan basin.

13. Municipal sources accounted for most of the phosphorus point source load to the Great Lakes. Municipal sources also accounted for most of the nitrogen and a large part of the chloride load, although all of the industrial point sources for each of these parameters may not have been identified. Point source inputs of suspended solids to tributaries appear to have little impact on the total suspended solids tributary load. Several chloride point sources associated with mining or industrial operations had major impacts on the chloride load.

14. Analysis of available information indicates that municipal point sources discharging less than 0.1 mgd (2.83×10^{-3} m^3/s), although numerous in some areas, do not significantly affect loads, at least on a Lake basin approach.

15. Under existing flow conditions found for municipal wastewater treatment plants, discharging into U. S. tributaries (does not include direct sources), a reduction of effluent total phosphorus concentrations from 1 mg/ℓ to 0.5 mg/ℓ would have a relatively minor effect on the total tributary phosphorus load to the Great Lakes. This is particularly true for Lake Superior and Lake Huron.

16. Although the relationship between flow and the concentration of various flow sensitive parameters (e. g., phosphorus or suspended solids) varies widely among tributaries, two broad groups of tributary responses were noted. Certain tributaries seem to be greatly influenced by runoff events. These are referred to as "event response" tributaries. However, other tributaries are not dominated by runoff events because concentrations do not vary greatly with flow, and the flow itself tends to be less eratic (less flashy). These are referred to as "stable response" tributaries. Event response tributaries, such as many of the Lake Erie U. S. tributaries, tend to have high annual diffuse unit area loads associated with flow sensitive parameters, such as phosphorus and suspended solids. On the other hand, stable response tributaries, such as Lake Michigan's Grand River and many other Lake Michigan tributaries, tend to have relatively small annual diffuse unit area loads associated with these parameters.

17. Although there are probably many factors which influence whether a stream fits either an event response or tributary response classification, the texture of the soil in the watershed appears to be very important. Those watersheds with surface soils containing considerable amounts of fine clay-sized particles tend to contribute significantly higher unit area loads of flow sensitive substances than watersheds that have more coarse-grained sandy soils. Streams draining sandy soils generally had more stable chemical concentrations and flows than streams draining clayey watersheds. The differences in the chemical and physical characteristics of clay-sized particles and coarse-grained particles and the infiltration capacity of sandy soils versus clayey soils are major factors which cause a different loading response. Detailed information on soil texture characteristics of U. S. Great Lakes watersheds have been compiled, and further analysis of the effect of soil texture on tributary loads will be conducted in Subactivity 3-4 of U. S. Task D (PLUARG).

18. Because of the differences between stable response and event response tributaries, it is felt that not every stream needs to be sampled routinely during runoff events for the purpose of calculating loads. By examining watershed characteristics, including but not limited to surface soil textures, it may be possible to predict whether an event response or stable response can be expected. Where possible, however, limited sampling during one or more runoff events, particularly during the spring, would provide more definitive information on whether routine event sampling is necessary to characterize the annual load. Also, in many streams where concentration remains fairly stable, sampling over several years on a monthly basis may produce representative data which can be used to estimate loads in future years. In other words, for certain rivers a knowledge of the daily flow over a given year may be all that is necessary to reasonably estimate the load, assuming no major changes occur in the characteristics of the watershed or in the point source inputs.

INTRODUCTION

Both Canada and United States define the major activities under Task D of the Pollution from Land Use Activities Reference Group (PLUARG) as (1) assessment of shoreline erosion, (2) survey of river sediments and associated water quality, and (3) assessment of the effects of river inputs on Boundary waters. In April of 1975, a Plan of Study was developed to further define the United States portion of Task D. This Plan of Study posed the following general questions.

(1) Is shore erosion a significant pollutant source to the lake?

(2) What is the tributary loading to the lake that is attributable to land drainage, including the pollutant loading associated with river sediments?

(3) How have river inputs derived from land drainage affected the lake?

In order to help answer the second question, Subactivity 2-3 of Task D was defined as indicated below:

> "Based on existing data, a careful estimate of the tributary output (input to the Great Lakes) of pollutants, including total suspended solids and chemical pollutants in particulate and soluble forms, will be made. In recognition of the importance of high flow conditions, particularly spring runoff, to the loading of many substances, the output from river mouths during high flow and base flow (no surface runoff) will be considered. Based on estimates of point source inputs to the tributaries, estimates of the pollutant output attributable to diffuse sources will be made. In all cases, estimates of U. S. loading will be delineated according to individual major watersheds, the 15 planning subareas, and the 5 lake basins."

This report represents the completion of Subactivity 2-3 of U. S. Task D by presenting estimations of U. S. tributary loads of selected chemicals and solids, including both point and non-point tributary contributions.

Two previous subactivities of U. S. Task D provided essential background information for Subactivity 2-3. First, existing river mouth flow and concentration data were inventoried in Subactivity 2-1 of U. S. Task D. The report from this task, entitled "Existing River Mouth Loading Data in the U. S. Great Lakes Basin" (Hall, et al., 1976) served as a major reference for this work. Information on watershed demarkations, monitored tributaries, parameters monitored, frequency of monitoring, and others, were used in sorting out data useful for actual load calculations. Second, information from Subactivity 2-2 of U. S. Task D, which consisted of a detailed monitoring program of the Grand River near the river's entrance into Lake Michigan, was very useful to this study. This specialized monitoring program, which was recommended as a result of an interim report of Subactivity 2-1 of U. S. Task D, has provided some extremely valuable and unique information of basinwide application.

Subactivity 2-3 also is intended to serve as baseline information for other U. S. Task D studies, such as Subactivity 2-5 (phosphorus availability), Subactivity 3-2 (biological impacts of loads), and Subactivity 3-4 (summary of Task D). Importantly, this study is paramount to the central theme of Task D, which is to determine the relative importance of non-point sources of pollution with respect to other sources or other factors which affect the water quality of the Great Lakes. This study will also be useful to other Tasks in PLUARG, particularly the "overview modeling" integration activity.

While much specific information is contained in this report, quite a large amount of supplementary information, such as loads from individual point sources, were not included due to the volume of the material. This supplemental information is available, however, and interested persons should contact the authors at the Great Lakes Basin Commission offices for further information.

METHODOLOGY

PARAMETERS

Loadings have been calculated for total phosphorus, soluble ortho phosphorus, suspended solids, total nitrogen, nitrate (+ nitrite) nitrogen, ammonia nitrogen, and chloride. Phosphorus, nitrogen, and suspended solids are all important non-point source pollutants which are being emphasized in the PLUARG study. Suspended solids are of concern not only as a non-point source pollutant, but also because toxic trace substances and nutrients are often associated with suspended material. Chloride is important because of its conservative nature and the fact that it can be used as a "tracer" to provide general insight on loadings to the lakes. Chloride can also be contributed by non-point sources, such as runoff from urban or residential areas where salt compounds have been applied for road de-icing purposes.

There are other substances for which it would be useful to have loading information. For example, detailed annual loads to the Great Lakes of certain toxic heavy metals, such as cadmium or zinc, would be useful information. However, there are very little data available on these and similar substances from which loadings may be calculated. It is likely that more information will be available in the near future on these parameters from which Great Lakes loadings can be calculated (loads of certain toxic substances will likely be estimated or projected as part of the Great Lakes Basin Plan planning process of the Great Lakes Basin Commission). For a discussion of the availability of river mouth data for a number of parameters that were not discussed in this report, such as total solids, particle size, silica, total soluble phosphorus, chloride, manganese, iron, total and dissolved heavy metals, pesticides, and industrial organics, refer to Hall et al. (1976).

All loadings were calculated based on existing data and no attempt was made to determine the quality of the data used. No determinations were made, for example, on the adequacy of the analytical techniques used to generate the data or the quality control employed in the analysis. Further, the statistical validity of the data was not critiqued. Since any one parameter could be determined by a variety of methods, many of which are operationally defined and not always directly comparable, a certain amount of judgement was used in determining whether the data found for a certain tributary were reasonable. For example, in the case of dissolved reactive phosphorus, the type of filter paper used may have a bearing on the results reported. Soluble phosphorus data obtained using a glass fiber filter may not correlate exactly with data obtained using a 0.45 micron membrane filter. However, where results from two operationally defined techniques define approximately the same form or fraction of a given pollutant, for the purposes of these loading estimations, they were generally considered as the same parameter. For the purposes of these river mouth loading estimates, slight modifications in methodology were not assumed to have any significant bearing on the results.

There were some problems (although rare) associated with the terminology used for certain parameters, especially in the case of phosphorus. A variety of terms have been used for different phosphorus fractions, and it is sometimes difficult to determine which form of phosphorus is actually implied. For example, the term "phosphate P" could mean several different fractions, including total inorganic phosphorus or soluble reactive phosphorus. In cases such as these, it was sometimes necessary to look at the analytical methods used to see what form of phosphorus was actually implied. Again, even if slight differences in techniques were determined to have occurred, the effect on the loading estimates would generally be very small, if not undetectable. In order to get a better understanding of the different types of phosphorus forms and how they are analyzed and thus operationally defined, the reader is referred to Figure 4 page 25 in Hall et al. (1976).

Nitrogen data used in the calculations generally caused few problems. Nitrate nitrogen was often measured in combination with nitrite nitrogen. Since nitrite is absent or present only in minute quantities in most the waters due to its instability in the presence of oxygen, no distinction was made between nitrate loads and nitrate + nitrite loads.

Total nitrogen loads were calculated based on reported total nitrogen values whenever possible. When total nitrogen was not reported, the sum of inorganic plus organic nitrogen concentrations or total Kjeldahl nitrogen plus nitrate (+ nitrite) nitrogen was used.

TOTAL RIVER MOUTH LOAD CALCULATIONS

All river mouth loads that were calculated and used in this report are presented in Appendix A. These loads, calculated for individual tributaries, serve as the basis for other calculations such as the computation of unit area loadings.

Data Sources

River mouth loads were calculated using the best available concentration and flow information. Every effort was made to utilize all data available for any given tributary, since the confidence in a loading estimate is generally improved as the number of data points is increased. Primary sources of data include State water surveillance programs, U. S. Geological Survey programs, International Joint Commission PLUARG and Upper Lakes Reference Group studies, the U. S. Army Corps of Engineers Lake Erie Wastewater Management Study, and other work done by universities and special State or Federal projects.

In general, data on the seven parameters considered were available on all major U. S. Great Lakes tirbutaries. Appendix A indicates the number of flow and concentration data pairs that were used in each loading calculation.

The primary source of daily and mean annual flow information was U. S. Geological Survey Water Resources Data Reports. Some State surveillance programs also collected flow data (generally at the time of the sample collection) which were used where appropriate.

Base Years

All loadings were calculated according to the water year as standardized by the U. S. Geological Survey. In an effort to make this report as current as possible and compatible with other PLUARG work, water years 1975 (October 1, 1974-September 30, 1975) and 1976 (October 1, 1975-September 30, 1976) were chosen as the base periods for annual load calculations. For many tributaries the mean annual daily flow during water year 1975 was similar to the mean annual daily flow for the historical period of record. Although it would be improper to call water year 1975 a "typical" year, since no year is "typical," water year 1975 does provide a good base for comparison with other years.

Watershed Areas

In this report tributaries and their watersheds have been organized according to individual tributaries, hydrologic areas, river basin groups, and lake basins following the procedure used in Subactivity 2-1 of U. S. Task D, PLUARG (Hall et al., 1976). Each of the 72 hydrologic areas consists of a single major watershed or a complex of small watersheds draining individual tributaries. Hydrologic areas are grouped into 15 larger river basin groups which contain anywhere from one to eight hydrologic areas. Each lake basin consists of two or more river basin groups. A description of the U. S. tributaries, their organization and maps of their drainage basins have been previously recorded in Hall et al. (1976).

Table 1 shows the watershed areas used in this study. Watershed area measurements were obtained primarily from the Great Lakes Basin Framework Study, Appendix 1, Alternative Frameworks. Additional drainage area information, especially for areas containing the smaller rivers, was obtained from a computerized list of watershed areas compiled for the Conservation Needs Inventory by the U. S. Soil Conservation Service.

Table 1

DRAINAGE AREA MEASUREMENT (HYDROLOGIC)[1]

	AREA 1,000 Hectares	1,000 Acres
LAKE SUPERIOR BASIN	4,400	10,871
River Basin Group 1.1	2,391	5,907
1. Superior Slope Complex (Minnesota)	595	1,470
2. Saint Louis River	944	2,334
3. Apostle Island Complex	514	1,269
4. Bad River (Wisconsin)	258	637
5. Montreal River Complex	80	197
River Basin Group 1.2	2,009	4,964
1. Porcupine Mountains Complex	272	672
2. Ontonagon River	353	872
3. Keweenaw Peninsula Complex (Michigan)	350	865
4. Sturgeon River (Michigan)	183	452
5. Huron Mountain Complex (Michigan)	252	622
6. Grand Marais Complex (Michigan)	311	768
7. Tahquamenon River (Michigan)	218	540
8. Sault Complex (Michigan)	70	173
LAKE MICHIGAN BASIN	11,741	29,011
River Basin Group 2.1	4,367	10,791
1. Menominee Complex (Michigan)	273	674
2. Menominee River	1,061	2,621
3. Peshtigo River (Wisconsin)	298	737
4. Oconto River (Wisconsin)	275	680
5. Suamico Complex (Wisconsin)	125	310
6. Fox River (Wisconsin)	1,710	4,225
7. Green Bay Complex (Wisconsin)	625	1,544
River Basin Group 2.2	563	1,392
1. Chicago-Milwaukee Complex	563	1,392
River Basin Group 2.3	3,356	8,292
1. Saint Joseph River	1,211	2,992
2. Black River (South Haven) Complex (Michigan)	93	229
3. Kalamazoo River (Michigan)	520	1,285
4. Black River (Ottawa Co.) Complex (Michigan)	66	163
5. Grand River (Michigan)	1,466	3,623
River Basin Group 2.4	3,455	8,536
1. Muskegon River (Michigan)	685	1,692
2. Sable Complex (Michigan)	503	1,242

[1]Area measurements also include small watersheds, streams, and land areas that drain directly into Basin Lakes. Source: Great Lakes Basin Framework Study, Appendix 13, Land Use and Management. Does not include major inland water.

Table 1 (Continued)

DRAINAGE AREA MEASUREMENT (HYDROLOGIC)

	AREA 1,000 Hectares	1,000 Acres
3. Manistee River (Michigan)	520	1,284
4. Traverse Complex (Michigan)	683	1,689
5. Seul Choix-Groscap Complex (Michigan)	142	352
6. Manistique River (Michigan)	375	926
7. Bay De Noc Complex (Michigan)	310	765
8. Escanaba River (Michigan)	237	586
LAKE HURON BASIN	4,192	10,358
River Basin Group 3.1	2,108	5,208
1. Les Cheneaux Complex (Michigan)	364	901
2. Cheboygan River (Michigan)	409	1,010
3. Presque Isle Complex (Michigan)	145	358
4. Thunder Bay River (Michigan)	327	808
5. Au Sable and Alcona Complex (Michigan)	576	1,422
6. Rifle-Au Gres Complex (Michigan)	287	709
River Basin Group 3.2	2,084	5,150
1. Kawkawlin Complex (Michigan)	100	248
2. Saginaw River (Michigan)	1,617	3,995
3. Thumb Complex (Michigan)	367	907
LAKE ERIE BASIN	5,559	13,735
River Basin Group 4.1	1,347	3,328
1. Black River (Michigan)	180	446
2. St. Clair Complex (Michigan)	155	383
3. Clinton River (Michigan)	203	501
4. Rouge Complex (Michigan)	189	468
5. Huron River (Michigan)	220	543
6. Swan Creek Complex (Michigan)	74	182
7. Raisin River	326	805
River Basin Group 4.2	2,685	6,635
1. Ottawa River	44	109
2. Maumee River	1,711	4,229
3. Toussaint-Portage Complex (Ohio)	266	656
4. Sandusky River (Ohio)	397	980
5. Huron-Vermilion Complex (Ohio)	267	661
River Basin Group 4.3	843	2,082
1. Black-Rocky Complex (Ohio)	230	568
2. Cuyahoga River (Ohio)	234	578
3. Chagrin Complex (Ohio)	77	189
4. Grand River (Ohio)	212	525
5. Ashtabula-Conneaut Complex	90	222

Table 1 (Continued)

DRAINAGE AREA MEASUREMENT (HYDROLOGIC)

	AREA 1,000 Hectares	1,000 Acres
River Basin Group 4.4	684	1,690
1. Erie-Chautauqua Complex	169	418
2. Cattaraugus Creek (New York)	144	355
3. Tonawanda Complex (New York)	371	917
LAKE ONTARIO BASIN	4,577	11,309
River Basin Group 5.1	911	2,250
1. Niagara-Orleans Complex (New York)	269	664
2. Genesee River	642	1,586
River Basin Group 5.2	1,766	4,363
1. Wayne-Cayuga Complex (New York)	177	437
2. Oswego River (New York)	1,316	3,252
3. Salmon Complex (New York)	273	674
River Basin Group 5.3	1,900	4,696
1. Black River (New York)	521	1,289
2. Perch Complex (New York)	126	311
3. Oswagatchie River (New York)	430	1,062
4. Grass-Raquette-St. Regis Complex (New York)	823	2,034

To Convert From	To	Multiply By
Hectares (ha)	Acres (ac)	2.471

Table 1

DRAINAGE AREA MEASUREMENT (HYDROLOGIC)

		AREA 1,000 Hectares		AREA 1,000 Hectares
STATE SUMMARY				
	Illinois	16	New York	5,146
	Indiana	944	Ohio	3,027
	Michigan	15,030	Pennsylvania	156
	Minnesota	1,591	Wisconsin	4,558
GREAT LAKES TOTAL				30,468

To Convert From	To	Multiply By
Hectares (ha)	Acres (ac)	2.471

Correcting Loads to the River Mouth

Not all chemical stations and flow gaging stations are located at the river mouth. In order to present a total river mouth load in these situations, it was necessary to adjust flow and some concentrations to account for the area below monitoring stations.

In order to adjust flow measurements to the river mouth, gage flow was multiplied by the ratio of the total drainage area over the gaged drainage area. For example, if a river drains a total area of 1,000 square kilometers, but the farthest downstream flow gage is located 15 river kilometers upstream from the mouth and accounts for only 900 square kilometers, the gaged flow would be multiplied by 1,000/900 or 1.11 to provide a corrected flow. All flows used in loading calculations in this report were corrected in this matter, if not already reported as accounting for the total watershed drainage area.

In most cases, chemical monitoring stations were located at or very near the river mouth. Consequently, no concentration adjustments were made, and it was assumed that concentrations at the mouth were the same as those measured at the monitoring station. An exception to this procedure occurred if the monitoring station were above a major impoundment. In these few cases, the load was calculated at the station above the impoundment, and the remaining area was considered to be unmonitored and treated in a manner similar to those streams that have no chemical or flow information on them (as will be discussed in a later section).

Loads determined by the U. S. Army Corps of Engineers Lake Erie Wastewater Management Study (U. S. Army Corps of Engineers, 1975) were used in determining Lake Erie tributary inputs. These loads were not corrected for the distance between the gage and the lake. Consequently, for this study the Corps river loads were extrapolated from the gage to the river mouth using the area ratio approach for flow outlined above.

Method of Calculating Loadings

Loadings calculated for this report, other than those to Lake Erie, were done using the ratio estimator method, employing a computer program developed specifically for applying the calculation method (Clark, 1976). This method has been widely reviewed and is generally accepted by the Great Lakes research and surveillance community as the preferred and, importantly, standard method for calculating tributary loads. Table 2 illustrates a sample calculation of load using the ratio estimator program.

The ratio estimator method calculates an average daily load at the river mouth adjusted to some extent for the variability of flow over an annual cycle. For example, monitoring programs that employ monthly sampling may miss high flow events. If a mean daily flow were calculated based on the days sampled, an improper estimate of the total annual load would result. However, if the mean daily load is adjusted by multiplying it by the ratio of the mean daily flow for the year over the mean daily sample flow, some of the bias can be removed from the calculated load. It is also desirable

TABLE 2

EXAMPLE OF LOAD CALCULATION USING
THE RATIO ESTIMATOR PROGRAM

TRIB: FOX BASIN: MICHIGAN RBG: 1
WATER YEAR: 1975 PARAMETER: TOTAL PHOSPHORUS

LOADINGS kg/day	FLOWS m3sec	cfs	CONCENTRATIONS mg/liter
481	39.8	1405.5	0.140
914	105.8	3736.3	0.100
1228	118.4	4181.3	0.120
562	50.0	1765.7	0.130
838	97.0	3425.5	0.100
795	115.0	4061.2	0.080
1692	178.0	6286.0	0.110
1547	199.0	7027.6	0.090
2955	171.0	6038.8	0.200
1854	58.0	2048.2	0.370
626	29.0	1024.1	0.250
847	70.0	2472.0	0.140

MEAN SAMPLE FLOW = 102.58 m3/sec

MEAN SAMPLE LDG = 1194.9 kg/day
MEAN ANNUAL FLOW = 118.393 m3/sec or 4181 cfs

THE BIASED RATIO ESTIMATE = 1379.1 kg/day
APPROX. UNBIASED RATIO EST. = 1369.0 kg/day
CORRECTION FOR BIAS OF EST. = -10.0 kg/day

RATIO OF MEAN ANNUAL FLOW TO MEAN SAMPLE FLOW IS 1.15
BASED ON VALUES OF 118.39 and 102.58 m3/sec, RESPECTIVELY

EST. MEAN DAILY LOADING IS THEREFORE 1369.0 kg/day

EST. MEAN EFFOR OF THIS EST. IS 168.5 kg
EST. LOADING FOR YEAR = 499698 kg, or 499.7 METRIC TONS
EST. MEAN ERROR FOR THIS TOTAL = 61520 kg or 61.5 METRIC TONS
EST. ARE BASED ON 11 DEGREES OF FREEDOM
SUM-OF-SQUARES-ERROR = 340906 (kg/d)**2 or 45417 (t/year)**2
ARE THE DATA CORRECT FOR ENTRY TO THE FILE
1
FOX MICH 1 499.7 3784.8 12
DATA HAS BEEN ENTERED.
EXECUTION TERMINATED

ro provide an error statement associated with the calculations based on the variability of the data, such as a mean square error term. The ratio estimator method provides such an error estimate.

The following equations summarize how the ratio estimator, as well as how the mean square error term, is calculated.

The ratio estimator, $\tilde{\mu}$, is defined in International Joint Commission (1976) as

$$\tilde{\mu}_y = \mu_x \cdot \frac{m_y}{m_x} \cdot \frac{\left(1 + \frac{1}{n} \cdot \frac{S_{xy}}{m_y m_x}\right)}{\left(1 + \frac{1}{n} \cdot \frac{S_x^2}{m_x^2}\right)}$$

where μ_x = mean daily flow for the water year

m_y = mean daily loading for the days concentrations were determined

m_x = mean daily flow for the days concentrations were determined

n = number of days concentrations were determined

$$S_{xy} = \frac{\sum_{i=1}^{n} X_i Y_i - n \cdot m_y \cdot m_x}{n-1}$$

$$S_x^2 = \frac{\sum_{i=1}^{n} X_i^2 - n \cdot m_x^2}{n-1}$$

and the X_i and Y_i are the individual measured flow and calculated loading, respectively, for each day concentrations were determined.

The mean-square-error of this estimator may be estimated to terms of the order n^{-2}, assuming the population size is very large by,

$$\hat{E}\{(\tilde{\mu} - \mu_y)^2\} = m_y^2 \cdot \left[\frac{1}{n} \cdot \left(\frac{S_x^2}{m_x^2} + \frac{S_y^2}{m_y^2} - 2\frac{S_{xy}}{m_x m_y} \right) + \frac{1}{n^2} \cdot \left[2 \cdot \left(\frac{S_x^2}{m_x^2} \right)^2 - 4\frac{S_x^2}{m_x^2} \cdot \frac{S_{xy}}{m_x m_y} + \left(\frac{S_{xy}}{m_x m_y} \right)^2 + \frac{S_x^2}{m_x^2} \cdot \frac{S_y^2}{m_y^2} \right] \right]$$

Where S_y^2 is calculated analagously to S_x^2.

For a further explanation of the ratio estimator used, see Menominee River Pilot Watershed Study (1977).

If the mean annual daily flow is not known, loadings are estimated using the sample mean of the calculated daily loadings. Also, in some cases the sampling program was designed to collect data during high flow events. For situations such as this, the data were divided into two or three flow strata and a separate load and error were calculated for each strata. Table 3 illustrates the use of the ratio estimator program using two strata.

All loads and the mean square error terms derived from the ratio estimator approach are presented in Appendix A. It is important to note that error statements generated by this procedure do not necessarily reflect the accuracy of the calculated load. This point will be discussed in detail in a later section.

In order to avoid duplicating work, some loading estimates were not calculated from concentration and flow data, but were obtained directly from other reports. U. S. Army Corps of Engineers have developed a flow interval calculation method for use in the Lake Erie Wastewater Management Study. This approach is analagous to the ratio estimator method in that it uses additional flow information for the year to weight the loads. It also provides an error statement. In our report all Lake Erie mean annual loads were obtained directly from the Lake Erie Wastewater Management Study, and no attempt was made to recalculate loads using the ratio estimator approach.

TABLE 3

EXAMPLE OF RATIO ESTIMATOR RIVER MOUTH LOAD CALCULATION USING STRATA

TRIB: BAD RIVER BASIN: SUPERIOR RBG: 1
WATER YEAR: 1975 PARAMETER: SUSPENDED SOLIDS

STRATUM 1 UPPER FLOW CUTOFF = 1000.0000 # DAYS: 342

LOADINGS kg/day	FLOWS m3/sec	cfs	CONCENTRATIONS mg/liter
2334	9.0	318.0	3.000
1620	9.4	331.0	2.000
10036	8.3	293.0	14.000
13486	12.0	424.0	13.000
3190	9.2	326.0	4.000
4392	10.2	359.0	5.000
31928	14.8	522.0	25.000
24363	21.7	766.0	13.000
47209	22.8	804.0	24.000
14009	11.6	409.0	14.000
8573	8.3	292.0	12.000
11470	8.3	293.0	16.000
5926	4.9	173.0	14.000
6275	4.8	171.0	15.000
6068	4.4	155.0	16.000
11528	4.3	152.0	31.000
2496	5.8	204.0	5.000
6028	10.0	352.0	7.000
14004	18.0	636.0	9.000
4587	10.6	375.0	5.000
11377	13.2	465.0	10.000
17136	11.7	412.0	17.000
7724	12.8	451.0	7.000
24275	12.8	451.0	22.000
4551	3.5	124.0	15.000
9214	7.6	269.0	14.000
4541	3.3	116.0	16.000

MEAN SAMPLE FLOW = 10.11 m3/sec

MEAN SAMPLE LDG = 11419.9 kg/day
MEAN STRATUM FLOW = 15.631 m3/sec or 552 cfs

THE BIASED RATIO ESTIMATE = 17650.3 kg/day
APPROX. UNBIASED RATIO EST. = 17707.8 kg/day
CORRECTION FOR BIAS OF EST. = 57.5 kg/day

RATIO OF MEAN STRATUM FLOW TO MEAN SAMPLE FLOW IS 1.55
BASED ON VALUES OF 15.63 and 10.11 m3/sec, respectively

EST. MEAN STRATUM LOADING IS THEREFORE 17707.8 kg

TABLE 3 CONTINUED...

EST. MEAN ERROR OF THIS EST. IS 1368.2 kg
EST. ARE BASED ON 26 DEGREES OF FREEDOM.
SUM-OF-SQUARES-ERROR = 50544992.(kg/d)**2 or 6733851.(t/year)**2

TRIB: BAD RIVER BASIN: SUPERIOR RBG: 1
WATER YEAR: 1975 PARAMETER: SUSPENDED SOLIDS

STRATUM 2 #DAYS: 23

LOADINGS	FLOWS		CONCENTRATIONS
kg/day	m3/sec	cfs	mg/liter
19930[illegible]	67.8	2396.0	34.000
5399084	173.1	6113.0	361.000
83453[illegible]7	173.1	6113.0	558.000
182406	48.0	1695.0	44.000
740314	66.9	2364.0	128.000
140140	101.4	3580.0	16.000
6597989	178.4	6301.0	428.000
2756731	185.5	6551.0	172.000
10959018	332.0	11726.0	382.000
127144	46.0	1624.0	32.000

MEAN SAMPLE FLOW = 137.23 m3/sec

MEAN SAMPLE LDG = 3544755.0 kg/day
MEAN STRATUM FLOW = 156.366 m3/sec or 5522 cfs

THE BIASED RATIO ESTIMATE = 4038986.0 kg/day
APPROX. UNBIASED RATIO EST. = 4134327.0 kg/day
CORRECTION FOR BIAS OF EST. = 95341.0 kg/day

RATIO OF MEAN STRATUM FLOW TO MEAN SAMPLE FLOW IS 1.14
BASED ON VALUES OF 156.37 and 137.23 m3/sec, RESPECTIVELY

EST. MEAN STRATUM LOADING IS THEREFORE 4134327.0 kg

EST MEAN ERROR OF THIS EST IS 698087.4 kg
EST. ARE BASED ON 9 DEGREES OF FREEDOM.
SUM-OF-SQUARES-ERROR = 4873259057152 (kg/d)**2 or 649239461888, (t/year)**2

SUMMARY FOR THE BAD RIVER
OVER 2 STRATA:

EST. MEAN DAILY LOADING IS THEREFORE 277111.1 kg/day

EST. MEAN ERROR OF THIS EST. IS 44007.7 kg
EST. LOADING FOR YEAR = 101145552 kg, or 101145.5 METRIC TONS
EST. MEAN ERROR FOR THIS TOTAL = 16062825 kg, or 16062.8 METRIC TONS

EST ARE BASED ON 9.02 EFFECTIVE DEGREES OF F
ARE THE DATA CORRECT FOR ENTRY TO THE FILE??
1
BAD RIVER SUPE 1 101145.5 258014192.0 10
DATA HAS BEEN ENTERED.

The Upper Lakes Reference Group (ULRG) also calculated mean daily river loads (Upper Lakes Reference Group, 1976) for Lake Superior and Huron tributaries. Their sampling program was monthly with extra samples taken in the spring. To calculate a mean daily load, a load for each day that samples were taken was generated and then averaged. This procedure is shown mathematically below:

$$L = \frac{\sum_{i=1}^{n} QiXCi}{n}$$

L = mean daily river load

Qi = river flow for any given day i

Ci = concentration for day i

n = total number of days sampled

At first it was thought that these loads could be used directly in this report. However, a significant difficulty was observed with this calculation technique in that it is strongly biased toward the springtime (and generally high flow events) sampling. For example, if 16 samples were taken over the year, one in each month except for the month of April where five samples were taken, the mean daily load calculated from these data would be biased toward the April samples. If the April data were obtained during high flows (and higher concentrations for some parameters), the annual load for some parameters could have been over-estimated. Because of this problem, mean annual loads reported by ULRG were not used in this report except where no mean annual daily flow data were available for recalculation of the loads using the ratio estimator method. In many cases significant differences were observed between the mean annual load calculated by the ratio estimator method and the ULRG method, despite the fact the same data were used.

In calculating river mouth loads, an understanding of the influence of high flow events is crucial. For example, for tributaries draining into parts of Lake Erie it is clear that high flow events have a major impact on the total load of sediment and certain chemical substances. However, the relationship between flow and concentration varies widely over the U. S. Great Lakes Basin. The importance of high flow events will be discussed in a later section, but it should be noted here that all data, including high flow event data that were available, were used in calculating river mouth loads.

POINT SOURCE LOADS

In order to determine the relative importance of non-point or diffuse sources to the total river mouth load, municipal and industrial discharges which potentially contribute to river mouth loadings have been determined. The difference between total load and point source inputs delivered to the river mouth provides an estimate of non-point or diffuse load to the Great Lakes from a tributary.

Data Sources

Point source dischargers within the U. S. Great Lakes Basin were identified from a number of different sources. Summaries or computerized files of point source information were consulted whenever possible. A brief description of the major sources of information used is discussed below:

National Pollution Discharge Elimination System

(NPDES) - This system was the basis for much of the information used in this report. The U. S. Environmental Protection Agency (EPA) maintains this file. Region V of U. S. EPA supplied most of the information which was in turn collected and supplied to EPA from the Great Lakes States.

International Joint Commission

The 1975 and 1976 Water Quality Board reports provided information on phosphorus discharges for municipal plants with discharges greater than one million gallons per day. Appendices B and C of the Water Quality Board reports (the Surveillance Subcommittee and the Remedial Programs Subcommittee Reports) also provided information, particularly with regard to municipal and industrial discharges in defined problem areas. Industrial point source information compiled for the Upper Lakes Reference Group, which was for the most part derived from NPDES permit information, formed the basis of industrial point source information for Lakes Huron and Superior. Other information compiled by the IJC Great Lakes Regional Office, such as a computerized list of municipal facilities with design flow and type of treatment, was also used to supplement this information.

New York

The New York Department of Environmental Conservation supplied most of the New York State point source information through a computer printout from the State's Pollution Discharge Elimination System. The Department of Environmental Conservation's "Water Quality Management Plan for the St. Lawrence Basin" (1975) and "St. Lawrence River Basin Plan for Pollution Abatement" (1971) also were used, particularly for point sources affecting the international section of the St. Lawrence.

Wisconsin

The Wisconsin Department of Natural Resources' "Water Quality Management Basin Plan for the Rivers of the Northwest Shore of Lake Michigan" (1975) provided location of most point sources in the area as well as limited discharge information for municipal plants. "Southeast Wisconsin River Basins - A Drainage Basin Report" (Southeast Wisconsin Regional Planning Commission, 1976) provided point source information on the southern part of the state. The "Manitowoc River Basin Report" (Wisconsin Department of Natural Resources, 1977) was used to obtain information on the Manitowoc River Basin. The Southeast Wisconsin Regional Basin Commission kindly provided preliminary information on municipal and industrial point sources identified in their area. Finally, while some NPDES summaries of Wisconsin were used, complete and extensive computerized NPDES list of point source dischargers provided by the state was received too late to be reviewed in detail for this report. However, preliminary examination indicated that most of the point sources were accounted for through other sources of information.

Michigan

A listing of industrial and municipal point source discharges was obtained from the Michigan Department of Natural Resources. Available DNR files in Lansing were also surveyed to obtain additional details on point source inputs. Information on point sources was also partially derived from the East Central Michigan Planning and Development Region (Chester Engineers, 1977).

Lake Erie Wastewater Management Study

The Lake Erie Wastewater Management Study (U. S. Army Corps of Engineers, 1975) provided a large amount of information on point source discharges to Lake Erie. Information available included a detailed listing of non-industrial point source loads. No data were available on industrial inputs to the Lake Erie Basin except for information provided by the New York Department of Environmental Conservation.

U. S. EPA Special Reports

Special reports, particularly the Water Pollution Investigation Series (Sargent, 1975; Patterson et al., 1975) were used to gain supplemental point source information.

In compiling point source information, NPDES records and IJC information (supplied basically by the states) were the primary information sources used. Other information was used to supplement this data. In some cases, a combination of information sources was used to obtain the required information (for example, the receiving water of the discharger may have been obtained from one source and the load of certain parameters from another).

Location of Point Sources

A great deal of effort was expended in locating where a point source enters a tributary to the Great Lakes. Obviously, many physio-chemical and biological factors may affect the delivery of point source discharges to the river mouth of a tributary. Consequently, all point source inputs to a Great Lakes tributary were classified as an "upstream" or "downstream" source. The cut-off between upstream and downstream was arbitrarily chosen as approximately 50 river kilometers upstream from the river mouth or at the outlet of an impoundment or lake-like widening of the river where such occurs within 50 river kilometers of the mouth. Grouping data into these upstream and downstream categories permits calculations of different point source deliveries to the river mouth when different delivery or transmission ratios are known or assumed.

Base Years

As discussed previously, water years 1975 and 1976 were chosen as base years for loading calculations. Consequently, point source annual loads for these periods were also sought.

In many instances, point source discharges were not available for all parameters for both base years. When an annual load was available for only one year, that load was assumed to apply to the other year. If data were not available for either year in question, but were presented for another year previous to 1975, then the most recent data were used to calculate an annual pollutant discharge, on the assumption that these data are typical of the two base years. If known upgrading of the point source wastewater treatment facility had occurred between the year of available data and the base year, such as often occurred in the case of phosphorus removal at municipal treatment plants, non-base year data were not used and a load estimated as described below.

Some point source annual loads are reported according to the calendar year instead of the water year. However, since annual loads are often determined from a few samples per year (or even less), no attempt was made to adjust annual point source inputs to the water year. Any annual discharges reported or calculated for the calendar year were assumed to apply to the water year (if loads for the water year were not available).

Estimation of Point Source Loads

Point source loads were estimated for both municipal and industrial dischargers. Because of the differences in available data, municipal loads were determined somewhat differently than industrial loads.

Municipal Point Sources. For each municipal discharger identified (over 800), information was collected on the name of the discharger, the receiving tributary, the water year in which the data were collected, the data source, the load for that year for available parameters of interest, whether the source was discharged into an upstream or downstream segment, the effluent flow per day, and the plant's location in relation to the river mouth water quality sampling station. In terms of loading information, data on phosphorus and suspended solids were most often found. Actual loading figures for the other five parameters considered in this study were often not readily available from the various data sources.

In cases where phosphorus and suspended solids data were not available for loading calculation work, an average phosphorus concentration obtained from an analysis of those municipal plants with existing loading information was multiplied by the known flow to obtain a load. Actual flow data, or in some cases design flow, was found for all municipal dischargers identified as a contributor. In a few of the more obscure plants, where only a load was found, the flow was back-calculated using average concentrations as described below.

In determining an "average" phosphorus and suspended solids concentration, known municipal concentration data were grouped according to treatment type as shown in Table 4. The combined average of primary and secondary treatment plants and the average of tertiary plants given in Table 4 were used in estimating loads for primary and secondary plants and for tertiary plants, respectively, for which concentration information was not available.

In gathering information for Table 4, it was noticed that several plants that were listed as having tertiary treatment (phosphorus removal) had relatively high phosphorus concentrations in their effluents. While these concentrations or the actual treatment were suspect, they were still used for calculating an average concentration. Consequently, the average effluent phosphorus concentration from tertiary plants (1.3 mg/ℓ P) could be slightly high.

Table 4 also shows the average phosphorus concentration for those plants that have a flow of between 0.1 mgd and 1 mgd. The average concentration obtained for these small plants compares very closely with the average concentration calculated for primary treatment plants. This indicates that while the small plants may be insignificant as far as total flow is concerned because of their higher concentration, they may indeed provide a significant phosphorus load.

TABLE 4

MEAN EFFLUENT CONCENTRATIONS FOR GREAT LAKES MUNICIPAL TREATMENT PLANTS

(Plants generally 1 mgd or greater except as noted)

Type of Treatment	Parameter	mg/ℓ	Number of Plants	Standard Deviation
Primary	Phosphorus (as P)	5.5	9	1.8
Secondary	"	3.9	57	2.2
Primary + Secondary	"	4.1	66	2.2
Tertiary (P removal)	"	1.3	94	0.7
Small Plants [1]	"	5.2	12	3.4
Primary	Suspended Solids	59.3	7	26.9
Secondary	"	31.6	30	20.7
Primary + Secondary	"	36.8	37	24.2
Tertiary	"	24.8	63	16.7
All Plants (Primary + Seconary + Tertiary)	"	29.2	100	20.5

[1] 12 plants considered with flow between 0.1 and 1.0 mgd. Data from Lake Erie Wastewater Management Study (Preliminary Feasibility Report, Volume 11, Appendix A, 1975)

Only very limited information was available on the parameters of interest other than phosphorus and suspended solids. To estimate point source loadings for these other parameters, average effluent concentrations determined by the U. S. Army Corps of Engineers Lake Erie Wastewater Management Study, as shown in Table 5, were used as representative concentrations for all Great Lakes municipal point sources. Note that soluble ortho phosphorus concentrations were estimated to be fifty percent of the total phosphorus concentration reported or derived from Table 4.

TABLE 5

MUNICIPAL PLANT EFFLUENT CONCENTRATIONS [1]

Soluble Ortho Phosphorus (as P)	0.5 x Total Phosphorus Concentration
Nitrate (Nitrite) Nitrogen	6.6 mg/ℓ
Ammonia Nitrogen	7.9 mg/ℓ
Organic Nitrogen	2.33 mg/ℓ
Chloride	160 mg/ℓ

[1] Provided by U. S. Army Corps of Engineers Lake Erie Wastewater Management Study (1975)

Only those municipal plants that had a continuous discharge were considered as a pollutant point source. Further, facilities with a discharge less than 0.1 mgd were not considered. Any plants that discharged to a lagoon or that discharged very infrequently were not considered when calculating total point source loads. It was felt that there was no accurate way to assess the annual pollutant impact of a lagoon, which may discharge only one or two times a year. Lagoon treatment systems were identified and located, however, so information is available on lagoons for further analysis beyond this report.

Industrial Point Sources. Of the 700 industrial point sources identified as possible contributors of the pollutants under consideration, loads were determined for about 200 dischargers. These dischargers were thought to represent most of the major industrial point sources contributing to U. S. streams draining into the Great Lakes. Industries identified but for which no loads were estimated, had no or insufficient data available on the pollutants of concern to permit estimating an annual load. A special effort was made, however, to include all dischargers that might be significant, particularly in terms of dischargers of phosphorus and suspended solids. For industrial dischargers it was not possible to estimate the output of all seven pollutants considered, but if annual outputs of some parameters were available or computable, they were used.

In a few cases special assumptions were made with regard to point sources that are worth mentioning. Point source contributions to the Indiana Harbor Canal and Burns Ditch, although located in a major urban area on the south shore of Lake Michigan, were not considered as part of the tributary load. Due to the unusual hydrology involved, these waters were considered direct dischargers (direct dischargers will be compiled in Subactivity 3-4 of U. S. Task D). In the Lake Ontario watershed, the New York Barge Canal intersects (through a lock system) with the Genesee and Oswego Rivers. Point source inputs to the canal were thus assigned either to the Genesee or Oswego River. Point sources entering the Barge Canal east of the Genesee were assigned to the Oswego. Otherwise, the point sources were considered to contribute to the Genesee system. Also, since Tonawanda Creek (located in the western part of the Lake Ontario basin) flows into the Niagara River (ultimately) about fifty percent of the year and into the Barge Canal the rest of the year, half of the annual point source load was assigned to Tonawanda Creek and half to the Genesee River.

Any point source that was found below the river mouth water quality station was considered to be a direct discharge to the lake and was not included in the total river mouth load. These direct sources, along with other point sources discharging directly to a lake rather than to a tributary, were not included in the river mouth or diffuse loading calculations as they do not influence tributary water quality within the monitored areas.

DIFFUSE LOADS

For the purposes of this report, diffuse loads were considered to be that portion of the total tributary load not attributable to a point source. Examples of diffuse pollutant sources are agricultural runoff, highway deicing activities, sheet and gully erosion and streambank erosion. Another source included in the diffuse category is base flow or groundwater input to streams, which for some tributaries and parameters, contributes a large fraction of the total diffuse load.

Two methods of calculating diffuse loads were utilized. One method was applicable to river basins for which river mouth monitoring data (i. e., field data) were available. The second, more indirect method, was used to estimate diffuse loads from areas where no river mouth monitoring data were found. The following section explains these two methods.

Monitored Areas

Diffuse loads from monitored areas were calculated by subtracting point source inputs from the total river mouth loads. However, since all point sources discharged may not actually reach the Great Lakes, subtracting all point source inputs from the total tributary load, regardless of where they entered the tributary system (far upstream or near the mouth), may result in an underestimation of the diffuse or non-point source load. Since the actual ratio of point source inputs contributed to a tributary to that delivered to the river mouth is unknown, the point source data were aggregated in such a way that permits varying assumptions on point source transmission.

For the purposes of this report, two transmission assumptions were made and used to calculate point source loads delivered to the river mouth. The first assumption was simply that all relevant point source pollutants discharged into watershed reached the river mouth. The second assumption was that only fifty percent of the upstream sources but all of the downstream sources reached the river mouth (the definition of upstream and downstream sources was presented earlier). Comparison of the diffuse loads calculated with these two scenarios provide insight into how point source transmission may affect the distribution of point and non-point contributions to the total tributary load. While only two point source transmission scenarios have been calculated for this report, the methodology was designed to permit the effect of other assumptions of point source transmissions on the diffuse/point source load ratio to be readily calculated.

Unmonitored Areas

Unmonitored areas were those hydrologic areas and individual tributaries which were insufficiently monitored so as to prevent a loading calculation using the ratio estimator method. In order to estimate a load from these areas, an annual diffuse unit area load (kg/ha/year) from a monitored area with similar basin characteristics was multiplied by the watershed area to provide an annual loading.

Unit area loads for monitored areas were calculated by dividing the diffuse load (total load minus point source load) by the area of drainage. Because of the two different point source transmission scenarios used, two different unit area loads were calculated for each monitored area. Consequently, two different estimates of loads for unmonitored areas were generally calculated for each water year.

In applying a diffuse unit area load factor from a monitored area to an unmonitored area, care was taken to be sure the unit area load applied was a reasonable representation of actual conditions. For example, the comparability of watersheds with respect to soil texture, soil erodibility, surficial geology, and runoff characteristics were considered in the application of diffuse unit area annual loads to unmonitored areas. In addition, an attempt was made to consider the effects of geographic variations in rainfall, atmospheric inputs, and land use practices. Whenever feasible, adjacent or nearly adjacent areas with calculated diffuse unit area loads were used to estimate unmonitored diffuse loads.

Once a diffuse load was calculated for an unmonitored area, identified point source inputs were added to give a total load for a given year. Two different total loads were thus calculated for each water year, one assuming 100 percent delivery of point source inputs to the river mouth and the other assuming delivery of 50 percent of upstream point source inputs and 100 percent of the downstream point source inputs.

In most cases unmonitored areas had few if any point sources in their watersheds.

RESULTS

Tables 6 and 7 present tributary and land runoff loading information for the entire U. S. Great Lakes drainage basin. Table 6 gives information on by Lake and total U. S. Great Lakes Basin, while Table 7 gives information on an individual hydrologic area and river basin group basis. All values presented in these tables are based upon analysis of point and non-point inputs to individual rivers draining in the U. S. Basin. The numbers for the hydrologic areas have been rounded to two significant figures. The river basin group totals, lake totals, and U. S. Great Lakes Basin totals are summations of the hydrologic area numbers.

Data are presented for seven parameters for both 1975 and 1976, except for Lake Erie, for which 1976 data are not yet available. The "Total Load" column represents the total diffuse and point source load coming into the Lakes from the tributaries within a given area. The "Monitored Load" column gives that portion of the total load that was calculated from existing flow and concentration field data on individual tributaries within a particular area. An estimated load was also made for the unmonitored areas based on a best judgement application on unit area loads to unmonitored areas. The estimated unmonitored load plus the monitored load equals the total load. The "Percent Diffuse" column represents that portion of the total load which is non-point or from diffuse sources (includes base flow, see page 100). This value is obtained by subtracting all known point source loads contributing to the area in question. It was assumed that 100 percent of all point source inputs within a given basin are delivered to the Lake in calculating this diffuse load (point source loads assuming a 50 percent delivery of upstream sources have also been calculated but are not presented here). The "Unit Area" column presents the total (monitored plus unmonitored area) diffuse unit area load. This value was obtained by dividing the total diffuse load by the given area.

Values presented in the U. S. Great Lakes Tributary Loading Summary table for total load and monitored load are summations of the river basin group information. The percent diffuse and unit area loads are calculated for each Lake based on the diffuse load and the diffuse load divided by the drainage area of the given Lake, respectively. All values presented in these tables are based upon the best available data for both river mouth and point source loading information.

Table 6

U.S. GREAT LAKES

TRIBUTARY LOADINGS

Lake		Total Phosphorus 1975				Total Phosphorus 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit Area
1	Lake Superior	1,389	999	90	.28	964	464	86	.20
2	Lake Michigan	3,190	2,772	55	.15	3,596	3,062	63	.19
3	Lake Huron	1,720	1,472	66	.27	1,954	1,563	83	.40
4	Lake Erie	8,639	6,899	81	1.3	NA	NA	NA	NA
5	Lake Ontario	1,966	1,424	53	.23	3,513	2,580	72	.56
	TOTAL	16,904	13,566	71	.40	-	-	-	-
Lake		Soluble Ortho Phosphorus 1975				Soluble Ortho Phosphorus 1976			
1	Lake Superior	464	133	68	.09	361	86	86	.07
2	Lake Michigan	1,224	1,055	56	.06	1,153	933	55	.05
3	Lake Huron	456	365	45	.05	843	663	83	.17
4	Lake Erie*	2,070	1,320	62	.23	NA	NA	NA	NA
5	Lake Ontario	522	374	45	.05	549	416	32	.04
	TOTAL*	4,736	3,247	60	.10	-	-	-	-
Lake		Suspended Solids 1975				Suspended Solids 1976			
1	Lake Superior	1,380,500	1,011,200	96	300	720,800	447,030	93	150
2	Lake Michigan	608,800	455,700	93	49	742,400	602,100	95	57
3	Lake Huron	467,300	256,300	98	110	765,100	424,100	99	180
4	Lake Erie*	6,054,900	3,822,000	99	1,100	NA	NA	NA	NA
5	Lake Ontario	1,054,000	779,000	95	220	1,545,000	1,316,000	96	330
	TOTAL*	9,565,500	6,324,200	98	310	-	-	-	-

Total load from Hydrologic Area (metric tons/yr)

Portion of total load that was monitored (metric tons/yr)

1976 Lake Erie data not available (NA)

[3] Percent of total load from diffuse sources (nonpoint)

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 6

U.S. GREAT LAKES

TRIBUTARY LOADINGS

Lake Number	Lake Name	Total Nitrogen 1975 Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area	Total Nitrogen 1976 Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit Area
1	Lake Superior	13,530	9,830	96	2.9	10,900	4,440	94	2.3
2	Lake Michigan	47,410	39,940	79	3.2	54,530	44,930	82	3.6
3	Lake Huron	29,130	23,772	88	6.4	27,470	20,130	86	5.9
4	Lake Erie*	111,670	79,550	92	19.	NA	NA	NA	NA
5	Lake Ontario	24,970	19,220	66	3.6	35,260	26,300	76	6.0
	TOTAL*	226,710	172,292	85	6.4	-	-	-	-
Lake		**Nitrate (Nitrite) N 1975**				**Nitrate (Nitrite) N 1976**			
1	Lake Superior	3,118	2,381	94	.66	2,145	830	91	.44
2	Lake Michigan	20,050	16,950	81	1.4	22,697	18,717	84	1.6
3	Lake Huron	18,250	14,873	94	4.1	15,011	10,154	93	3.4
4	Lake Erie*	85,918	63,650	96	15.	NA	NA	NA	NA
5	Lake Ontario	13,500	10,210	82	2.4	17,920	13,160	86	3.4
	TOTAL*	140,836	108,064	92	4.3	-	-	-	-
Lake		**Ammonia N 1975**				**Ammonia N 1976**			
1	Lake Superior	1,565	1,061	87	.31	895	443	75	.15
2	Lake Michigan	5 361	4,761	49	.24	5,160	4,321	33	.15
3	Lake Huron	2,423	2,236	32	.19	1,740	1,517	25	.10
4	Lake Erie*	6,236	3,551	40	.82	NA	NA	NA	NA
5	Lake Ontario	3,419	2,350	35	.26	3,844	2,826	26	.22
	TOTAL*	19,604	13,959	44	.28	-	-	-	-

Total load from Hydrologic Area (metric tons/yr)

Portion of total load that was monitored (metric tons/yr)

1976 Lake Erie data not available (NA)

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 6

U.S. GREAT LAKES

TRIBUTARY LOADINGS

Lake		Chloride 1975				Chloride 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area
1	Lake Superior	92,680	50,520	61	13	81,600	26,680	55	10
2	Lake Michigan	775,500	636,960	65	43	711,600	563,650	72	42
3	Lake Huron	377,400	351,290	66	60	422,100	359,030	70	74
4	Lake Erie*	855,600	577,800	90	91	NA	NA	NA	NA
5	Lake Ontario	1,199,900	1,149,200	52	140	1,607,800	1,553,300	64	220
	Total*	3,301,080	2,765,770	66	74	-	-	-	-

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

*1976 Lake Erie data not available (NA)

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE SUPERIOR

Hydrologic Area		Total Phosphorus 1975				Total Phosphorus 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area
1.1.1	Superior Slope Complex	180	140	100	.30	180	0	100	.30
1.1.2	Saint Louis River	260	260	67	.18	120	120	58	.08
1.1.3	Apostle Island Complex	420	140	100	.80	280	95	100	.54
1.1.4	Bad River	160	160	100	.60	52	52	100	.20
1.1.5	Montreal River Complex	33	27	81	.33	22	19	71	.20
	River Basin Group 1.1 Total	1,053	727	91	.39	654	286	91	.25
1.2.1	Porcupine Mountains Complex	26	20	79	.07	28	0	80	.08
1.2.2	Ontonagon River	160	160	100	.45	100	100	99	.28
1.2.3	Keweenaw Peninsula Complex	22	0	97	.06	22	0	97	.06
1.2.4	Sturgeon River	19	19	100	.10	39	39	100	.21
1.2.5	Huron Mountain Complex	46	38	28	.05	51	0	25	.05
1.2.6	Grand Marais Complex	31	12	100	.10	31	0	100	.10
1.2.7	Tahquamenon River	13	13	64	.04	20	20	77	.07
1.2.8	Sault Complex	19	10	100	.27	19	19	100	.27
	River Basin Group 1.2 Total	336	272	87	.14	310	178	77	.13

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE MICHIGAN

Hydrologic Area		Total Phosphorus 1975				Total Phosphorus 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
2.1.1	Menominee Complex	11	5	100	.04	35	15	100	.13
2.1.2	Menominee River	87	87	83	.05	73	73	66	.05
2.1.3	Peshtigo River	59	59	100	.20	39	39	100	.13
2.1.4	Oconto River	51	51	99	.19	57	57	98	.22
2.1.5	Suamico Complex	44	16	100	.35	92	32	100	.73
2.1.6	Fox River	500	500	24	.07	520	520	31	.09
2.1.7	Green Bay Complex	220	150	52	.32	200	120	83	.26
	River Basin Group 2.1 Total	972	868	56	.12	1,016	856	59	.14
2.2.1	Chicago-Milwaukee Complex*	300	160	81	.42	470	300	86	.73
2.3.1	Saint Joseph River 450	450	450	44	.16	490	490	56	.23
2.3.2	Black River (S.Haven) Complex	14	0	100	.15	18	0	100	.19
2.3.3	Kalamazoo River	230	230	34	.15	230	230	35	.15
2.3.4	Black River (Ottawa Co.) Comp.	78	0	16	.19	81	0	15	.23
2.3.5	Grand River	760	760	46	.24	840	840	55	.31
	River Basin Group 2.3 Total	1,532	1,440	42	.19	1,659	1,560	51	.25
2.4.1	Muskegon River	81	79	90	.10	100	100	92	.13
2.4.2	Sable Complex	94	64	99	.20	130	91	99	.29
2.4.3	Manistee River	53	53	61	.06	61	56	66	.08
2.4.4	Traverse Complex	51	12	84	.06	51	12	84	.06
2.4.5	Seul Choix-Groscap Complex	11	0	100	.08	13	0	100	.09
2.4.6	Manistique River	46	46	85	.10	51	51	86	.12
2.4.7	Bay De Noc Complex	13	13	100	.04	13	3.6	100	.04
2.4.8	Escanaba River	37	37	99	.15	32	32	98	.13
	River Basin Group 2.4 Total	386	304	88	.10	451	346	90	.12

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

* Point sources to the Indiana Harbor Canal and Burns Ditch are considered direct; see page 87.

[3] Percent of total load from diffuse sources (nonpoint)

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE HURON

Hydrologic Area		Total Phosphorus 1975				Total Phosphorus 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif- fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif- fuse	Unit[4] Area
3.1.1	Les Cheneaux Complex	78	18	100	.26	94	22	100	.31
3.1.2	Cheboygan River	30	29	100	.07	24	23	99	.06
3.1.3	Presque Isle Complex	5.7	2.5	100	.04	15	6.6	100	.10
3.1.4	Thunder Bay River	33	33	100	.10	15	15	100	.05
3.1.5	Au Sable and Alcona Complex	33	30	100	.06	40	36	100	.07
3.1.6	Rifle-Au Gres Complex	58	54	84	.17	45	24	80	.13
	River Basin Group 3.1 Total	238	166	96	.11	233	127	96	.11
3.2.1	Kawkawlin Complex	42	18	73	.31	41	0	73	.03
3.2.2	Saginaw River	1,200	1,200	53	.39	1,400	1,400	77	.68
3.2.3	Thumb Complex	240	88	99	.64	280	36	99	.78
	River Basin Group 3.2 Total	1,482	1,306	61	.43	1,721	1,436	81	.68

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE ERIE

Hydrologic Area		Total Phosphorus 1975				Total Phosphorus 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area
4.1.1	Black River	46	46	86	.22				
4.1.2	St. Clair Complex	64	23	92	.40				
4.1.3	Clinton River	260	260	58	.76				
4.1.4	Rouge Complex	320	200	96	1.6				
4.1.5	Huron River	250	250	60	.70				
4.1.6	Swan Creek Complex	60	0	100	.70				
4.1.7	Raisin River	310	280	72	.70				
	River Basin Group 4.1 Total	1,310	1,059	76	.74				
4.2.1	Ottawa River	69	0	95	1.0				
4.2.2	Maumee River	2,600	2,600	86	1.3				
4.2.3	Toussaint-Portage Complex	240	150	85	.77				
4.2.4	Sandusky River	620	600	81	1.3				
4.2.5	Huron-Vermilion Complex	310	220	86	1.0				
	River Basin Group 4.2 Total	3,839	3,570	85	1.2				
4.3.1	Black-Rocky Complex	750	660	76	2.5				
4.3.2	Cuyahoga River	790	790	65	2.2				
4.3.3	Chagrin Complex	160	140	96	2.0				
4.3.4	Grand River	380	330	100	1.8				
4.3.5	Ashtabula-Conneaut Complex	190	170	97	2.0				
	River Basin Group 4.3 Total	2,270	2,090	79	2.1				
4.4.1	Erie-Chautauqua Complex	300	0	92	1.6				
4.4.2	Cattaraugus Creek	180	180	94	1.2				
4.4.3	Tonawanda Complex	740	0	63	1.6				
	River Basin Group 4.4 Total	1,220	180	75	1.5				

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

[3] Percent of total load from diffuse sources (nonpoint

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE ONTARIO

Hydrologic Area		Total Phosphorus 1975				Total Phosphorus 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
5.1.1	Niagara-Orleans Complex	290	0	56	.61	360	0	68	.90
5.1.2	Genesee River	590	530	71	.61	800	720	78	.90
	River Basin Group 5.1 Total	880	530	66	.61	1,160	720	75	.90
5.2.1	Wayne-Cayuga Complex	83	0	92	.61	120	0	95	.90
5.2.2	Oswego River	510	510	0	-	920	920	39	.27
5.2.3	Salmon Complex	66	0	93	.25	190	0	98	.76
	River Basin Group 5.2 Total	659	510	21	.08	1,230	920	53	.39
5.3.1	Black River	154	154	85	.25	410	410	96	.76
5.3.2	Perch Complex	33	0	100	.27	83	0	100	.66
5.3.3	Oswagatchie River	130	130	91	.27	290	290	96	.67
5.3.4	Grass-Raquette-St. Regis Comp.	110	100	42	.06	340	240	77	.32
	River Basin Group 5.3 Total	427	384	77	.17	1,123	940	90	.54

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE SUPERIOR

Hydrologic Area		Soluble Ortho Phosphorus 1975				Soluble Ortho Phosphorus 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area
1.1.1	Superior Slope Complex	60	0	100	.10	60	0	100	.10
1.1.2	Saint Louis River	120	0	78	.10	73	0	65	.05
1.1.3	Apostle Island Complex	140	48	100	.27	94	0	100	.18
1.1.4	Bad River	32	32	100	.12	11	0	100	.04
1.1.5	Montreal River Complex	6.2	5.6	48	.04	11	9.4	71	.01
	River Basin Group 1.1 Total	358	86	92	.14	249	9.4	88	.09
1.2.1	Porcupine Mountains Complex	16	0	38	.02	4.1	1.4	100	.01
1.2.2	Ontonagon River	19	19	99	.05	39	39	99	.11
1.2.3	Keweenaw Peninsula Complex	7.3	0	96	.02	7.0	0	100	.02
1.2.4	Sturgeon River	4.7	4.7	100	.03	8.2	8.2	100	.04
1.2.5	Huron Mountain Complex	24	2.8	36	.04	25	24	35	.04
1.2.6	Grand Marais Complex	21	7.9	100	.07	20	0	100	.07
1.2.7	Tahquamenon River	7.9	7.9	71	.03	4.1	4.1	44	.01
1.2.8	Sault Complex	6.6	4.4	100	.07	4.6	0	100	.07
	River Basin Group 1.2 Total	106	47	74	.04	112	77	83	.05

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

[3] Percent of total load from diffuse sources (nonpoin

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE MICHIGAN

Hydrologic Area		Soluble Ortho Phosphorus 1975				Soluble Ortho Phosphorus 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
2.1.1	Menominee Complex	6.4	2.8	100	.02	7.3	3.2	100	.03
2.1.2	Menominee River	37	37	61	.02	23	23	37	.01
2.1.3	Peshtigo River	34	34	100	.11	10	10	100	.03
2.1.4	Oconto River	15	15	96	.06	9.4	9.4	94	.03
2.1.5	Suamico Complex	21	7.5	100	.17	20	7.0	100	.16
2.1.6	Fox River	220	220	65	.08	110	110	41	.03
2.1.7	Green Bay Complex	140	80	88	.20	110	64	85	.15
	River Basin Group 2.1 Total	473	396	77	.08	293	227	66	.04
2.2.1	Chicago-Milwaukee Complex**	68	45	64	.08	99	24	74	.13
2.3.1	Saint Joseph River	96	96	0	-	160	160	32	.04
2.3.2	Black River (S.Haven) Complex	3.9	0	100	.04	4.2	0	100	.04
2.3.3	Kalamazoo River	95	95	23	.04	87	87	30	.05
2.3.4	Black River (Ottawa Co.) Comp.	14	0	61	.13	11	0	48	.08
2.3.5	Grand River	320	320	36	.08	340	340	46	.11
	River Basin Group 2.3 Total	529	511	28	.05	602	587	41	.06
2.4.1	Muskegon River	29	29	87	.04	38	37	67	.04
2.4.2	Sable Complex	24	0	95	.05	34	0	97	.07
2.4.3	Manistee River	19	19	8	.03	18	18	4	.01K*
2.4.4	Traverse Complex	23	4.7	83	.02	24	5.4	80	.03
2.4.5	Seul Choix-Groscap Complex	6.7	0	100	.05	5.9	0	99	.04
2.4.6	Manistique River	26	26	100	.07	20	20	100	.05
2.4.7	Bay De Noc Complex	2.5	0	100	.01	2.5	.7	100	.01
2.4.8	Escanaba River	24	24	100	.10	14	14	100	.06
	River Basin Group 2.4 Total	154	103	83	.04	157	95	77	.04

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

[*] K = less than

[**] Point sources to the Indiana Harbor Canal and Burns Ditch are considered direct; see page 87.

[3] Percent of total load from diffuse sources (nonpoint

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE HURON

Hydrologic Area		Soluble Ortho Phosphorus 1975				Soluble Ortho Phosphorus 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
3.1.1	Les Cheneaux Complex	36	8.5	100	.12	28	6.5	100	.09
3.1.2	Cheboygan River	13	12	100	.03	5.9	5.7	100	.01
3.1.3	Presque Isle Complex	8.6	2.2	100	.06	4.3	0	100	.03
3.1.4	Thunder Bay River	10	10	100	.03	2.7	2.7	100	.01
3.1.5	Au Sable and Alcona Complex	21	20	100	.04	13	12	100	.02
3.1.6	Rifle-Au Gres Complex	22	21	82	.06	14	6.8	73	.04
	River Basin Group 3.1 Total	111	74	96	.05	68	23	94	.03
3.2.1	Kawkawlin Complex	15	5.1	61	.09	15	0	61	.09
3.2.2	Saginaw River	260	260	7	.01	620	620	78	.30
3.2.3	Thumb Complex	70	26	99	.19	140	20	99	.38
	River Basin Group 3.2 Total	345	291	28	.05	775	640	82	.30

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE ERIE

Hydrologic Area		Soluble Ortho Phosphorus 1975				Soluble Ortho Phosphorus 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
4.1.1	Black River	26	26	87	.12				
4.1.2	St. Clair Complex	21	0	89	.12				
4.1.3	Clinton River	78	0	32	.12				
4.1.4	Rouge Complex	170	110	96	.86				
4.1.5	Huron River	40	40	0	-				
4.1.6	Swan Creek Complex	11	0	100	.12				
4.1.7	Raisin River	100	0	58	.18				
	River Basin Group 4.1 Total	446	176	67	.22				
4.2.1	Ottawa River	17	0	90	.24				
4.2.2	Maumee River	610	610	68	.24				
4.2.3	Toussaint-Portage Complex	77	52	75	.22				
4.2.4	Sandusky River	85	33	31	.07				
4.2.5	Huron-Vermilion Complex	55	44	59	.12				
	River Basin Group 4.2 Total	844	789	64	.20				
4.3.1	Black-Rocky Complex	320	140	72	1.0				
4.3.2	Cuyahoga River	180	180	32	.25				
4.3.3	Chagrin Complex	24	22	85	.26				
4.3.4	Grand River	57	0	99	.26				
4.3.5	Ashtabula-Conneaut Complex	27	0	89	.26				
	River Basin Group 4.3 Total	608	342	64	.47				
4.4.1	Erie-Chautauqua Complex	39	0	67	.16				
4.4.2	Cattaraugus Creek	13	13	54	.05				
4.4.3	Tonawanda Complex	120	0	12	.05				
	River Basin Group 4.4 Total	172	13	28	.07				

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoi

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE ONTARIO

Hydrologic Area		Soluble Ortho Phosphorus 1975				Soluble Ortho Phosphorus 1976			
Number	Name	Total Load[1]	Monitored Load[2]	% Diffuse[3]	Unit Area[4]	Total Load[1]	Monitored Load[2]	% Diffuse[3]	Unit Area[4]
5.1.1	Niagara-Orleans Complex	58	0	15	.03	68	0	25	.06
5.1.2	Genesee River	86	68	25	.03	110	89	40	.06
	River Basin Group 5.1 Total	144	68	21	.03	178	89	34	.06
5.2.1	Wayne-Cayuga Complex	7.2	0	56	.03	11	0	72	.06
5.2.2	Oswego River	120	120	0	-	200	200	0	-
5.2.3	Salmon Complex	49	0	97	.20	21	0	92	.08
	River Basin Group 5.2 Total	176	120	29	.03	232	200	12	.02
5.3.1	Black River	110	110	90	.20	50	50	83	.08
5.3.2	Perch Complex	7.5	0	100	.06	8.0	0	100	.06
5.3.3	Oswagatchie River	31	31	82	.06	33	33	83	.06
5.3.4	Grass-Raquette-St. Regis Comp.	54	45	42	.03	48	44	19	.01
	River Basin Group 5.3 Total	202	186	76	.08	139	127	62	.04

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

[3] Percent of total load from diffuse sources (nonpoint

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE SUPERIOR

Hydrologic Area		Suspended Solids 1975				Suspended Solids 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
1.1.1	Superior Slope Complex	43,000	35,000	100	72	61,000	3,800	100	100
1.1.2	Saint Louis River	70,000	70,000*	32*	24	27,000	27,000*	0*	-
1.1.3	Apostle Island Complex	470,000	160,000	100	900	220,000	74,000	100	420
1.1.4	Bad River	100,000	100,000	100	390	150,000	150,000	100	590
1.1.5	Montreal River Complex	5,900	4,700	99	75	3,400	2,700	99	43
	River Basin Group 1.1 Total	688,900	369,700	93	270	461,400	257,500	94	180
1.2.1	Porcupine Mountains Complex	36,000	17,000	66	88	34,000	4,700	35	50
1.2.2	Ontonagon River	580,000	580,000	100	1600**	150,000	150,000	100	410**
1.2.3	Keweenaw Peninsula Complex	17,000	0	100	41	12,000	0	100	35
1.2.4	Sturgeon River	20,000	20,000	100	110	26,000	26,000	100	140
1.2.5	Huron Mountain Complex	12,000	5,100	100	48	8,700	930	100	35
1.2.6	Grand Marais Complex	9,900	3,800	100	32	11,000	0	100	35
1.2.7	Tahquamenon River	7,400	7,400	100	34	7,900	7,900	100	36
1.2.8	Sault Complex	9,300	8,200	100	130	9,800	0	100	140
	River Basin Group 1.2 Total	691,600	641,500	98	330	259,400	189,530	91	120

*Over 46,000 MT/yr from point sources

**Drains a large clay area

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE MICHIGAN

Hydrologic Area		Suspended Solids 1975				Suspended Solids 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
2.1.1	Menominee Complex	5,700	2,500	100	21	17,000	7,500	100	63
2.1.2	Menominee River	13,000	13,000	68	11	16,000	16,000	91	14
2.1.3	Peshtigo River	4,000	4,000	100	13	6,000	6,000	100	20
2.1.4	Oconto River	7,300	7,300	83	24	10,000	10,000	88	36
2.1.5	Suamico Complex	26,000	9,300	100	210	52,000	18,000	100	42
2.1.6	Fox River	60,000	60,000	65	23	100,000	100,000	87	52
2.1.7	Green Bay Complex	78,000	41,000	100	120	24,000	13,000	100	39
	River Basin Group 2.1 Total	194,000	137,100	88	38	225,000	170,500	93	38
2.2.1	Chicago-Milwaukee Complex *	100,000	50,000	96	180	67,000	32,000	94	110
2.3.1	Saint Joseph River	82,000	82,000	97	66	110,000	110,000	98	91
2.3.2	Black River (S.Haven) Complex	3,600	2,800	100	39	4,900	0	100	53
2.3.3	Kalamazoo River	27,000	27,000	82	43	37,000	37,000	82	59
2.3.4	Black River (Ottawa Co.) Comp.	2,700	0	93	39	3,700	0	95	53
2.3.5	Grand River	76,000	76,000	94	49	150,000	150,000	97	98
	River Basin Group 2.3 Total	191,300	187,800	94	54	305,600	297,000	96	87
2.4.1	Muskegon River	41,000	40,000	100	57	63,000	61,000	100	89
2.4.2	Sable Complex	16,000	0	99	36	14,000	0	99	31
2.4.3	Manistee River	20,000	20,000	91	36	18,000	16,000	90	31
2.4.4	Traverse Complex	21,000	4,700	99	32	19,000	4,200	99	28
2.4.5	Seul Choix-Groscap Complex	4,800	0	100	33	5,900	0	100	41
2.4.6	Manistique River	12,000	12,000	100	33	16,000	16,000	100	41
2.4.7	Bay De Noc Complex	4,900	0	100	16	4,900	1,400	100	16
2.4.8	Escanaba River	4,100	4,100	96	16	4,000	4,000	96	16
	River Basin Group 2.4 Total	123,800	80,800	98	36	144,800	102,600	98	42

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

* Point sources to the Indiana Harbor Canal and Burns Ditch are considered direct; see page 87.

[3] Percent of total load from diffuse sources (nonpoint)

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE HURON

Hydrologic Area		Suspended Solids 1975				Suspended Solids 1976			
Number	Name	Total Load[1]	Monitored Load[2]	% Diffuse[3]	Unit Area[4]	Total Load[1]	Monitored Load[2]	% Diffuse[3]	Unit Area[4]
3.1.1	Les Cheneaux Complex	180,000	43,000	100	600	57,000	13,000	100	190
3.1.2	Cheboygan River	7,200	6,900	100	17	8,800	8,400	100	21
3.1.3	Presque Isle Complex	8,700	2,200	100	60	11,000	0	100	74
3.1.4	Thunder Bay River	6,000	6,000	100	18	6,900	6,900	100	21
3.1.5	Au Sable and Alcona Complex	12,000	11,000	100	21	16,000	15,000	100	28
3.1.6	Rifle-Au Gres Complex	30,000	27,000	100	103	22,000	13,000	100	77
	River Basin Group 3.1 Total	243,900	96,100	100	120	121,700	56,300	100	60
3.2.1	Kawkawlin Complex	3,400	2,200	98	33	3,400	0	98	33
3.2.2	Saginaw River	120,000	120,000	91	68	360,000	360,000	97	220
3.2.3	Thumb Complex	100,000	38,000	100	280	280,000	8,800	100	850
	River Basin Group 3.2 Total	223,400	160,200	95	100	643,400	368,800	98	300

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE ERIE

Hydrologic Area		Suspended Solids 1975				Suspended Solids 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
4.1.1	Black River	16,000	16,000	100	86				
4.1.2	St. Clair Complex	13,000	0	100	86				
4.1.3	Clinton River	18,000	0	96	86				
4.1.4	Rouge Complex	23,000	17,000	26	86				
4.1.5	Huron River	23,000	23,000	82	92				
4.1.6	Swan Creek Complex	7,900	0	100	92				
4.1.7	Raisin River	150,000	0	99	460				
	River Basin Group 4.1 Total	250,900	56,000	91	177				
4.2.1	Ottawa River	54,000	0	100	840				
4.2.2	Maumee River	1,400,000	1,400,000	100	840				
4.2.3	Toussaint-Portage Complex	110,000	66,000	100	420				
4.2.4	Sandusky River	340,000	320,000	100	860				
4.2.5	Huron-Vermilion Complex	280,000	180,000	100	1,000				
	River Basin Group 4.2 Total	2,184,000	1,966,000	100	817				
4.3.1	Black-Rocky Complex	460,000	240,000	100	2,000				
4.3.2	Cuyahoga River	630,000	630,000	99	2,700				
4.3.3	Chagrin Complex	270,000	250,000	100	3,600				
4.3.4	Grand River	570,000	0	100	2,700				
4.3.5	Ashtabula-Conneaut Complex	240,000	0	100	2,700				
	River Basin Group 4.3 Total	2,170,000	1,120,000	100	2,600				
4.4.1	Erie-Chautauqua Complex	450,000	0	100	2,700				
4.4.2	Cattaraugus Creek	680,000	680,000	100	4,800				
4.4.3	Tonawanda Complex	320,000	0	98	1,100				
	River Basin Group 4.4 Total	1,450,000	680,000	100	2,300				

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoi

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE ONTARIO

Hydrologic Area		Suspended Solids 1975				Suspended Solids 1976			
Number	Name	Total Load[1]	Monitored Load[2]	% Dif-fuse[3]	Unit Area[4]	Total Load[1]	Monitored Load[2]	% Dif-fuse[3]	Unit Area[4]
5.1.1	Niagara-Orleans Complex	75,000	0	96	270	75,000	0	96	270
5.1.2	Genesee River	590,000	540,000	99	840	1,100,000	1,100,000	100	1,600
	River Basin Group 5.1 Total	665,000	540,000	99	680	1,175,000	1,100,000	99	1,200
5.2.1	Wayne-Cayuga Complex	45,000	0	76	270	40,000	0	86	270
5.2.2	Oswego River	100,000	100,000	76	56	141,000	141,000	77	82
5.2.3	Salmon Complex	49,000	0	100	200	52,000	0	80	170
	River Basin Group 5.2 Total	194,000	100,000	78	93	233,000	141,000	79	110
5.3.1	Black River	73,000	73,000	94	130	41,000	41,000	88	70
5.3.2	Perch Complex	53,000	0	100	420	53,000	0	100	420
5.3.3	Oswagatchie River	44,000	44,000	100	100	20,000	20,000	100	45
5.3.4	Grass-Raquette-St. Regis Comp.	25,000	22,000	98	30	23,000	14,000	98	28
	River Basin Group 5.3 Total	195,000	139,000	98	100	137,000	75,000	96	69

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

[3] Percent of total load from diffuse sources (nonpoint)

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE SUPERIOR

Hydrologic Area		Total Nitrogen 1975				Total Nitrogen 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
1.1.1	Superior Slope Complex	3,100	2,500	100	5.2	2,600	0	100	4.4
1.1.2	Saint Louis River	2,500	2,500	91	2.4	1,200	1,200	81	1.0
1.1.3	Apostle Island Complex	1,400	490	100	2.8	1,300	430	100	2.4
1.1.4	Bad River	640	640	100	2.5	650	650	100	2.5
1.1.5	Montreal River Complex	400	320	89	4.5	280	230	85	3.0
	River Basin Group 1.1 Total	8,040	6,450	97	3.3	6,030	2,510	95	2.4
1.2.1	Porcupine Mountains Complex	700	420	82	2.1	580	150	76	1.6
1.2.2	Ontonagon River	1,100	1,100	100	3.1	740	740	100	2.1
1.2.3	Keweenaw Peninsula Complex	940	0	100	2.7	1,000	0	100	2.9
1.2.4	Sturgeon River	490	490	100	2.6	360	360	100	1.9
1.2.5	Huron Mountain Complex	810	420	83	2.7	880	210	84	2.9
1.2.6	Grand Marais Complex	700	270	100	2.2	640	0	100	2.0
1.2.7	Tahquamenon River	500	500	96	2.2	470	470	96	2.0
1.2.8	Sault Complex	250	180	100	2.2	200	0	100	2.9
	River Basin Group 1.2 Total	5,490	3,380	95	2.5	4,870	1,930	94	2.2

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE MICHIGAN

Hydrologic Area		Total Nitrogen 1975				Total Nitrogen 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area
2.1.1	Menominee Complex	450	200	100	1.6	560	250	100	2.1
2.1.2	Menominee River	1,600	1,600	94	1.5	1,600	1,600	94	1.4
2.1.3	Peshtigo River	600	600	100	2.0	840	840	100	2.8
2.1.4	Oconto River	1,400	1,400	100	5.5	1,700	1,700	100	6.7
2.1.5	Suamico Complex	450	160	100	3.6	410	140	100	3.2
2.1.6	Fox River	4,700	4,700	63	1.7	4,600	4,600	65	1.8
2.1.7	Green Bay Complex	2,400	1,300	94	3.7	3,400	1,800	95	5.2
	River Basin Group 2.1 Total	11,600	9,960	83	2.2	13,110	10.930	86	2.6
2.2.1	Chicago-Milwaukee Complex*	4,000	2,000	88	6.2	4,200	2,100	88	6.5
2.3.1	Saint Joseph River	7,700	7,700	70	4.5	10,000	10,000	77	6.4
2.3.2	Black River (S.Haven) Complex	940	750	100	10	940	0	100	10
2.3.3	Kalamazoo River	3,800	3,800	57	4.2	3,600	3,600	52	3.6
2.3.4	Black River (Ottawa Co.) Comp.	710	0	45	4.8	730	0	46	5.2
2.3.5	Grand River	11,000	11,000	73	5.4	13,000	13,000	77	6.7
	River Basin Group 2.3 Total	24,150	23,250	70	5.0	28,270	26,600	74	5.2
2.4.1	Muskegon River	1,600	1,600	96	2.2	2,200	2,100	96	3.0
2.4.2	Sable Complex	1,000	0	96	2.2	1,400	0	97	3.0
2.4.3	Manistee River	1,200	1,200	95	2.3	1,300	1,100	95	2.3
2.4.4	Traverse Complex	1,100	1,100	92	1.5	1,400	360	94	2.0
2.4.5	Seul Choix-Groscap Complex	420	0	100	2.9	430	0	100	3.0
2.4.6	Manistique River	1,100	1,100	100	2.9	1,100	1,100	100	3.0
2.4.7	Bay De Noc Complex	690	0	100	2.3	590	110	100	2.2
2.4.8	Escanaba River	550	550	100	2.3	530	530	100	2.2
	River Basin Group 2.4 Total	7,660	4,730	97	2.2	8,950	5,300	97	2.5

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

*Point sources to the Indiana Harbor Canal and Burns Ditch are considered direct; see page 87.

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE HURON

Hydrologic Area		Total Nitrogen 1975				Total Nitrogen 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area
3.1.1	Les Cheneaux Complex	1,100	250	100	3.6	440	100	100	1.5
3.1.2	Cheboygan River	590	560	100	1.4	520	500	100	1.3
3.1.3	Presque Isle Complex	360	92	100	2.5	290	0	100	2.0
3.1.4	Thunder Bay River	530	530	100	1.6	380	380	100	1.2
3.1.5	Au Sable and Alcona Complex	750	690	100	1.3	770	700	100	1.3
3.1.6	Rifle-Au Gres Complex	1,000	970	98	3.6	1,000	580	99	3.5
	River Basin Group 3.1 Total	4,330	3,092	99	2.1	3,400	2,260	100	1.7
3.2.1	Kawkawlin Complex	1,100	580	96	10	970	0	95	9.2
3.2.2	Saginaw River	18,000	18,000	81	9.3	17,000	17,000	79	8.1
3.2.3	Thumb Complex	5,800	2,100	100	16	6,100	870	100	17
	River Basin Group 3.2 Total	24,800	20,680	86	10	24,070	17,870	85	9.7

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

[3] Percent of total load from diffuse sources (nonpoint)

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE ERIE

Hydrologic Area		Total Nitrogen 1975				Total Nitrogen 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
4.1.1	Black River	1,100	1,100	98	5.9				
4.1.2	St. Clair Complex	800	0	98	5.9				
4.1.3	Clinton River	2,500	0	47	5.9				
4.1.4	Rouge Complex	620	580	17	.57				
4.1.5	Huron River	1,200	1,200	36	2.0				
4.1.6	Swan Creek Complex	170	0	100	2.0				
4.1.7	Raisin River	5,300	0	88	14				
	River Basin Group 4.1 Total	11,770	2,880	72	6.3				
4.2.1	Ottawa River	1,700	0	99	27				
4.2.2	Maumee River	48,000	48,000	96	27				
4.2.3	Toussaint-Portage Complex	5,300	3,200	95	19				
4.2.4	Sandusky River	7,300	6,900	96	18				
4.2.5	Huron-Vermilion Complex	3,900	2,700	96	14				
	River Basin Group 4.2 Total	66,200	60,800	96	23				
4.3.1	Black-Rocky Complex	16,000	8,300	97	67				
4.3.2	Cuyahoga River	4,800	4,800	50	10				
4.3.3	Chagrin Complex	1,100	970	98	14				
4.3.4	Grand River	2,900	0	100	14				
4.3.5	Ashtabula-Conneaut Complex	1,200	0	98	14				
	River Basin Group 4.3 Total	26,000	14,070	88	27				
4.4.1	Erie-Chautauqua Complex	2,200	0	97	13				
4.4.2	Cattaraugus Creek	1,800	1,800	98	12				
4.4.3	Tonawanda Complex	3,700	0	94	12				
	River Basin Group 4.4 Total	7,700	1,800	96	12				

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoint

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE ONTARIO

Hydrologic Area		Total Nitrogen 1975				Total Nitrogen 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area
5.1.1	Niagara-Orleans Complex	2,800	0	66	6.8	3,600	0	74	9.9
5.1.2	Genesee River	5,300	4,800	88	6.8	7,500	6,900	91	9.9
	River Basin Group 5.1 Total	8,100	4,800	80	6.8	11,100	6,900	86	9.9
5.2.1	Wayne-Cayuga Complex	880	0	97	6.8	1,300	0	98	9.9
5.2.2	Oswego River	8,400	8,400	23	1.5	12,000	12,000	47	4.4
5.2.3	Salmon Complex	680	0	98	2.8	1,300	0	99	5.2
	River Basin Group 5.2 Total	9,960	8,400	35	2.0	14,600	12,000	56	4.9
5.3.1	Black River	2,200	2,200	94	4.0	3,200	3,200	98	6.1
5.3.2	Perch Complex	510	0	100	4.0	760	0	100	6.1
5.3.3	Oswagatchie River	1,400	1,400	97	3.2	1,900	1,900	98	4.2
5.3.4	Grass-Raquette-St. Regis Comp.	2,800	2,400	94	3.2	3,700	2,300	94	4.3
	River Basin Group 5.3 Total	6,910	6,000	95	3.5	9,560	7,400	96	4.9

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

[3] Percent of total load from diffuse sources (nonpoin

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE SUPERIOR

Hydrologic Area		Nitrate (Nitrite) N 1975				Nitrate (Nitrite) N 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area
1.1.1	Superior Slope Complex	820	670	100	1.4	600	37	100	1.0
1.1.2	Saint Louis River	880	880	90	.83	230	230	61	.15
1.1.3	Apostle Island Complex	210	71	100	.40	210	72	100	.41
1.1.4	Bad River	120	120	100	.47	100	100	100	.40
1.1.5	Montreal River Complex	84	70	80	.86	64	55	74	.61
	River Basin Group 1.1 Total	2,114	1,811	95	.84	1,204	494	91	.46
1.2.1	Porcupine Mountains Complex	160	81	62	.34	130	22	50	.24
1.2.2	Ontonagon River	140	140	100	.39	140	140	100	.38
1.2.3	Keweenaw Peninsula Complex	140	0	99	.39	140	0	99	.39
1.2.4	Sturgeon River	98	98	100	.54	64	64	100	.35
1.2.5	Huron Mountain Complex	120	64	81	.39	110	25	78	.39
1.2.6	Grand Marais Complex	220	84	100	.71	220	0	100	.71
1.2.7	Tahquamenon River	74	74	90	.30	85	85	91	.37
1.2.8	Sault Complex	52	29	100	.71	52	0	100	.75
	River Basin Group 1.2 Total	1,004	570	91	.45	941	336	90	.42

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE MICHIGAN

Hydrologic Area		Nitrate (Nitrite) N 1975				Nitrate (Nitrite) N 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
2.1.1	Menominee Complex	71	31	100	.26	64	28	100	.23
2.1.2	Menominee River	450	450	91	.39	410	410	90	.35
2.1.3	Peshtigo River	320	320	100	1.1	230	230	100	.75
2.1.4	Oconto River	190	190	99	.72	170	170	99	.66
2.1.5	Suamico Complex	170	59	100	1.3	68	24	100	.54
2.1.6	Fox River	940	940	29	.16	370	310	0	-
2.1.7	Green Bay Complex	1,100	580	94	1.6	1,800	990	97	2.8
	River Basin Group 2.1 Total	3,241	2,570	76	.56	3,112	2,162	86	.61
2.2.1	Chicago-Milwaukee Complex *	2,300	1,100	90	3.6	2,700	1,300	92	4.4
2.3.1	Saint Joseph River	4,300	4,300	79	2.8	6,000	6,000	85	4.2
2.3.2	Black River (S.Haven) Complex	310	250	100	3.4	220	0	100	2.4
2.3.3	Kalamazoo River	1,800	1,800	73	2.6	1,800	1,800	71	2.4
2.3.4	Black River (Ottawa Co.) Comp.	240	0	73	2.6	220	0	72	2.4
2.3.5	Grand River	5,500	5,500	78	2.9	5,700	5,700	78	3.0
	River Basin Group 2.3 Total	12,150	11,850	78	2.8	13,940	13,500	80	3.3
2.4.1	Muskegon River	580	470	94	.64	790	770	96	1.1
2.4.2	Sable Complex	300	0	98	.64	490	0	99	1.1
2.4.3	Manistee River	450	450	96	.84	490	440	97	.91
2.4.4	Traverse Complex	460	110	95	.65	580	150	94	.83
2.4.5	Seul Choix-Groscap Complex	99	0	100	.69	95	0	100	.67
2.4.6	Manistique River	260	260	100	.69	250	250	100	.67
2.4.7	Bay De Noc Complex	170	0	100	.57	130	25	100	.50
2.4.8	Escanaba River	140	140	100	.57	120	120	100	.50
	River Basin Group 2.4 Total	2,359	1,430	97	.67	2,945	1,755	93	.81

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

* Point sources to the Indiana Harbor Canal and Burns Ditch are considered direct; see page 87.

[3] Percent of total load from diffuse sources (nonpoint)

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE HURON

Hydrologic Area		Nitrate (Nitrite) N 1975				Nitrate (Nitrite) N 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area
3.1.1	Les Cheneaux Complex	110	27	100	.38	63	15	100	.21
3.1.2	Cheboygan River	110	100	100	.26	120	120	100	.29
3.1.3	Presque Isle Complex	99	25	100	.68	99	0	100	.68
3.1.4	Thunder Bay River	71	71	100	.22	49	49	100	.15
3.1.5	Au Sable and Alcona Complex	140	130	100	.24	150	140	100	.27
3.1.6	Rifle-Au Gres Complex	430	400	98	1.5	470	270	98	1.6
	River Basin Group 3.1 Total	960	753	99	.46	951	594	99	.46
3.2.1	Kawkawlin Complex	490	320	96	4.7	460	0	96	4.4
3.2.2	Saginaw River	12,000	12,000	92	6.8	8,900	8,900	88	4.9
3.2.3	Thumb Complex	4,800	1,800	100	13	4,700	660	100	13
	River Basin Group 3.2 Total	17,290	14,120	94	7.8	14,060	9,560	92	6.2

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE ERIE

Hydrologic Area		Nitrate (Nitrite) 1975				Nitrate (Nitrite) 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif- fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif- fuse	Unit[4] Area
4.1.1	Black River	710	710	98	3.9				
4.1.2	St. Clair Complex	580	0	94	3.9				
4.1.3	Clinton River	1,300	0	60	3.9				
4.1.4	Rouge Complex	290	180	98	1.5				
4.1.5	Huron River	450	450	33	.68				
4.1.6	Swan Creek Complex	58	0	100	.68				
4.1.7	Raisin River	4,200	0	94	12				
	River Basin Group 4.1 Total	7,588	1,340	85	4.8				
4.2.1	Ottawa River	1,500	0	100	23				
4.2.2	Maumee River	41,000	41,000	98	23				
4.2.3	Toussaint-Portage Complex	4,800	2,900	98	18				
4.2.4	Sandusky River	6,500	6,200	98	16				
4.2.5	Huron-Vermilion Complex	2,900	1,900	98	10				
	River Basin Group 4.2 Total	56,700	52,000	98	20				
4.3.1	Black-Rocky Complex	12,000	6,200	98	51				
4.3.2	Cuyahoga River	2,600	2,600	64	7.2				
4.3.3	Chagrin Complex	570	510	98	7.3				
4.3.4	Grand River	1,500	0	100	7.3				
4.3.5	Ashtabula-Conneaut Complex	660	0	98	7.3				
	River Basin Group 4.3 Total	17,330	9,310	93	19				
4.4.1	Erie-Chautauqua Complex	1,200	0	98	7.0				
4.4.2	Cattaraugus Creek	1,000	1,000	98	7.0				
4.4.3	Tonawanda Complex	2,100	0	96	7.0				
	River Basin Group 4.4 Total	4,300	1,000	97	7.0				

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

[3] Percent of total load from diffuse sources (nonpo

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE ONTARIO

Hydrologic Area		Nitrate (Nitrite) N 1975				Nitrate (Nitrite) N 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
5.1.1	Niagara-Orleans Complex	1,200	0	76	3.4	1,800	0	84	5.6
5.1.2	Genesee River	2,600	2,400	90	3.4	4,100	3,800	94	5.6
	River Basin Group 5.1 Total	3,800	2,400	86	3.4	5,900	3,800	91	5.6
5.2.1	Wayne-Cayuga Complex	440	0	98	3.4	710	0	99	5.6
5.2.2	Oswego River	3,500	3,500	49	1.3	5,900	5,900	70	3.2
5.2.3	Salmon Complex	700	0	99	2.8	810	0	99	3.3
	River Basin Group 5.2 Total	4,640	3,500	61	1.7	7,420	5,900	76	3.4
5.3.1	Black River	2,300	2,300	98	4.4	1,800	1,800	98	3.5
5.3.2	Perch Complex	550	0	100	4.4	440	0	100	3.5
5.3.3	Oswagatchie River	610	610	97	1.4	460	460	96	1.0
5.3.4	Grass-Raquette-St. Regis Comp.	1,600	1,400	94	1.8	1,900	1,200	96	2.2
	River Basin Group 5.3 Total	5,060	4,310	97	2.6	4,600	3,460	97	2.4

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

[3] Percent of total load from diffuse sources (nonpoint)

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE SUPERIOR

Hydrologic Area		Ammonia N 1975				Ammonia N 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
1.1.1	Superior Slope Complex	240	190	100	.40	140	0	100	.24
1.1.2	Saint Louis River	280	280	62	.19	120	120	8	.01
1.1.3	Apostle Island Complex	230	78	100	.44	130	44	100	.25
1.1.4	Bad River	85	85	100	.33	64	64	100	.25
1.1.5	Montreal River Complex	42	38	58	.28	13	13	0	-
	River Basin Group 1.1 Total	877	671	86	.31	467	241	74	.14
1.2.1	Porcupine Mountains Complex	31	24	76	.08	32	2.9	26	.03
1.2.2	Ontonagon River	150	150	100	.43	74	74	98	.21
1.2.3	Keweenaw Peninsula Complex	154	0	99	.43	74	0	98	.21
1.2.4	Sturgeon River	29	29	100	.16	12	12	100	.07
1.2.5	Huron Mountain Complex	250	140	74	.73	180	98	65	.36
1.2.6	Grand Marais Complex	37	14	100	.12	28	0	100	.09
1.2.7	Tahquamenon River	19	19	54	.05	15	15	43	.03
1.2.8	Sault Complex	18	14	100	.12	13	0	100	.19
	River Basin Group 1.2 Total	688	390	88	.30	428	202	77	.16

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

[3] Percent of total load from diffuse sources (nonpoint

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE MICHIGAN

Hydrologic Area		Ammonia N 1975				Ammonia N 1975			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
2.1.1	Menominee Complex	49	22	100	.18	52	23	100	.19
2.1.2	Menominee River	240	240	81	.18	43	43	0	0
2.1.3	Peshtigo River	80	80	100	.27	73	73	100	.24
2.1.4	Oconto River	1,100	1,100	100	4.2	750	750	100	2.8
2.1.5	Suamico Complex	95	33	100	.76	72	25	100	.58
2.1.6	Fox River	740	740	0	0	710	710	0	0
2.1.7	Green Bay Complex	280	180	75	.34	250	160	71	.29
	River Basin Group 2.1 Total	2,584	2,395	66	.39	1,950	1,784	58	.26
2.2.1	Chicago-Milwaukee Complex *	630	260	65	.73	240	43	9	.04
2.3.1	Saint Joseph River	390	390	0	-	580	580	0	0
2.3.2	Black River (S.Haven) Complex	47	37	100	.51	47	0	100	.51
2.3.3	Kalamazoo River	250	250	0	0	180	180	0	0
2.3.4	Black River (Ottawa Co.) Comp.	280	0	12	.51	160	0	21	.51
2.3.5	Grand River	980	980	0	.18	1,400	1,400	0	0
	River Basin Group 2.3 Total	1,947	1,657	17	.09	2,367	2,160	3	.02
2.4.1	Muskegon River	50	49	42	.03	86	85	53	.06
2.4.2	Sable Complex	96	0	75	.16	53	0	55	.06
2.4.3	Manistee River	150	150	98	.29	82	74	97	.15
2.4.4	Traverse Complex	130	50	71	.14	220	70	82	.27
2.4.5	Seul Choix-Groscap Complex	34	0	100	.24	25	0	100	.17
2.4.6	Manistique River	90	90	100	.24	65	65	100	.17
2.4.7	Bay De Noc Complex	140	0	100	.47	36	3.6	100	.15
2.4.8	Escanaba River	110	110	100	.47	36	36	100	.15
	River Basin Group 2.4 Total	800	449	88	.21	603	334	82	.14

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

*Point sources to the Indiana Harbor Canal and Burns Ditch are considered direct; see page 87.

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE HURON

Hydrologic Area		Ammonia N 1975				Ammonia N 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
3.1.1	Les Cheneaux Complex	99	23	100	.32	69	0	100	.23
3.1.2	Cheboygan River	32	30	100	.08	19	18	100	.04
3.1.3	Presque Isle Complex	16	4.2	100	.11	12	0	100	.07
3.1.4	Thunder Bay River	39	39	100	.12	12	12	100	.04
3.1.5	Au Sable and Alcona Complex	27	24	100	.05	29	26	100	.05
3.1.6	Rifle-Au Gres Complex	48	45	75	.13	35	17	66	.08
	River Basin Group 3.1 Total	261	165	95	.12	176	73	93	.08
3.2.1	Kawkawlin Complex	32	21	93	.33	44	0	51	.22
3.2.2	Saginaw River	2,000	2,000	19	.23	1,400	1,400	9	.08
3.2.3	Thumb Complex	130	50	97	.34	120	44	97	.24
	River Basin Group 3.2 Total	2,162	2,071	24	.25	1,564	1,444	17	.13

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE ERIE

Hydrologic Area		Ammonia 1975				Ammonia 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
4.1.1	Black River	47	47	73	.19				
4.1.2	St. Clair Complex	37	0	75	.19				
4.1.3	Clinton River	650	0	58	.19				
4.1.4	Rouge Complex	230	230	0	-				
4.1.5	Huron River	270	270	0	-				
4.1.6	Swan Creek Complex	12	0	100	.14				
4.1.7	Raisin River	340	0	14	.14				
	River Basin Group 4.1 Total	1,586	547	10	.12				
4.2.1	Ottawa River	12	0	47	.09				
4.2.2	Maumee River	1,100	1,100	13	.09				
4.2.3	Toussaint-Portage Complex	83	78	0	-				
4.2.4	Sandusky River	260	250	52	.34				
4.2.5	Huron-Vermilion Complex	110	89	47	.19				
	River Basin Group 4.2 Total	1,565	1,517	22	.13				
4.3.1	Black-Rocky Complex	1,200	600	78	4.0				
4.3.2	Cuyahoga River	620	620	0	-				
4.3.3	Chagrin Complex	95	87	88	1.1				
4.3.4	Grand River	230	0	99	1.1				
4.3.5	Ashtabula-Conneaut Complex	110	0	90	1.1				
	River Basin Group 4.3 Total	2,255	1,307	60	1.6				
4.4.1	Erie-Chautauqua Complex	220	0	84	1.1				
4.4.2	Cattaraugus Creek	180	180	87	1.1				
4.4.3	Tonawanda Complex	430	0	76	1.1				
	River Basin Group 4.4 Total	830	180	80	1.1				

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

[3] Percent of total load from diffuse sources (nonpoint

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE ONTARIO

Hydrologic Area		Ammonia N 1975				Ammonia N 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
5.1.1	Niagara-Orleans Complex	660	0	17	.42	730	0	25	.68
5.1.2	Genesee River	590	500	49	.42	780	670	61	.68
	River Basin Group 5.1 Total	1,250	500	32	.42	1,510	670	43	.68
5.2.1	Wayne-Cayuga Complex	64	0	83	.42	97	0	89	.68
5.2.2	Oswego River	1,200	1,200	0	-	1,800	1,800	0	-
5.2.3	Salmon Complex	130	0	95	.52	29	0	78	.09
	River Basin Group 5.2 Total	1,394	1,200	13	.11	1,926	1,800	6	.06
5.3.1	Black River	330	330	83	.52	86	86	57	.09
5.3.2	Perch Complex	65	0	100	.52	12	0	100	.09
5.3.3	Oswagatchie River	140	140	88	.30	100	100	79	.18
5.3.4	Grass-Raquette-St. Regis Comp.	240	180	58	.07	210	170	52	.13
	River Basin Group 5.3 Total	775	650	77	.32	408	356	61	.13

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

[3] Percent of total load from diffuse sources (nonpoint)

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE SUPERIOR

Hydrologic Area		Chloride 1975				Chloride 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area
1.1.1	Superior Slope Complex	8,800	7,100	100	15	5,900	360	100	10
1.1.2	Saint Louis River	25,000	25,000	93	25	14,000	14,000	85	14
1.1.3	Apostle Island Complex	2,800	940	100	5.4	2,000	700	100	4.0
1.1.4	Bad River	2,400	2,400	100	9.1	1,600	1,600	100	6.1
1.1.5	Montreal River Complex	1,400	1,200	72	13	1,300	1,100	69	11
	River Basin Group 1.1 Total	40,400	36,640	94	16	25,200	17,760	90	9.5
1.2.1	Porcupine Mountains Complex	36,000*	2,600	9	12	36,000*	820	8	11
1.2.2	Ontonagon River	3,700	3,700	99	10	3,400	3,400	99	10
1.2.3	Keweenaw Peninsula Complex	2,400	0	98	6.7	6,200	0	100	18
1.2.4	Sturgeon River	2,000	2,000	100	11	1,300	1,300	100	7.1
1.2.5	Huron Mountain Complex	3,000	2,000	56	6.7	5,700	1,800	77	18
1.2.6	Grand Marais Complex	2,600	1,000	100	8.4	1,700	0	100	5.4
1.2.7	Tahquamenon River	1,700	1,700	88	6.8	1,600	1,600	89	6.6
1.2.8	Sault Complex	880	610	100	8.4	560	0	100	8.1
	River Basin Group 1.2 Total	52,280	13,610	34	9.0	56,400	8,920	39	11

*33,000 Metric Tons/Yr from point sources on the Mineral River

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

[3] Percent of total load from diffuse sources (nonpoi

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE MICHIGAN

Hydrologic Area		Chloride 1975				Chloride 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area
2.1.1	Menominee Complex	2,200	980	100	8.2	1,700	750	100	6.2
2.1.2	Menominee River	3,200	3,200	72	2.2	4,000	4,000	77	2.9
2.1.3	Peshtigo River	2,100	2,100	100	7.1	1,900	1,900	100	6.5
2.1.4	Oconto River	6,200	6,200	99	24	6,300	6,300	99	25
2.1.5	Suamico Complex	1,600	580	100	13	3,800	1,300	100	30
2.1.6	Fox River	51,000	51,000	72	21	56,000	56,000	76	25
2.1.7	Green Bay Complex	23,000	13,000	92	35	32,000	18,000	96	50
	River Basin Group 2.1 Total	89,300	77,060	81	17	105,700	88,250	85	21
2.2.1	Chicago-Milwaukee Complex*	59,000	29,000	93	97	72,000	36,000	94	120
2.3.1	Saint Joseph River	78,000	78,000	72	46	87,000	87,000	75	54
2.3.2	Black River (S.Haven) Complex	4,300	0	100	46	5,000	0	100	54
2.3.3	Kalamazoo River	60,000	60,000	79	91	57,000	57,000	76	84
2.3.4	Black River (Ottawa Co.) Comp.	4,200	0	73	46	4,700	0	76	54
2.3.5	Grand River	170,000	170,000	83	97	150,000	150,000	81	83
	River Basin Group 2.3 Total	316,500	308,000	80	76	303,700	294,000	79	60
2.4.1	Muskegon River	48,000	46,000	99	67	48,000	46,000	98	66
2.4.2	Sable Complex	63,000	0	48	67	66,000	0	46	66
2.4.3	Manistee River	160,000	160,000	5	15	87,000	86,000	11	18
2.4.4	Traverse Complex	11,000	2,800	93	15	13,000	3,300	94	18
2.4.5	Seul Choix-Groscap Complex	1,600	0	100	11	1,500	0	100	10
2.4.6	Manistique River	4,100	4,100	100	11	3,900	3,900	100	10
2.4.7	Bay De Noc Complex	13,000	0	100	44	5,700	1,100	100	21
2.4.8	Escanaba River	10,000	10,000	100	44	5,100	5,100	100	21
	River Basin Group 2.4 Total	310,700	222,900	40	37	230,200	145,400	50	34

[1] Total load from Hydrologic Area (metric tons/yr)

[2] Portion of total load that was monitored (metric tons/yr)

[3] Percent of total load from diffuse sources (nonpoint)

[4] Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

* Point sources to the Indiana Harbor Canal and Burns Ditch are considered direct; see page 87.

Table 7

HYDROLOGIC AREA LOADS

LAKE HURON

Hydrologic Area		Chloride 1975				Chloride 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Diffuse	Unit[4] Area
3.1.1	Les Cheneaux Complex	4,700	1,100	100	16	2,000	460	100	6.6
3.1.2	Cheboygan River	6,500	6,200	100	16	6,700	6,500	100	16
3.1.3	Presque Isle Complex	1,100	490	100	7.8	1,500	670	100	10
3.1.4	Thunder Bay River	5,500	5,500	100	17	4,300	4,300	100	13
3.1.5	Au Sable and Alcona Complex	11,000	9,900	100	19	11,000	10,000	100	19
3.1.6	Rifle-Au Gres Complex	14,000	13,000	98	48	17,000	9,800	99	59
	River Basin Group 3.1 Total	42,800	36,190	99	21	42,500	31,730	99	22
3.2.1	Kawkawlin Complex	7,600	5,100	94	72	7,600	0	94	72
3.2.2	Saginaw River	300,000	300,000	58	100	320,000	320,000	61	120
3.2.3	Thumb Complex	27,000	10,000	100	74	52,000	7,300	100	140
	River Basin Group 3.2 Total	334,600	315,100	62	98	379,600	327,300	67	120

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoint)

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE ERIE

Hydrologic Area		Chloride 1975				Chloride 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
4.1.1	Black River	8,100	7,800	97	43				
4.1.2	St. Clair Complex	6,600	0	97	43				
4.1.3	Clinton River	26,000	0	52	70				
4.1.4	Rouge Complex	29,000	18,000	99	150				
4.1.5	Huron River	29,000	29,000	74	96				
4.1.6	Swan Creek Complex	8,300	0	100	96				
4.1.7	Raisin River	37,000	0	84	96				
	River Basin Group 4.1 Total	144,000	54,800	82	87				
4.2.1	Ottawa River	9,600	0	99	150				
4.2.2	Maumee River	270,000	270,000	93	150				
4.2.3	Toussaint-Portage Complex	32,000	20,000	92	110				
4.2.4	Sandusky River	49,000	47,000	95	120				
4.2.5	Huron-Vermilion Complex	26,000	17,000	95	92				
	River Basin Group 4.2 Total	386,600	354,000	93	130				
4.3.1	Black-Rocky Complex	53,000	27,000	90	210				
4.3.2	Cuyahoga River	110,000	110,000	79	380				
4.3.3	Chagrin Complex	24,000	22,000	99	310				
4.3.4	Grand River	66,000	0	100	310				
4.3.5	Ashtabula-Conneaut Complex	28,000	0	99	310				
	River Basin Group 4.3 Total	281,000	159,000	90	300				
4.4.1	Erie-Chautauqua Complex	12,000	0	94	68				
4.4.2	Cattaraugus Creek	10,000	10,000	95	68				
4.4.3	Tonawanda Complex	22,000	0	90	68				
	River Basin Group 4.4 Total	44,000	10,000	92	68				

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoi

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

Table 7

HYDROLOGIC AREA LOADS

LAKE ONTARIO

Hydrologic Area		Chloride 1975				Chloride 1976			
Number	Name	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area	Total[1] Load	Monitored[2] Load	%[3] Dif-fuse	Unit[4] Area
5.1.1	Niagara-Orleans Complex	26,000	0	74	72	26,000	0	74	72
5.1.2	Genesee River	140,000	130,000	96	190	140,000	130,000	96	190
	River Basin Group 5.1 Total	166,000	130,000	92	160	166,000	130,000	92	160
5.2.1	Wayne-Cayuga Complex	9,400	0	98	72	9,400	0	98	72
5.2.2	Oswego River	1,000,000	1,000,000	44	350	1,400,000	1,400,000	60	630
5.2.3	Salmon Complex	3,200	0	96	13	3,600	0	96	14
	River Basin Group 5.2 Total	1,012,600	1,000,000	45	280	1,413,000	1,400,000	61	500
5.3.1	Black River	7,500	7,500	85	12	8,600	8,600	87	14
5.3.2	Perch Complex	1,400	0	100	11	1,900	0	100	15
5.3.3	Oswagatchie River	4,800	4,800	91	10	7,300	7,300	94	16
5.3.4	Grass-Raquette-St. Regis Comp.	7,600	6,900	72	6.7	11,000	7,400	87	12
	River Basin Group 5.3 Total	21,300	19,200	83	9.3	28,800	23,300	90	14

[1]Total load from Hydrologic Area (metric tons/yr)

[2]Portion of total load that was monitored (metric tons/yr)

[3]Percent of total load from diffuse sources (nonpoin

[4]Total diffuse unit area load (kg/hectare/yr or 10^{-1} metric tons/km^2/yr)

D I S C U S S I O N

ACCURACY OF TRIBUTARY LOADING ESTIMATES

The results of the tributary loading study presented in the previous section are based upon the best available data. The loading estimates probably represent the most complete compilation of such data ever made for the entire U.S. Great Lakes Basin. It must be remembered, however, when utilizing this information that the loading estimates are only as good as the available field data and that many potential sources of error exist in the collection of data for load calculations.

Perhaps the most significant source of error during any given year is the frequency of sampling. It is often impossible to precisely characterize the annual load contributed by any given river with, for example, twelve monthly samples. The effect of hydrologic and chemical factors (i. e., runoff events, droughts, point source spills and chemical exchange reactions) may be overlooked if the sampling is infrequent. Consequently, it is possible within any given year to misrepresent the actual load if the sampling program misses critical runoff events or other occurrences.

During the analysis it was often noted that data points collected for a given tributary exhibited a high degree of variation. It was then necessary to carefully examine these points to determine if they could be readily explained by a high flow event or some other phenomenon. In several cases extreme concentration data were rejected, especially if they did not coincide with long-term historical trends or highflow runoff events and were therefore perceived as potential sources of reporting or data handling error.

As part of the ratio estimator method an estimated mean-square-error (the square root of which is the estimated standard error of the mean) is calculated along with each annual load estimate. Appendix A contains these mean-square-error values calculated for individual tributaries. While these mean-square-error terms are useful statistical information, a low mean-square-error does not necessarily imply that the estimated load is an accurate representation of the "true" load.

The mean-square-error is only an estimate of the error of the load determined from a limited number of daily samples, based on the premise that the true load can be determined by sampling flow and concentration at the river mouth each and every day of the year. Thus, the error estimate implies that the true total annual load is that load given by

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the sum of 365 daily observations. This assumption, of course, implies that sampling instrumentation and measurement errors may be neglected and that an instantaneous flow/concentration measurement is a perfect representation of tributary conditions on a particular day. Consequently, while the mean-square-error terms are useful, they do not necessarily reflect how close the estimated load is to the true load. For more information on the statistical theory, statistical texts such as Kendall and Stuart (1968) should be consulted.

In summary, the major source of error in estimating river mouth loads is likely to be the inability of the sampling program to provide a representative temporal and spatial distribution of samples. Sampling programs must be tailored to the unique characteristics of individual streams if they are to be both effective and efficient. Importantly, all streams will not require high sampling frequencies in order to accurately characterize their loading contributions, e. g., monthly instead of daily or weekly sampling may be sufficient to provide a reasonable estimate of load. These individual tributary characteristics which require consideration in the design of the sampling program will be discussed in subsequent sections.

<u>IJC Surveillance Versus U. S. Task D Total Phosphorus Loads</u>

Total phosphorus loads have also been calculated by the Surveillance Subcommittee of the International Joint Commission. It is important to point out the differences (and similarities) between the Surveillance Subcommittee total phosphorus loads and the U. S. Task D (this study) loads.

Table 8 compares the U. S. total tributary loads estimated to be delivered to Lakes Superior, Huron, and Michigan during 1976. Loads estimated for Lakes Ontario and Erie were not directly comparable due to the unavailability of 1976 Erie data as well as differences in drainage demarcations.

Both estimates were based on the same computation method (ratio-estimator method), but considerably more data were used in computing the Task D load. Table 8 shows the total number of samples and the number of rivers from which the loads were computed. State surveillance data were the primary data source used by the Surveillance Subcommittee, but for U. S. Task D, in addition to the state surveillance data, other data were also used from university studies, the U. S. Geological Survey, special EPA studies, and PLUARG Pilot Watershed studies. Consequently, differences in loads as shown in Table 8 can be accounted for in part by the differences in sample numbers. Note that in this study (U. S. Task D) loads were calculated for different parameters, while the Surveillance Subcommittee calculated loads for total phosphorus only.

TABLE 8

COMPARISON OF SURVEILLANCE SUBCOMMITTEE AND U. S. TASK D 1976 TOTAL PHOSPHORUS TRIBUTARY LOADS

Lake	Surveillance Subcommittee	U. S. Task D (This Study)
	metric tons/year	
Superior	845	964
Huron	1854	1954
Michigan	3894	3596

COMPARISON OF THE TOTAL NUMBER OF SAMPLES AND NUMBER OF RIVERS MONITORED WHICH WERE USED IN CALCULATING 1976 TOTAL PHOSPHORUS LOADS BY SURVEILLANCE SUBCOMMITTEE AND U. S. TASK D

Lake	No. of Samples		Rivers Considered	
	Surveillance Subcommittee	U. S. Task D	Surveillance Subcommittee	U. S. Task D
Superior	95	157	10	11
Huron	127	402	9	15
Michigan	3[illegible]4	740	27	27

EVALUATION OF U. S. GREAT LAKES TRIBUTARY LOAD ESTIMATES

Flow

In order to evaluate the changes in load that occur from one year to the next, it is helpful to first consider the variability in flow. Table 9 contains the Annual Mean Daily Tributary Flow to the Great Lakes for water years 1975, 1976, and the historical average. These flows are based on USGS gaging station records. Flows from gaged rivers were adjusted to river mouths. Also, flow from ungaged tributaries were estimated by extrapolating flow from gaged areas so that the flows estimated in Table 9 account for the total Lake watershed area. Flow from ungaged area was estimated by multiplying the unmonitored areas by the ratio of the appropriate monitored flow to monitored area.

TABLE 9

ESTIMATED TOTAL ANNUAL MEAN DAILY TRIBUTARY FLOW TO THE GREAT LAKES [1]

cfs (m^3/s)

Lake	1975	1976	Historical Record
Superior	16,380 (463.88)	14,250 (403.56)	15,660 (443.49)
Michigan	42,780 (1211.53)	45,540 (1289.70)	37,530 (1064.27)
Huron	14,910 (422.25)	17,660 (500.13)	11,610 (328.80)
Erie	22,520 (637.77)	22,340 (632.67)	17,930 (507.78)
Ontario	28,860 (817.32)	41,100 (1163.95)	25,820 (731.22)
Total Basin	125,460 (3553.03)	140,910 (3990.57)	108,600 (3075.55)

[1] Flows based on measured flow plus estimated flow for ungaged areas

Table 9 shows that the total annual mean daily discharge during water years 1975 and 1976 was generally higher than the historical discharge. Flows were higher in 1976 compared to 1975 for the Basin as a whole and specifically for Ontario, Huron, and Michigan tributaries. The 1976 tributary flow to Lake Ontario was particularly high.

Table 10 contains Basin tributary flows normalized according to the area of drainage. Interestingly, the flow per unit area of watershed was approximately equivalent for Lakes Superior, Michigan, Huron, and Erie. The unit area tributary flow into Lake Ontario was significantly higher than the flow into the other Lakes, particularly during 1976.

Table 11 provides more detailed information on the discharge from individual tributaries. All tributary flows have been adjusted to the river mouths (see methodology for discussion). Significant differences occurred in the discharge of tributaries between water year 1975 and 1976.

TABLE 10

TOTAL ANNUAL DAILY FLOW PER UNIT AREA OF WATERSHED

$m^3/km^2/year$

Lake	1975	1976	Historical
Superior	330,000	290,000	320,000
Michigan	330,000	350,000	290,000
Huron	320,000	380,000	250,000
Erie	360,000	360,000	290,000
Ontario	570,000	810,000	510,000
Total Basin	370,000	420,000	320,000

TABLE 11

INDIVIDUAL ANNUAL MEAN FLOW
FROM U.S. GREAT LAKES TRIBUTARIES

RIVER	DRAINAGE AREA, km2	1975 FLOW cfs(m3/s)	1976 FLOW cfs(m3/s)	HISTORICAL AVG. FLOW cfs(m3/s)
Superior Basin				
Pigeon	1,554	505(14.30)	-----	505(14.30)
Baptism	363	155(4.39)	153(4.33)	168(4.76)
St. Louis	9.440	2,984(84.51)	1,684(47.70)	2,432(68.87)
Nemadji	1,290	437(12.38)	347(9.83)	-----
Bois Brule	492	261(13.93)	262(7.42)	270(7.65)
Bad	2,580	866(24.52)	1,087(30.78)	999(28.29)
Tahquamenon	2,180	1,014(28.72)	984(27.87)	989(28.01)
Black	612	270(7.65)	323(9.15)	282(7.99)
Presque Isle	886	342(9.69)	360(10.20)	356(10.08)
Sturgeon	1,828	888(25.15)	810(22.94)	848(24.02)
Carp	192	91(2.58)	100(2.83)	86(2.44)
Ontonagon	3 530	1,459(41.32)	1,453(41.15)	1,470(41.63)
% of Total Basin Accounted for by Gaged Rivers		57	53	54
Michigan Basin				
Menominee	10,610	3,558(100.76)	3,382(95.78)	3,406(96.46)
Peshtigo	2,983	1,007(28.52)	1,006(28.49)	946(26.79)
Oconto	2,551	947(26.82)	966(27.36)	912(25.83)
Pensaukee	414	113(3.20)	118(3.34)	-----
Fox	17,100	4,183(118.46)	4,386(124.21)	4,478(126.82)
Kewaunee	354	108(3.06)	94(2.66)	90(2.55)
East Twin	344	81(2.29)	103(2.92)	-----
Manitowoc	1,443	296(8.38)	368(10.42)	-----
Sheboygan	1,127	298(8.44)	261(7.39)	241(6.83)
Milwaukee	1,893	547(15.49)	462(13.08)	424(12.01)
Menomonee	344	107(3.03)	85(2.41)	95(2.69)
Root	514	124(3.51)	154(4.36)	162(4.59)
St. Joseph	12,110	4,637([illegible]1.32)	5,236(148.28)	4,182(118.43)
Black(South Haven)	742	429(12.15)	398(11.27)	350(9.91)
Kalamazoo	5,200	2,492(70.57)	2,446(69.27)	1,772(50.18)

TABLE 11 continued...

RIVER	DRAINAGE AREA, km2	1975 FLOW cfs(m3/s)	1976 FLOW cfs(m3/s)	HISTORICAL AVG. FLOW cfs(m3/s)
Michigan Basin cont'd...				
Black (Ottawa Co.)	494	208(5.89)	259(7.33)	173(4.90)
Grand	14,660	5,683(160.94)	6,491(183.83)	4,029(114.10)
Muskegon	7,118	2,694(76.29)	3,401(96.32)	2,200(62.30)
White	1,352	681(19.29)	876(24.81)	566(16.03)
Pere Marquette	1,909	839(23.76)	953(26.99)	671(19.00)
Manistee	5,487	2,692(76.24)	2,476(70.12)	2,313(65.50)
Boardman	740	252(7.14)	298(8.44)	246(6.97)
Manistique	3,746	2,177(61.65)	2,257(63.92)	1,861(52.70)
Escanaba	2,370	905(25.63)	917(25.97)	968(27.41)
Ford	1,236	457(12.94)	412(11.67)	399(11.30)
% of Total Basin Accounted for by Gaged Rivers		83	83	81
Lake Huron Basin				
Pine	644	371(10.51)	306(8.67)	-----
Cheboygan	4,090	1,724(48.82)	1,748(49.50)	1,488(42.14)
Thunder Bay	4,271	1,030(29.17)	1,013(28.69)	1,004(28.43)
Au Sable	5,756	2,306(65.30)	2,387(67.60)	1,996(56.53)
Au Gres	727	132(3.74)	189(5.35)	162(4.59)
Rifle	1,013	378(10.70)	428(12.12)	376(10.65)
Kawkawlin	582	146(4.13)	291(8.24)	130(3.68)
Saginaw	16,170	5,950(168.50)	7,849(222.28)	4,026(114.02)
Pigeon	322	83(2.35)	144(4.08)	70(1.98)
% of Total Basin Accounted for by Gaged Rivers		81	81	80
Lake Erie Basin				
Black	1,800	396(11.21)	687(19.46)	400(11.33)
Belle	544	185(5.24)	189(5.35)	119(3.37)
Clinton	2,030	931(26.37)	962(27.24)	546(15.46)
Rouge	1,188	388(10.99)	495(14.02)	283(8.01)
Stony Cr.	306	72(2.04)	104(2.95)	76(2.15)
Raisin	3,206	901(25.52)	1,136(32.17)	836(23.68)
Huron	2,200	653(18.49)	842(23.85)	521(4.75)

TABLE 11 continued...

RIVER	DRAINAGE AREA, km2	1975 FLOW cfs(m3/s)	1976 FLOW cfs(m3/s)	HISTORICAL AVG. FLOW cfs(m3/s)
Lake Erie Basin cont'd...				
Ottawa	440	141(3.99)	122(3.46)	134(3.79)
Maumee	17,110	5,545(157.03)	5,848(165.62)	4,989(141.29)
Portage	1,566	458(12.97)	513(14.53)	434(12.29)
Sandusky	3,970	1,418(40.16)	1,060(30.02)	1,168(33.08)
Huron	1,041	369(10.45)	322(9.12)	319(9.03)
Vermillion	704	310(8.78)	252(7.14)	249(7.05)
Black	1,209	583(16.51)	323(9.15)	379(10.73)
Rocky	746	424(12.01)	256(7.25)	281(7.96)
Cuyahoga	2,340	1,783(50.49)	1,384(39.19)	1,001(28.35)
Chagrin	692	507(14.36)	441(12.49)	352(9.97)
Grand	2,120	1,410(39.93)	1,196(33.87)	-----
Ashtabula	355	218(6.17)	210(5.95)	167(4.73)
Conneaut	500	306(8.67)	356(10.08)	280(7.93)
Cattaraugus	1,440	1,055(29.88)	1,150(32.57)	925(26.20)
Buffalo	1,129	651(18.44)	858(24.30)	576(16.31)
Tonawanda	1,573	787(22.29)	-----	702(19.88)
% of Total Basin Accounted for by Gaged Rivers		87	84	83
Lake Ontario Basin				
Genesee	6,420	3,326(94.19)	3,991(113.03)	2,752(77.94)
Sterling	261	171(4,84)	-----	141(3.99)
Oswego	1,3160	7,618(215.74)	11,030(312.37)	6,305(178.56)
Sandy	368	308(8.72)	473(13.40)	276(7.82)
Black	5,210	4,521(128.03)	6,405(181,39)	3,902(110.50)
Oswegatchie	4,309	2,654(75.16)	4,431(125.49)	2,874(81.39)
Grass	1,668	1,230(34.83)	1,655(46.87)	1,150(32.57)
Raquette	3,253	2,220(62.87)	3,354(94.99)	2,180(61.74)
St. Regis	2,207	1,391(39.39)	1,808(51.20)	1,391(39.39)
% of Total Basin Accounted for by Gaged Rivers		81	81	81

Often the 1975 and/or 1976 flows were different from the historical record flow. Even within a lake basin, both relatively high and low flows can occur during the same year.

Important differences in flow can occur during the spring period when for some streams a large fraction of the annual load (of some substances) is delivered. Table 12 gives the ratio of the 1975 to 1976 spring river mouth flow for a number of tributaries. As can be seen, many of the tributaries in Table 12 had higher spring flows in 1976 compared to 1975 (ratio less than one). Notably, two major tributaries, the St. Louis River (draining into Lake Superior) and the Maumee River (draining into Lake Erie) had higher spring flow in 1975 compared to 1976. Important high flow events also often occur in February or other fall-winter months which are not accounted for in Table 12. Also, short-term peak flow events may have a major effect on mean daily flows.

TABLE 12

RATIO OF SPRING (MARCH + APRIL + MAY) FLOWS FOR SEVERAL GREAT LAKES TRIBUTARIES

	1975/1976
St. Louis River	1.783
Nemadji River	1.085
Bad River	0.650
Ontonagan River	0.917
Grand River (Lake Michigan)	0.771
Muskegon River	0.500
Rifle River	0.694
Au Sable River	0.795
Black River (Mich., Lake Erie)	0.641
Rouge River	0.806
Huron River	0.643
Maumee River	1.134
Sandusky River	0.220
Cuyahoga River	0.312
Genesee River	0.718
Oswego River	0.604
Oswegatchie River	0.552

Differences in flow from year-to-year certainly account for some of the variation in loads and will be considered in the ensuing discussion. However, other factors, such as the time, amount and intensity of precipitation, meteorological conditions, year-to-year differences in land use and agricultural practices, variances in point source inputs, and many other factors affect the load for any one year. Ideally, a long period of record for loads, such as is available for discharge on many tributaries, would give a better indication of year-to-year variabilities in loads. For several streams a long-term data base is beginning to be built up, and it is imperative that such monitoring be continued. Until more long-term information is available, however, it must be realized that tributary loads are the result of dynamic processes and can be expected to vary widely from year-to-year.

Great Lakes Load Summary

Table 6 presented in the Results section summarizes loads to the Great Lakes on a total Great Lakes Basin level and by individual Lake basins. Summarized 1975 and 1976 loads are given for seven different parameters, except for Lake Erie, where 1976 data were not available at the time of this writing. It should be noted that discussion of the loading data should not be taken to imply the estimated loads are necessarily absolute. While they are believed to be the best estimates available, an understanding of the limitations of the data is necessary for proper use and interpretation of the estimated loads.

The largest and smallest total phosphorus tributary loads were received by Lake Erie and Lake Huron, respectively. Lake Erie and Lake Michigan tributaries received the largest point source input of total phosphorus. Lake Erie received the largest annual diffuse total phosphorus load per unit area of watershed. The monitored load (calculated from actual flow and concentration data) comprised a large portion of the total load to each Lake, particularly during 1975. Total phosphorus loadings were higher in 1975 than in 1976 for Lake Superior, while the reverse was true for the other Lakes. This is attributable in part to fluctuations in annual discharge, but is also probably attributable to many other factors, such as variations in the sampling program, the accuracy of the data reported, the temporal and spatial distribution of precipitation in different watersheds, and the intensity of precipitation.

Suspended solids tributary loads during water year 1975 (Table 6) were highest for Lake Erie, followed by Lake Superior and Lake Ontario. In 1976 the Lake Ontario suspended solids load exceeded the Lake Superior suspended solids load, which decreased significantly in water year 1976. Other lakes (with the exception of Lake Erie, for which no 1976 loading data were available) received larger suspended solids in water year 1976 than water year 1975.

Further examination of Table 6 reveals that Lake Erie and Lake Michigan received the largest loading of soluble ortho phosphorus. Assuming 100 percent transmission from the point of entry to the river mouth, a significant portion of the soluble ortho phosphorus input can be accounted for by point source inputs. It is also interesting to note that despite the large increase in flow into Lake Ontario during 1976, the soluble ortho phosphorus load was not substantially increased.

The summary of total nitrogen loadings to the Great Lakes (Table 6) reveals that Lake Erie received the largest tributary contribution. Furthermore, approximately 15 percent of the total Basin tributary load was associated with inputs from point source discharges. Table 6 indicates that Lake Erie also recieved the highest inputs of nitrate and ammonia nitrogen. Although 80 percent or more of the nitrate nitrogen loadings to the different Lakes was associated with diffuse sources, point source inputs seemed to be the primary contributor of ammonia nitrogen loads (assuming 100 percent delivery). Nitrate nitrogen and ammonia nitrogen exhibited similar variation patterns over the 1975 and 1976 water years.

The chloride loading summary given in Table 6 indicates that Lake Ontario received the highest chloride load during water years 1975 and 1976. The chloride load to all the Lakes appear to vary between 1975 and 1976 in the same proportion as tributary flow varied. This is evidenced by Table 6, which compares the ratio of 1975 to 1976 chloride load with 1975 to 1976 flow.

TABLE 13

RATIOS OF CHLORIDE LOAD AND ANNUAL FLOW BETWEEN WATER YEARS 1975 AND 1976

	1975/1976	
Basin	Chloride Load	Annual Flow
Lake Superior	1.14	1.15
Lake Michigan	1.09	1.04
Lake Huron	0.89	0.84
Lake Erie		
Lake Ontario	0.74	0.70

Table 7, presented in the Results section, summarizes loads to the Great Lakes from individual hydrologic areas, and is discussed below. Maps of River Basin Groups and hydrologic areas are presented in Appendix B.

LAKE SUPERIOR

River Basin Group 1.1. The St. Louis River is the largest river in this region. Portions of the River Basin Group 1.1 drainage area are characterized by heavy clay soils which appear to significantly affect tributary loads. Flow volumes varied considerably during the 1975 and 1976 water years. For example, flow from the St. Louis and Nemadji Rivers significantly decreased from 1975 to 1976, while certain streams in the eastern portion of the Basin (e. g., the Bad River) exhibited increased flow. During water year 1975 the monitored load (i. e., the load as determined from field measurements of flow and concentration) accounted for a majority of the estimated total load from this basin group. The number of monitored streams (and subsequent ratio of monitored load to estimated total load) decreased for the 1976 water year as a result of the termination of the Upper Lakes Reference Group monitoring program.

As can be seen from examination of Table 7, the Superior Slope Complex, the St. Louis River, and the Apostle Island Complex are the largest contributors of total phosphorus in this river basin group. With the exception of the St. Louis River, most of the total phosphorus load is derived from diffuse sources. The Superior Slope Complex, which is composed of many small tributaries, was monitored extensively during the 1975 water year. However, monitored 1976 total phosphorus data were unavailable for this complex.

The Apostle Island Complex also contributed a larger total phosphorus load in 1975 than in 1976. The Apostle Island Complex contains several tributaries, such as the Nemadji River, which drain a watershed characterized by red clay. As shown in Table 7, this complex represented the largest source of total phosphorus in River Basin Group 1.1.

Total Lake loadings of total phosphorus from 1.1 decreased between water years 1975 and 1976. This may be directly attributable to decreased tributary flows during this time period. It should be noted that the highest phosphorus concentrations were most often recorded on days having high associated flow levels. This condition, in combination with the overall increase in annual flow, may explain the high loads contributed by the St. Louis River in 1975.

Further inspection of Table 7 reveals that soluble ortho phosphorus generally comprised less than 50 percent of the total phosphorus load from the tributaries included in River Basin Group 1.1. The ratio of soluble ortho phosphorus to total phosphorus was relatively consistent for most streams between 1975 and 1976. Importantly, the St. Louis River had the highest ratio of soluble ortho phosphorus to total phosphorus. However, because monitoring of soluble ortho phosphorus was limited, especially during 1976, the soluble ortho phosphorus load could be underestimated.

Suspended solids loads for River Basin Group 1.1 are relatively high, reflecting the high clay content of soils in various portions of the watershed. The Apostle Island Complex and the Bad River Complex contributed the largest suspended solids loadings. The suspended solids loadings from the St. Louis River were not particularly high, despite its large basin area and significant discharges of suspended solids from point sources within the Basin. This point source loading data is primarily associated with extensive mining operations within the watershed. The amount of suspended solids from these point sources which actually reach Lake Superior is not known, but significant transport loss is possible. Since the annual diffuse unit area load of suspended solids is so low for the St. Louis basin, assuming 100 percent delivery of these point sources, it is in fact likely that a large fraction of the estimated point source load does not find its way to the Lake. The lake-like widenings of the St. Louis near its mouth, in combination with the large wetland area contained in the drainage basin, probably accounts for the relatively low quantity of suspended solids discharged to Lake Superior.

The variation in the suspended solids loading from River Basin Group 1.1 during the 1975 and 1976 water years was similar to that of total phosphorus (see Table 7). The Bad River represents one exception. Here the suspended solids load was higher in 1976 than in 1975, although the annual total phosphorus load decreased over the same period. However, this increased suspended solids load is consistent with the increase in flow which occurred in the Bad River between 1975 and 1976. Furthermore, the high total phosphorus load calculated for 1975 may be overestimated due to some unusually high concentrations reported during the 1975 water year and thus the calculated load for 1975 may not be representative of actual conditions.

Table 7 indicates that the highest total nitrogen loads from River Basin Group 1.1 were from the Superior Slope Complex and the St. Louis River basin. This may reflect the larger quantity or organic matter present in the watersheds of these basins. The Apostle Island Complex, which had the largest suspended solids and total phosphorus input, did not contribute the largest total nitrogen input. Generally, total nitrogen loads decreased between 1975 and 1976, which reflects the overall decrease in flow for the tributaries in this river basin group. Nitrate nitrogen loads most often exceeded the inputs of ammonia nitrogen for River Basin Group 1.1. Diffuse sources accounted for a majority of the nitrate nitrogen loads, while point source inputs accounted for a large fraction of the ammonia nitrogen load.

Chloride loadings for River Basin Group 1.1 (see Table 7) reflect the relatively undeveloped nature of the watershed. Only the St. Louis River basin and the Montreal River Complex contain extensive urban areas within their watersheds, and both receive significant point source inputs of chloride. Chloride loads generally decreased between 1975 and 1976; this again coincides with decreased flows in 1976 (see Table 11). The Bad River represents one exception. Here the chloride load decreased in spite of increased flow between 1975 and 1976. Upon review of the Bad

River loading data, it was noted that an unusually high chloride concentration was reported in 1975. This high concentration may have biased the loading estimate, resulting in an unrepresentative estimate of the 1975 chloride load from the Bad River.

River Basin Group 1.2. Several small rivers which drain relatively undeveloped land characterize this region. Measured flow from this river basin group did not change significantly between 1975 and 1976. In fact, measured flows during 1975 and 1976 were very close to the long-term average historical flows. The flows during the spring months of water years 1975 and 1976 were also relatively constant. Roughly two-thirds of all estimated loads for River Basin Group 1.2 were based on monitored data.

Table 7 indicates that calculated total phosphorus loadings varied little between 1975 and 1976. The Ontonagon River was the largest phosphorus contributor in this hydrologic area, and also had the highest annual diffuse unit area loading rate for total phosphorus. The calculated total phosphorus did decrease between 1975 and 1976, although the mean annual flow from the Ontonagon River did not.

Soluble ortho phosphorus loads were comparatively low from River Basin Group 1.2 during the 1975 and 1976 water years (see Table 11). The calculated load from the Ontonagon River increased over this period, while other hydrologic areas exhibited little variation in their calculated soluble ortho phosphorus output. Municipal point source discharges accounted for a large fraction of the soluble ortho phosphorus load. Examination of the ratio of soluble ortho phosphorus to total phosphorus loads revealed a wide variation over this two-year period of study. The lowest ratio of soluble ortho phosphorus to total phosphorus for this river basin group was associated with the Ontonagon River in 1975.

Monitored loads of suspended solids to Lake Superior comprised 70 percent or more of the total suspended solids loadings from River Basin Group 1.2. The Ontonagon River represented the largest contributor. As will be discussed later, the Ontonagon River drains a watershed containing extensive clay soil areas. It is interesting to note that a large decrease in suspended solids loadings occurred between 1975 and 1976 from the Ontonagon River. This decrease coincides with the decrease observed for total phosphorus. Diffuse source inputs accounted for all the suspended solids loadings from River Basin Group 1.2, except in Hydrologic Area 1.2.1 - the Porcupine Mountains Complex. Discharges from mining operations in the Mineral and Iron River watersheds accounted for much of the load from this complex.

Monitored loads of total nitrogen accounted for approximately 50 percent of the total load in 1975. In 1976 this percentage was somewhat less. The Ontonagon River was the largest contributor of total nitrogen in water year 1975 (see Table 7), while the Keweenaw Peninsula Complex contributed the largest load in 1976. However, because the tributaries within the Keweenaw Peninsula Complex were not monitored, the Keweenaw load is only a rough approximation. The Huron Mountain Complex and the

Porcupine Mountains Complex both received significant point source inputs of total nitrogen.

Nitrate nitrogen loads remained relatively constant between 1975 and 1976. Ammonia nitrogen loads were small during both water years. Point source contributions were substantial in the Porcupine Mountains Complex, the Huron Mountain Complex, and the Tahquamenon River hydrologic area.

The major source of chloride loads from River Basin Group 1.2 is the Porcupine Mountains Complex. Discharges of brine from mining operations into the Mineral River appear to account for this high chloride load. In fact, point source loads from these operations of 33,000 metric tons per year have been estimated which accounts for 35 to 40 percent of the total U. S. tributary load of chloride to Lake Superior. Municipal discharges comprise the other point source inputs of chloride to the Iron Mountain Complex and to the Tahquamenon River. The Carp River received all the municipal discharges to the Huron Mountain Complex.

Lake Michigan

River Basin Group 2.1. This river basin group is comprised of undeveloped watersheds in the north and more developed agriculturalized watersheds in the south. The area was extensively monitored and approximately 70 percent of the loads estimated for this group were based on field data. The 1975 and 1976 monitored flows in River Basin Group 2.1 were similar. Additionally, the 1975 and 1976 mean annual flows were approximately equal to the long-term average flows. The Menominee, Fox, Peshtigo, and Oconto Rivers had the largest mean annual flow.

Table 7 shows the Fox River to be the largest contributor of total phosphorus in this river basin group. The Green Bay Complex, which includes the Manitowoc and Sheboygan Rivers as well as a number of smaller tributaries, also contributed a significant amount of phosphorus to Lake Michigan. The Fox River had a large point source component (assuming 100 percent delivery of point source loads). Similarly, the Green Bay Complex contained significant point source inputs, particularly for 1975 as shown in Table 7. Significant portions of the Fox River and the Green Bay Complex are located in the more agriculturalized and urbanized southern portion of the river basin group.

Despite the fact that the Fox River contributed the largest total phosphorus load, its annual diffuse unit area load was quite small. This is a result of at least two factors--the large size of the Fox River watershed and the fact that the majority of this area drains into Lake Winnebago, where many constituents settle out. Therefore, diffuse drainage to the Fox River is less than would normally be expected for a watershed of this size.

Few significant differences were observed in total phosphorus loads between 1975 and 1976 for the major hydrologic areas. Areas having small associated loads understandably exhibited a greater percent variation from year-to-year, but the magnitude of the total load remained small in comparison to the input from other watersheds. The generally small variation in total phosphorus loads reflects the relatively constant flow conditions between 1975 and 1976 for these tributaries.

As was the case for total phosphorus, the largest contributors of soluble ortho phosphorus to Lake Michigan in River Basin Group 2.1 were the Fox River and the Green Bay Complex (see Table 7). Point source inputs of soluble ortho phosphorus were significant in the Green Bay Complex, the Fox River, and the Menominee River. Although soluble ortho phosphorus loads comprised roughly 50 percent of the total phosphorus loads to the Menominee River during 1975, there was significant reduction in the soluble ortho phosphorus to total phosphorus ratio in 1976. The Green Bay Complex maintained a relatively high soluble ortho phosphorus to total phosphorus load ratio in both water years 1975 and 1976.

The Fox River and the Green Bay Complex also were the largest sources of suspended solids to Lake Michigan from River Basin Group 2.1. Point source contributions were significant for the Fox River, as well as for the Oconto and Menominee Rivers during both 1975 and 1976. Suspended solids increased between 1975 and 1976 with the exception of the Green Bay Complex. The large reduction in suspended solids loadings for the Green Bay Complex was primarily due to a large decrease in loadings from the Manitowoc River. The reason for this decrease is not obvious, although it may be related to the fact that some high flow and field concentration measurements were coincidently collected during 1975 but not in 1976.

The Fox River and the Green Bay Complex again contributed the largest quantities of total nitrogen from River Basin Group 2.1. The Fox River also received the largest contribution from point sources in terms of the percentage of the total nitrogen load. Generally, there was little difference between the 1975 and the 1976 total nitrogen load.

Ammonia nitrogen and nitrate nitrogen loadings were unlike some of the other parameters in that the Fox River was not the largest contributor. The Oconto River contributed the largest ammonia nitrogen input from River Basin Group 2.1. The Green Bay Complex was the largest contributor of nitrate nitrogen. Assuming 100 percent delivery, point sources of ammonia accounted for all the ammonia nitrogen discharged from the Fox River. Point sources also accounted for all the nitrate nitrogen loads from the Fox River in 1976 and approximately 70 percent in 1975. In most cases both nitrate nitrogen and ammonia nitrogen loadings were higher in 1975 than in 1976.

With respect to chloride, the Fox River was again the largest contributor from River Basin Group 2.1. Identified point sources accounted for portions of the load delivered by the Menominee River, the Fox River, and the Green Bay Complex (see Table 7). The Suamoco Complex showed the greatest variation in chloride loading between 1975 and 1976.

River Basin Group 2.2. This river basin group consists of the Chicago-Milwaukee Complex, which includes the Milwaukee River, Menomonee River, Root River, Waukeegan River, Burns Ditch, Indiana Harbor Canal, and Galien River. Table 11 indicates that the flow for some of these tributaries is highly variable. The flow for the Milwaukee River in 1975 was higher than in 1976, and both exceeded the long-term historical average. On the other hand, the Root River had a higher flow in 1976 than in 1975, and the total flow was below the long-term historical average. Loads were only calculated for the Milwaukee River, the Menomonee River, and the Root River. Several tributaries, including the Indiana Harbor Canal, Burns Ditch, and the Galien River, while potentially important due to their highly urban drainage, lacked sufficient flow and concentration data to estimate their associated loads. Point sources associated with the Indiana Harbor Canal, while significant, were assumed for the purposes of this report to be direct sources and will be included in Subactivity 3-4 of U. S. Task D, PLUARG. Evaluating loads for these tributaries is further complicated by diversions of water to the Mississippi drainage and the fact that flows tend to be intermittent.

Overall total phosphorus loads in 1976 exceeded those in 1975 in River Basin Group 2.2. Additionally, soluble ortho phosphorus loadings increased from water year 1975 to water year 1976. The soluble ortho phosphorus loads were about 20 percent of the total phosphorus loads during both years.

Unlike phosphorus loads, suspended solids loads decreased between 1975 and 1976 from both the Menomonee and Milwaukee Rivers. These changes account for the overall drop in the River Basin Group 2.2 suspended solids loadings over the two-year period. Flow for both rivers also decreased between water years 1975 and 1976.

Loadings of total nitrogen from River Basin Group 2.2 were fairly constant between water years 1975 and 1976. Nitrate nitrogen loadings also exhibited little variation over the two water years, while ammonia nitrogen loadings decreased. Assuming 100 percent delivery, point sources accounted for about 10 percent of the nitrate nitrogen load. Chloride loads increased between water year 1975 and 1976. Most of the chloride load was apparently derived from diffuse sources.

River Basin Group 2.3. This basin group is comprised of relatively large rivers (e. g., the St. Joseph River, the Kalamazoo River, and the Grand River). Gaging stations in the region indicated relatively little change in flow between water years 1975 and 1976 for the Kalamazoo River, while the St. Joseph and the Grand River exhibited a marked increase in annual mean daily flow during 1976. In all cases, flows monitored during water years 1975 and 1976 were greater than the long-term average annual mean daily flow.

Monitored loads for all parameters accounted for nearly all the total load in River Basin Group 2.3. Thus, only a small percentage of this basin group's total loading was based on extrapolated information.

As shown in Table 7 the Grand River contributes the largest quantity of total phosphorus of any tributary draining into Lake Michigan. Other rivers which deliver major inputs from River Basin Group 2.3 are the Kalamazoo, St. Joseph, and the Black River (in Ottawa County). Differences in total phosphorus loads between 1975 and 1976 were generally consistent with differences in the flow between these two water years. Point source inputs accounted for a large part of the total phosphorus load from this river basin group.

Soluble ortho phosphorus loads from River Basin Group 2.3 varied in roughly the same fashion as total phosphorus loads between water years 1975 and 1976. The St. Joseph River was one exception. Here the soluble ortho phosphorus load increased significantly between 1975 and 1976. The relative importance of point sources varied widely within the river basin group, and in some cases, point source inputs accounted for all the total soluble ortho phosphorus load.

The St. Joseph River contributed the largest quantity of suspended solids of any tributary in River Basin Group 2.3 and, in fact, of any Lake Michigan tributary during water year 1975 (see Table 7). During 1976, the Grand River was found to be the largest contributor of suspended solids to Lake Michigan. Suspended solids loads were generally higher in 1975 than 1976. A particularly large increase in suspended solids load was observed for the Grand River between water year 1975 and 1976 (primarily due to an increase in flow). The Kalamazoo River had some significant point source loads from both municipal and industrial inputs.

Total nitrogen loads varied little between water years 1975 and 1976. The Grand River was not only the largest contributor of total nitrogen in River Basin Group 2.3, but also the largest contributor to Lake Michigan (see Table 7). Assuming 100 percent delivery, point sources of total nitrogen account for up to 50 percent of the tributary load from River Basin Group 2.3. Nitrate nitrogen behaved similarly to total nitrogen during 1975 and 1976. Point sources accounted for as much as 70 percent of the nitrate load. The ammonia nitrogen load from rivers within River Basin Group 2.3 was variable between 1975 and 1976. Estimated point source inputs of ammonia accounted for all the total load from the St. Joseph River, the Kalamazoo River, and the Grand River (assuming 100 percent delivery).

The Grand River was the largest contributor of chlorides to Lake Michigan for both water years. Despite the fact that the flow of the Grand River was significantly higher in 1976, the chloride load decreased from the 1975 value. Assuming 100 percent delivery, point source inputs of chloride accounted for up to 30 percent of the chloride loads in River Basin Group 2.3, as shown in Table 7.

River Basin Group 2.4. The Muskegon, Pere Marquette, Betsie, Boardman, Manistique, and Escanaba Rivers are the major rivers included in River Basin Group 2.4. About 60 percent of all the total loads associated with this river basin group are based on field data. Generally, loads were higher during 1976 than 1975. The Muskegon River, one of the largest rivers in this river basin group, had a significantly higher mean annual flow in 1976 than in 1975. Also, flow levels during March, April, and May were significantly higher in 1976 than in 1975. With the exception of the Escanaba River in Michigan's Upper Peninsula, measured mean annual flows during both 1975 and 1976 were above the historical average.

The Muskegon River and the Sable Complex, which includes the Pere Marquette, the Big Sable, and the White Rivers, were the largest contributors of total phosphorus in River Basin Group 2.4. With the exception of the Escanaba River, total phosphorus loads were the same or higher in water year 1976 than in water year 1975. Point sources accounted for the greatest percentage of the total load in the Manistee River.

Soluble ortho phosphorus loads generally increased between water years 1975 and 1976 with the exception of the several Upper Peninsula (Michigan) hydrologic areas. Point source inputs accounted for most of the soluble ortho phosphorus load from the Manistee River. The ratio of soluble ortho phosphorus to total phosphorus, although slightly less in 197[illegible], was fairly consistent over both water years.

The Muskegon River was the largest contributor of suspended solids to Lake Michigan from River Basin Group 2.4 during both 1975 and 1976. It also exhibited a sharp increase in suspended solids load between 1975 and 1976. As usual, point sources accounted for only a small percent of the total suspended solids load.

As indicated in Table 7, the Muskegon River was the largest contributor of total nitrogen from River Basin Group 2.4. Total nitrogen loadings from River Basin Group 2.4 were generally higher in water year 1976 with the exception of the Bay De Noc Complex and the Escanaba River. Total nitrogen loads in these two complexes were low for both years, however. The Muskegon River was also the largest contributor of nitrate nitrogen. On the other hand, contributions of ammonia nitrogen were higher from other hydrologic areas in both 1975 and 1976. Point sources accounted for a large fraction of the total ammonia nitrogen loads from tributaries draining into Lake Michigan from the Lower Peninsula to the State of Michigan.

Chloride loads either remained relatively constant or decreased over the 1975 and 1976 water years. The Manistee River contributed the largest chloride load. Almost all these loads during 1975 and 1976 could be attributed to point source inputs. Industrial salt operations in the Manistee watershed apparently contributed to the high chloride load associated with the river. In addition, point sources also accounted for a large portion of the chloride loading from the Sable Complex.

Lake Huron

River Basin Group 3.1. River Basin Group 3.1 is relatively undeveloped and its tributaries are all comparatively small. Discharges of tributaries in 1975 and 1976 were generally higher than the long-term historical record. Tributaries located in the southern part of this river basin group exhibited significantly higher flows in 1976 compared to 1975. The monitored load accounted for less than 50 percent of the total load for some parameters during both 1975 and 1976, indicating the relative scarcity of field monitoring data near the river mouths of these tributaries.

Contributions of phosphorus from the hydrologic areas in River Basin Group 3.1 were generally low (see Table 7). The largest contributing hydrologic area was the Les Cheneaux area. Only in the Rifle-Au Gres Complex did point source inputs account for a significant portion of the total phosphorus load. Soluble ortho phosphorus loads were also relatively low, usually less than 50 percent of the total phosphorus loads. In the case of Presque Isle Complex, the estimated soluble ortho phosphorus load in 1975 exceeded the total phosphorus load. This, of course, is an impossibility and is an anomaly resulting in part from the fact that two different data sets were used in calculating the load. Further, both soluble ortho phosphorus and total phosphorus concentrations were bordered on the analytical detection limit, so that a small difference in concentration could result in a relatively large change in the load.

The suspended solids loads from River Basin Group 3.1 were dominated by the Les Cheneaux Complex (see Table 7). This complex produced a significantly higher load during water year 1975 and 1976. The only monitored river in this complex was the Pine River and the high load for 1975 was apprently the result, in part, of a high concentration measured during the high flow conditions in 1975. Because of this excessive suspended solids load from the Pine River in water year 1975, the overall suspended solids load from River Basin Group 3.1 was approximately twice as high in water year 1975 than in 1976.

As shown in Table 7 , diffuse sources accounted for the majority of the total nitrogen loads from River Basin Group 3.1. Diffuse sources also appear to be responsible for most of the nitrate nitrogen loading (see Table 7). Point source inputs of ammonia nitrogen accounted for a significant portion of the ammonia nitrogen load in the Rifle-Au Gres Complex. The Rifle-Au Gres Complex was a major source of all forms of nitrogen in River Basin Group 3.1.

The Rifle-Au Gres Complex and the Au Sable-Alcona Complex were the largest contributors of chloride to Lake Huron during the 1975 and 1976 water years from River Basin Group 3.1 (see Table 7). The contributions of chloride from identified point sources in this river basin group were quite small.

River Basin Group 3.2. This particular river basin group consists of only three hydrologic areas. The dominate of these is the Saginaw River basin, which includes major industrialized areas. The Thumb Complex is an agriculturalized watershed characterized by extensive man-made drains located in much of the complex. As shown in Table 11, rivers within these complexes had a greater discharge in water year 1976 than in water year 1975. In addition, discharges during both years were greater than the long-term historical average. The monitored load accounted for the majority of the loads reported in River Basin Group 3.2 (see Table 7).

The Saginaw River represented the major source of total phosphorus loads from River Basin Group 3.2 and from the entire U. S. Lake Huron basin. About 70 percent of the total phosphorus load from U. S. tributaries comes from the Saginaw River. This large percentage is also found for other parameters. Point source inputs accounted for a significant portion of the total phosphorus load for both the Saginaw River and Kawkawlin Complex. The ratio of soluble ortho phosphorus to total phosphorus was equal to or less than 0.5 for all three complexes.

The suspended solids loads from River Basin Group 3.2 were also dominated by the Saginaw River. Although a significant portion of the total suspended solids load from the Thumb Complex was based on projected estimates rather than monitored data, the results indicate that this complex also contributes a large portion of the suspended solids load from this river basin group. A sharp increase in the suspended solids loading was observed between 1975 and 1976 in the Saginaw River and the Thumb Complex.

The Saginaw River was also the largest contributor of total nitrogen from River Basin Group 3.2. Nitrate nitrogen loads were relatively high in this complex compared to the total nitrogen loads. Approximately 12 percent of the Saginaw River load could be atributed to point source inputs of nitrate. The Saginaw River also represented the most significant source of ammonia nitrogen loads. Ammonia point sources accounted for the majority of the load contributed to Lake Huron from the Saginaw River.

As might be expected, the Saginaw River contributed the highest chloride loads from River Basin Group 3.2. Chloride loads from the Saginaw River and Thumb Complex increased between water year 1975 and 1976 (see Table 7). Approximately 40 percent of the chloride load from the Saginaw River could be attributed to point source discharges.

Lake Erie

As discussed in the methodology, the Lake Erie loads are basically the same loads reported by the U. S. Army Corps of Engineers in their Lake Erie Wastewater Management Study. Because Lake Erie tributaries have been extensively discussed and analyzed (Corps of Engineers, 1975), only a brief evaluation of inputs from Lake Erie tributaries will be given here. Furthermore, 1976 loading data were not available from the Corps of Engineers at the time of this writing. For additional information on

Lake Erie tributaries, one may consult the reports of the Lake Erie Wastewater Management Study.

River Basin Group 4.1. This river basin group includes a number of tributaries draining into the St. Clair River, Lake St. Clair, and the Detroit River. Total phosphorus loadings were highest from the Rouge Complex and the Raisin River. Point source inputs of phosphorus were significant except in the Swan Creek Complex. Soluble ortho phosphorus to total phosphorus ratios exhibited large variations within this river basin group. Analysis of the data indicated that the Raisin River was a large contributor of suspended solids. Less than 25 percent of the 1975 suspended solids load for River Basin Group 4.1 was based on monitored data. As shown in Table 7 , the Rouge Complex, which drains some heavily industrialized land in the Detroit area, received a large point source input of suspended solids.

Total nitrogen loads in River Basin Group 4.1 were largely estimated from unit area load factors rather than monitored data. The Raisin River was the largest contributor of both total nitrogen and nitrate nitrogen during water year 1975. The monitored load of ammonia nitrogen also comprised less than half of the total estimated load. Point source inputs of ammonia were significant, accounting for the total load from the Rouge complex and the Huron River hydrologic area. The Raisin River contributed the largest amount of chloride from tributaries in River Basin Group 4.1. Examination of the data indicated that chloride point sources were again significant in some of the hydrologic areas.

River Basin Group 4.2. This river basin group consists of tributaries which drain into the western basin of Lake Erie. The Maumee River is the dominant member of this river basin in terms of loading contributions. As can be seen from Table 7 , the total phosphorus and suspended solids loads from the Maumee River exceeded those of any other tributary in this river basin group. Soluble ortho phosphorus inputs accounted for about 20 percent of the total phosphorus load.

Total nitrogen loads were again highest from the Maumee River, as were nitrate and ammonia loads. Point source contributions of ammonia were significant and, in the case of the Maumee River and the Toussaint-Portage Complex, accounted for a majority of the total ammonia load. The Maumee River was the primary source of chloride from River Basin Group 4.2, and identified point sources accounted for only a small percentage of the total.

River Basin Group 4.3. River Basin Group 4.3 contains a number of similar-sized rivers and includes the drainage of the Cleveland metropolitan area. Inspection of Table 7 reveals that Cuyahoga River was the largest contributor of total phosphorus from this group. The largest contributor of soluble ortho phosphorus, however, was the Black-Rocky Complex. Point sources accounted for a large portion of phosphorus loads from the Cuyahoga River. The Cuyahoga River was also the largest contributor of suspended solids. Essentially all the suspended solid load for the river basin group were derived from diffuse sources.

The Black-Rocky Complex dominated the total nitrogen loads from River Basin Group 4.3 and also contributed the highest quantity of ammonia nitrate nitrogen. Identified point sources accounted for a large percent of the total nitrogen and nitrate nitrogen load from the Cuyahoga, as well as 100 percent of the ammonia nitrogen load during water year 1975. The Cuyahoga River contributed the largest chloride load to Lake Erie from River Basin Group 4.3.

River Basin Group 4.4. River Basin Group 4.4 drains into the eastern basin of Lake Erie. Its watershed includes portions of Pennsylvania and New York. Of the three hydrologic areas in River Basin Group 4.4, only the loads estimated for Cattaraugus Creek were based on field data. The Tonawanda Complex, which drains the Buffalo area was estimated to contribute the largest amount of total phosphorus from River Basin Group 4.4 (see Table 7). A large fraction of this load could be attributed to point source inputs. The ratio of soluble ortho phosphorus loads to total phosphorus loads was consistently low, and point source inputs accounted for a large portion of the soluble ortho phosphorus load. Cattaraugus Creek contributed the largest amount of suspended solids from River Basin Group 4.4.

Table 7 indicates that the Tonawanda Complex was estimated to be the largest contributor of total nitrogen, nitrate nitrogen, and ammonia nitrogen from River Basin Group 4.4. Point source discharges of ammonia accounted for up to 25 percent of the total load from the hyrologic areas in River Basin Group 4.4. Additionally, the Tonawanda Complex was estimated to contribute the largest chloride load from River Basin Group 4.4.

Lake Ontario

River Basin Group 5.1. River Basin Group 5.1 consists of two complexes, from which only the Genesee River was monitored. The Genesee River significantly increased in discharge between 1975 and 1976, as shown in Table 11. Also, the discharge during both years was greater than the historical average.

Total phosphorus loads from the Genesee River increased between 1975 and 1976. Point source inputs of total phosphorus accounted for 20 to 30 percent of the total load. Soluble ortho phosphorus loads comprised roughly 15 percent of the Genesee River total phosphorus load during both 1975 and 1976. Point source inputs could account for a large fraction of soluble ortho phosphorus load in River Basin Group 5.1.

Suspended solids loadings from the Genesee River nearly doubled between 1975 and 1976. All the suspended loads from the Genesee River were apparently attributable to diffuse source inputs.

As shown in Table 7, total nitrogen loads also increased between 1975 and 1976 in River Basin Group 5.1. Point source inputs account for about 10 to 30 percent of the total nitrogen load. Similarly, nitrate nitrogen loads increased between 1975 and 1976, as did ammonia nitrogen loads. Point source inputs accounted for a large percentage of the total load of ammonia nitrogen in River Basin Group 5.1.

Interestingly, chloride loads were the same for 1975 and 1976 for River Basin Group 5.1, despite the fact that the tributaries experienced a significant increase in flow. Point source inputs of chloride to the Niagara-Orleans Complex were relatively large.

River Basin Group 5.2. This river basin group includes three hydrologic areas. As was the case for River Basin Group 5.1, only one of these areas, the Oswego River, was monitored. The Oswego River is by far the largest river in this river basin group, however. Discharge from the Oswego was significantly higher in 1976 than in 1975. In fact, the 1976 discharge from the Oswego was about twice the long-term average.

Inspection of Table 7 reveals a significant increase in total phosphorus loads from 1975 to 1976. The Oswego River total phosphorus load was entirely attributable to point sources during 1975 (assuming 100 percent delivery). In 1976, point source inputs could account for 60 percent of the total phosphorus load from the Oswego. The soluble ortho phosphorus load behaved similarly to the total phosphorus load in all areas except the Salmon Complex during water year 1975. Here a relatively high (compared to the total load) soluble ortho phosphorus load was recorded. During both 1975 and 1976 point sources accounted for all the soluble ortho phosphorus load from the Oswego River (see Table 7). Suspended solids loads increased between 1975 and 1976 from both the Oswego River and the Salmon Complex. There was a decrease, however, of suspended solids loads from the Wayne-Cayuga Complex. About 25 percent of the Oswego River suspended solids loads could be attributed to point source inputs.

Nitrogen loads from River Basin Group 5.2 were also dominated by the Oswego River. All the hydrologic areas in 5.2 had higher total nitrogen and nitrate nitrogen loads in 1976 than in 1975. Ammonia nitrogen loads were higher in 1976 except in the Salmon Complex, which had a very low ammonia nitrogen load. Point source inputs accounted for a significant portion of the total nitrogen load, as well as all the ammonia nitrogen load from the Oswego River.

The Oswego River contributed large chloride loads to Lake Ontario, and these loads increased between 1975 and 1976. In fact, the Oswego River is responsible for about 85 percent of the U. S. tributary load of chloride to Lake Ontario. Identified point sources accounted for about 50 percent of the chloride load from the Oswego River. These discharges were apparently largely the result of industrial operations in the watershed. An additional discussion on the Oswego River chloride load may be found in a later section.

River Basin Group 5.3. This river basin group drains into eastern Lake Ontario. The largest river in the group is the Black River. As Table 11 shows, flow was significantly higher in water year 1976 than in 1975, and in both years the flow was higher than the average over the historical period of record. A relatively high percentage of the total loads reported for these tributaries was based on field monitoring data.

Phosphorus loads increased markedly from 1975 and 1976 (see Table 7). Point sources total phosphorus contributions were significant in the Grass-Raquette-St. Regis Complex and the Black River hydrologic area. The soluble ortho phosphorus to total phosphorus ratios were considerably lower in water year 1976. The estimated soluble ortho phosphorus load from the Black River in water year 1975 was comparatively high. Point source inputs of soluble ortho phosphorus were significant for the Black River, Oswagatchie River, and the Grass-Raquette-St. Regis Complex. Unlike total phosphorus, little or no increase in soluble ortho phosphorus loads was noted between 1975 and 1976.

Suspended solids loads from the Black River were highest in water year 1975. Despite the large increases in flow, none of the hydrologic areas, except for the Black River, had higher suspended solids loadings in 1976 than 1975. The reason for this is not clear, but it may be a result of sampling during periods of high flow in 1975 but not in 1976.

Total nitrogen loads generally increased between 1975 and 1976. On the other hand, three out of four hydrologic areas from River Basin Group 5.3 had decreased nitrate nitrogen loads in 1976 than in 1975. Of the three nitrogen forms measured, ammonia nitrogen point source inputs were the largest.

The Grass-Raquette-St. Regis Complex was the largest contributor of chloride during water year 1975 and 1976. Less than 30 percent of the total loads were attributable to point source inputs. In all cases total loads of chloride from River Basin Group 5.3 were higher in water year 1976 than in 1975. In comparison to the load of shloride delivered by the Oswego River in River Basin Group 5.2, the chloride loads from River Basin Group 5.3 were small.

DIFFUSE LOADS

An effective pollution management strategy must recognize the relative importance of point and diffuse sources. As discussed earlier, diffused sources account for a large fraction of the total tributary load. If the actual delivery of point source inputs is less than 100 percent (which is likely often the case), the diffuse loads would represent an even larger percentage of the total.

Transmission of Point Sources

Table 14 shows the diffuse tributary load for several tributaries assuming either 50 percent or 100 percent delivery of upstream point sources. The definition of upstream and downstream was discussed in an earlier section. Tributaries included in Table 14 generally had at least 24 or more samples available over the 1975 water year.

As shown in Table 14, the estimated diffuse load from the Oswego River presents an interesting situation. It can be seen that if all point sources are considered to be delivered to the river mouth (100 percent diffuse load column), the point source load accounts for the total load from the basin. The Oswego River has many very large lakes within the basin which likely impede the transport of point sources to the river mouth. For example, in the case of phosphorus, it is well known that lake bottom sediments serve as a phosphorus sink. Thus, phosphorus derived from point sources may be lost permanently to sediments of an impoundment or lake-like widening of the river before reaching the Great Lakes. Consequently, assuming 50 percent delivery of upstream point sources may be more realistic for many parameters. However, although the actual transport of point sources is not known over the long-term, at least for tributaries that do not have major impoundments impeding transport, the percent transported may be close to 100 over the long term (i. e., several years).

TABLE 14

TOTAL PHOSPHORUS DIFFUSE LOADS ASSUMING 50 AND 100 PERCENT DELIVERY OF UPSTREAM POINT SOURCES 1975 (MT/YR)

River	Total River Mouth Load	Diffuse Load[1] (50 % Delivery of Upstream Point Sources)	Diffuse Load[2] (100% Delivery of Upstream Point Sources)
St. Louis	260	210	170
Kalamazoo	230	150	78
Grand (MI)	760	550	350
Saginaw	1200	890	640
Maumee	2600	2400	2200
Cuyahoga	790	620	510
Oswego	510	210	0
Fox	500	190	120

[1] Diffuse Load = Total river mouth load minus (100% of downstream plus 50% of upstream point sources).

[2] Diffuse Load = Total river mouth load minus (100% of downstream plus 100% of upstream point sources).

Because of the uncertainty of the transmission of point sources, point source data have been grouped according to upstream and downstream sources. This information has been computerized (see Table 15) and to permit easy computations of the effect of different assumptions on deliveries of point source loads. This work will be further explored as part of subactivity 3-4 of U. S. Task D, PLUARG.

Diffuse Unit Area Loads

The results (Table 7) presented in an earlier section indicate a wide variety of annual diffuse unit area loads were found for different watersheds in the Great Lakes Basin. Further, a diffuse unit area load can vary greatly from one year to the next, depending on factors such as variation in flow, types and frequency of storms, frequency at which samples were taken, and whether runoff events were sampled or not. All these factors must be considered when trying to interpret the meaning of a diffuse unit area load. The diffuse unit area loads are also an integration of the overall characteristics of the watershed. Individual portions of watersheds may have quite different unit area loading rates than the overall unit area load at the river mouth.

Keeping the limitations of the diffuse unit area load data in mind, large differences in diffuse unit area loads can be used to differentiate between watersheds. Maps contained in Appendix B illustrate differences in diffuse unit area loads for total phosphorus and suspended solids. Appendix B figures are arranged according to river basin groups. Diffuse unit area loads in the figures are the average diffuse loads over 1975 and 1976 (with the exception of Lake Erie watersheds, for which only 1975 data were available). Unit area loads have been divided into three different ranges to illustrate major differences between watersheds.

The first set of figures in Appendix B show diffuse unit area loads for total phosphorus. Inspection of these figures indicates that unit area loads are highest in the Lake Erie basin, the thumb area of the Lake Huron basin, and parts of the Lake Ontario basin. Some relatively high diffuse unit area loads are also found in parts of the Lake Superior basin and Lake Michigan basin. A fairly large part of the Lake Michigan basin has low diffuse total phosphorus unit area loading rates.

Suspended solids diffuse unit area loads generally follow the same pattern as total phosphorus. Highest unit area loads of suspended solids were found for the Lake Erie basin, the thumb area of the Lake Huron basin, and parts of Lake Ontario. Interestingly, the Pine River and Carp River draining from Michigan's Upper Peninsula also had high unit area load rates for suspended solids. Differences in unit area load rates appear to reflect different characteristics of watersheds. For example, those watersheds that are rich in clay soils, such as found in the Lake Erie basin, have high unit area load rates. A further discussion of the effect of the watersheds on the diffuse contributions will be discussed in a later section.

Table 15

EXAMPLE COMPUTER PRINTOUT OF UPSTREAM AND DOWNSTREAM POINT SOURCE LOADS - TOTAL PHOSPHORUS 1975 (mt/yr)

----RIVER----		LOAD AT	STANDARD	# OF	------POINT SOURCE LOADS------			
NUMBER	NAME	MOUTH	ERROR	SAMP	MUN-DN	MUN-UP	IND-DN	IND-UP
21501	PENSAUKEE	15.5	6.0	12	0.0	0.0	0.0	0.0
21601	FOX	499.6	61.5	12	44.0	112.0	58.5	26.1
21701	KEWAUNEE	19.7	1.7	12	1.1	0.0	0.0	0.0
21711	EAST TWIN	8.9	0.6	12	0.0	0.0	0.0	0.0
21712	WEST TWIN	15.2	1.3	12	2.5	0.0	0.0	0.0
21713	MANITOWOC	42.6	7.0	13	1.8	10.4	0.0	0.0
21718	SHEBOYGAN	60.1	10.7	12	15.9	1.0	0.0	0.0
22102	MILWAUKEE	109.2	31.9	6	12.2	4.8	0.0	0.0
22103	MENOMONEE	35.6	4.6	48	20.6	0.0	0.0	0.0
22106	ROOT	20.1	2.1	6	0.7	10.4	0.0	0.0
23101	ST JOSEPH	446.1	56.0	8	56.2	193.6	0.0	1.4
23203	BLACK SHAVE	109.5	33.5	3	0.0	0.0	0.0	0.0
23301	KALAMAZOO	227.3	13.7	22	0.0	134.5	0.0	16.7
23501	GRAND	758.0	96.0	9	5.8	401.7	0.0	2.4
24102	MUSKEGON	78.6	10.6	22	1.8	5.8	0.0	0.0
24202	WHITE	25.0	5.7	11	0.0	0.6	0.0	0.0
24206	PERE MARQUET	39.2	6.8	9	0.0	0.0	0.0	0.4
24301	LITTLE MANIS	1.6	0.3	3	0.0	0.0	0.0	0.0
24302	MANISTEE	51.6	5.6	21	0.0	0.0	0.0	20.8
24402	BETSIE	6.5	2.4	3	0.0	0.0	0.0	0.0
24406	BOARDMAN	5.2	0.8	6	2.3	0.0	0.0	0.0
24601	*MANISTIQUE	45.6	8.1	22	0.0	0.0	7.0	0.0
24801	ESCANABA	36.9	10.7	22	0.0	0.0	57.2	0.0

MUN - Municipal
IND - Industrial
UP - Upstream of a point 50 river kilometers (or major impoundments) from the river mouth
DN - Downstream of a point 50 river kilometers (or major impoundments) from the river mouth

Types of Diffuse Sources

The diffuse load consists of inputs such as rural runoff, urban runoff, combined sewer overflows, and base flow. In other words, the diffuse load consists of the load not attributable to identified point sources. Unfortunately, at this time it is not possible to accurately evaluate the relative magnitudes of these various diffuse load components. However, despite limited availability of information, some perspective can be given to the importance of the diffuse load components at this time. This will be discussed below.

Although urban runoff generally has been found to contribute slightly more total phosphorus than agricultural runoff on a unit area basis (the actual values of the unit area loading rates from agricultural and urban land varies widely between watersheds), the larger amount of rural land causes the rural or agricultural load to many watersheds to be dominant. In a study done by the Ontario Ministry of the Environment on the Canadian Grand River basin (Lake Erie) and the Saugeen River basin (Lake Huron) (Van Fleet, 1977), preliminary results indicate that urban runoff accounts for only one percent or less of the annual total phosphorus loads. Agriculture, on the other hand, was estimated to account for 70 percent or more of the total phosphorus loads. In a study of many watersheds and subwatersheds in Erie and Niagara Counties in the U. S. portion of the Lake Erie/Niagara River basin (Wendel Engineers, 1977), urban runoff contributions of suspended solids averaged about six percent of the total, while rural runoff averaged approximately 90 percent. Combined sewer overflows averaged less than one percent. Since total phosphorus loads would likely be correlated with suspended solids loads, rural runoff would likely represent a more significant source of total phosphorus for this area than would urban runoff.

The City of Rochester, New York, which is located near the mouth of the Genesee River, represents one of the major urban areas influencing water quality in Lake Ontario. In order to gain some perspective on the potential suspended solids load associated with the area, a version of U. S. EPA's Needs Estimation Model for Urban Runoff (NEMUR) (U. S. EPA, 1977), was used in conjunction with input from U. S. EPA Needs Survey data to generate an urban load associated with a 90th percentile storm (the magnitude of which is approximately 2 percent of the average annual rainfall). This load, which includes contributions from both urban runoff and combined sewer overflow, was estimated to be 567 metric tons of suspended solids. Assuming a ratio of 3 mg of total phosphorus per gram of suspended solids (a national average for urban runoff, U. S. EPA, 1974), a load of about 1.7 metric tons of total phosphorus is associated with the storm. This load is less than one percent of the 1975 diffuse total phosphorus load from the Genesee River. Consequently, although the above calculations are extremely crude, and it is difficult to extrapolate the effect of individual storms over an annual basis, it would appear that the urban runoff load from the Rochester area may be less than the annual load from other sources (e. g., rural runoff) in the Genesee River basin.

As previously mentioned, base flow and combined sewer overflow are also components of the overall diffuse load. Base flow, which is derived from ground water inputs, can represent a very large portion of the diffuse tributary load. This is particularly true for undeveloped regions with good drainage characteristics and minimal runoff, e. g., sandy soils. Combined stormwater overflows can be significant in certain densely populated areas such as Cleveland or Detroit. Although highly variable, combined sewer overflows often increase the total phosphorus load from large treatment plants by about 10 percent.

In summary, although current information is very limited, it would appear that rural runoff generally is the largest contributor to the total phosphorus diffuse load in many areas.

Control of Diffuse Sources

It appears that diffuse sources represent a large fraction of the total tributary load. Effective control of these sources will not be easily accomplished. However, for many tributaries it seems likely that approximately 30 to 50 percent of the diffuse load may be controlled through existing technology, i. e., improved conservation practices, specialized plowing techniques, and control of street litter. Furthermore, a large fraction of the total diffuse load may be attributable to a few specific "problem" areas. Treatment of these problem areas, as opposed to the whole basin, may lead to substantial reductions in the diffuse load at a relatively small cost.

In conclusion, control of diffuse sources will not likely be achieved rapidly. Socio-economic factors will undoubtedly have a major impact on the implementation of diffuse control procedures over the next 20 years. More information on diffuse source remedial measures is expected to be available in the near future as a result of ongoing PLUARG activities.

POINT SOURCE LOADS

A considerable effort was expended in determining point source loads delivered to tributaries draining into the Great Lakes. However, it must be remembered these estimates are still rather rough estimates, particularly the industrial point source estimates, due to the limited data available. In some cases, point source loads were estimated based on only a few concentration measurements a year (which may not necessarily have been representative measurements).

Municipal Versus Industrial Sources

Municipal loads were estimated based on actual, or in some cases, estimated concentration data (see Table 5). However, because actual flow data were available for almost all municipal point sources, it is felt that the municipal point source loads are reasonable estimates of true conditions. In terms of industrial sources, however, no attempt was made to estimate an effluent concentration when no field measurements were available. Consequently, the industrial load represents only the load from those sources identified as contributors of the parameter of concern, and thus may underestimate the true load. In particular, industrial inputs of nitrogen and chloride, which were given less emphasis in this study compared to phosphorus and suspended solids, may be an underestimate of the true industrial load. No industrial loads were given for Lake Erie in the Lake Erie Wastewater Management Study (U.S. Army Corps of Engineers, 1975).

Table 16 compares the summarized municipal and industrial contributions to U. S. Great Lakes tributaries. Based on these data, municipal sources contribute far more phosphorus than industrial sources. This is not unexpected, however, since only certain industrial operations are likely to discharge phosphorus in significant quantities. Municipal sources also appear to contribute more suspended solids than identified industrial sources. High industrial suspended solids inputs, such as found for parts of the Lake Superior drainage, are generally associated with mining operations. While suspended solid discharges can be high, the amount which reaches the Great Lakes may be low. Also, suspended solids discharged from municipal treatment plants may consist of a large percentage of volatile solids, which may be degraded before reaching the river mouth. Thus, the suspended solids measured in point source discharges may be physically different than that measured in tributaries. In future work it might be useful to distinguish between suspended sediment and suspended solids. Suspended sediments would be defined as that portion of the suspended solids consisting of soil particles. Consequently, although suspended solids point source discharge to tributaries may be high, the suspended sediment component may be low. The effect of these discharges on the Great Lakes is uncertain, especially relative to the suspended solids (or suspended sediment) derived from land runoff.

Table 16 also summarizes point source loads for nitrogen and soluble ortho phosphorus. Again, municipal inputs appear to be large compared to identified industrial point source inputs. As discussed previously, while it is believed that essentially all municipal plants with flow greater than 0.1 mgd (2.82×10^{-3} m^3/s) have been identified in the Great Lakes Basin, some industrial plants could have been neglected due to lack of available information. Nevertheless, it appears that for the parameters considered, identified industrial sources are of no major importance, with the possible exception of ammonia nitrogen. When considering other parameters, such as heavy metals or other toxic substances, industrial discharges could have a much more significant role.

Point source loads of chloride, including industrial inputs (Table 16), do appear to be a significant fraction of the total tributary chloride load. Large chloride inputs were identified for the Oswego River draining into Lake Ontario, the Mineral River draining into Lake Superior, and the Manistee River draining into Lake Michigan. Importantly, the Mineral River and Manistee River industrial inputs were not based on discharge monitoring data, but were determined by subtracting an estimated diffuse load (determined from appropriate annual diffuse unit area load rates) from the total load. As discussed earlier, the Mineral River chloride load is the result of discharge of brine from mining operations. The Manistee River receives inputs from industrial salt operations. The Oswego River

TABLE 16

1975 TOTAL TRIBUTARY POINT SOURCE LOADS (mt/yr) FROM MUNICIPAL (M) AND INDUSTRIAL (I) PLANTS

		Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario	St. Lawrence	TOTAL	TOTAL M+I
Total Phosphorus (TP)	M	102.1	1,090.8	493.6	1,683.5	900.3	90.0	4,360.3	4,811.3
	I	33.1	247.3	80.5	71.9	18.3	0	451.0	
Ortho Phosphorus (OP)	M	58.36	549.5	249.9	857.1	428.9	45.0	2,188.7	2,206.6
	I	0	17.9	0	0	0	0	17.9	
Suspended Solids (SS)	M	943.3	30,668.2	4,264.2	16,938.7	27,616.8	462.4	80,893.6	178,545.3
	I	46,716.6	13,255.6	7,263.8	6,092.3	24,323.3	0	97,651.6	
Total Nitrogen (TN)	M	456.0	9,005.0	2,643.2	9,002.3	6,020.0	266.3	27,392.8	31,502.7
	I	30.0	1,049.0	879.1	0	2,150.4	1.4	4,109.9	
Nitrate + Nitrite (NO_2-NO_3)	M	179.1	3,652.0	1,036.5	3,509.9	2,382.8	104.5	10,864.7	10,886.8
	I	0	22.1	0	0	0	0	22.1	
Ammonia (NH_3)	M	214.2	4,232.8	1,237.5	4,728.2	2,822.9	120.2	13,355.7	16,594.9
	I	30.0	650.6	406.8	0	2,150.4	1.4	3,239.2	
Chloride (Cl^-)	M	4,284.6	86,254.1	26,224.4	85,542.0	56,478.9	2,532.2	261,316.2	1,139,533.1
	I	32,788.8	193,990.2	100,729.9	0	550,698.0	0	878,206.9	

TABLE 16 (continued)

1976 TOTAL TRIBUTARY POINT SOURCE LOADS (mt/yr) FROM MUNICIPAL (M) AND INDUSTRIAL (I) PLANTS

		Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario	St. Lawrence
Total Phosphorus	M	107.24	598.1	269.4	-	874.4	90.0
(TP)	I	33.1	192.7	80.9	-	51.8	0
Ortho Phosphorus	M	58.46	491.4	143.02	-	420.15	27.11
(OP)	I	0	17.5	0	-	0	0
Suspended Solids	M	939.1	25,253.3	4,051.6	-	28,473.6	432.33
(SS)	I	48,558.0	12,182.0	7,313.3	-	23,904.8	0
Total Nitrogen	M	451.1	8,871.9	2,761.3	-	5,700.0	266.3
(TN)	I	30.0	1,049.0	879.1	-	2,150.4	1.4
Nitrate + Nitrite	M	177.2	3,692.3	1,082.8	-	2,351.7	104.5
(NO_2-NO_3)	I	0	22.1	0	-	0	0
Ammonia (NH_3)	M	211.9	4,173.1	1,296.2	-	2,785.7	125.05
	I	30.0	650.2	0	-	2,150.4	1.4
Chloride (Cl^-)	M	4,331.3	87,052.4	25,101.4	-	57,231.7	2,532.2
	I	32,788.8	114,829.3	97,729.9	-	510,779.2	0

chloride load is heavily influenced by a Solvay process plant located on Onodaga Lake. Onodaga Lake, which drains into the Oswego, has extremely high chloride concentrations, presumably the result of the industrial operations on or near the lake. The estimated point source chloride input to the Oswego River accounts for about one-third to one-half the total point source chloride load to the Great Lakes. Despite this high point source load, the total tributary load is higher than would be expected, indicating the point source chloride load may be underestimated. Natural ground water from areas rich in salt draining into tributaries may also contribute to the chloride load, but the contribution is likely small relative to point sources (Kramer, J., 1977).

Effect of Small Point Sources

It should also be mentioned that any municipal or industrial plants discharging less than 0.1 mgd (2.83×10^{-3} m^3/s) were not considered in the point source load estimate. Also, plants that had intermittent discharges to a river, such as many lagoon systems, were not included as part of the contributing point sources.

The relative effect of small point source operations (less than 0.1 mgd), particularly when situated in a developed area, would be small. However, it is possible that in certain undeveloped areas, point sources from many small industrial operations or municipal plants could collectively have a measurable impact. For example, the Door Peninsula of Wisconsin and the thumb area of Michigan both have many small packaging and dairy operations. These dischargers were not included in the point source loads, but which collectively could have a measurable, although probably minor, impact.

In order to get some idea of the effect of not including small discharges, the estimate of the Lake Erie tributary point source load calculated for this study considering only those point sources with a flow greater than 0.1 mgd (2.83×10^{-1} m^3/s) (and excluding intermittent point sources such as lagoons) were compared with point source loads calculated by the Lake Erie Wastewater Management Study (Corps of Engineers, 1975). In the Lake Erie Wastewater Management Study, an intensive survey was made of municipal point sources, which included many small municipal point sources, such as motels, service stations, supermarkets, shopping centers, camp grounds, small villages, mobile homes, schools, lagoons, and other extremely small point sources. Table 17 compares the point sources calculated for Lake Erie tributaries by the Lake Erie Wastewater Management Study with the results of this study. As can be seen, there is very little difference between the two estimates, indicating that exclusion of small point sources likely does not significantly affect the point source load. The fact that all point source loads calculated in this study were slightly higher than the Corps of Engineers estimate, despite the fact that some of the smaller point sources were excluded, is due primarily to differences in the gaged drainage areas considered as well as some differences in the point source data used.

TABLE 17

COMPARISON OF POINT SOURCE PHOSPHORUS INPUTS TO LAKE ERIE TRIBUTARIES COMPILED BY THE LAKE ERIE WASTEWATER MANAGEMENT STUDY[1] AND GLBC (THIS STUDY)

	1975 Point Source Load (metric tons/yr)	
	COE	U. S. Task D
Huron River	193	185
Raisin River	69	86
Maumee River	318	445
Portage River	40	36
Sandusky River	38	117
Huron River	44	44
Vermilion River	4	1
Black River	78	36
Rocky River	81	145
Cuyahoga River	385	279
Chagrin River	17	7
Grand River	13	1
Cattaraugus Creek	32	12
TOTAL	1312	1394

[1] Corps of Engineers (1975)

Effect of Reducing Municipal Loads

Table 18 summarizes the reductions in phosphorus loadings to be expected from various limitations of the phosphorus concentration in municipal plant effluents. This table assumes 100 percent delivery of point sources to the river mouth. Total tributary loads are 1976 load estimates, with the exception of the 1975 Lake Erie data. The reductions in total loads are based on current flow from municipal plants. However, if effluent flow increases due to population growth, the percent reduction over current conditions obtained by the effluent limitations could be less. Note that the effect of direct municipal inputs, which include some of the large coastal municipal plants (e. g., Detroit) are not included in Table 18.

It is clear from Table 18 that, given current flows from treatment plants, the percent reduction in the tributary total phosphorus loads to the Great Lakes that would be achieved by limiting phosphorus concentrations in municipal effluents to one milligram per liter is not particularly great (the load reduction could be significant to local stream segments, however). Further, reducing concentrations beyond one milligram per liter will not have a major effect on total loads. This is particularly true for Lake Superior and Lake Huron. More detailed information on costs projected for various phosphorus removal programs, as well as detergent control programs, may be found in McClarren (1977).

TABLE 18

U.S. TRIBUTARY TOTAL PHOSPHORUS LOADS ASSUMING DIFFERENT MUNICIPAL EFFLUENT PHOSPHORUS CONCENTRATIONS

LAKE	1976 TOTAL TRIBUTARY mt/yr.	TOTAL POINT LOAD mt/yr.	TOTAL TRIBUTARY LOAD (mt/yr) UNDER DIFFERENT MUNICIPAL EFFLUENT P LIMITATIONS (% REDUCTION IN TOTAL LOAD)		
			1.0 mg/ℓ	0.5 mg/ℓ	0.1 mg/ℓ
Superior	964	107	884(8)	870(10)	860(11)
Michigan	3,595	1,191	3,130(13)	2,864(20)	2,651(26)
Huron	1,954	350	1,849(5)	1,767(10)	1,701(13)
Erie (1975)	8,639	1,756	7,519(13)	7,237(16)	7,011(19)
Ontario (not including St. Lawrence River)	2,874	926	2,351(18)	2,175(24)	2,035(29)
St. Lawrence	639	90	565(12)	557(13)	551(14)

1. Assumes 100% delivery of point sources to the mouth.

FLOW/CONCENTRATION RELATIONSHIPS

The variability of man's influences as well as unpredictable changes in natural systems make it very difficult to characterize the impact that an individual river has on the Great Lakes for any given year. Most sampling programs are set up on a once or twice per month basis which in many cases is inadequate to characterize the trends for a particular water year. A number of the major variables that influence the load during any one year are discussed below.

Variability of Flow

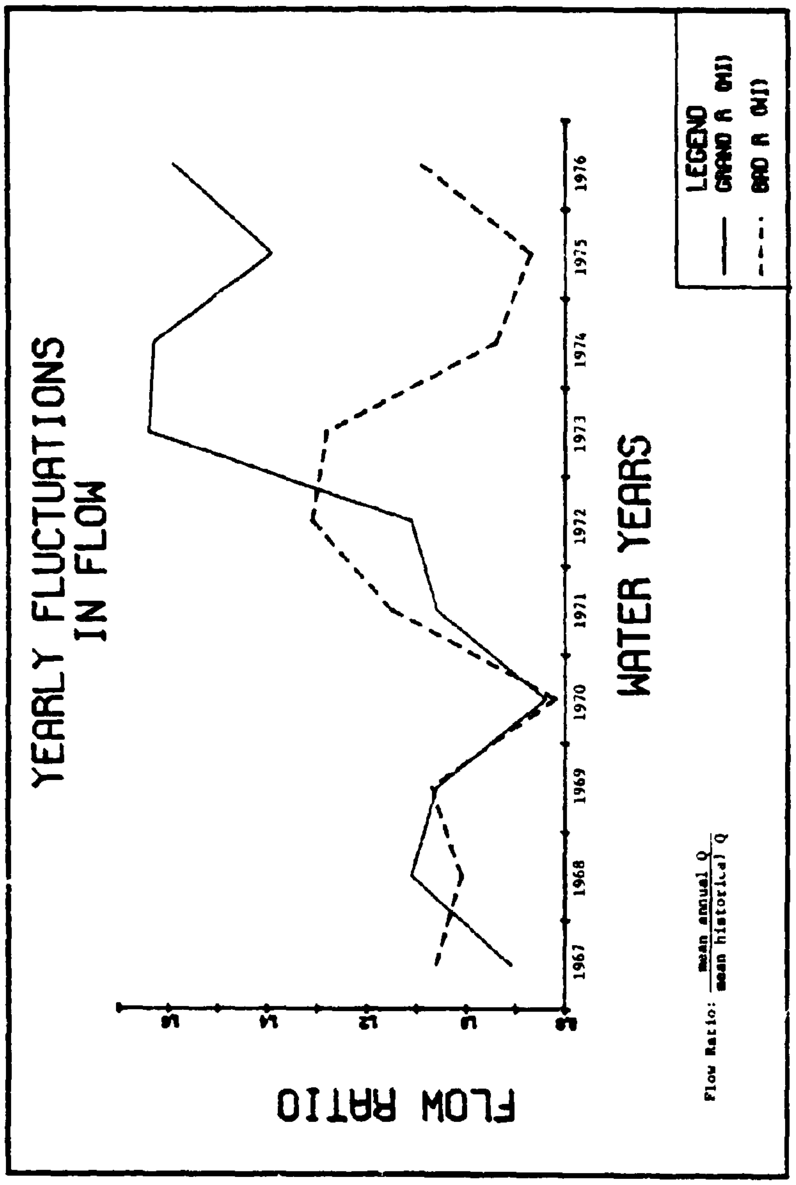
Many rivers undergo dramatic changes in flow over a period of hours during a storm runoff event. Changes also occur from month-to-month and year-to-year within a given basin depending upon precipitation and snow melt.

Since the Great Lakes Basin extends over a large geographical area, the climate may vary considerably within the basin during the same year. For example, within a given year one portion of the Great Lakes Basin can suffer from a drought while another can experience unusually heavy precipitation. Figure 1 compares the mean annual flows of two different rivers for water years 1967 through 1976. The mean annual flows have been divided by the mean historical flow for each river so that a direct comparison can be made of each flow ratio. As can be readily seen from Figure 1 , the Bad River and Grand River (draining into Lake Superior and Lake Michigan) respectively, can have similar or vastly different flow trends. Both of these rivers show a substantial rise in discharge between the years 1970 and 1974. During this period the flows are in general above the mean historic flow which is indicated by a flow ratio of 1.0. However, between 1973 and 1974 the Bad River decreased in flow, while the Grand River experienced a dramatic increase in mean annual flow.

In order to compare a load from a tributary from any given year with that from another year, the mean annual flow must be considered. Annual decreases in load can occur as a result of decreased flow, while no appreciable changes in water quality occur. For many rivers flow was greater during water year 1976 than in water year 1975, and in a number of instances there was an increase in load for the same period (see Table 7).

Perhaps a more important factor to consider in evaluating loads are the more short term fluctuations in flow. For example, a large portion of the total annual discharge can occur during a runoff event. Figure 2 presents the mean monthly variations in flow of the Grand River and the Nemadji River (draining into Lake Superior near the Bad River) during water year 1976. Discharge is higher for both rivers during the spring period of February through May. However, the pattern that evolves is much different for these two rivers. The Nemadji, judging by the monthly figures, may exhibit a relatively high flashy flow over a short period, while the Grand River has a more gradual flow change over a longer period. Characteristics of the watershed may greatly affect the flow patterns of individual rivers.

FIGURE 1


YEARLY FLUCTUATIONS IN FLOW
FLOW RATIO
WATER YEARS
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
LEGEND
GRAND R (WI)
BAD R (WI)
Flow Ratio: mean annual Q / mean historical Q

FLOW/CONCENTRATION RELATIONSHIPS

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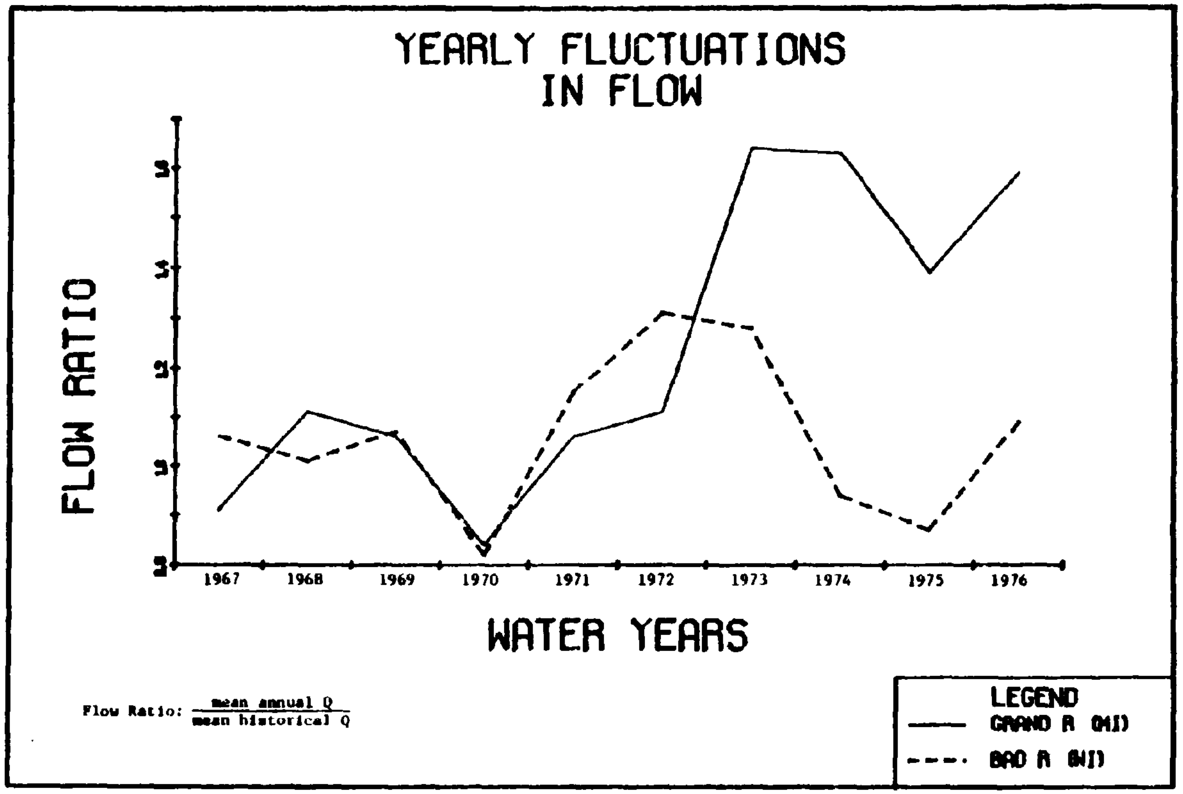
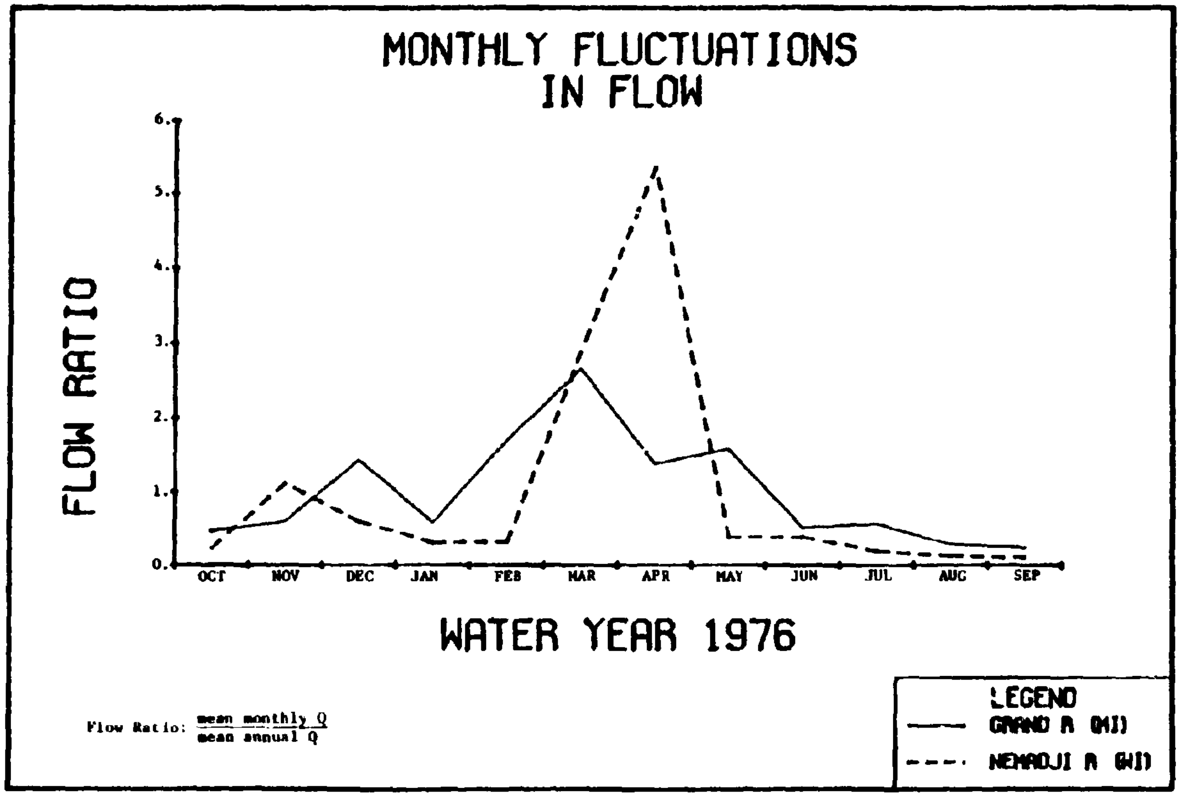

YEARLY FLUCTUATIONS
IN FLOW
FLOW RATIO
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
WATER YEARS
Flow Ratio: mean annual Q / mean historical Q
LEGEND
GRAND R (MI)
BAD R (WI)

FIGURE 2


MONTHLY FLUCTUATIONS
IN FLOW
FLOW RATIO
6.
5.
4.
3.
2.
1.
0.
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
WATER YEAR 1976
Flow Ratio: mean monthly Q / mean annual Q
LEGEND
GRAND R (MI)
NEMADJI R (WI)

Aside from monthly fluctuations, daily or even hourly fluctuations can be very important in many streams. A river that rises quickly can potentially transport more sediment than one that rises gradually, as velocities are often higher and overland runoff rates are usually greater. Individualities of stream discharge patterns must be remembered when comparing loading results.

<u>Variability of Concentration</u>

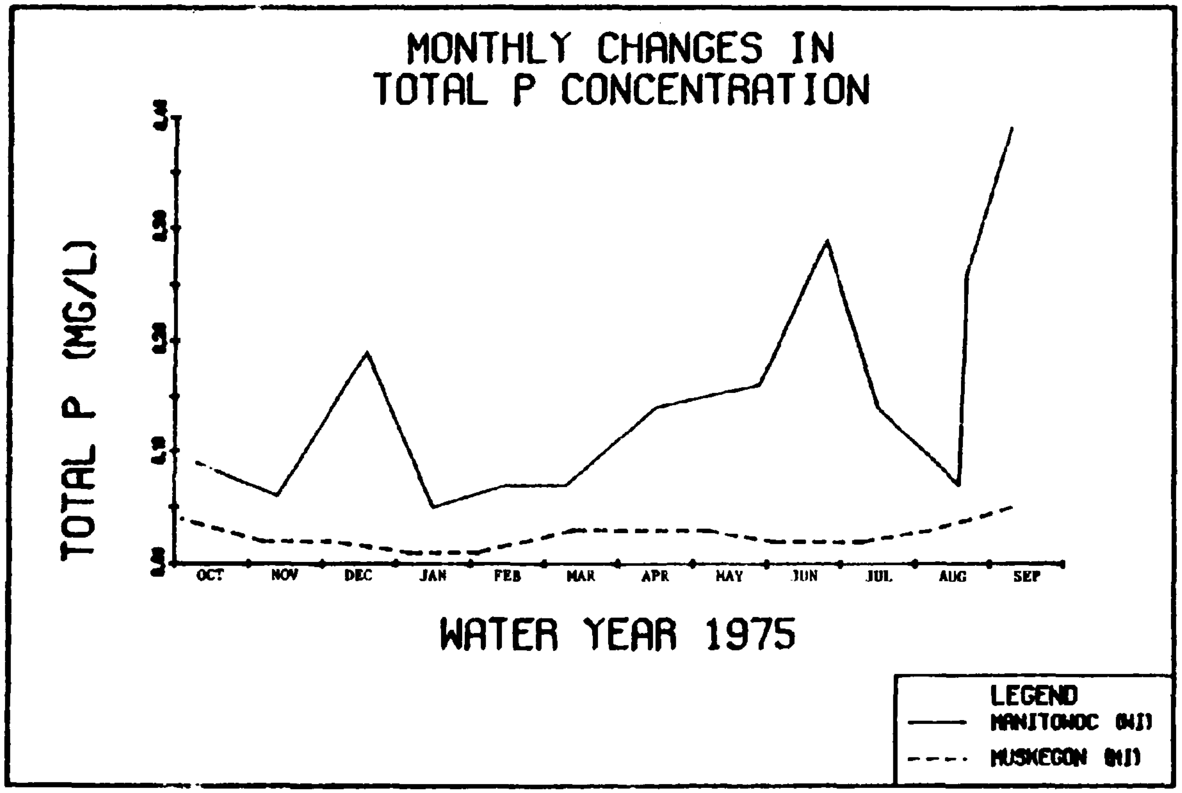
It is well known that concentrations of chemical constituents may vary with flow. The variance depends on the chemical constituent as well as on the particular hydrologic characteristics of the tributary. For example, total phosphorus concentrations may increase with flow, while total dissolved solids concentrations may decrease with flow. Similarly, the extent with which these constituents vary with flow are different for the Maumee River compared to the Grand River. Further, within a given tributary, the nature of the flow event may greatly affect the relationship between flow and concentration.

Based on the field data used in this study, it was obvious that for some tributaries throughout the Great Lakes Basin the concentration of certain parameters was flow dependent. Unfortunately, due to the relative lack of concentration data during periods of high flow (except for Lake Erie tributaries), information gained on flow-concentration relationships was limited.

Despite the scarcity of field data during periods of high flow, some significant observations can be made. Figure 3 compares the total phosphorus concentration measured in Wisconsin's Manitowoc River (which drains into Lake Michigan) and Michigan's Muskegon River (which also drains into Lake Michigan) during water year 1975. As can be readily seen from Figure 3, there are significant differences between the rivers not only in concentration values, but also in the change in concentration that occurs between any two data points. Total phosphorus concentrations in the Muskegon River were very stable, never exceeding 0.05 mg/ℓ P and never varying more than 0.02 mg/ℓ P between any two data points. Total phosphorus concentrations in the Manitowoc River, on the other hand, varied from 0.05 to 0.39 mg/ℓ P over the sampling period. Further, between August 18 and September 10 the total phosphorus concentration changed by over 0.3 mg/ℓ P.

There are many factors in addition to flow that may influence the variability in concentration observed in Figure 3. Point sources in a basin can discharge at various rates and at various times of the year. Canning and food processing plants, for example, may only discharge seasonally and some municipal operations, such as lagoons and spray irrigation facilities, may discharge slugs of treated waste periodically. Farming operations and the application of fertilizers and pesticides can also cause seasonal fluctuations in concentration. Street litter may also vary seasonally with seed and leave fall, which in turn affects the concentration of contaminants in urban runoff.

FIGURE 3


MONTHLY CHANGES IN
TOTAL P CONCENTRATION
TOTAL P (MG/L)
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
WATER YEAR 1975
LEGEND
MANITOWOC (WI)
MUSKEGON (MI)

Perhaps one of the most significant factors, however, is the soil texture and erodibility of that soil within a given basin. Overland runoff is more prevelant on clay soils than sandy soils, since sandy soils tend to have higher water infiltration rates. Referring back to the rivers in Figure 3, the Muskegon River drains a predominately sandy basin while the soils of the Manitowac tend to be more clayey. Consequently, the soil texture of the watersheds may explain, at least in part, the variability in total phosphorus concentration as noted in Figure 3. The soil conditions not only affect what is transported but the volume of water that actually moves over the basin on a unit area basis. The effect that soil texture has on a given basin will be discussed in more detail in a following section.

Variability of Loads

When you combine flow and concentration to get a load, you are combining the variable nature of those flows and concentrations. Because of the variability, the calculated mean daily loads can vary by orders of magnitude from one sampling day to another. For example, refer to Table 19, which lists daily suspended solids loading data for the Manitowoc River. While the mean annual flow for 1975 was substantially less than for 1976, the load for 1975 was over four times greater than for 1976. The primary reason for this difference is that in 1975 two samples were taken during very high flows. Suspended solids concentrations were also very high at these times. These two days accounted for 94 percent of the sum of the daily loads calculated for the 19 days sampled. In 1976 the highest flow encountered on a sampling day was only about half as great as the high flows encountered in 1975. Also, the corresponding suspended solids concentrations were relatively lower for the high flows in 1976 than they were for 1975. This example provides a good illustration of the difficulty that can be encountered in accurately characterizing the loads in streams from one year to the next, using a limited data base. It should be noted, however, that not all streams encountered in this study appear to be this difficult to characterize. Many rivers examined show a remarkable stability in concentration, as was indicated by the Musekgon River in Figure 3. Generally, those rivers draining sandy watersheds were more stable both in terms of flow and concentrations. It is important to realize that while the data in Table 19 indicates the importance of sampling the Manitowac River during high flows, it may not be necessary to sample all tributaries in the U. S. Great Lakes Basin in this fashion.

Tributary Response Variations

In an effort to determine any correlations of concentration with flow, linear regressions were run using total phosphorus and suspended solids data from several tributaries for which there was considerable data. Slopes and regression coefficients from these calculations are given in Table 20.

TABLE 19

MANITOWOC RIVER (WISCONSIN)
SUSPENDED SOLIDS LOADING DATA

	1975			1976	
LOAD kg/day	FLOW cfs(m^3/s)	CONCENTRATION mg/ℓ	LOAD kg/day	FLOW cfs(m^3/s)	CONCENTRATION mg/ℓ
9,343	67(1.90)	57	1,859	40(1.13)	19
250	34(0.96)	3	1,167	53(1.50)	9
8,592	439(12.43)	8	4,167	131(3.71)	13
916,144	2,370(67.12)	158	1,177	37(1.05)	13
485,253	2,110(59.76)	94	18,496	315(8.92)	24
5,683	101(2.86)	23	50,615	1,293(36.62)	16
1,468	40(1.13)	15	38,460	1,048(29.68)	15
506	69(1.95)	3	19,215	561(15.89)	14
5,152	162(4.59)	13	528	36(1.02)	6
3,083	90(2.55)	14	396	18(0.51)	9
1,057	36(1.02)	12			
778	53(1.50)	6			
15,575	1,061(30.05)	6			
3,205	131(3.71)	10			
5,064	207(5.86)	10			
1,431	65(1.84)	9			
440	18(0.51)	10			
8,769	28(0.79)	128			
23,634	345(9.77)	28			
MEAN 79,000	390(11.04)	32	14,000	350(9.91)	14

Mean Flow for Year 296 cfs (8.38) — Mean Flow for Year 368 cfs (10.42)

Estimated Load for Year 23,000 metric tons — Estimated Load for Year 5,200 metric tons

TABLE 20

LINEAR REGRESSION OF FLOW (cfs) vs CONCENTRATION (mg/l)

RIVER	TOTAL PHOSPHORUS		SUSPENDED SOLIDS	
	SLOPE (multiply by 10^{-3})	r^2	SLOPE (multiply by 10^{-3})	r^2
St. Louis	-0.001	0.01	2.2	0.79
Nemadji	0.052	0.48	188.1	0.68
Carp (L. Superior)	1.107	0.05	331.8	0.30
Fox	-0.005	0.05	1.3	0.07
Black (L. Michigan)	-0.157	0.16	10.6	0.08
Grand	-0.003	0.10	0.5	0.06
Saginaw	-0.002	0.07	4.0	0.70
Genesee	-0.001	0.01	56.6	0.48
Oswego	-0.003	0.10	0.9	0.10
Black (L. Ontario)	0.000	0.00	0.9	0.19
Maumee[1.]	0.029		11.1	
Portage[1.]	0.175		62.8	
Sandusky[1.]	0.038		32.2	
Huron[1.]	0.106		89.2	
Vermilion[1.]	0.040		108.2	
Black (L. Erie)[1.]	-0.028		46.0	
Cuyahoga[1.]	-0.011		145.2	
Chagrin[1.]	0.100		10.3	
Cattaraugus[1.]	0.043		444.0	

1. Slopes estimated from Lake Erie Wastewater Management Study (Corps. of Engineers, 1975) plots

The linear regression results presented in this table were computed with flow in cfs as the x variable and total phosphorus or suspended solids as the y variable. The slope of the line generated gives a general relationship between flow and concentration with the large positive slope showing a rise in concentration with a rise in flow, and the small or negative slope showing no change in concentration with an increase in flow or an actual decrease in concentration with larger flows.

The coefficient of linear correlation (r^2) between flow and concentration is a measure of the strength of the linear relationship between flow and concentration. The proportion of the variance of concentration explained by a linear regression on flow is indicated by r^2. If $r^2 = \pm 1$, there is a perfect linear relationship between flow and concentration; if $r^2 = 0$, there is no linear relationship. In Table 20 there is generally little linear relationship between flow and total phosphorus concentration, while there are some strong linear relationships between flow and suspended solids concentration.

Data used in this analysis were taken primarily from 1975 and 1976 water years. All regressions were run on at least 40 samples with some on as many as 365 samples. The Lake Erie data were taken from graphs presented in the Lake Erie Wastewater Management Study Report (Corps of Engineers, 1975). These slope values were approximated, thus no r^2 values could be obtained. While many of these coefficients do not indicate a high linear correlation between flow and concentration, general trends are evident. Figure 4 illustrates the general trend between flow and total phosphorus concentration for the Maumee River. As one can see, while the trend is toward increasing concentration with flow, there is considerable scatter in the data. Many streams (but not all) show this type of relationship between flow and concentration.

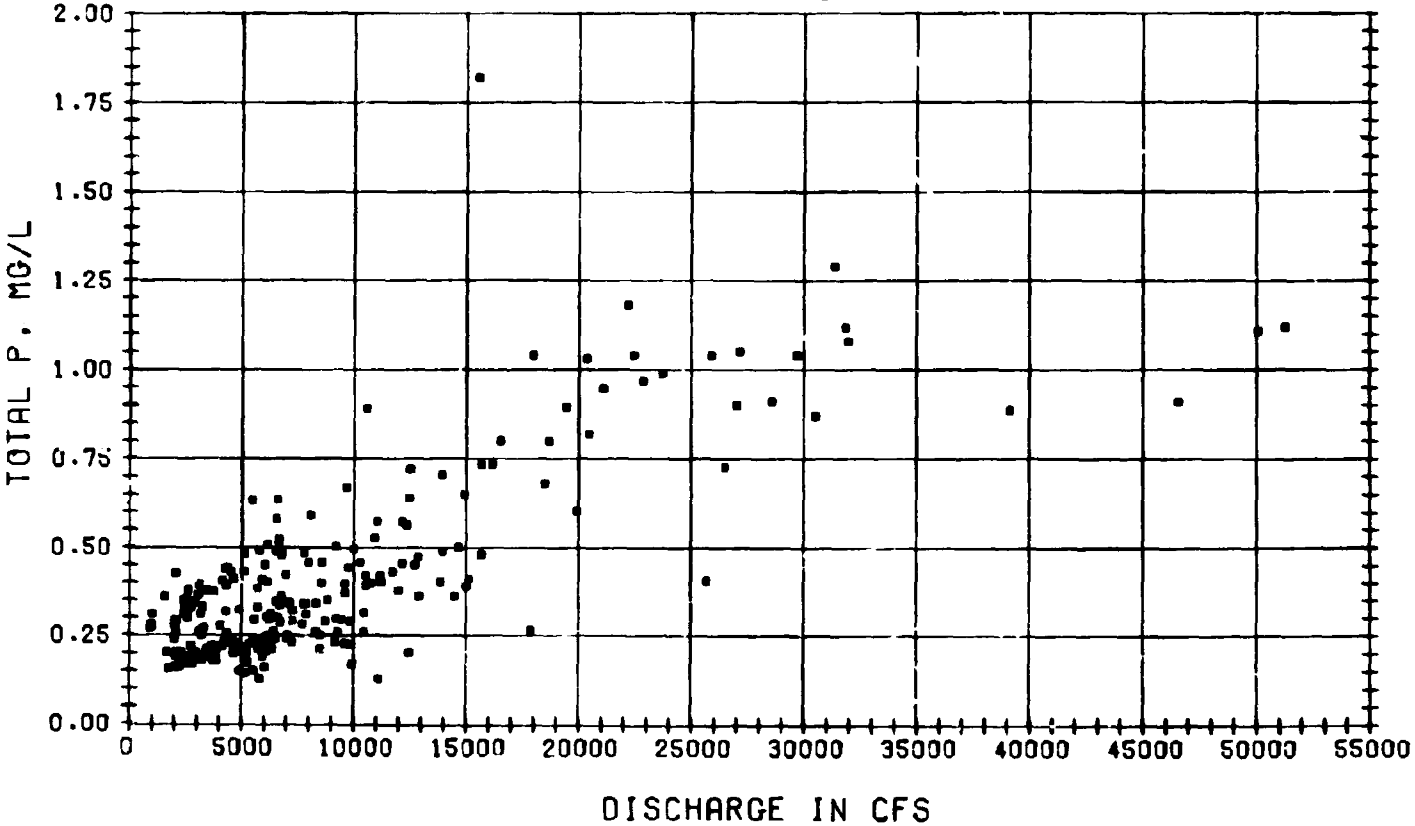
The slopes in Table 20 indicate a general pattern around the basin. Total phosphorus concentrations in the Maumee, Portage, Sandusky, Huron, Vermilion, Chagrin, Cattauragus, and Canadway tributaries, all from the Lake Erie basin, tend to increase with a rise in flow. The Carp River, draining into Lake Superior, also showed this same trend. However, the Ohio, Black, and Cuyahoga Rivers draining into Lake Erie, the Genesee, Black, and Oswego Rivers draining into Lake Ontario, and Grand and Fox Rivers draining into Lake Michigan, the trend was one of a slight decrease in total phosphorus concentration with flow. For these rivers it would appear that phosphorus concentrations are less variable and less correlated with flow or possibly that the sampling program, at least for some of the streams, was inadequate in terms of collecting representative high flow total phosphorus data.

Slopes of regressions of suspended solids concentrations versus flow are also given in Table 20. All the rivers in Table 20 show a general increase in suspended solids concentration with an increase in flow. The tributaries, however, fall into three distinct groups. The first group contains several of the tributaries flowing into Lake Erie, such as the Maumee River, as well as the Genesee in the Ontario Basin and the Nemadji in the Superior basin. The general trend for these streams is for suspended solids to increase with an increase in flow. The streams in the second group, which includes the Sandusky, Vermilion, Huron, Portage,

FIGURE 4

MAUMEE RIVER AT WATERVILLE, OHIO

(U. S. Army Corps of Engineers, 1975)



Black (Ohio), Saginaw, and Carp Rivers, also shows an upward trend in concentration as flows increase, although the slope of the increase is less than the first group. The third group contains streams that show a very slight to non-existent increase in concentration with increase in flow. These include the Fox, St. Louis, Oswego, Grand (Michigan), and two Black Rivers (one draining into Ontario, and the other into Lake Michigan at South Haven, Michigan).

Assuming the data are representative, it can be concluded that not all tributaries respond to runoff events in the same fashion. The loads from some tributaries, termed "stable response" tributaries, are not dominated by runoff events because the concentrations of many parameters such as total phosphorus and suspended solids, do not vary greatly with flow and the flow itself tends to be relatively stable (less flashy). The loads of other tributaries, termed "event response" tributaries, are greatly influenced by runoff events. Obviously, these are only two general classifications, and many individual variations do exist.

<u>Example of Stable Response Tributary - Grand River.</u> The Grand River, which was one of the tributaries where total phosphorus generally decreased with flow and suspended solids increased only slightly (Table 20), is of particular interest since it was sampled on a daily basis for over a year as part of Subactivity 2-2 of U. S. Task D. Consequently, the data available for the Grand is probably representative of actual conditions and interpretations of these data are not confused by data gaps.

Because of the fact that total phosphorus and suspended solids concentrations near the mouth of the Grand River varied relatively slightly with the flow, the (1976) loads calculated based on daily sampling would likely differ little from the load calculated using only monthly samples given adequate flow data. In order to verify this assertion, 1976 suspended solids and total phosphorus loads were calculated assuming the only data available were monthly samples taken on the first of the month (when the Grand River was usually sampled over the years). The load was then compared to the load based on daily sampling over a large part of the water year. Table 21 presents the results of the loads calculated based on these data sets. As can be seen the differences in the loads based on 10 samples and 212 samples was not large, especially with regard to total phosphorus. Consequently, for many purposes the load estimated from only a few samples per year may be satisfactory for a river such as the Grand, especially given the cost of daily versus monthly sampling.

There has also been very little change in suspended solids and total phosphorus concentrations over the years. Table 22 shows the average yearly concentrations measured for the Grand River beginning as early as 1963. This indicates the stability of this river in terms of concentration over the years. Significantly, average concentrations for 1976, whether based on monthly observations or a large data set, are also similar to the historical averages, again indicating the stability of the Grand River.

Example of Event Response Tributary - Nemadji River. Importantly, the Grand River is an example of a group of rivers that are not greatly affected by runoff events. An example of a river that undergoes more dramatic concentration/flow changes is the Nemadji River, which drains into western Lake Superior. A daily sediment station was established near the mouth of the Nemadji in 1973, so that a good suspended solids data base is obtainable for the last few years.

Table 23 contains a set of daily sediment data collected near the mouth of the Nemadji. The data show that during a 15-day period in June of 1975, concentrations and flows were extremely variable. Also, the concentration of suspended solids generally increased with flow. The computed daily sediment load also shown in Table 23 indicates the need to sample for chemical constituents at various representative flows if the annual loads are to be estimated for this tributary. The probability of not collecting representative samples if the sampling program consisted of one sample per month on the first of the month would be relatively high. Consequently, such limited data would lead to inaccurate estimate of the load.

Interestingly, the Grand River is one of the largest tributaries to the Great Lakes, while the Nemadji River is relatively small. In fact, the watershed of the Nemadji is less than 10 percent of the watershed area of the Grand River. Nevertheless, the estimated 1976 suspended solids load from the Nemadji, 71,000 metric tons, is almost 50 percent of the load estimated for the Grand River. On a unit area basis, the Nemadji watershed contributed 550 kg/ha-year, while the Grand River contributed only 98 kg/ha-year.

TABLE 21

GRAND RIVER TOTAL PHOSPHORUS AND SUSPENDED SOLIDS LOADS CALCULATED BASED ON DAILY SAMPLING AND A MONTHLY SUBSET OF THESE SAMPLES (DURING WATER YEAR 1976)

	Metric Tons/Yr	
	Total Phosphorus	Suspended Solids
All Samples (212)	840	150,000
Samples from First of Month Only (10)	710	102,000

TABLE 22

AVERAGE ANNUAL TOTAL PHOSPHORUS AND SUSPENDED SOLIDS CONCENTRATIONS MEASURED NEAR THE MOUTH OF THE GRAND RIVER SINCE 1963

WATER YEAR	AVERAGE SUSPENDED SOLIDS mg/1	NO. OF SAMPLES	AVERAGE TOTAL PHOSPHORUS mg/1 P	NO. OF SAMPLES
1963	26.3	12		
1964	22.1	15		
1965	31.1	8		
1966	18.4	18		
1967	18.3	7		
1968	15.0	17	.204	7
1969	18.5	13	.247	13
1970	16.2	12	.263	12
1971	14.5	10	.175	10
1972	17.6	12	.186	12
1973	21.1	7	.170	7
1974	17.2	8	.180	8
1975	16.4	7	.167	9
Weighted Average	19.2		0.204	

TABLE 23

NEMADJI RIVER (WISCONSIN)

SUSPENDED SOLIDS DATA

DATE	MEAN DISCHARGE cfs(m^3/s)	MEAN CONCENTRATION mg/l	SEDIMENT LOAD Metric Ton/Day
6/11/75	112(3.17)	15	4.1
6/12/75	772(21.86)	610	2,585
6/13/75	2,560(72.50)	1,070	7,220
6/14/75	1,330(37.67)	302	980
6/15/75	1,100(31.15)	722	2,304
6/16/75	1,520(43.05)	646	2,594
6/17/75	895(25.35)	145	329
6/18/75	650(18.41	94	151
6/19/75	536(15.18)	72	95
6/20/75	440(12.46)	63	67
6/21/75	617(17.47)	646	1,179
6/22/75	1,310(37.10)	801	2,703
6/23/75	803(22.74)	146	291
6/24/75	533(15.09)	101	133
6/25/75	407(11.53)	77	77

1975 Mean Daily Flow = 437 cfs (12.38 m^3/s)

Suspended Solids Load for 1975 = 154,000 Metric Tons (based on 365 samples)

Watershed Characteristics Versus Tributary Response

The reason for the difference in loading rates of the Grand River and the Nemadji is probably the result of many factors. However, as mentioned previously, one factor that stands out in importance is the soil texture of their basins. Figures 5 and 6 present the soil textures of River Basin Group 1.1 and 2.3 which contain the Grand River basin and the Nemadji basin, respectively. These figures show that the Grand River watershed is composed of sandy to loamy surface soils, while the Nemadji River watershed surface soils are predominately clay. The Nemadji River basin is part of the well known red clay area located in the western basin of Lake Superior.

Investigation of the soil texture characteristics reveal that, in general, those watersheds with surface soils that contain considerable amounts of clay-sized particles tend to contribute significantly higher loads per unit area of suspended solids and phosphorus than watersheds that have more coarse grained (sandy) soils. Also, water quality of the rivers draining sandy type soils is often much better than those rivers draining clay. Further, as discussed previously, streams draining clay soils appear to be more flashy in terms of the variability of concentrations with flow. Streams draining sandy soils are often less variable in terms of their chemical constituents and have flows which are more stable.

Lake Erie streams, at least western basin streams, are good examples of streams draining predominately clayey surface soils. Parts of the Lake Michigan basin (predominately the Wisconsin side) and parts of the Lake Superior basin also have high clay content and the rivers appear to act accordingly. Interestingly, the Superior basin has patches of clay soil interspersed with more sandy soils. This accounts for the fact, at least in part, that certain streams in this basin, despite the undeveloped status of the region, are often turbid in appearance and contribute relatively high suspended solids loads. Parts of the Lake Huron (thumb area) and Lake Ontario watersheds also have soils tending toward the clay side.

Sandy soils are prevelant in the Lake Michigan basin, particularly on the Michigan portion of the basin. Streams from these areas generally have good water quality.

Intuitively, it is not surprising that clayey soils produce higher loads of suspended solids and certain chemicals than sandy soils. As was discussed in detail in Monteith and Sonzogni (1977), clay soils generally have more pollutants associated with them due to the chemical and physical characteristics of clay particles. Also, once clay-sized particles get suspended, they are much less prone to settle out compared to larger-sized particles. Therefore, the likelihood of clay-sized particles being transported over the land to the river mouth is comparatively high. Also, in clay soils water is less likely to infiltrate compared to sandy soils, thus, there is a greater possibility for runoff to occur following a

SOIL TEXTURE
River Basin Group 1.1

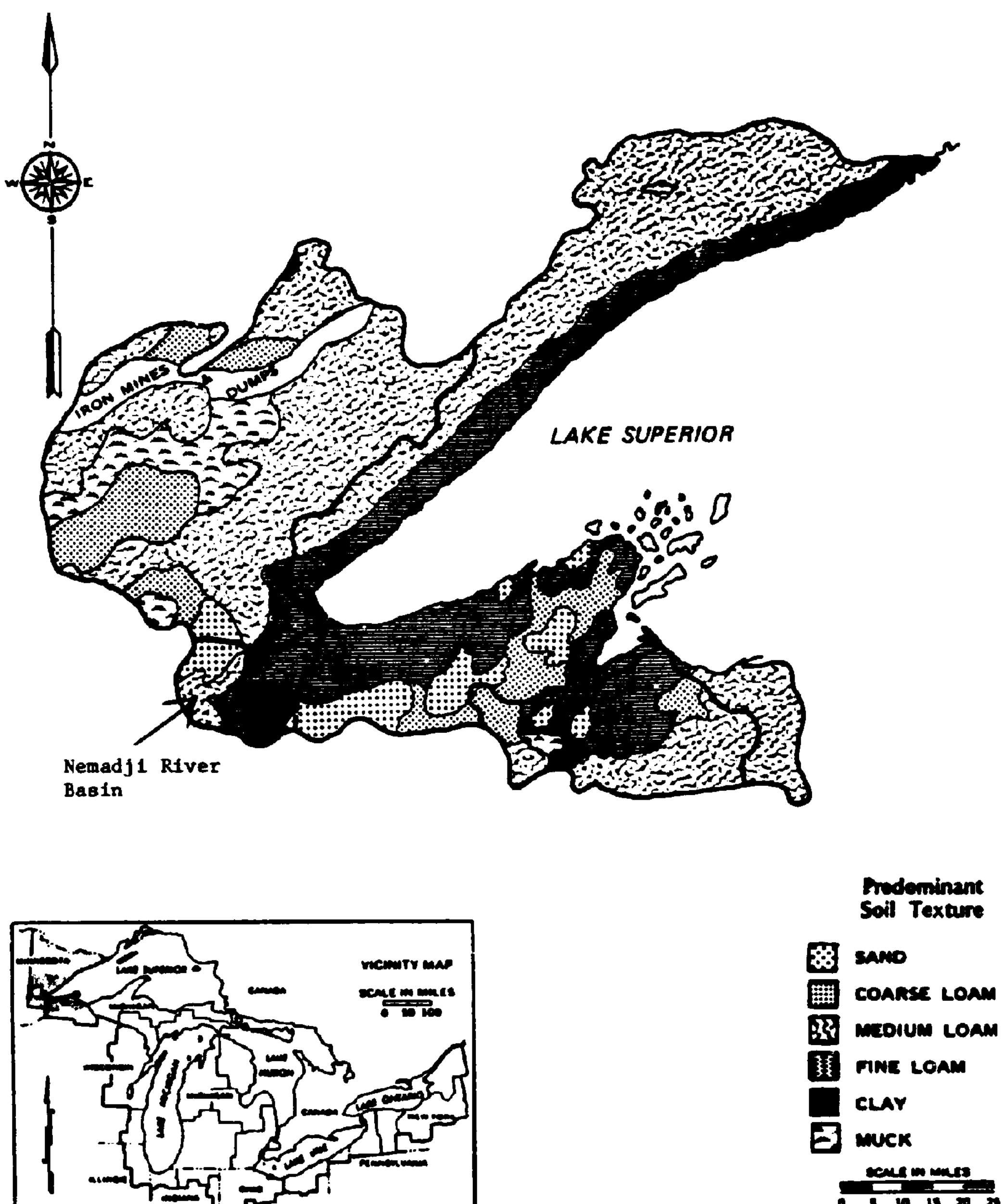
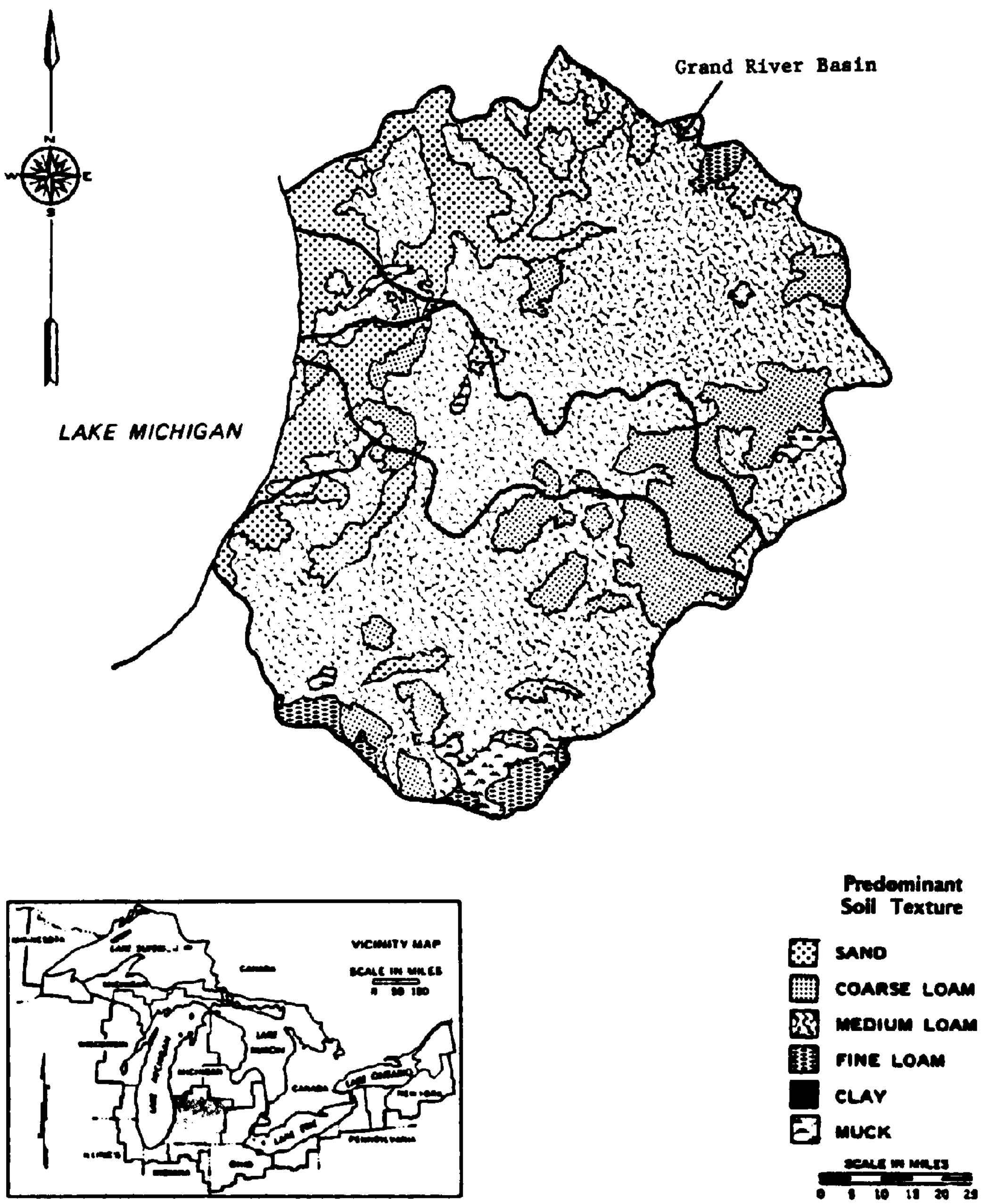


Figure 6

SOIL TEXTURE
River Basin Group 2.3



precipitation event in clay soils. Land cover or use, while certainly important and related to soil texture, is certainly not exclusively responsible for non-point source problems as may be implied by some investigators. For example, the Nemadji River watershed is heavily forested, yet produces relatively large unit area loads of suspended solids.

Soil maps showing the predominate texture of surface soils have been prepared for all U. S. river basin groups. These maps will be presented in the report on Subactivity 3-4 of the U. S. Task D, PLUARG. In addition, information as to the percent of the different soil textures in individual watersheds has been digitized, and the information has been computerized. An example of this type of information stored is given in Table 24 . Note that in addition to soil texture, information is available on other factors such as watershed area, flow (both current and the historical mean) and erodibility (K factor). It is intended that this data, along with loading information, also computerized, will be analyzed for statistical correlations and other relationships. The results of this analysis will also be reported as part of Subactivity 3-4 of U. S. Task D, PLUARG.

Recommended Sampling Strategy for Stable Response Versus Event Response Streams

It is clear that rivers behave in very different ways and that precipitation events can have substantially different impacts on the total river mouth loads. As a result of flow, concentration and load trends observed in this study, it is felt that for the purpose of calculating loads not every stream needs to be sampled routinely during runoff events. By examining watershed characteristics, including (but not limited to) surface soil textures, it is believed possible to predict whether an event response or stable response can be expected. Where possible, however, limited sampling during one or more runoff events, particularly during spring, would provide further and more definitive information on whether routine event sampling is necessary to characterize the annual load. The cost of event sampling is obviously prohibitive in many cases, but fairly precise sampling strategies can still be established at a minimal cost by interpreting existing data. For example, in the western half of the lower peninsula of Michigan, almost every stream examined behaves in a manner similar to that of the Grand River. This would indicate that these tributaries can be sampled on a monthly basis (as is currently the case) to obtain an adequate estimate of tributary loadings. In northwestern Ohio streams draining into Lake Erie are clearly event response streams and require extensive sampling to accurately characterize their loads, as the Lake Erie Wastewater Management Study (Corps of Engineers, 1975) has demonstrated.

On many streams in which concentration remains fairly stable, sampling over several years on a monthly basis may produce representative data which can be used to calculate loads for future years. In order to verify this point, the 1976 load of suspended solids was computed using the ratio estimator method (the mean annual flow based on continuous gaging was used to adjust the load) from 212 measurements of suspended solids and flow collected at daily intervals between March 1, 1976, and

Table 24

LAKE HURON
HYDROLOGIC AREA SUMMARY

SOIL DATA

#	NAME	AREA	SAND		COARSE LOAM		MEDIUM LOAM		FINE LOAM		CLAY		MUCK		ERODIBIL-ITY K	POTENTIAL CON-TRIBUTING AREA	
		KM2	HA	%	HA	%	HA	%	HA	%	HA	%	HA	%		HA	%
31100	LES CHENEAUX	3640.	109200.	30.	109200.	30.	36400.	10.	36400.	10.	72800.	20.	0.	0.	MED	145600.	40.
31203	CHEB YGAN	4090.	306750.	75.	12270.	3.	40900.	10.	0.	0.	8180.	2.	40900.	10.	LOW	4090.	1.
31300	PRESQUE ISLE	1450.	65250.	45.	43500.	30.	36250.	25.	0.	0.	0.	0.	0.	0.	MED	1450.	1.
31401	THUNDER BAY	3270.	245250.	75.	9810.	3.	49050.	15.	22890.	7.	0.	0.	0.	0.	LOW	3270.	1.
31500	AU SABLE-ALC	5760.	535680.	93.	0.	0.	28800.	5.	11520.	2.	0.	0.	0	0.	LOW	5760.	1.
31600	RIFLE-AUGRES	2870.	143500.	50.	0.	0.	100450.	35.	43050.	15.	0.	0.	0.	0.	MED	43050.	15.
32100	KAWKAWLIN CO	1000.	35000.	35.	0.	0.	25000.	25.	40000.	40.	0.	0.	0.	0.	HIGH	[illegible]	50.
32201	SAGINAW	16170.	727650.	45.	0.	0.	646800.	40.	242550.	15.	0.	0.	0.	0.	HIGH	[illegible]	30.
32300	THUMP COM	3670.	0.	0.	0.	0.	91750.	25.	275250.	75.	0.	0.	0.	0.	HIGH	367000.	100.
TOTAL	9	41920.	2168280.	52.	174780.	4.	1055400.	25.	671660.	16.	80980.	2.	40900.	1.		1105320.	26.

September 30, 1976, from the Grand River. This load was then compared to the load calculated using 143 monthly measurements of flow and concentration taken between 1963 and 1975, which were adjusted to the 1976 mean annual flow using the ratio estimator method. The load generated using the flow adjusted historical samples was 120,000 metric tons per year, or about 80 percent of the suspended solids load calculated using the 1976 data. This would indicate that for rivers such as the Grand, it might even be possible to estimate a load by adjusting historical concentration and flow data with the observed mean annual flow. In other words, for certain rivers a knowledge of the flow for a given year would be all that is necessary to calculate a reasonable estimate of the load, assuming no major changes occur in the characteristics of the watershed (e. g., land use) or point source inputs.

In conclusion, many streams require detailed and expensive sampling to characterize loads of certain parameters. However, it appears that all rivers need not necessarily be sampled in such a manner. Applying knowledge of watershed characteristics and careful interpretation of existing data could lead to a more limited and economical sampling program for many streams.

Critical Erosion Period

Generally greatest amounts of sediment and associated materials are eroded from the land when the surface is unvegetated, such as after plowing. The longer the soil remains unvegetated, the greater the possibility for extensive erosion. Fall plowing, then, would appear to provide a greater opportunity for erosion than plowing in the spring. However, erosion can occur even without plowing.

As discussed earlier, the Nemadji River, despite the fact its watershed is mostly forested, still contributes significant amounts of sediment. Apparently, in watersheds like the Nemadji with clayey soils, erosion can occur despite a vegetative cover. Some of this erosion may be attributable to streambank erosion as well as sheet and gully or overland erosion. Once clay soils are eroded and dispersed in water, they, in general, settle out very slowly. Consequently, when clay-sized sediment is suspended, it has a relatively high probability of being transported for considerable distances. Certainly, however, land use may affect the amount of material contributed from a clayey watershed, but it does not appear to be the dominant factor based on the admittedly limited data available.

Burwell et al. (1975) in a study of erosion of loam soils, considered three seasonal periods: (1) a critical runoff period during snowmelt, (2) a critical erosion period between the spring melt and two months after a crop cover was established, and (3) a noncritical erosion period. They concluded that much of the annual sediment and total nutrient losses occurred during the critical erosion period (2). Snowmelt, however, accounted for much of the water loss as well as the soluble nutrient losses. This pattern likely holds for much of the Great Lakes Basin's agricultural land. Should fall plowing occur, the critical erosion period probably extends to the fall between the time it is plowed and when the ground becomes snow covered or frozen.

In a study of phosphorus and nitrogen losses from disposal of dairy manure during winter (Klausner *et al.*, 1976), it was found that manure applied to the land during active thaw periods can result in increased nutrient losses. By applying manure over the winter so it was covered by snow which melted at a later date, nutrient losses were minimized.

The above examples indicate that critical periods exist which can affect the erosion and loss of materials from the watershed. Tributaries, at least at the river mouth, are the integrated effect of many different factors and activities in the watershed. More research and information is needed on these factors and activities to effectively and economically manage watersheds to minimize loads of pollutants to the Great Lakes.

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APPENDIX A

INDIVIDUAL TRIBUTARY
RIVER MOUTH LOADING DATA

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TOTAL PHOSPHORUS 1975

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
1	OSWEGATCHIE	ONTA	3	125.5	685.8	9
2	GRASS	ONTA	3	47.3	35.6	8
3	RAQUETTE	ONTA	3	35.9	36.9	9
4	ST REGIS	ONTA	3	20.2	3.3	12
5	GENESEE	ONTA	1	529.8	4281.8	30
6	OSWEGO	ONTA	2	510.8	1006.9	17
7	BLACK NY	ONTA	3	153.8	561.8	20
8	MAUMEE	ERIE	2	2628.0	5329.0	262
9	PORTAGE	ERIE	2	154.0	9.0	281
10	SANDUSKY	ERIE	2	595.0	361.0	277
11	HURON	ERIE	2	136.0	25.0	399
12	VERMILION	ERIE	2	84.0	169.0	43
13	BLACK	ERIE	3	351.0	256.0	42
14	CUYAHOGA	ERIE	3	788.0	3249.0	45
15	CHAGRIN	ERIE	3	144.0	100.0	41
16	CATTARAGUS	ERIE	4	185.0	225.0	41
17	HURON	ERIE	1	253.0	3249.0	12
18	RAISIN	ERIE	1	279.0	25.0	12
19	ROCKY	ERIE	3	313.0	8281.0	12
20	GRAND	ERIE	3	332.0	64.0	12
21	ASHTABULA	ERIE	3	69.0	1.0	12
22	CONNEAUT	ERIE	3	104.0	4.0	12
23	BLACK MICH	ERIE	1	46.4	59.9	8
24	ROUGE	ERIE	1	199.8	591.6	5
25	BELLE	ERIE	1	22.6	5.0	10
26	CLINTON	ERIE	1	256.0	796.7	8
27	ST LOUIS	SUPE	1	257.6	1135.2	15
28	BAD	SUPE	1	156.0	7230.9	13
29	MONTREAL	SUPE	1	27.2	8.1	14
30	BOIS BRULE	SUPE	1	17.1	25.4	13
31	NEMADJI	SUPE	1	124.3	3175.3	12
32	BAPTISM	SUPE	1	10.4	278.7	12
33	PIGEON	SUPE	1	65.0	289.0	31
34	BRULE	SUPE	1	10.0	4.0	31
35	CASCADE	SUPE	1	5.0	4.0	31
36	TEMPERANCE	SUPE	1	6.0	1.0	31
37	CROSS	SUPE	1	4.0	1.0	30
38	MANITOU	SUPE	1	4.0	1.0	31
39	BEAVER	SUPE	1	7.0	4.0	31
40	SPLIT ROCK	SUPE	1	4.0	4.0	31
41	KNIFE	SUPE	1	6.0	4.0	31
42	LESTER	SUPE	1	5.0	4.0	31
43	FRENCH	SUPE	1	1.0	1.0	31
44	GOOSEBERRY	SUPE	1	5.0	4.0	31
45	POPLAR	SUPE	1	8.0	4.0	31
46	SUCKER	SUPE	1	3.0	1.0	31
47	TAHQUAMENON	SUPE	2	12.5	6.7	27
48	ONTONAGON	SUPE	2	158.1	7573.7	27

TOTAL PHOSPHORUS 1975

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
49	CARP	SUPE	2	34.3	75.2	15
50	BLACK G	SUPE	2	6.7	2.6	12
51	PRESQUE ISLE	SUPE	2	4.7	1.3	15
52	STURGEON	SUPE	2	18.5	25.7	15
53	IRON	SUPE	2	5.0	4.0	30
54	MINERAL	SUPE	2	4.0	1.0	26
55	FALLS	SUPE	2	1.0	1.0	30
56	SILVER	SUPE	2	1.0	1.0	30
57	DEAD	SUPE	2	2.0	1.0	30
58	CHOCOLAY	SUPE	2	9.0	4.0	30
59	TWO-HEARTED	SUPE	2	2.0	1.0	28
60	BETSY	SUPE	2	1.0	1.0	29
61	WAISKA	SUPE	2	10.0	9.0	52
62	AU GRES	HURO	1	9.0	14.4	12
63	RIFLE	HURO	1	19.0	13.6	15
64	MPINE	HURO	1	18.2	17.4	15
65	THUNDER BAY	HURO	1	32.7	134.6	15
66	AU SABLE	HURO	1	29.8	10.9	14
67	TAWAS	HURO	1	7.0	1.0	29
68	WHITNEY DRN	HURO	1	9.0	25.0	28
69	AFINE	HURO	1	10.0	9.0	30
70	CHEBOYGAN	HURO	1	29.2	38.0	19
71	GREENE CR	HURO	1	0.1	0.0	11
72	TROUT	HURO	1	0.3	0.0	11
73	MULLIGAN	HURO	1	0.1	0.0	11
74	OCQUEOC	HURO	1	1.8	0.0	11
75	SCHMIDTS CR	HURO	1	0.1	0.0	11
76	CARP CR	HURO	1	0.1	0.0	11
77	PINCONNING	HURO	2	3.0	1.0	30
78	SAGINAW	HURO	2	1189.9	4275.0	50
79	KAWKAWLIN	HURO	2	17.6	12.6	45
80	PIGEON	HURO	2	33.0	576.0	29
81	PINNEBOG	HURO	2	15.0	25.0	30
82	SEBEWAING	HURO	2	36.0	900.0	30
83	WILLOW	HURO	2	4.0	1.0	27
84	FORD	MICH	1	4.7	0.1	18
85	MENOMINEE	MICH	1	86.5	56.3	12
86	PESHTIGO	MICH	1	59.4	107.6	12
87	OCONTO	MICH	1	50.6	101.3	12
88	PENSAUKEE	MICH	1	15.5	36.0	12
89	FOX	MICH	1	499.6	3784.9	12
90	KEWAUNEE	MICH	1	19.7	3.0	12
91	EAST TWIN	MICH	1	8.9	0.4	12
92	WEST TWIN	MICH	1	15.2	1.6	12
93	MANITOWOC	MICH	1	42.6	48.7	13
94	SHEBOYGAN	MICH	1	60.1	113.6	12
95	MILWAUKEE	MICH	2	109.2	1016.0	6
96	MENOMONEE	MICH	2	35.6	21.0	48

TOTAL PHOSPHORUS 1975

		TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
:	97	ROOT	MICH	2	20.1	4.4	6
:	98	ST JOSEPH	MICH	3	446.1	3135.8	8
:	99	KALAMAZOO	MICH	3	227.3	187.3	22
:	100	GRAND	MICH	3	758.0	9220.3	9
:	101	BLACK SHAVE	MICH	3	109.5	1125.5	3
:	102	WHITE	MICH	4	25.0	33.0	11
:	103	PERE MARQUET	MICH	4	39.2	45.6	9
:	104	BOARDMAN	MICH	4	5.2	0.6	6
:	105	MANISTEE	MICH	4	51.6	30.9	21
:	106	*MANISTIQUE	MICH	4	45.6	65.9	22
:	107	LITTLE MANIS	MICH	4	1.6	0.1	3
:	108	BETSIE	MICH	4	6.5	5.6	3
:	109	MUSKEGON	MICH	4	78.6	112.6	22
:	110	ESCANABA	MICH	4	36.9	114.6	22
:							

TOTAL PHOSPHORUS 1976

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
1	OSWEGATCHIE	ONTA	3	294.5	2050.9	9
2	GRASS	ONTA	3	123.9	450.3	9
3	RAQUETTE	ONTA	3	112.4	1486.7	9
4	GENESEE	ONTA	1	719.2	13814.4	25
5	OSWEGO	ONTA	2	919.0	46354.8	13
6	BLACK NY	ONTA	3	410.9	5164.3	10
7	ONTONAGON	SUPE	2	100.0	210.8	24
8	TAQUAMENON	SUPE	2	19.9	1.3	24
9	ST LOUIS	SUPE	1	123.0	129.4	20
10	BOIS BRULE	SUPE	1	9.2	2.7	3
11	BAPTISM	SUPE	1	5.0	0.7	5
12	MONTREAL	SUPE	1	18.6	15.5	15
13	CARP	SUPE	2	49.1	143.0	12
14	PRESQUE ISLE	SUPE	2	8.0	22.6	12
15	STURGEON	SUPE	2	39.0	462.5	12
16	BAD	SUPE	1	52.2	68.2	15
17	NEMADJI	SUPE	1	85.8	1204.6	15
18	CHEBOYGAN	HURO	1	23.0	10.0	24
19	RIFLE	HURO	1	15.7	2.9	24
20	THUNDER BAY	HURO	1	15.4	1.0	12
21	AU SABLE	HURO	1	36.2	14.6	12
22	VAN ETTEN CR	HURO	1	6.6	3.4	12
23	AU GRES	HURO	1	8.2	3.4	11
24	PINE	HURO	1	21.9	101.6	11
25	PINNEBOG	HURO	2	35.8	212.3	12
26	SAGINAW	HURO	2	1428.9	23168.8	33
27	GREENE CR	HURO	1	0.2	0.0	43
28	TROUT	HURO	1	0.9	0.0	42
29	CARP	HURO	1	0.4	0.0	41
30	MULLIGAN CR	HURO	1	0.3	0.0	43
31	OCQUEOC	HURO	1	4.6	2.3	42
32	SCHMIDTS CR	HURO	1	0.2	0.0	40
33	FORD	MICH	1	15.4	23.7	23
34	MENOMINEE	MICH	1	73.1	20.6	24
35	EAST TWIN	MICH	1	11.9	0.4	12
36	KEWAUNEE	MICH	1	9.7	0.3	12
37	FOX	MICH	1	520.6	7894.2	12
38	PENSAUKEE	MICH	1	32.2	64.0	9
39	PESHTIGO	MICH	1	39.4	85.6	12
40	OCONTO	MICH	1	57.0	148.6	12
41	SHEBOYGAN	MICH	1	47.9	42.6	12
42	MANITOWOC	MICH	1	46.6	58.1	11
43	MILWAUKEE	MICH	2	69.3	67.9	12
44	MENOMONEE	MICH	2	29.6	1.0	163
45	ROOT	MICH	2	35.6	41.3	6
46	BURNS DITCH	MICH	2	151.2	3588.7	11
47	TRAIL CREEK	MICH	2	15.1	27.2	8
48	ST JOSEPH RI	MICH	3	488.9	4159.9	11

TOTAL PHOSPHORUS 1976

		TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
:	49	KALAMAZOO	MICH	3	226.1	289.7	23
:	50	MUSKEGON	MICH	4	100.4	34.3	23
:	51	MANISTEE	MICH	4	56.3	26.1	24
:	52	*MANISTIQUE	MICH	4	50.8	14.6	24
:	53	ESCANABA	MICH	4	32.2	58.7	24
:	54	GRAND	MICH	3	841.0	625.0	212
:	55	WHITE	MICH	4	23.7	8.6	12
:	56	PERE MARQUET	MICH	4	67.5	172.2	12
:	57	BETSIE	MICH	4	5.5	0.8	12
:	58	BOARDMAN	MICH	4	6.4	3.6	12
:	59	WHITEFISH	MICH	4	3.6	0.2	12

SUSPENDED SOLIDS 1975

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
1	OSWEGO	ONTA	2	105612.4	81792368.0	16
2	BLACK NY	ONTA	3	73393.7	532197632.0	23
3	OSWEGATCHIE	ONTA	3	43962.6	396244480.0	9
4	GRASS	ONTA	3	8583.4	3447278.0	8
5	RAQUETTE	ONTA	3	6824.5	2524028.0	9
6	ST REGIS	ONTA	3	6102.0	2354574.0	12
7	GENESEE	ONTA	1	544823.0	3040279040.0	183
8	FORD	MICH	1	2501.9	226213.8	22
9	MENOMINEE	MICH	1	12684.4	4501624.0	9
10	PESHTIGO	MICH	1	3911.6	285778.4	12
11	OCONTO	MICH	1	7324.8	2171340.0	11
12	PENSAUKEE	MICH	1	9287.1	65144496.0	24
13	FOX	MICH	1	60078.6	79819280.0	23
14	KEWAUNEE	MICH	1	5033.8	1176637.0	23
15	E TWIN	MICH	1	6418.1	3551395.0	22
16	MANITOWOC	MICH	1	23325.6	118421824.0	19
17	SHEBOYGAN	MICH	1	6422.6	1927074.0	12
18	MILWAUKEE	MICH	2	22046.4	40959440.0	24
19	MENOMONEE	MICH	2	15516.0	1.0	273
20	ROOT	MICH	2	12698.9	71983088.0	19
21	ST JOSEPH	MICH	3	82440.7	386562560.0	8
22	BLACK SHAVEN	MICH	3	2846.4	207947.6	3
23	KALAMAZOO	MICH	3	27303.9	10947752.0	22
24	GRAND	MICH	3	76557.3	98265696.0	7
25	MUSKEGON	MICH	4	39655.9	55361616.0	22
26	LITTLE MANIS	MICH	4	1530.5	113357.9	3
27	MANISTEE	MICH	4	18766.1	4841869.0	20
28	BETSIE	MICH	4	3128.5	4152027.0	3
29	BOARDMAN	MICH	4	1583.9	339008.8	6
30	*MANISTIQUE	MICH	4	12511.8	1265363.0	23
31	ESCANABA	MICH	4	4086.8	226662.2	23
32	AU GRES	HURO	1	6624.4	21814480.0	12
33	AU SABLE	HURO	1	11249.1	4514902.0	14
34	VAN ETTEN CR	HURO	1	1197.0	48841.0	26
35	CHEBOYGAN	HURO	1	6868.7	1986628.0	25
36	OCQUEOC	HURO	1	2216.0	833569.0	30
37	MPINE	HURO	1	42831.3	357356288.0	15
38	RIFLE	HURO	1	11818.2	20546704.0	15
39	TAWAS	HURO	1	912.0	32041.0	29
40	THUNDER BAY	HURO	1	6017.3	920254.7	15
41	WHITNEY DRN	HURO	1	6680.0	16112196.0	28
42	APINE	HURO	1	1292.0	508369.0	30
43	PINCONNING	HURO	2	226.0	10201.0	30
44	KAWKAWLIN	HURO	2	2016.3	818777.7	29
45	SAGINAW	HURO	2	121022.8	138531056.0	37
46	PIGEON	HURO	2	14746.0	153859216.0	29
47	PINNEBOG	HURO	2	2135.0	537289.0	30
48	SEBEWAING	HURO	2	20476.0	353139200.0	30

SUSPENDED SOLIDS 1975

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
49	WILLOW	HURO	2	821.0	101761.0	27
50	ONTONAGON	SUPE	2	578559.4	107476353024.0	4
51	TAHQUAMENON	SUPE	2	7425.0	5516052.0	25
52	CARP	SUPE	2	3188.1	5488907.0	15
53	PRESQUE ISLE	SUPE	2	3293.1	3621554.0	15
54	STURGEON	SUPE	2	20455.9	41498192.0	6
55	IRON	SUPE	2	9746.0	25654224.0	30
56	MINERAL	SUPE	2	12264.0	80066704.0	26
57	BLACK G	SUPE	2	3879.6	3140850.0	12
58	FALLS	SUPE	2	438.0	18225.0	30
59	SILVER	SUPE	2	602.0	72361.0	30
60	DEAD	SUPE	2	898.0	72361.0	30
61	CHOCOLAY	SUPE	2	1285.0	98596.0	30
62	TWO-HEARTED	SUPE	2	1763.0	276676.0	28
63	BETSY	SUPE	2	726.0	24649.0	29
64	WAISKA	SUPE	2	8220.0	11758041.0	52
65	MONTREAL	SUPE	1	4708.0	3196944.0	24
66	ST LOUIS	SUPE	1	69564.9	125412176.0	22
67	BAD	SUPE	1	101145.5	258014192.0	10
68	BOIS BRULE	SUPE	1	4684.4	1447500.0	76
69	NEMADJI	SUPE	1	154323.0	1.0	365
70	PIGEON	SUPE	1	19126.0	72624480.0	31
71	BRULE	SUPE	1	1194.0	285156.0	31
72	CASCADE	SUPE	1	1237.0	266256.0	31
73	TEMPERANCE	SUPE	1	1208.0	229441.0	31
74	CROSS	SUPE	1	518.0	24336.0	30
75	MANITOU	SUPE	1	610.0	46225.0	31
76	BAPTISM	SUPE	1	906.7	30697.8	21
77	BEAVER	SUPE	1	1329.0	291600.0	31
78	SPLIT ROCK	SUPE	1	573.0	54289.0	31
79	KNIFE	SUPE	1	1657.0	986049.0	31
80	LESTER	SUPE	1	2238.0	1669264.0	31
81	FRENCH	SUPE	1	254.0	14641.0	21
82	GOOSEBERRY	SUPE	1	1836.0	1155625.0	31
83	POPLAR	SUPE	1	1599.0	339889.0	31
84	SUCKER	SUPE	1	478.0	55696.0	31
85	MAUMEE	ERIE	2	1435696.0	1680999936.0	262
86	PORTAGE	ERIE	2	66000.0	28090000.0	281
87	SANDUSKY	ERIE	2	321840.0	249640000.0	277
88	HURON	ERIE	2	78707.0	26010000.0	399
89	VERMILION	ERIE	2	102592.0	510759936.0	43
90	BLACK	ERIE	3	239904.0	118810000.0	42
91	CUYAHOGA	ERIE	3	631281.0	11024998400.0	45
92	CHAGRIN	ERIE	3	246132.0	4147360000.0	41
93	CATTARAGUS	ERIE	4	684180.0	8537759744.0	41
94	BLACK MICH	ERIE	1	15616.7	36342144.0	8
95	ROUGE	ERIE	1	16650.0	26339264.0	5
96	HURON	ERIE	1	23255.6	31996336.0	7

SUSPENDED SOLIDS 1976

		TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
:	1	OSWEGO	ONTA	2	140524.0	240267680.0	13
:	2	BLACK NY	ONTA	3	41085.8	41882928.0	10
:	3	OSWEGATCHIE	ONTA	3	19624.7	13576520.0	9
:	4	GRASS	ONTA	3	5407.7	389327.8	9
:	5	RAQUETTE	ONTA	3	8631.0	1571103.0	9
:	6	GENESEE	ONTA	1	1056506.0	1.0	366
:	7	FORD	MICH	1	7526.1	2911374.0	18
:	8	MENOMINEE	MICH	1	16210.2	4457253.0	12
:	9	PESHTIGO	MICH	1	5989.4	533105.7	10
:	10	OCONTO	MICH	1	10394.4	12265794.0	12
:	11	PENSAUKEE	MICH	1	18320.0	33782416.0	8
:	12	FOX	MICH	1	103360.0	5511121984.0	19
:	13	KEWAUNEE	MICH	1	1413.2	36330.1	11
:	14	E TWIN	MICH	1	1721.6	16534.2	12
:	15	MANITOWOC	MICH	1	5169.8	92249.1	10
:	16	SHEBOYGAN	MICH	1	4796.4	1414157.0	12
:	17	MILWAUKEE	MICH	2	11116.7	7357446.0	11
:	18	MENOMONEE	MICH	2	12238.4	1.0	163
:	19	ROOT	MICH	2	9239.4	6739663.0	6
:	20	ST JOSEPH	MICH	3	113285.4	211897824.0	11
:	21	KALAMAZOO	MICH	3	37091.7	34153840.0	23
:	22	GRAND	MICH	3	148666.9	43863600.0	212
:	23	MUSKEGON	MICH	4	61280.4	203384240.0	24
:	24	MANISTEE	MICH	4	15963.6	4368610.0	24
:	25	BETSIE	MICH	4	3205.3	522006.4	12
:	26	BOARDMAN	MICH	4	1024.0	30514.1	12
:	27	*MANISTIQUE	MICH	4	15515.0	4101016.0	23
:	28	WHITE FISH	MICH	4	1370.5	68135.4	12
:	29	ESCANABA	MICH	4	4052.9	1198793.0	22
:	30	THUNDER BAY	HURO	1	6900.1	2[illegible]20240.0	12
:	31	RIFLE	HURO	1	8403.2	1444538.0	24
:	32	AU GRES	HURO	1	4406.7	1712668.0	11
:	33	SAGINAW	HURO	2	362747.6	10631012352.0	33
:	34	CHEBOYGAN	HURO	1	8428.0	991941.1	25
:	35	PINNEBOG	HURO	2	8821.3	26449664.0	12
:	36	AU SABLE	HURO	1	10216.1	6142244.0	12
:	37	VAN ETTEN CR	HURO	1	1367.8	405419.9	12
:	38	MPINE	HURO	1	13271.2	96028880.0	11
:	39	TAHQUAMENON	SUPE	2	7898.9	5293305.0	18
:	40	MONTREAL	SUPE	1	2730.8	1049827.0	12
:	41	PRESQUE ISLE	SUPE	2	4659.8	15797813.0	12
:	42	STURGEON	SUPE	2	26260.6	377934608.0	12
:	43	CARP	SUPE	2	925.5	85029.0	12
:	44	ONTONAGON	SUPE	2	146083.9	3576136960.0	18
:	45	ST LOUIS	SUPE	1	26947.7	19252624.0	19
:	46	BOIS BRULE	SUPE	1	2756.1	314556.9	12
:	47	NEMADJI	SUPE	1	71080.0	1.0	253
:	48	BAD	SUPE	1	152578.0	7214981120.0	7
:	49	BAPTISM	SUPE	1	3767.2	30726.7	7

SOLUBLE ORTHO PHOSPHORUS 1975

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
1	GENESSEE	ONTA	1	67.6	28.0	14
2	OSWEGO	ONTA	2	119.4	1238.2	8
3	BLACK NY	ONTA	3	113.2	2892.4	12
4	OSWEGATCHIE	ONTA	3	31.3	80.3	9
5	GRASS	ONTA	3	16.4	66.5	8
6	RAQUETTE	ONTA	3	28.2	11.3	7
7	ST JOSEPH	MICH	3	96.2	159.2	8
8	BLACK SHAVE	MICH	3	32.3	34.4	3
9	KALAMAZOO	MICH	3	95.2	55.1	10
10	GRAND	MICH	3	320.9	1345.3	7
11	MUSKEGON	MICH	4	28.6	37.9	10
12	LITTLE MANIS	MICH	4	1.6	0.1	3
13	MANISTEE	MICH	4	17.5	4.8	9
14	BETSIE	MICH	4	2.5	0.7	3
15	BOARDMAN	MICH	4	2.2	0.2	6
16	*MANISTIQUE	MICH	4	26.3	16.3	13
17	ESCANABA	MICH	4	23.8	24.5	12
18	FORD	MICH	1	2.8	0.1	12
19	MENOMINEE	MICH	1	37.4	48.3	9
20	PESHTIGO	MICH	1	33.7	147.1	9
21	OCONTO	MICH	1	15.3	11.2	8
22	PENSAUKEE	MICH	1	7.5	3.2	9
23	FOX	MICH	1	219.8	4432.4	9
24	KEWAUNEE	MICH	1	9.2	1.2	9
25	E TWIN	MICH	1	3.5	0.2	9
26	MANITOWOC	MICH	1	30.7	96.8	10
27	SHEBOYGAN	MICH	1	36.5	108.0	9
28	MILWAUKEE	MICH	2	27.4	31.3	4
29	MENOMONEE	MICH	2	10.3	7.1	3
30	ROOT	MICH	2	7.0	6.0	9
31	TAHQUMENON	SUPE	2	7.9	0.6	15
32	BLACK G	SUPE	2	2.0	0.9	12
33	PRESQUE ISLE	SUPE	2	2.1	0.3	16
34	STURGEON	SUPE	2	4.7	0.2	15
35	CARP	SUPE	2	16.3	18.6	15
36	ONTONAGON	SUPE	2	18.6	15.2	15
37	BOIS BRULE	SUPE	1	8.2	10.1	13
38	BAD	SUPE	1	32.2	862.9	13
39	BETSY	SUPE	2	0.7	0.0	29
40	CHOCOLAY	SUPE	2	5.4	1.9	30
41	DEAD	SUPE	2	1.7	0.2	30
42	FALLS	SUPE	2	0.5	0.0	30
43	IRON	SUPE	2	2.3	1.0	30
44	MINERAL	SUPE	2	2.1	0.2	26
45	SILVER	SUPE	2	0.6	0.0	30
46	TWO-HEARTED	SUPE	2	1.8	0.0	28
47	WAISKA	SUPE	2	4.4	1.0	26
48	MONTREAL	SUPE	1	5.6	1.2	11

SOLUBLE ORTHO PHOSPHORUS 1975

		TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
:	49	NEMADJI	SUPE	1	40.1	45.1	17
:	50	OCQUEOC	HURO	1	2.2	1.8	30
:	51	PIGEON	HURO	2	8.5	10.9	29
:	52	SAGANAW	HURO	2	259.4	595.0	50
:	53	KAWKAWLIN	HURO	2	5.1	1.9	45
:	54	PINCONNING	HURO	2	2.0	0.2	30
:	55	APINE	HURO	1	4.8	2.2	30
:	56	PINNEBOG	HURO	2	9.6	10.3	30
:	57	SEBEWAING	HURO	2	6.7	12.5	30
:	58	TAWAS	HURO	1	2.8	0.2	29
:	59	THUNDER BAY	HURO	1	10.1	4.3	15
:	60	RIFLE	HURO	1	6.2	0.8	15
:	61	AU GRES	HURO	1	4.8	10.4	12
:	62	CHEBOYGAN	HURO	1	12.2	4.1	15
:	63	AU SABLE	HURO	1	19.6	0.9	14
:	64	MPINE	HURO	1	8.5	2.1	15
:	65	VAN ETTEN	HURO	1	2.6	0.4	26
:	66	WHITNEY DRN	HURO	1	2.3	0.8	28
:	67	WILLOW	HURO	2	1.7	0.4	27
:	68	MAUMEE	ERIE	2	612.0	355.1	262
:	69	PORTAGE	ERIE	2	52.2	1.5	281
:	70	SANDUSKY	ERIE	2	83.4	1.5	277
:	71	HURON	ERIE	2	33.4	18.1	399
:	72	VERMILION	ERIE	2	10.1	1.5	43
:	73	BLACK	ERIE	3	141.1	62.5	42
:	74	CUYAHOGA	ERIE	3	183.0	310.8	45
:	75	CHAGRIN	ERIE	3	21.7	3.3	41
:	76	CATTARAGUS	ERIE	4	12.7	1.5	41
:	77	BLACK MICH	ERIE	1	25.9	34.8	8
:	78	ROUGE	ERIE	1	106.8	301.6	5
:	79	HURON	ERIE	1	39.8	26.2	7
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SOLUBLE ORTHO PHOSPHORUS 1976

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
1	GENESEE	ONTA	1	89.3	283.4	17
2	OSWEGO	ONTA	2	200.7	1388.2	9
3	BLACK NY	ONTA	3	49.9	150.7	10
4	OSWEGATCHIE	ONTA	3	33.1	58.2	9
5	GRASS	ONTA	3	16.2	6.2	8
6	RAQUETTE	ONTA	3	27.9	73.3	9
7	FORD	MICH	1	3.2	13.0	12
8	MENOMINEE	MICH	1	22.9	6.9	12
9	PESHTIGO	MICH	1	10.4	1.1	12
10	OCONTO	MICH	1	9.4	0.5	12
11	PENSAUKEE	MICH	1	7.0	0.8	9
12	FOX	MICH	1	113.4	1908.0	12
13	KEWAUNEE	MICH	1	4.6	0.2	12
14	E TWIN	MICH	1	4.7	0.2	12
15	MANITOWOC	MICH	1	27.0	39.3	11
16	SHEBOYGAN	MICH	1	27.9	18.0	12
17	MENOMONEE	MICH	2	8.4	1.0	163
18	ROOT	MICH	2	15.8	22.2	6
19	ST JOSEPH	MICH	3	158.8	2458.7	11
20	KALAMAZOO	MICH	3	86.7	87.0	12
21	GRAND	MICH	3	343.6	142.2	211
22	MUSKEGON	MICH	4	36.9	31.5	12
23	MANISTEE	MICH	4	18.1	4.6	12
24	BETSIE	MICH	4	1.5	0.0	12
25	BOARDMAN	MICH	4	3.9	4.1	12
26	*MANISTIQUE	MICH	4	19.8	13.2	12
27	WHITE FISH	MICH	4	0.7	0.0	12
28	ESCANABA	MICH	4	14.3	59.6	12
29	TAHQUMENON	SUPE	2	4.1	0.4	12
30	MONTREAL	SUPE	1	9.4	3.9	12
31	PRESQUE ISLE	SUPE	2	1.4	0.3	12
32	STURGEON	SUPE	2	8.2	10.6	12
33	CARP	SUPE	2	24.5	20.6	12
34	ONTONAGON	SUPE	2	38.6	19.1	12
35	SAGINAW	HURO	2	615.0	4747.7	23
36	CHEBOYGAN	HURO	1	5.7	1.3	12
37	THUNDER BAY	HURO	1	2.7	0.4	12
38	RIFLE	HURO	1	4.0	0.3	12
39	AU GRES	HURO	1	2.8	0.6	11
40	PINNEBOG	HURO	2	20.5	66.8	12
41	AU SABLE	HURO	1	12.3	2.8	12
42	VAN ETTEN CR	HURO	1	1.8	0.5	12
43	MPINE	HURO	1	6.5	7.5	11

CHLORIDE 1975

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
1	GENESEE	ONTA	1	129819.1	74638992.0	33
2	OSWEGO	ONTA	2	1057788.0	11548844032.0	16
3	BLACK NY	ONTA	3	7548.4	3239712.0	16
4	OSWEGATCHIE	ONTA	3	4834.5	289190.5	9
5	GRASS	ONTA	3	2798.0	2527699.0	8
6	RAQUETTE	ONTA	3	2481.3	93326.8	9
7	ST REGIS	ONTA	3	1599.6	22801.8	12
8	FORD	MICH	1	978.3	3334.8	22
9	MENOMINEE	MICH	1	3214.7	299902.2	8
10	PESHTIGO	MICH	1	2130.3	410943.3	11
11	OCONTO	MICH	1	6229.0	677186.8	12
12	PENSAUKEE	MICH	1	579.5	75777.6	11
13	FOX	MICH	1	51168.1	8983847.0	24
14	KEWAUNEE	MICH	1	1373.9	2192.1	12
15	E TWIN	MICH	1	857.9	2758.0	12
16	MANITOWOC	MICH	1	3779.2	181695.5	12
17	SHEBOYGAN	MICH	1	7066.7	420774.9	11
18	MILWAUKEE	MICH	2	14558.7	24316064.0	16
19	MENOMONEE	MICH	2	10336.1	3409737.0	48
20	ROOT	MICH	2	3923.0	10212406.0	24
21	ST JOSEPH	MICH	3	78264.8	10816331.0	8
22	KALAMAZOO	MICH	3	60226.6	5254486.0	22
23	GRAND	MICH	3	171490.2	41900128.0	7
24	MUSKEGON	MICH	4	46548.0	5107921.0	22
25	MANISTEE	MICH	4	163375.4	157896192.0	21
26	BETSIE	MICH	4	937.5	23635.2	3
27	BOARDMAN	MICH	4	1848.2	4459.1	6
28	*MANISTIQUE	MICH	4	4071.3	29090.3	23
29	ESCANABA	MICH	4	10511.5	4736482.0	23
30	GREENE CR	HURO	1	5.8	2.2	11
31	MULLIGAN CR	HURO	1	8.1	5.6	11
32	SCHMIDTS CR	HURO	1	27.2	38.3	11
33	CARP CR	HURO	1	17.9	11.5	11
34	OCQUEOC	HURO	1	316.0	803.6	11
35	TROUT	HURO	1	116.4	476.8	11
36	PIGEON	HURO	2	2784.9	457560.8	29
37	PINCONNING	HURO	2	668.0	14388.0	30
38	APINE	HURO	1	2514.9	166328.7	30
39	PINNEBOG	HURO	2	3215.7	462024.3	30
40	SEBEWAING	HURO	2	3084.3	527856.5	30
41	TAWAS	HURO	1	675.3	5259.6	29
42	VAN ETTEN CR	HURO	1	1277.5	26171.5	26
43	WHITNEY DRN	HURO	1	1259.3	65843.6	28
44	WILLOW	HURO	2	1051.2	43232.0	27
45	SAGINAW	HURO	2	295139.8	1798453504.0	48
46	KAKAWLIN	HURO	2	4434.8	484439.4	41
47	THUNDER BAY	HURO	1	5529.0	107080.9	15
48	RIFLE	HURO	1	5475.4	82691.4	15
49	AU GRES	HURO	1	2973.9	795724.1	12
50	CHEBOYGAN	HURO	1	6216.1	115453.9	25

CHLORIDE 1975

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
51	AU SABLE	HURO	1	9925.6	98168.8	14
52	MPINE	HURO	1	1100.4	12220.0	15
53	ST LOUIS	SUPE	1	25467.9	1658515.0	12
54	BOIS BRULE	SUPE	1	131.9	1999.3	16
55	NEMADJI	SUPE	1	811.8	8876.2	11
56	BAD	SUPE	1	2357.4	6252352.0	10
57	BAPTISM	SUPE	1	551.6	488053.0	12
58	BEAVER	SUPE	1	500.0	18772.3	31
59	BRULE	SUPE	1	638.8	20432.8	31
60	CASCADE	SUPE	1	331.8	9798.9	31
61	CROSS	SUPE	1	267.5	4920.3	31
62	FRENCH	SUPE	1	89.1	718.9	31
63	GOOSEBERRY	SUPE	1	208.4	3717.0	31
64	KNIFE	SUPE	1	358.4	7041.2	31
65	LESTER	SUPE	1	336.5	14228.9	30
66	MANITOU	SUPE	1	376.0	11418.2	31
67	PIGEON	SUPE	1	2069.6	155229.0	31
68	POPLAR	SUPE	1	605.9	25796.2	31
69	SPLIT ROCK	SUPE	1	223.4	4828.8	31
70	SUCKER	SUPE	1	165.0	4384.0	31
71	TEMPERANCE	SUPE	1	427.0	7737.0	30
72	MONTREAL	SUPE	1	1208.2	618017.0	23
73	TAHQUAMENON	SUPE	2	1670.4	51360.1	27
74	PRESQUE ISLE	SUPE	2	723.8	64400.7	15
75	STURGEON	SUPE	2	2036.9	131977.3	15
76	CARP	SUPE	2	1361.7	20632.3	14
77	ONTONAGON	SUPE	2	3697.3	236698.9	27
78	BETSY	SUPE	2	67.9	129.5	28
79	BLACK	SUPE	2	846.8	31895.8	30
80	CHOCOLAY	SUPE	2	781.1	4178.4	30
81	DEAD	SUPE	2	463.6	7620.9	30
82	FALLS	SUPE	2	125.2	234.9	30
83	IRON	SUPE	2	981.8	26438.9	30
84	MINERAL	SUPE	2	21243.0	5279860.0	26
85	SILVER	SUPE	2	50.7	123.8	30
86	TWO-HEARTED	SUPE	2	152.9	490.3	28
87	WAISKA	SUPE	2	606.2	4431.8	26
88	MAUMEE	ERIE	2	273017.6	44715040.0	262
89	PORTAGE	ERIE	2	19525.0	59127.3	281
90	SANDUSKY	ERIE	2	46845.6	175[illegible]4064.0	277
91	HURON	ERIE	2	12711.0	59127.3	399
92	VERMILION	ERIE	2	4715.2	2218198.0	43
93	BLACK	ERIE	3	27342.0	1629696.0	42
94	CUYAHOGA	ERIE	3	110964.3	49726080.0	45
95	CHAGRIN	ERIE	3	21672.0	5912732.0	41
96	CATTARAGUS	ERIE	4	10224.7	175940.7	41
97	BLACK MICH	ERIE	1	8075.0	3652481.0	8
98	ROUGE	ERIE	1	17724.5	4749344.0	5
99	HURON	ERIE	1	28599.9	1027752.9	7

CHLORIDE 1976

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
1	ST LOUIS	SUPE	1	14350.9	7773813.0	19
2	BOIS BRULE	SUPE	1	211.5	174.6	11
3	NEMADJI	SUPE	1	486.0	12652.6	23
4	BAD	SUPE	1	1566.1	104954.3	24
5	BAPTISM	SUPE	1	364.1	4348.9	7
6	TAHQUAMENON	SUPE	2	1622.2	29081.8	24
7	MONTREAL	SUPE	1	1120.1	74107.9	12
8	PRESQUE ISLE	SUPE	2	817.5	71386.5	12
9	STURGEON	SUPE	2	1293.4	68409.9	12
10	CARP	SUPE	2	1763.9	14717.6	12
11	ONTONAGON	SUPE	2	3380.8	183502.2	24
12	GENESEE	ONTA	1	129358.6	230125696.0	25
13	OSWEGO	ONTA	2	1386606.0	11063869440.0	13
14	BLACK NY	ONTA	3	8605.5	281966.7	10
15	OSWEGATCHIE	ONTA	3	7348.1	375263.0	9
16	GRASS	ONTA	3	4108.0	131971.8	9
17	RAQUETTE	ONTA	3	3308.1	49047.7	9
18	FORD	MICH	1	748.0	9409.5	24
19	MENOMINEE	MICH	1	3966.0	642851.9	4
20	PESHTIGO	MICH	1	1948.2	322458.4	12
21	OCONTO	MICH	1	6345.9	1089513.0	12
22	PENSAUKEE	MICH	1	1337.1	3441.4	9
23	FOX	MICH	1	55742.3	16032160.0	24
24	KEWAUNEE	MICH	1	1731.6	43073.9	12
25	E TWIN	MICH	1	1574.0	4663.5	12
26	MANITOWOC	MICH	1	7270.4	1044872.3	11
27	SHEBOYGAN	MICH	1	7231.4	208205.7	12
28	MILWAUKEE	MICH	2	18297.1	10915365.0	12
29	MENOMONEE	MICH	2	10834.2	1897349.0	72
30	ROOT	MICH	2	6665.6	1496772.0	6
31	ST JOSEPH	MICH	3	86846.1	8585668.0	11
32	KALAMAZOO	MICH	3	57017.1	15914057.0	23
33	GRAND	MICH	3	149924.3	17938864.0	212
34	MUSKEGON	MICH	4	46235.1	8313055.0	24
35	MANISTEE	MICH	4	85695.9	110266640.0	23
36	BETSIE	MICH	4	1092.9	12537.1	12
37	BOARDMAN	MICH	4	2176.9	9440.9	12
38	*MANISTIQUE	MICH	4	3929.0	75174.5	24
39	WHITE FISH	MICH	4	1118.6	98232.4	12
40	ESCANABA	MICH	4	5090.1	2801563.0	24
41	THUNDER BAY	HURO	1	4300.9	87940.0	12
42	RIFLE	HURO	1	6033.5	48825.0	24
43	AU GRES	HURO	1	3797.3	1049305.0	11
44	SAGINAW	HURO	2	320889.6	1941606144.0	33
45	CHEBOYGAN	HURO	1	6473.7	80014.5	25
46	PINNEBOG	HURO	2	7326.7	8461026.0	12
47	AU SABLE	HURO	1	10046.7	96088.6	12
48	VAN ETTEN CR	HURO	1	1068.8	42235.8	12
49	MPINE	HURO	1	465.7	14694.0	11
50	GREENE CR	HURO	1	16.5	20.3	43
51	MULLIGAN CR	HURO	1	21.5	20.0	43
52	SCHMIDTS CR	HURO	1	29.8	26.4	43
53	CARP CR	HURO	1	26.1	16.6	43
54	OCQUEOC	HURO	1	356.8	1575.0	43
55	TROUT	HURO	1	218.5	1433.1	43

TOTAL NITROGEN1975

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
1	GENESEE	ONTA	1	4838.6	26953.3	31
2	OSWEGO	ONTA	2	8375.2	45198.8	17
3	BLACK NY	ONTA	3	2228.6	990196.9	12
4	OSWEGATCHIE	ONTA	3	1435.0	15631.1	9
5	GRASS	ONTA	3	802.1	7992.4	8
6	RAQUETTE	ONTA	3	1023.9	19807.3	9
7	ST REGIS	ONTA	3	591.0	475.2	12
8	FORD	MICH	1	196.5	29.3	22
9	MENOMINEE	MICH	1	1645.5	23043.9	12
10	PESHTIGO	MICH	1	595.2	1368.9	9
11	OCONTO	MICH	1	1403.8	18779.2	9
12	PENSAUKEE	MICH	1	157.1	152.9	9
13	FOX	MICH	1	4698.2	156860.1	19
14	KEWAUNEE	MICH	1	211.6	241.6	9
15	E TWIN	MICH	1	117.9	456.0	9
16	MANITOWOC	MICH	1	408.8	814.0	10
17	SHEBOYGAN	MICH	1	599.4	9194.0	9
18	MILWAUKEE	MICH	2	1235.8	23221.7	18
19	MENOMONEE	MICH	2	212.2	506.6	3
20	ROOT	MICH	2	533.2	1837.8	5
21	ST JOSEPH	MICH	3	7749.4	484385.4	8
22	BLACK SHAVE	MICH	3	746.3	23094.2	3
23	KALAMAZOO	MICH	3	3828.8	18619.8	22
24	GRAND	MICH	3	11052.8	1554260.0	7
25	MUSKEGON	MICH	4	1550.6	11212.7	22
26	LITTLE MANIS	MICH	4	56.2	373.2	3
27	MANISTEE	MICH	4	1198.1	3832.2	21
28	BETSIE	MICH	4	128.3	1018.9	3
29	BOARDMAN	MICH	4	152.4	254.1	6
30	*MANISTIQUE	MICH	4	1104.1	8063.8	23
31	ESCANABA	MICH	4	549.5	1881.1	23
32	TAHQUAMENON	SUPE	2	489.8	852.6	27
33	BLACK G	SUPE	2	178.6	786.2	12
34	PRESQUE ISLE	SUPE	2	179.4	2536.9	15
35	STURGEON	SUPE	2	486.0	3804.6	15
36	CARP	SUPE	2	292.8	1367.2	15
37	ONTONAGON	SUPE	2	1087.8	33722.8	27
38	ST LOUIS	SUPE	1	2468.3	26245.9	4
39	BOIS BRULE	SUPE	1	119.1	321.7	14
40	NEMADJI	SUPE	1	374.8	5423.8	13
41	BAD	SUPE	1	642.7	39505.8	12
42	BAPTISM	SUPE	1	196.1	1550.8	12
43	BEAVER	SUPE	1	153.7	1519.8	30
44	BRULE	SUPE	1	229.6	1952.0	30
45	CASCADE	SUPE	1	127.0	689.4	30
46	CROSS	SUPE	1	109.1	540.5	29
47	FRENCH	SUPE	1	24.3	49.9	30
48	GOOSEBERRY	SUPE	1	75.9	534.7	30

TOTAL NITROGEN 1975

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
49	KNIFE	SUPE	1	77.4	531.6	30
50	LESTER	SUPE	1	73.0	848.1	30
51	MANITOU	SUPE	1	152.9	2182.2	30
52	PIGEON	SUPE	1	755.6	18120.4	30
53	POPLAR	SUPE	1	211.0	4195.6	30
54	SPLIT ROCK	SUPE	1	73.7	631.2	30
55	SUCKER	SUPE	1	46.7	194.0	30
56	TEMPERANCE	SUPE	1	197.8	1870.5	30
57	MONTREAL	SUPE	1	325.2	9210.0	13
58	BETSY	SUPE	2	45.6	49.7	29
59	CHOCOLAY	SUPE	2	117.5	150.3	30
60	DEAD	SUPE	2	79.6	132.9	30
61	FALLS	SUPE	2	20.2	5.7	29
62	IRON	SUPE	2	66.8	268.7	30
63	MINERAL	SUPE	2	112.4	511.7	26
64	SILVER	SUPE	2	28.5	58.7	30
65	TWO HEARTED	SUPE	2	105.8	236.6	28
66	WAISKA	SUPE	2	177.0	1037.6	26
67	THUNDER BAY	HURO	1	527.9	7387.6	15
68	RIFLE	HURO	1	336.6	4832.3	15
69	AU GRES	HURO	1	233.2	7377.2	12
70	CHEBOYGAN	HURO	1	564.2	3077.1	25
71	AU SABLE	HURO	1	688.5	10377.9	14
72	MPINE	HURO	1	250.9	1151.2	15
73	KAWKAWLIN	HURO	2	580.4	32373.7	30
74	OCQUEOC	HURO	1	92.3	407.7	30
75	PIGEON	HURO	2	636.2	54997.1	29
76	PINCONNING	HURO	2	74.1	742.9	30
77	APINE	HURO	1	147.8	1853.2	30
78	PINNEBOG	HURO	2	492.8	23492.0	30
79	SAGINAW	HURO	2	18542.0	11676595.0	44
80	SEBEWAING	HURO	2	846.8	117325.0	30
81	TAWAS	HURO	1	102.6	210.4	29
82	VAN ETTEN CR	HURO	1	129.6	531.3	26
83	WHITNEY DRN	HURO	1	154.4	2239.1	28
84	WILLOW	HURO	2	172.6	2215.0	27
85	MAUMEE	ERIE	2	47707.5	310070.0	262
86	PORTAGE	ERIE	2	3245.0	4231.0	281
87	SANDUSKY	ERIE	2	6886.1	6488.0	277
88	HURON	ERIE	2	1730.5	1490.0	399
89	VERMILION	ERIE	2	868.0	1138.0	43
90	BLACK	ERIE	3	8299.6	594633.0	42
91	CUYAHOGA	ERIE	3	4835.9	5774.0	45
92	CHAGRIN	ERIE	3	972.2	3549.0	41
93	CATTARAGUS	ERIE	4	1763.7	2395.0	41
94	BLACK MICH	ERIE	1	1089.8	24349.7	8
95	ROUGE	ERIE	1	579.0	1259.3	5
96	HURON	ERIE	1	1213.6	7850.0	7

TOTAL NITROGEN 1976

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
1	ST LOUIS	SUPE	1	1201.5	16039.4	3
2	BOIS BRULE	SUPE	1	87.9	418.2	3
3	NEMADJI	SUPE	1	339.9	6884.7	15
4	BAD	SUPE	1	649.3	1456.9	14
5	ONTONOGON	SUPE	2	743.4	1104.4	24
6	THAQUAMENON	SUPE	2	467.4	1990.4	24
7	MONTREAL	SUPE	1	230.7	4620.9	12
8	PRESQUE ISLE	SUPE	2	154.9	4242.6	12
9	STURGEON	SUPE	2	355.7	8930.3	12
10	CARP	SUPE	2	214.7	2025.8	12
11	GENESEE	ONTA	1	6871.1	262288.3	25
12	OSWEGO	ONTA	2	12139.0	664046.7	13
13	BLACK NY	ONTA	3	3236.6	114514.6	10
14	OSWEGATCHIE	ONTA	3	1881.3	15143.1	9
15	GRASS	ONTA	3	797.8	3204.8	9
16	RAQUETTE	ONTA	3	1514.0	27805.2	9
17	FORD	MICH	1	248.2	1144.2	24
18	MENOMINEE	MICH	1	1578.8	3266.8	12
19	PESHTIGO	MICH	1	842.1	11970.3	12
20	OCONTO	MICH	1	1713.7	86093.4	12
21	PENSAUKEE	MICH	1	142.9	110.7	8
22	FOX	MICH	1	4614.4	108251.3	24
23	KEWAUNEE	MICH	1	205.6	70.5	12
24	E TWIN	MICH	1	198.5	207.3	12
25	MANITOWOC	MICH	1	643.5	13143.2	11
26	SHEBOYGAN	MICH	1	792.6	9889.9	12
27	MILWAUKEE	MICH	2	1009.6	14172.7	12
28	MENOMONEE	MICH	2	259.3	398.3	40
29	ROOT	MICH	2	811.2	39152.5	6
30	ST JOSEPH	MICH	3	10040.0	226126.9	11
31	KALAMAZOO	MICH	3	3612.0	16848.2	23
32	GRAND	MICH	3	12652.7	632.3	321
33	MUSKEGON	MICH	4	2122.8	15263.5	23
34	MANISTEE	MICH	4	1131.5	3378.3	24
35	BETSIE	MICH	4	135.3	410.3	12
36	BOARDMAN	MICH	4	221.6	89.0	12
37	*MANISTIQUE	MICH	4	1139.6	8593.6	24
38	WHITE FISH	MICH	4	107.7	95.8	12
39	ESCANABA	MICH	4	529.7	708.1	24
40	THUNDER BAY	HURO	1	381.6	610.1	12
41	RIFLE	HURO	1	262.5	603.6	24
42	AU GRES	HURO	1	323.4	6010.0	11
43	SAGINAW	HURO	2	16730.9	1234414.0	33
44	CHEBOYGAN	HURO	1	497.7	674.5	25
45	PINNEBOG	HURO	2	867.4	125746.3	12
46	AU SABLE	HURO	1	705.8	1761.7	12
47	VAN ETTEN CR	HURO	1	114.3	1261.1	12
48	MPINE	HURO	1	103.5	1534.7	11

AMMONIA N 1975

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
1	GENESEE	ONTA	1	498.9	9845.1	14
2	OSWEGO	ONTA	2	1193.2	58580.4	8
3	BLACK NY	ONTA	3	326.6	10359.3	12
4	OSWEGATCHIE	ONTA	3	145.0	1847.2	9
5	GRASS	ONTA	3	87.6	2221.4	8
6	RAQUETTE	ONTA	3	97.2	1899.5	9
7	MENOMINEE	MICH	1	240.7	1290.9	12
8	PESHTIGO	MICH	1	79.9	238.3	12
9	OCONTO	MICH	1	1081.3	67839.9	12
10	PENSAUKEE	MICH	1	33.4	89.6	12
11	FOX	MICH	1	739.3	15723.1	12
12	KEWAUNEE	MICH	1	14.3	1.1	12
13	E TWIN	MICH	1	10.7	0.5	12
14	MANITOWOC	MICH	1	111.5	892.6	13
15	SHEBOYGAN	MICH	1	41.6	11.6	12
16	MILWAUKEE	MICH	2	240.1	2642.2	6
17	MENOMONEE	MICH	2	31.8	15.9	47
18	ROOT	MICH	2	21.3	27.0	18
19	ST JOSEPH	MICH	3	389.6	20120.4	8
20	BLACK SHAVE	MICH	3	37.3	3.6	3
21	KALAMAZOO	MICH	3	250.6	3478.0	10
22	GRAND	MICH	3	985.3	34630.3	7
23	MUSKEGON	MICH	4	49.3	84.4	10
24	LITTLE MANIS	MICH	4	3.8	0.0	3
25	MANISTEE	MICH	4	147.6	712.7	9
26	BETSIE	MICH	4	6.4	16.0	3
27	BOARDMAN	MICH	4	43.5	9.9	6
28	*MANISTIQUE	MICH	4	89.9	129.5	13
29	ESCANABA	MICH	4	110.6	216.3	13
30	FORD	MICH	1	21.7	14.6	12
31	TAHQUAMENON	SUPE	2	18.7	49.3	15
32	BLACK G	SUPE	2	4.2	12.3	12
33	PRESQUE ISLE	SUPE	2	2.7	1.1	15
34	STURGEON	SUPE	2	28.6	116.2	15
35	CARP	SUPE	2	132.8	767.0	15
36	ONTONAGON	SUPE	2	154.7	3015.1	15
37	ST LOUIS	SUPE	1	285.0	718.8	5
38	BOIS BRULE	SUPE	1	16.5	31.9	14
39	NEMADJI	SUPE	1	61.3	1737.1	12
40	BAD	SUPE	1	85.1	7644.5	13
41	BAPTISM	SUPE	1	12.8	107.1	12
42	BEAVER	SUPE	1	10.2	7.3	30
43	BRULE	SUPE	1	29.1	170.6	30
44	CASCADE	SUPE	1	8.9	5.5	30
45	CROSS	SUPE	1	7.2	3.4	29
46	FRENCH	SUPE	1	2.5	0.8	30
47	GOOSEBERRY	SUPE	1	5.5	3.3	30
48	KNIFE	SUPE	1	5.6	2.5	30

AMMONIA N 1975

		TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
:	49	LESTER	SUPE	1	5.8	5.5	30
:	50	MANITOU	SUPE	1	10.2	16.8	30
:	51	PIGEON	SUPE	1	58.0	234.9	30
:	52	POPLAR	SUPE	1	14.7	9.0	30
:	53	SPLIT ROCK	SUPE	1	6.7	12.9	30
:	54	SUCKER	SUPE	1	3.9	1.2	30
:	55	TEMPERANCE	SUPE	1	11.8	5.2	30
:	56	MONTREAL	SUPE	1	37.6	92.0	23
:	57	BETSY	SUPE	2	3.6	0.4	29
:	58	CHOCOLAY	SUPE	2	6.0	1.2	30
:	59	DEAD	SUPE	2	6.6	5.1	30
:	60	FALLS	SUPE	2	0.8	0.0	30
:	61	IRON	SUPE	2	3.3	0.7	30
:	62	MINERAL	SUPE	2	14.2	33.9	26
:	63	SILVER	SUPE	2	1.1	0.1	30
:	64	TWO-HEARTED	SUPE	2	4.5	0.8	28
:	65	WAISKA	SUPE	2	14.0	12.3	26
:	66	THUNDER BAY	HURO	1	38.7	145.0	15
:	67	RIFLE	HURO	1	12.2	17.2	16
:	68	AU GRES	HURO	1	9.6	12.5	12
:	69	CHEBOYGAN	HURO	1	30.3	25.0	15
:	70	AU SABLE	HURO	1	24.5	3.4	14
:	71	MPINE	HURO	1	23.0	28.6	15
:	72	OCQUEOC	HURO	1	4.2	1.4	30
:	73	PIGEON	HURO	2	20.7	222.3	29
:	74	PINCONNING	HURO	2	2.1	0.2	30
:	75	APINE	HURO	1	7.4	3.9	30
:	76	PINNEBOG	HURO	2	11.4	12.7	30
:	77	SEBEWAING	HURO	2	13.9	88.3	30
:	78	TAWAS	HURO	1	9.7	1.2	29
:	79	VAN ETTEN CR	HURO	1	11.6	14.3	26
:	80	WHITNEY DRN	HURO	1	6.4	4.8	28
:	81	WILLOW	HURO	2	4.0	1.1	27
:	82	SAGINAW	HURO	2	1976.4	40479.4	50
:	83	KAWKAWLIN	HURO	2	18.5	20.3	45
:	84	MAUMEE	ERIE	2	1136.8	4887.2	262
:	85	PORTAGE	ERIE	2	78.4	9.2	281
:	86	SANDUSKY	ERIE	2	253.9	269.4	277
:	87	HURON	ERIE	2	51.3	5.9	399
:	88	VERMILION	ERIE	2	38.1	5.9	43
:	89	BLACK	ERIE	3	596.2	33481.2	42
:	90	CUYAHOGA	ERIE	3	622.1	8204.3	45
:	91	CHAGRIN	ERIE	3	86.7	163.0	41
:	92	CATTARAGUS	ERIE	4	185.0	249.8	41
:	93	BLACK MICH	ERIE	1	47.3	24.6	8
:	94	ROUGE	ERIE	1	234.2	233.7	5
:	95	HURON	ERIE	1	267.5	3350.3	7
:							

AMMONIA N 1976

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
1	GENESEE	ONTA	1	673.8	4917.0	25
2	OSWEGO	ONTA	2	1838.1	42073.8	13
3	BLACK NY	ONTA	3	85.7	120.7	10
4	OSWEGATCHIE	ONTA	3	101.8	246.0	9
5	GRASS	ONTA	3	92.9	144.9	9
6	RAQUETTE	ONTA	3	74.1	198.7	9
7	FORD	MICH	1	22.7	482.4	12
8	MENOMINEE	MICH	1	43.3	62.2	12
9	PESHTIGO	MICH	1	73.1	48.6	12
10	OCONTO	MICH	1	752.2	33074.2	12
11	PENSAUKEE	MICH	1	25.4	19.1	9
12	FOX	MICH	1	711.0	26025.3	12
13	KEWAUNEE	MICH	1	13.1	2.6	12
14	E TWIN	MICH	1	16.7	4.2	12
15	MANITOWOC	MICH	1	78.3	699.4	11
16	SHEBOYGAN	MICH	1	52.7	73.9	12
17	MENOMONEE	MICH	2	25.2	7.4	74
18	ROOT	MICH	2	18.2	25.7	6
19	ST JOSEPH	MICH	3	583.9	20607.9	11
20	KALAMAZOO	MICH	3	183.4	1956.8	12
21	GRAND	MICH	3	1404.1	12704.3	212
22	MUSKEGON	MICH	4	84.7	405.5	12
23	MANISTEE	MICH	4	73.6	122.4	12
24	BETSIE	MICH	4	5.9	2.8	12
25	BOARDMAN	MICH	4	63.9	76.3	12
26	*MANISTIQUE	MICH	4	64.7	279.8	12
27	WHITE FISH	MICH	4	3.6	0.2	12
28	ESCANABA	MICH	4	35.8	226.9	12
29	THUNDER BAY	HURO	1	11.9	10.0	12
30	RIFLE	HURO	1	9.7	6.5	12
31	AU GRES	HURO	1	7.0	4.8	11
32	SAGINAW	HURO	2	1389.8	42579.4	23
33	CHEBOYGAN	HURO	1	17.9	4.7	12
34	PINNEBOG	HURO	2	44.0	704.6	12
35	AU SABLE	HURO	1	26.1	27.4	12
36	VAN ETTEN CR	HURO	1	3.8	2.2	12
37	MPINE	HURO	1	5.9	3.7	11
38	TAHQUAMENON	SUPE	2	15.1	7.2	12
39	MONTREAL	SUPE	1	13.3	18.6	12
40	PRESQUE ISLE	SUPE	2	2.9	0.9	12
41	STURGEON	SUPE	2	12.1	12.8	12
42	CARP	SUPE	2	98.4	375.5	12
43	ONTONAGON	SUPE	2	74.4	488.2	12
44	ST LOUIS	SUPE	1	115.8	348.2	3
45	BOIS BRULE	SUPE	1	13.5	10.9	3
46	NEMADJI	SUPE	1	30.6	4.6	3
47	BAD	SUPE	1	64.0	913.5	3

NITRATE (NITRITE) 1975

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
1	GENESEE	ONTA	1	2383.7	56557.1	31
2	OSWEGO	ONTA	2	3497.1	126737.4	17
3	BLACK NY	ONTA	3	2326.5	80293.8	16
4	OSWEGATCHIE	ONTA	3	609.6	20166.4	9
5	GRASS	ONTA	3	379.3	12328.9	8
6	RAQUETTE	ONTA	3	701.1	6134.5	9
7	ST REGIS	ONTA	3	312.1	1397.6	12
8	FORD	MICH	1	31.4	30.1	22
9	MENOMINEE	MICH	1	451.6	8331.0	9
10	PESHTIGO	MICH	1	315.4	11978.5	9
11	OCONTO	MICH	1	185.3	1186.8	9
12	PENSAUKEE	MICH	1	59.2	78.1	9
13	FOX	MICH	1	943.2	36117.8	18
14	KEWAUNEE	MICH	1	128.2	180.5	9
15	E TWIN	MICH	1	61.5	261.5	9
16	MANITOWOC	MICH	1	79.2	42.4	9
17	SHEBOYGAN	MICH	1	311.6	8170.9	9
18	MILWAUKEE	MICH	2	585.4	3463.7	15
19	MENOMONEE	MICH	2	143.2	692.2	42
20	ROOT	MICH	2	417.9	3762.5	5
21	ST JOSEPH	MICH	3	4344.7	340880.3	8
22	BLACK SHAVE	MICH	3	248.6	1122.5	3
23	KALAMAZOO	MICH	3	1812.1	14697.7	22
24	GRAND	MICH	3	5495.7	1349343.0	7
25	MUSKEGON	MICH	4	467.2	10439.4	22
26	LITTLE MANIS	MICH	4	14.9	29.4	3
27	MANISTEE	MICH	4	436.5	2150.6	21
28	BETSIE	MICH	4	44.9	15.1	3
29	BOARDMAN	MICH	4	65.1	94.7	6
30	*MANISTIQUE	MICH	4	259.0	1597.7	23
31	ESCANABA	MICH	4	135.6	186.9	23
32	TAHQUAMENON	SUPE	2	73.8	297.9	27
33	BLACK G	SUPE	2	31.9	90.8	12
34	PRESQUE ISLE	SUPE	2	38.6	405.6	15
35	STURGEON	SUPE	2	98.2	485.1	15
36	CARP	SUPE	2	22.3	5.4	15
37	ONTONAGON	SUPE	2	138.1	482.1	27
38	ST LOUIS	SUPE	1	876.2	70941.1	4
39	BOIS BRULE	SUPE	1	20.2	29.9	13
40	NEMADJI	SUPE	1	51.0	764.6	13
41	BAD	SUPE	1	121.2	5528.6	13
42	BAPTISM	SUPE	1	90.1	2364.2	12
43	BEAVER	SUPE	1	34.7	134.5	30
44	BRULE	SUPE	1	49.6	126.8	30
45	CASCADE	SUPE	1	37.6	83.4	30
46	CROSS	SUPE	1	31.7	74.1	29
47	FRENCH	SUPE	1	4.5	2.5	30
48	GOOSEBERRY	SUPE	1	13.0	34.4	30

NITRATE (NITRITE) 1975

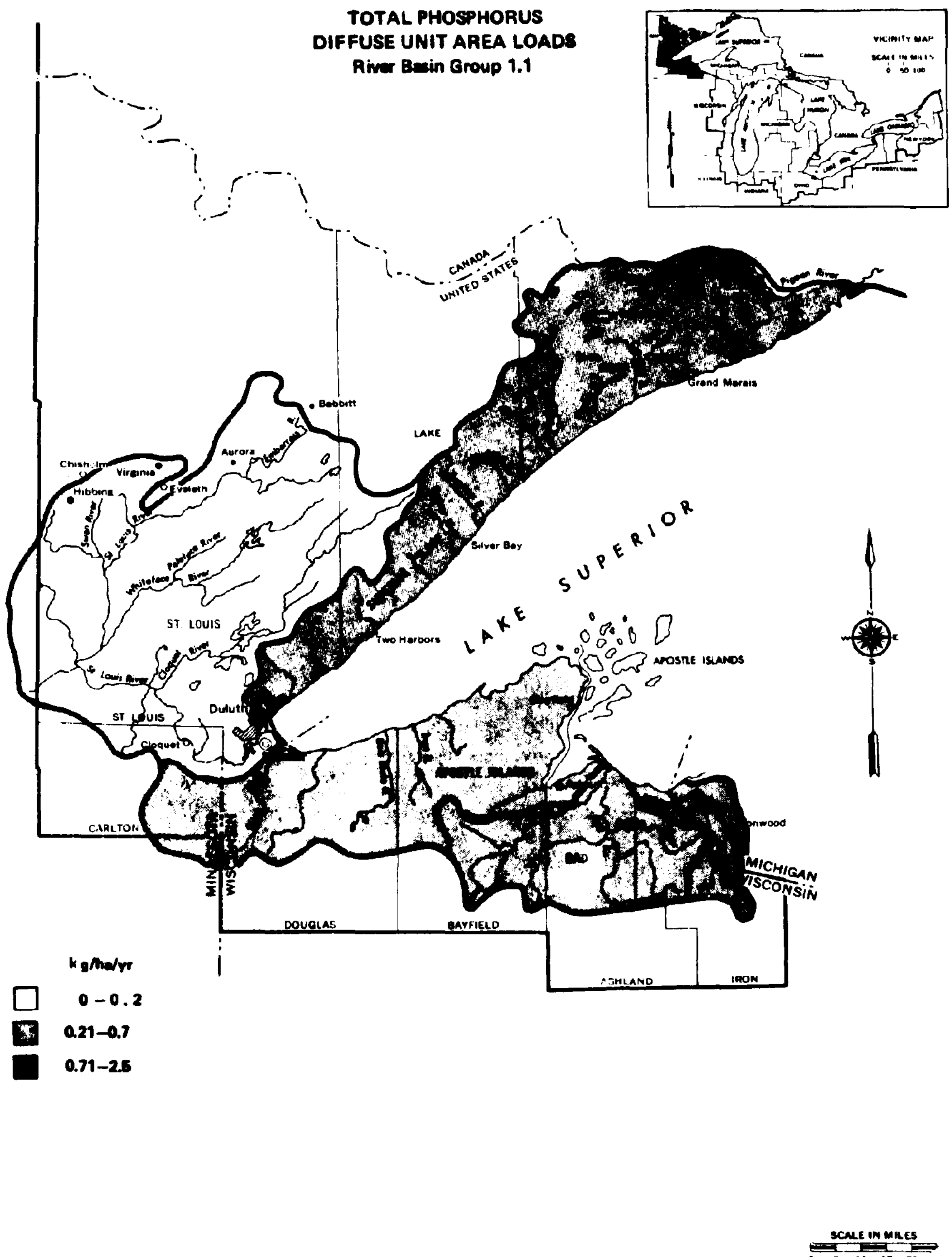
		TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
:	49	KNIFE	SUPE	1	15.3	32.2	30
:	50	LESTER	SUPE	1	15.3	93.4	30
:	51	MANITOU	SUPE	1	47.1	309.5	30
:	52	PIGEON	SUPE	1	150.0	1252.1	30
:	53	POPLAR	SUPE	1	83.2	1002.0	30
:	54	SPLIT ROCK	SUPE	1	20.3	78.6	30
:	55	SUCKER	SUPE	1	10.4	14.8	30
:	56	TEMPERANCE	SUPE	1	70.1	348.2	30
:	57	MONTREAL	SUPE	1	70.4	292.7	13
:	58	BETSY	SUPE	2	6.3	1.8	29
:	59	CHOCOLAY	SUPE	2	51.8	18.2	30
:	60	DEAD	SUPE	2	30.4	58.7	30
:	61	FALLS	SUPE	2	5.7	0.7	30
:	62	IRON	SUPE	2	10.7	10.8	30
:	63	MINERAL	SUPE	2	54.0	179.2	26
:	64	SILVER	SUPE	2	5.3	1.3	30
:	65	TWO-HEARTED	SUPE	2	26.4	5.4	28
:	66	WAISKA	SUPE	2	29.1	54.3	26
:	67	THUNDER BAY	HURO	1	71.0	318.5	15
:	68	RIFLE	HURO	1	104.7	1604.5	15
:	69	AU GRES	HURO	1	128.0	6175.2	12
:	70	CHEBOYGAN	HURO	1	103.4	127.6	25
:	71	AU SABLE	HURO	1	127.1	424.0	14
:	72	MPINE	HURO	1	26.6	6.6	15
:	73	OCQUEOC	HURO	1	25.2	34.9	30
:	74	PIGEON	HURO	2	518.3	27575.3	29
:	75	PINCONNING	HURO	2	60.2	566.0	30
:	76	APINE	HURO	1	85.8	651.4	30
:	77	PINNEBOG	HURO	2	394.2	16370.7	30
:	78	SEBEWAING	HURO	2	711.8	668.5	30
:	79	TAWAS	HURO	1	21.4	28.9	29
:	80	VAN ETTEN CR	HURO	1	41.2	120.0	26
:	81	WHITNEY	HURO	1	56.9	439.7	28
:	82	WILLOW	HURO	2	130.3	1465.6	27
:	83	SAGINAW	HURO	2	11954.6	29138608.0	50
:	84	KAWKAWLIN	HURO	2	261.3	5284.0	45
:	85	MAUMEE	ERIE	2	40835.0	369546.0	262
:	86	PORTAGE	ERIE	2	2856.0	923.8	340
:	87	SANDUSKY	ERIE	2	6162.6	14781.8	277
:	88	HURON	ERIE	2	1315.7	923.8	399
:	89	VERMILION	ERIE	2	572.3	2424.6	43
:	90	BLACK	ERIE	3	6209.3	1921046.0	42
:	91	CUYAHOGA	ERIE	3	2640.1	9460.1	45
:	92	CHAGRIN	ERIE	3	512.4	3695.4	41
:	93	CATTARAGUS	ERIE	4	1030.1	1420.5	41
:	94	BLACK MICH	ERIE	1	712.7	15058.5	8
:	95	ROUGE	ERIE	1	130.2	208.3	5
:	96	HURON	ERIE	1	454.7	7719.7	7
:							

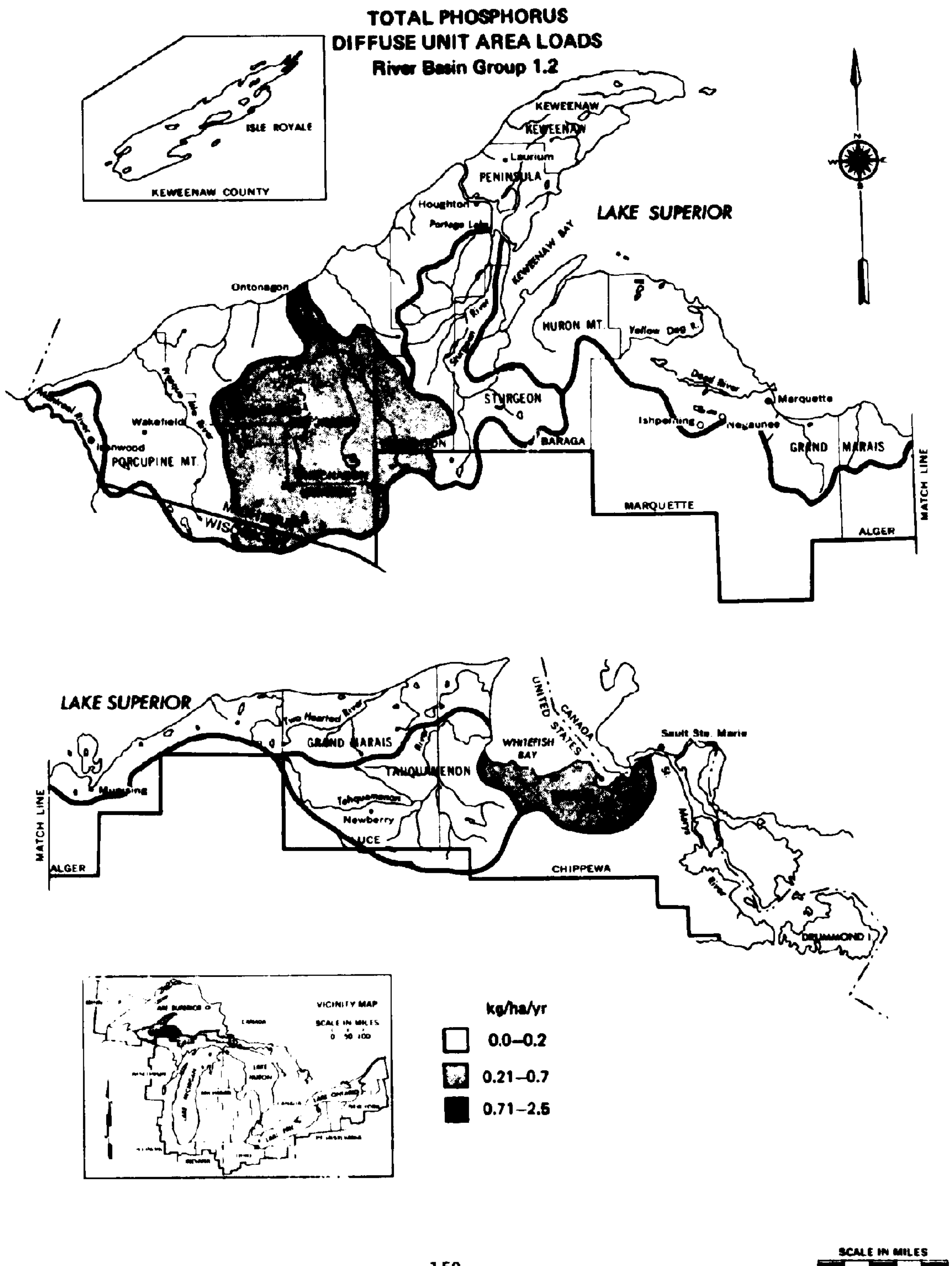
NITRATE (NITRITE) 1976

	TRIBUTARY NAME	LAKE BASIN	RIVER GROUP	LOAD MT\YR	MEAN SQUARE ERR(MT\YR)**2	NUM OF SAMPLES
1	GENESEE	ONTA	1	3779.8	50082.5	25
2	OSWEGO	ONTA	2	5929.0	385705.3	13
3	BLACK NY	ONTA	3	1839.5	197725.7	16
4	OSWEGATCHIE	ONTA	3	461.7	37[illegible].7	9
5	GRASS	ONTA	3	237.3	2364.3	9
6	RAQUETTE	ONTA	3	946.1	32531.3	9
7	FORD	MICH	1	28.1	82.1	24
8	MENOMINEE	MICH	1	408.8	2937.0	12
9	PESHTIGO	MICH	1	225.0	1107.2	12
10	OCONTO	MICH	1	169.6	1063.9	12
11	PENSAUKEE	MICH	1	23.8	14.4	8
12	FOX	MICH	1	312.2	5262.6	24
13	KEWAUNEE	MICH	1	138.9	92.9	12
14	E TWIN	MICH	1	106.0	210.9	12
15	MANITOWOC	MICH	1	255.5	9912.7	11
16	SHEBOYGAN	MICH	1	487.2	7622.6	12
17	MILWAUKEE	MICH	2	614.9	17243.9	12
18	MENOMONEE	MICH	2	116.6	100.3	66
19	ROOT	MICH	2	615.0	33965.8	6
20	ST JOSEPH	MICH	3	5973.2	214507.9	11
21	KALAMAZOO	MICH	3	1780.0	18963.8	23
22	GRAND	MICH	3	5672.5	105630.4	210
23	MUSKEGON	MICH	4	76[illegible].3	9992.2	24
24	MANISTEE	MICH	4	433.3	2651.7	24
25	BETSIE	MICH	4	51.0	88.9	12
26	BOARDMAN	MICH	4	95.2	22.9	12
27	*MANISTIQUE	MICH	4	249.7	3396.6	20
28	WHITE FISH	MICH	4	24.5	32.6	12
29	ESCANABA	MICH	4	118.4	311.2	24
30	THUNDER BAY	HURO	1	49.1	196.1	12
31	RIFLE	HURO	1	75.5	155.1	24
32	AU GRES	HURO	1	195.1	4449.5	11
33	SAGINAW	HURO	2	8928.6	1218295.0	33
34	CHEBOYGAN	HURO	1	115.3	158.4	25
35	FINNEBOG	HURO	2	658.9	81277.3	12
36	AU SABLE	HURO	1	140.3	972.2	12
37	VAN ETTEN CR	HURO	1	22.0	126.1	12
38	MPINE	HURO	1	14.6	18.3	11
39	TAHQUAMENON	SUPE	2	84.5	507.2	24
40	MONTREAL	SUPE	1	54.7	202.9	12
41	PRESQUE ISLE	SUPE	2	22.4	54.4	12
42	STURGEON	SUPE	2	63.7	322.1	12
43	CARP	SUPE	2	24.9	19.4	12
44	ONTONAGON	SUPE	2	135.3	343.0	24
45	ST LOUIS	SUPE	1	227.8	2969.2	11
46	BOIS BRULE	SUPE	1	13.0	21.4	3
47	NEMADJI	SUPE	1	59.4	298.1	14
48	BAD	SUPE	1	103.5	1124.6	14
49	BAPTISM	SUPE	1	37.1	100.8	6

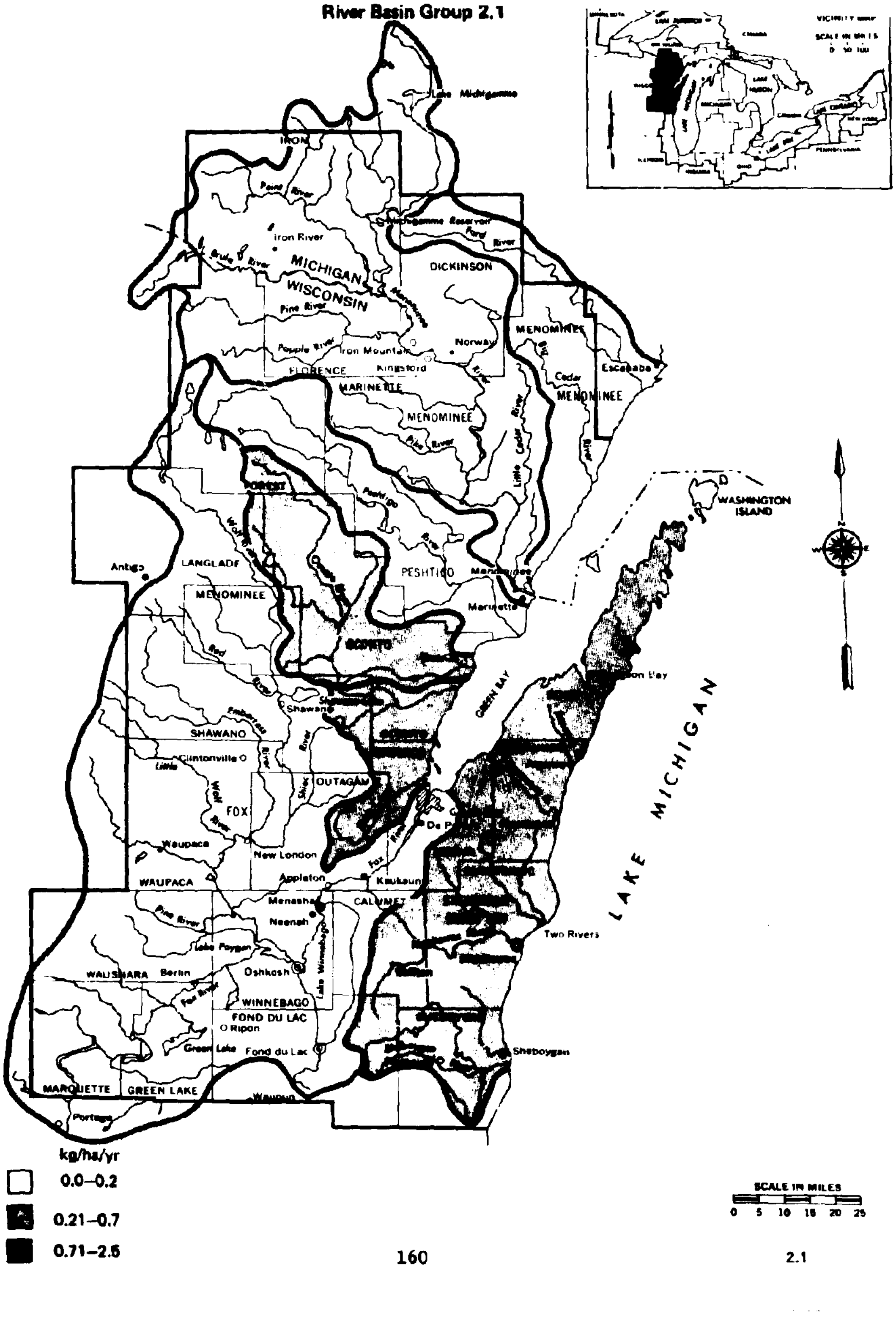
APPENDIX B

MAPS SHOWING REGIONAL DIFFERENCES IN THE TOTAL PHOSPHORUS AND SUSPENDED SOLIDS DIFFUSE UNIT AREA LOADS


TOTAL PHOSPHORUS
DIFFUSE UNIT AREA LOADS
River Basin Group 1.1
VICINITY MAP
CANADA
UNITED STATES
Pigeon River
Grand Marais
Babbitt
LAKE
Aurora
Chisholm
Virginia
Hibbing
Eveleth
Silver Bay
LAKE SUPERIOR
ST. LOUIS
Two Harbors
APOSTLE ISLANDS
Duluth
ST. LOUIS
Cloquet
CARLTON
MINNESOTA
WISCONSIN
MICHIGAN
WISCONSIN
DOUGLAS
BAYFIELD
ASHLAND
IRON
kg/ha/yr
0 - 0.2
0.21–0.7
0.71–2.5
SCALE IN MILES
0 5 10 15 20

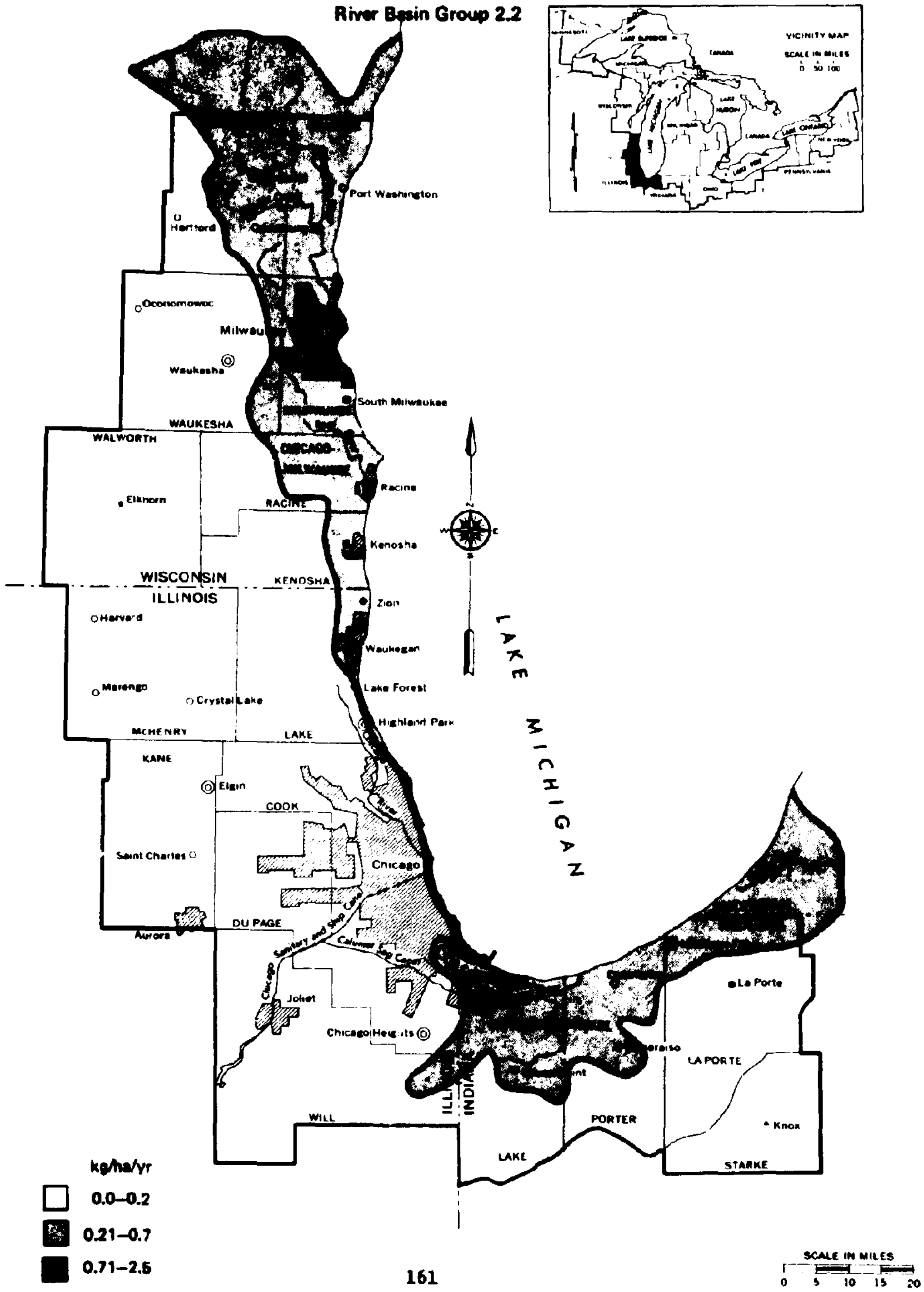

TOTAL PHOSPHORUS
DIFFUSE UNIT AREA LOADS
River Basin Group 1.2
ISLE ROYALE
KEWEENAW COUNTY
LAKE SUPERIOR
KEWEENAW
PENINSULA
Laurium
Houghton
Portage Lake
KEWEENAW BAY
Ontonagon
HURON MT.
Yellow Dog R.
Dead River
STURGEON
BARAGA
Marquette
Ishpeming
Negaunee
GRAND MARAIS
Wakefield
Ironwood
PORCUPINE MT.
MARQUETTE
ALGER
MATCH LINE
LAKE SUPERIOR
Two Hearted River
GRAND MARAIS
TAHQUAMENON
Tahquamenon
Newberry
Munising
WHITEFISH BAY
UNITED STATES
CANADA
Sault Ste. Marie
ALGER
CHIPPEWA
VICINITY MAP
SCALE IN MILES
0 50 100
kg/ha/yr
0.0–0.2
0.21–0.7
0.71–2.6
SCALE IN MILES
0 5 10 15 20 25

River Basin Group 2.1

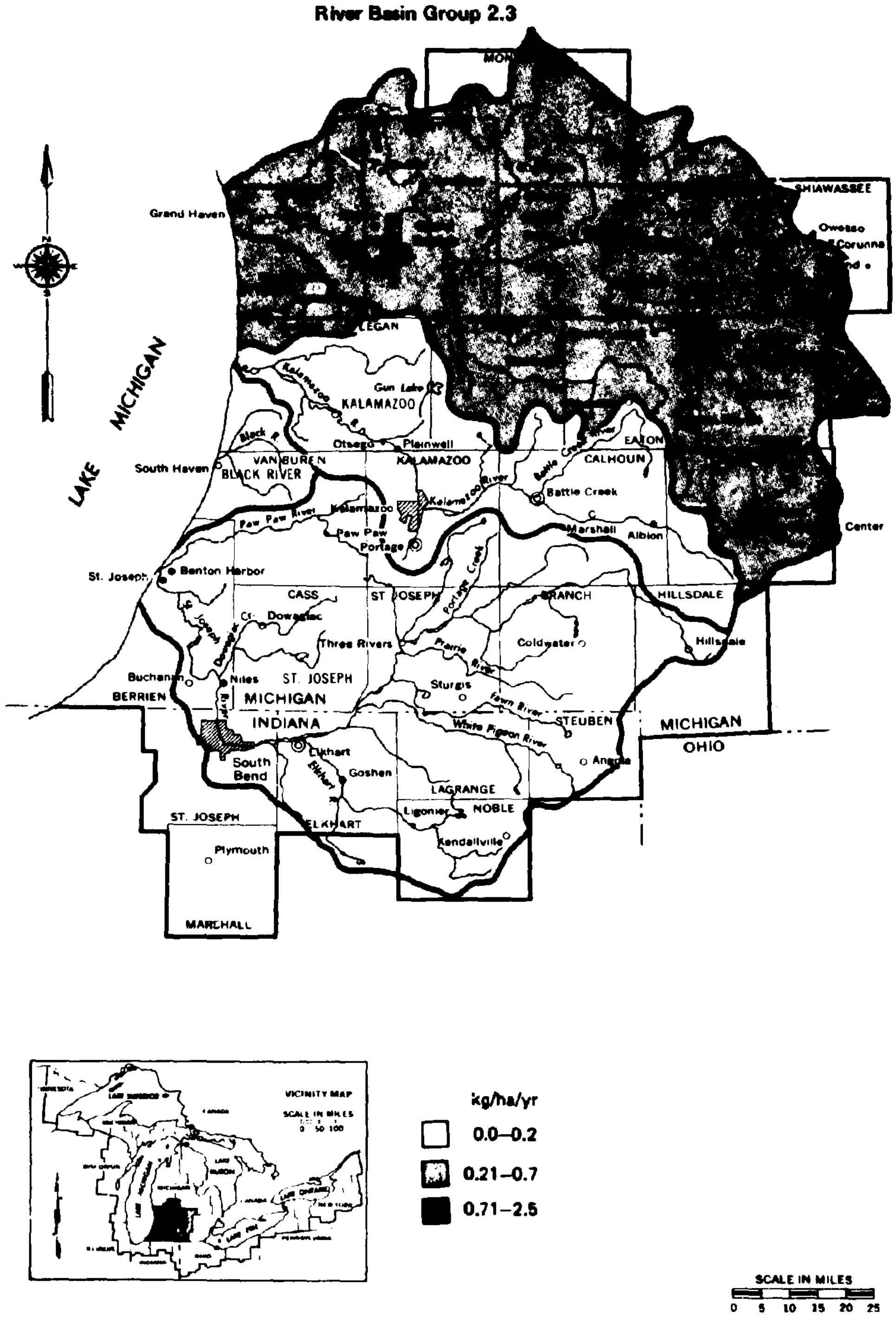


2.1

TOTAL PHOSPHORUS
DIFFUSE UNIT AREA LOADS
River Basin Group 2.2

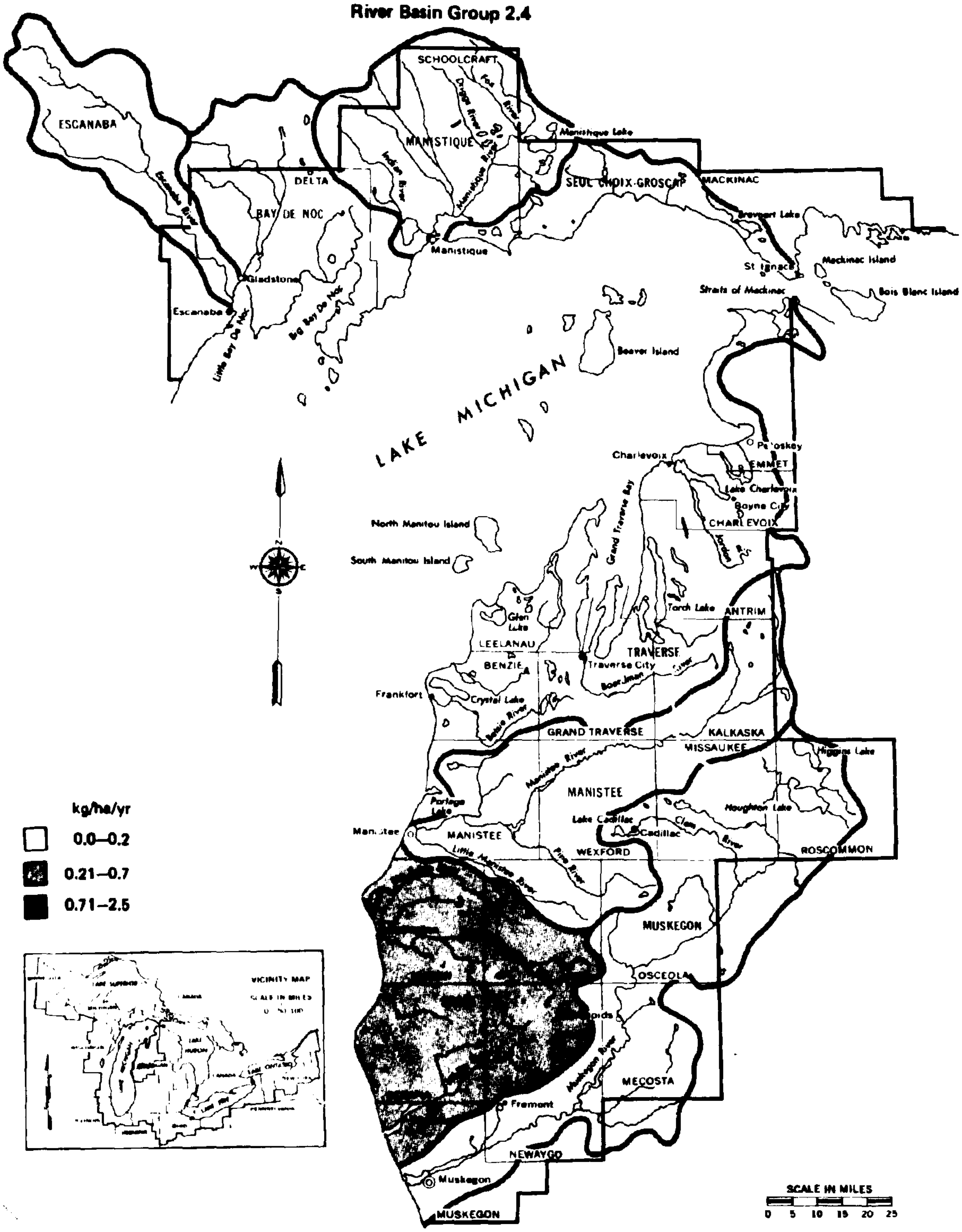


TOTAL PHOSPHORUS
DIFFUSE UNIT AREA LOADS
River Basin Group 2.3



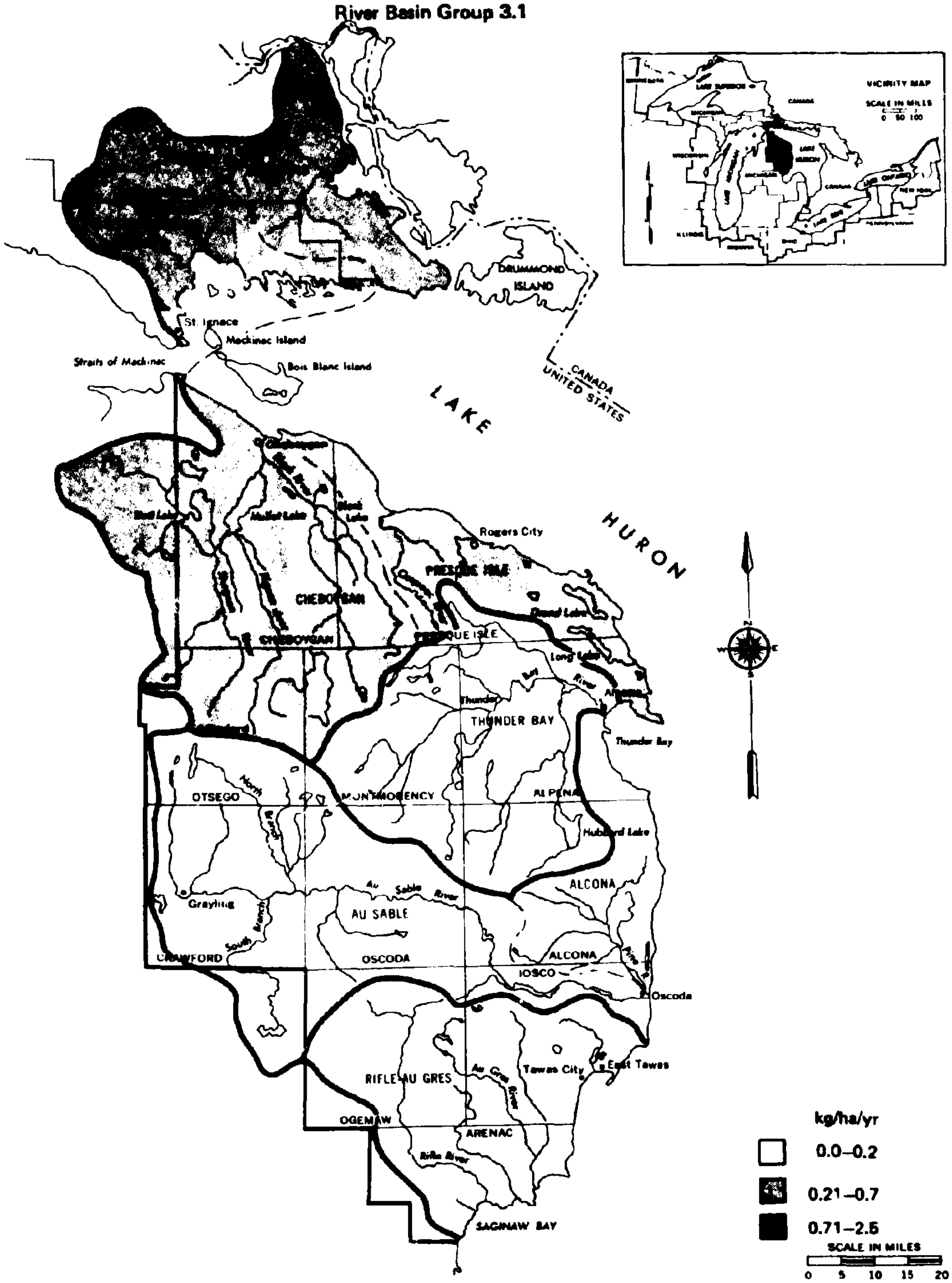
2.3

TOTAL PHOSPHORUS
DIFFUSE UNIT AREA LOADS
River Basin Group 2.4



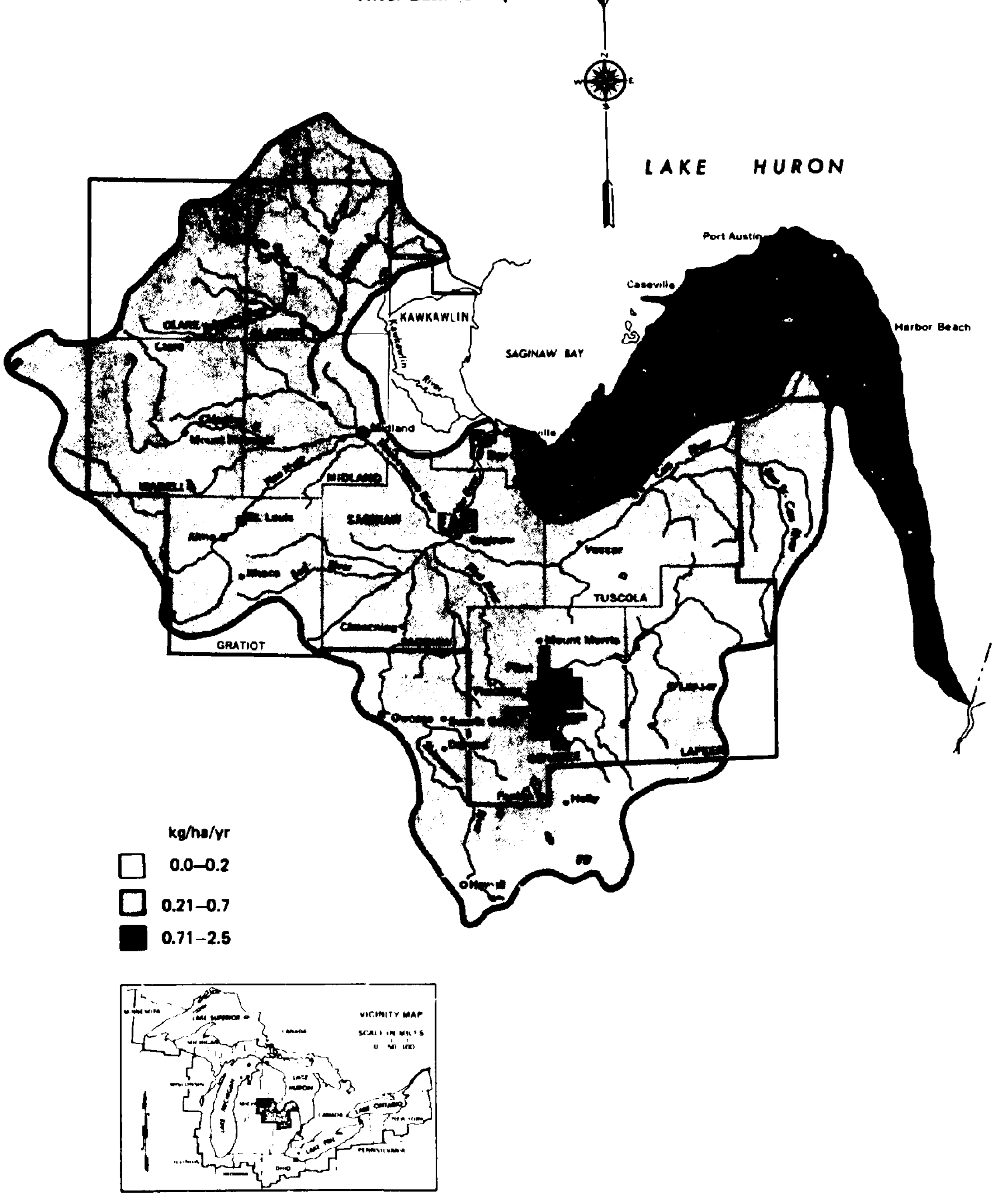
DIFFUSE UNIT AREA LOADS

River Basin Group 3.1

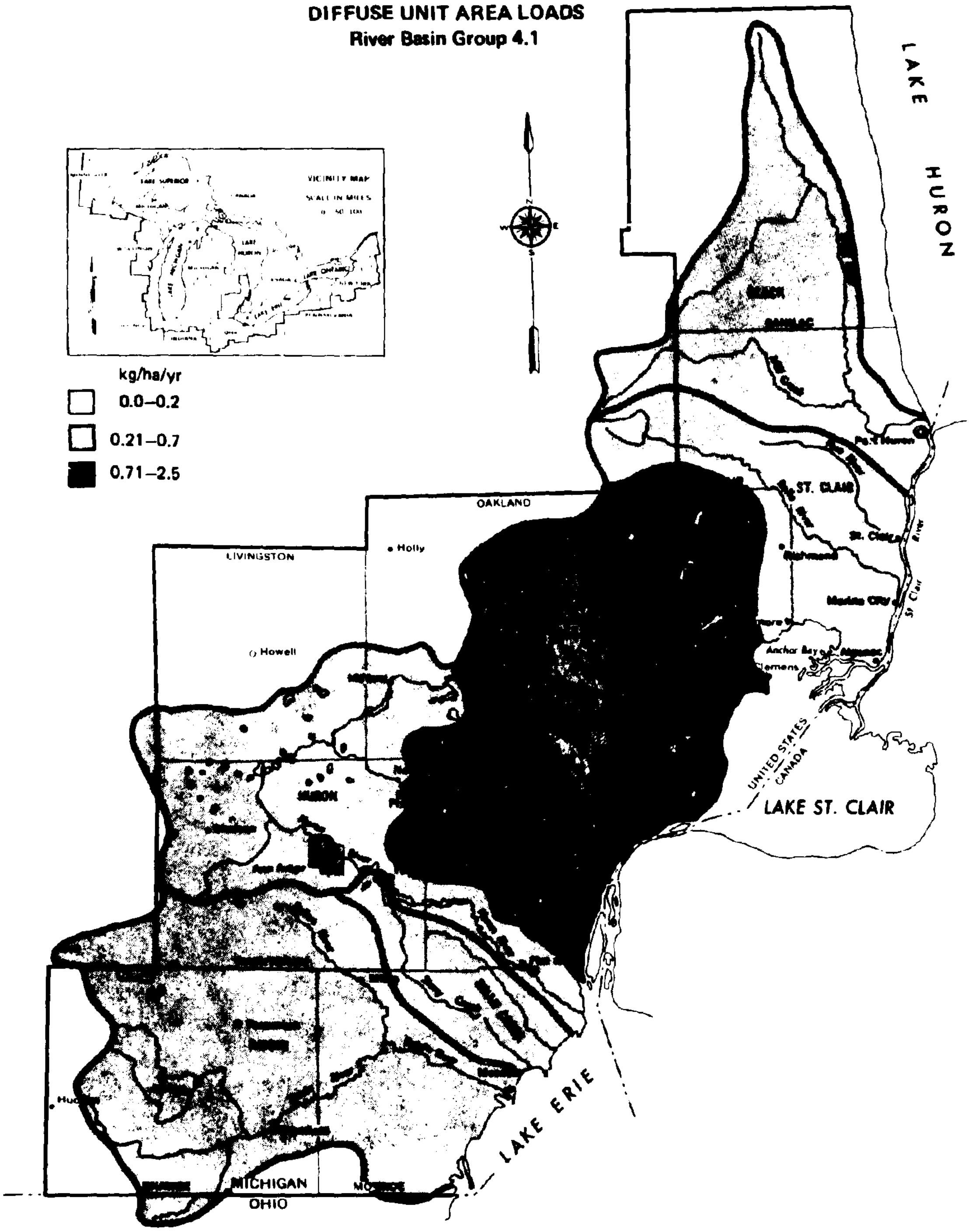


3.1

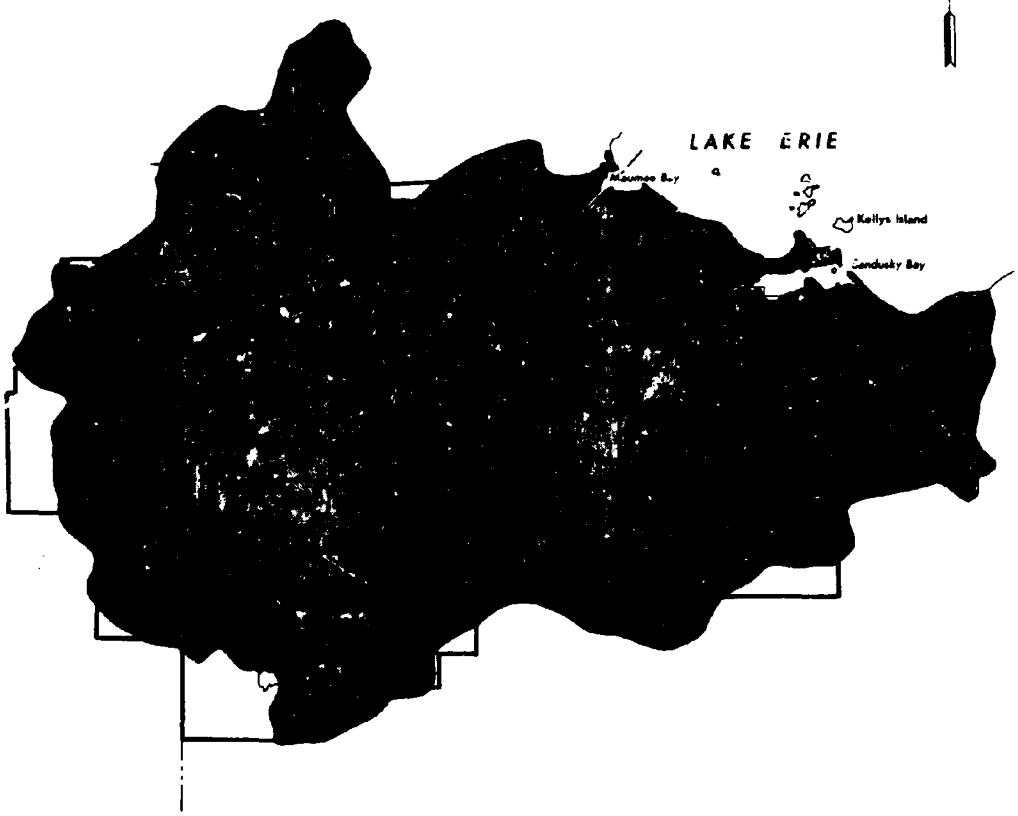
DIFFUSE UNIT AREA LOADS
River Basin Group 3.2

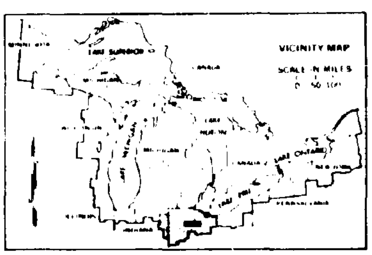


TOTAL PHOSPHORUS
DIFFUSE UNIT AREA LOADS
River Basin Group 4.1



TOTAL PHOSPHORUS
DIFFUSE UNIT AREA LOADS
River Basin Group 4.2



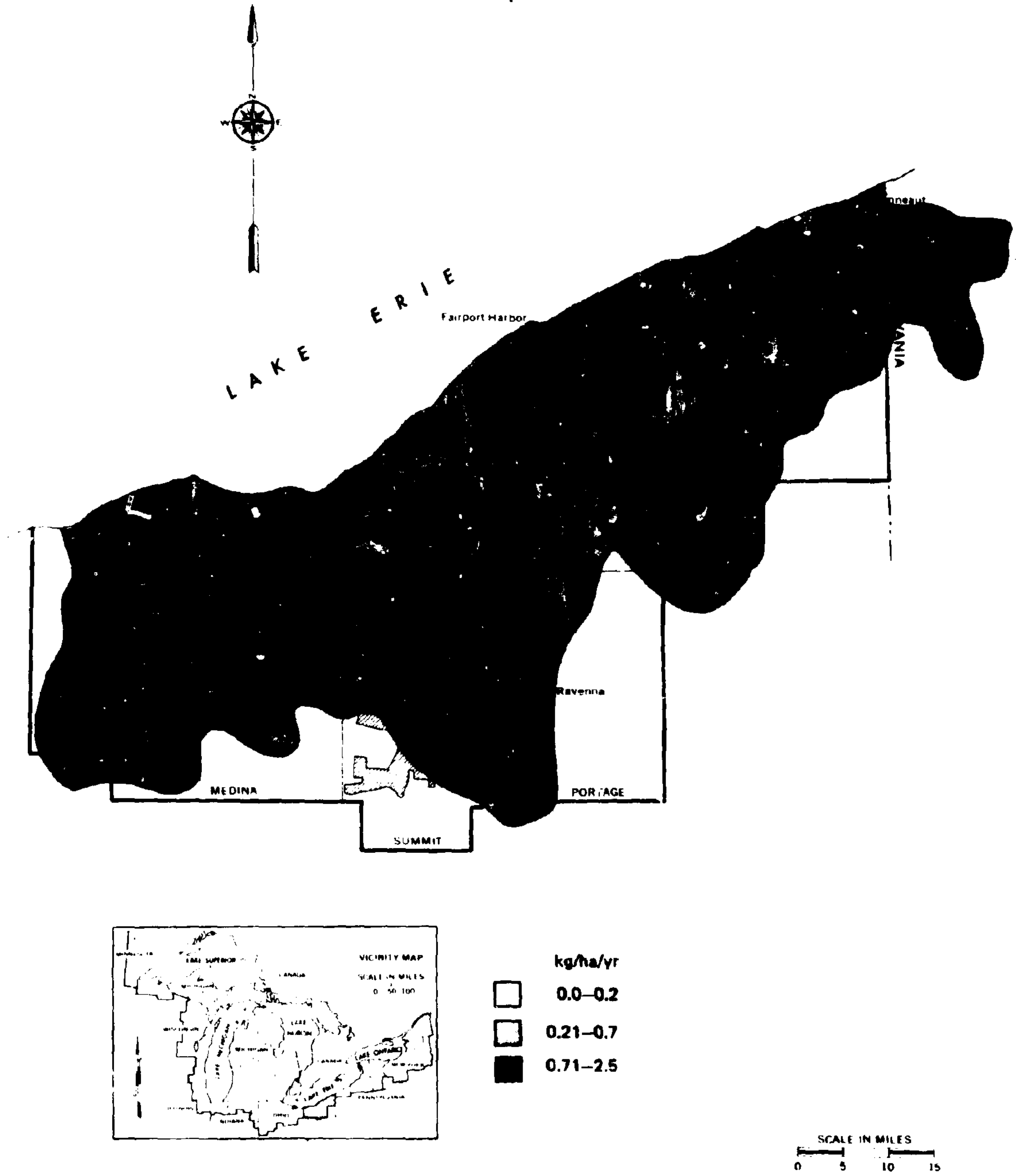


kg/ha/yr

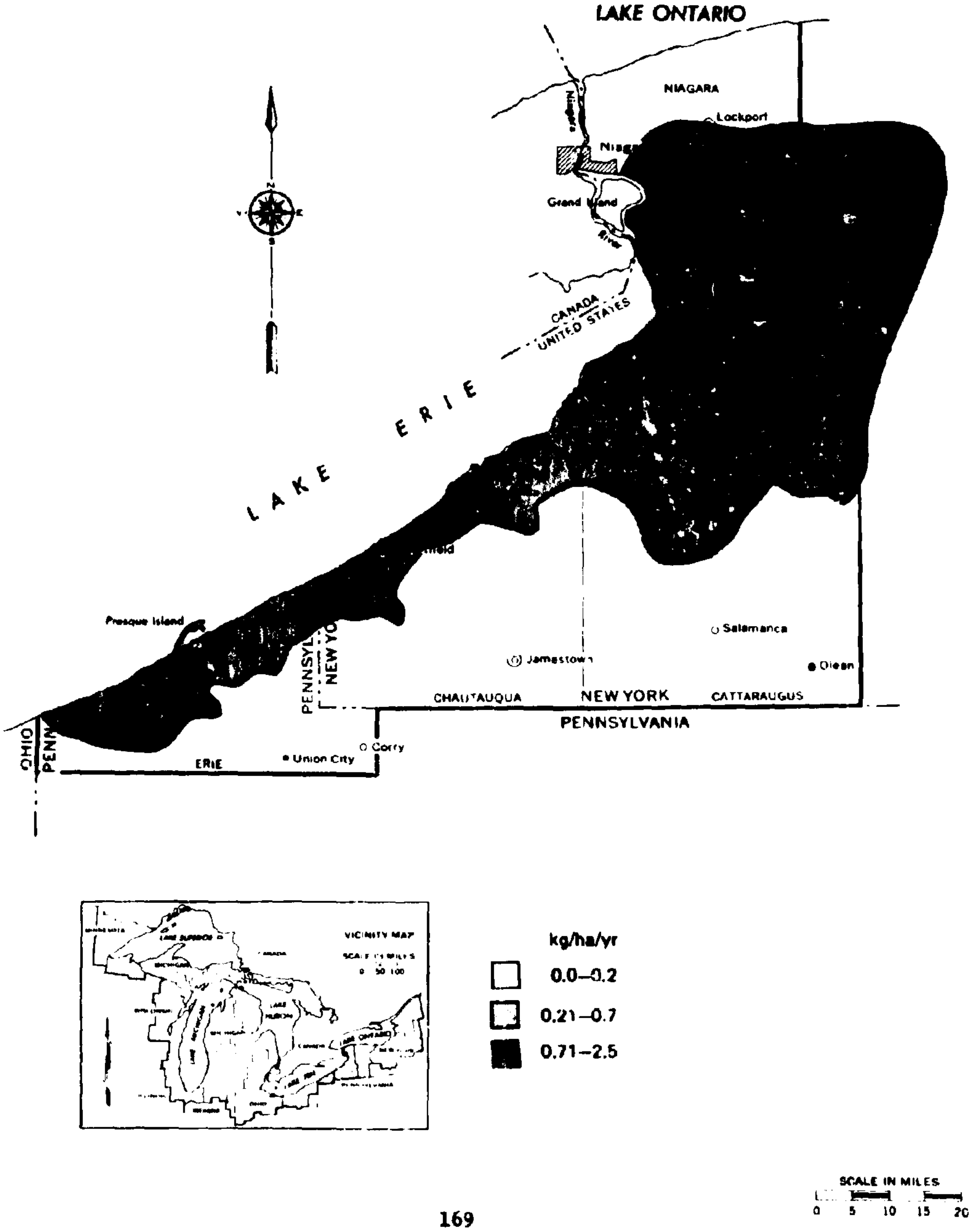
- 0.0–0.2
- 0.21–0.7
- 0.71–2.5

SCALE IN MILES
0 5 10 15 20 25

TOTAL PHOSPHORUS
DIFFUSE UNIT AREA LOADS
River Basin Group 4.3

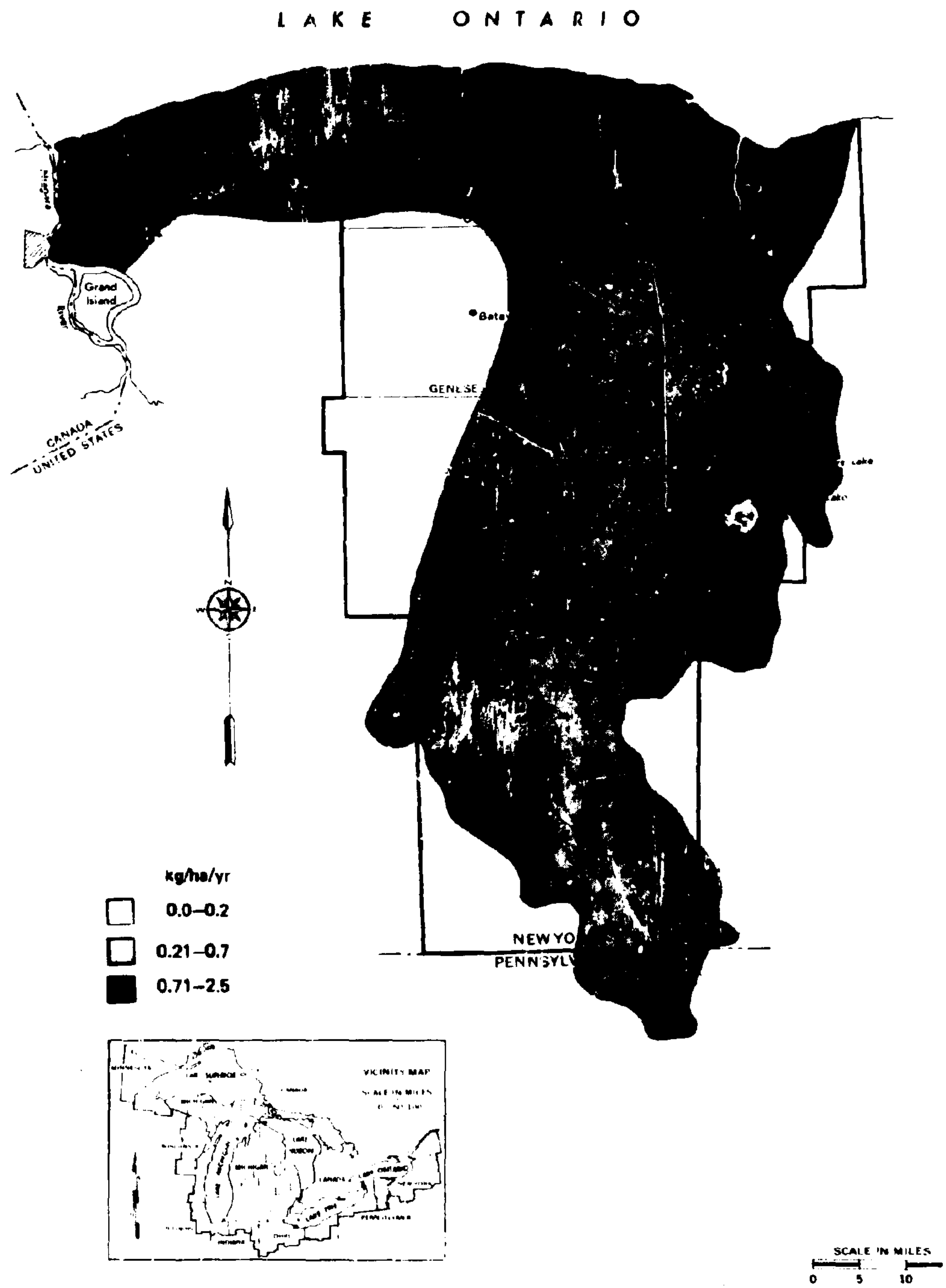


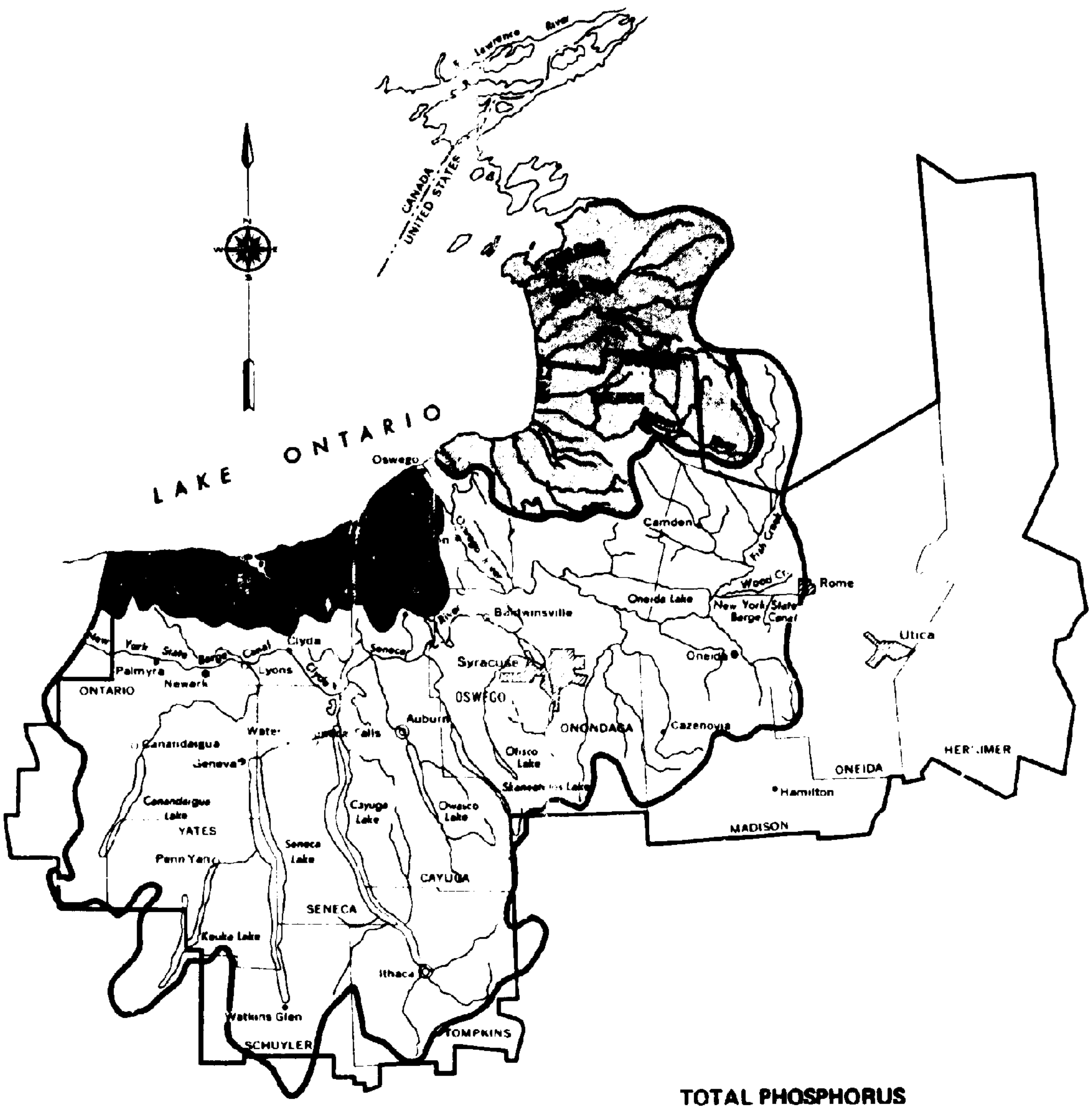
TOTAL PHOSPHORUS
DIFFUSE UNIT AREA LOADS
River Basin Group 4.4



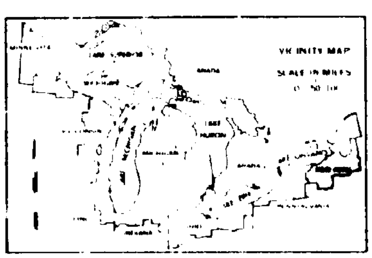
4.4

TOTAL PHOSPHORUS
DIFFUSE UNIT AREA LOADS
River Basin Group 5.1





TOTAL PHOSPHORUS
DIFFUSE UNIT AREA LOADS
River Basin Group 5.2

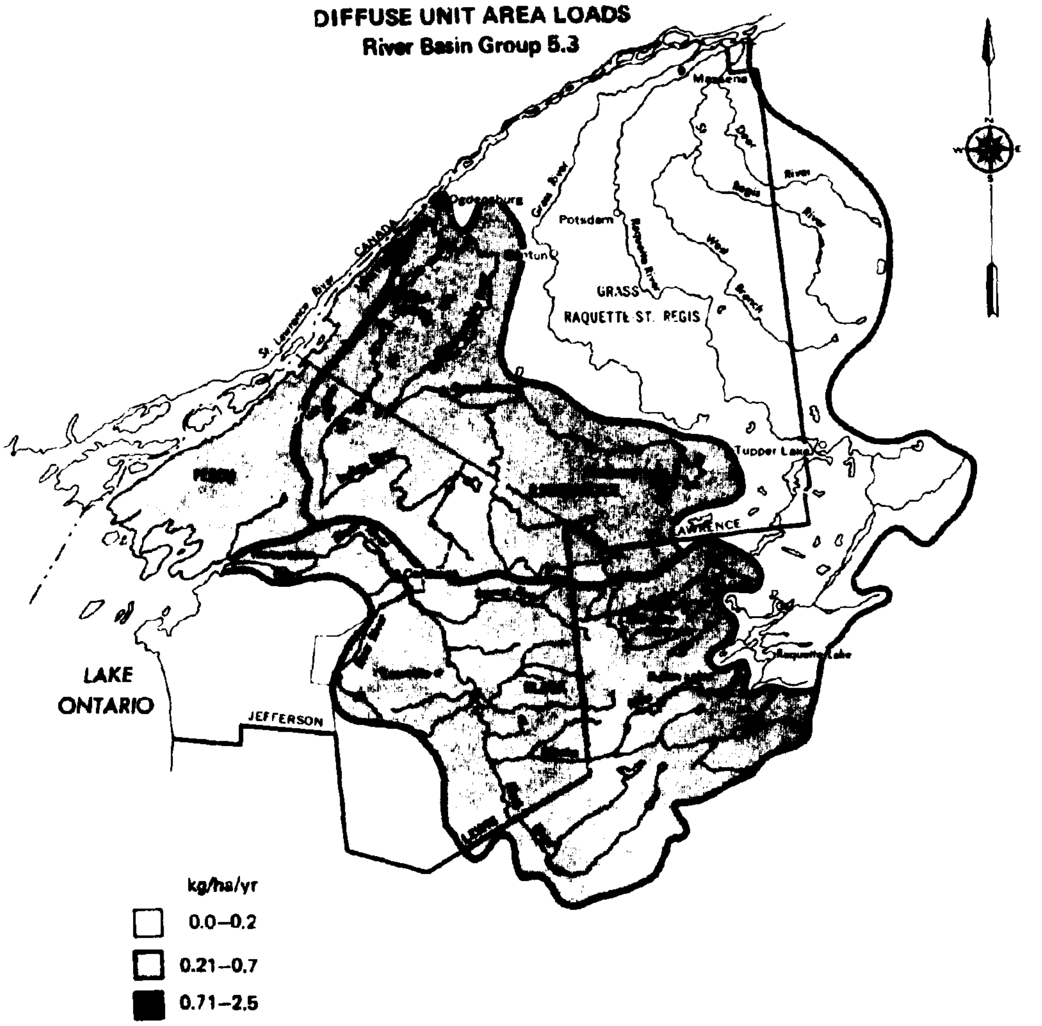


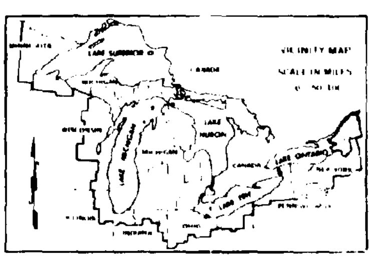
kg/ha/yr

- 0.0–0.2
- 0.21–0.7
- 0.71–2.5

SCALE IN MILES
0 5 10 15 20

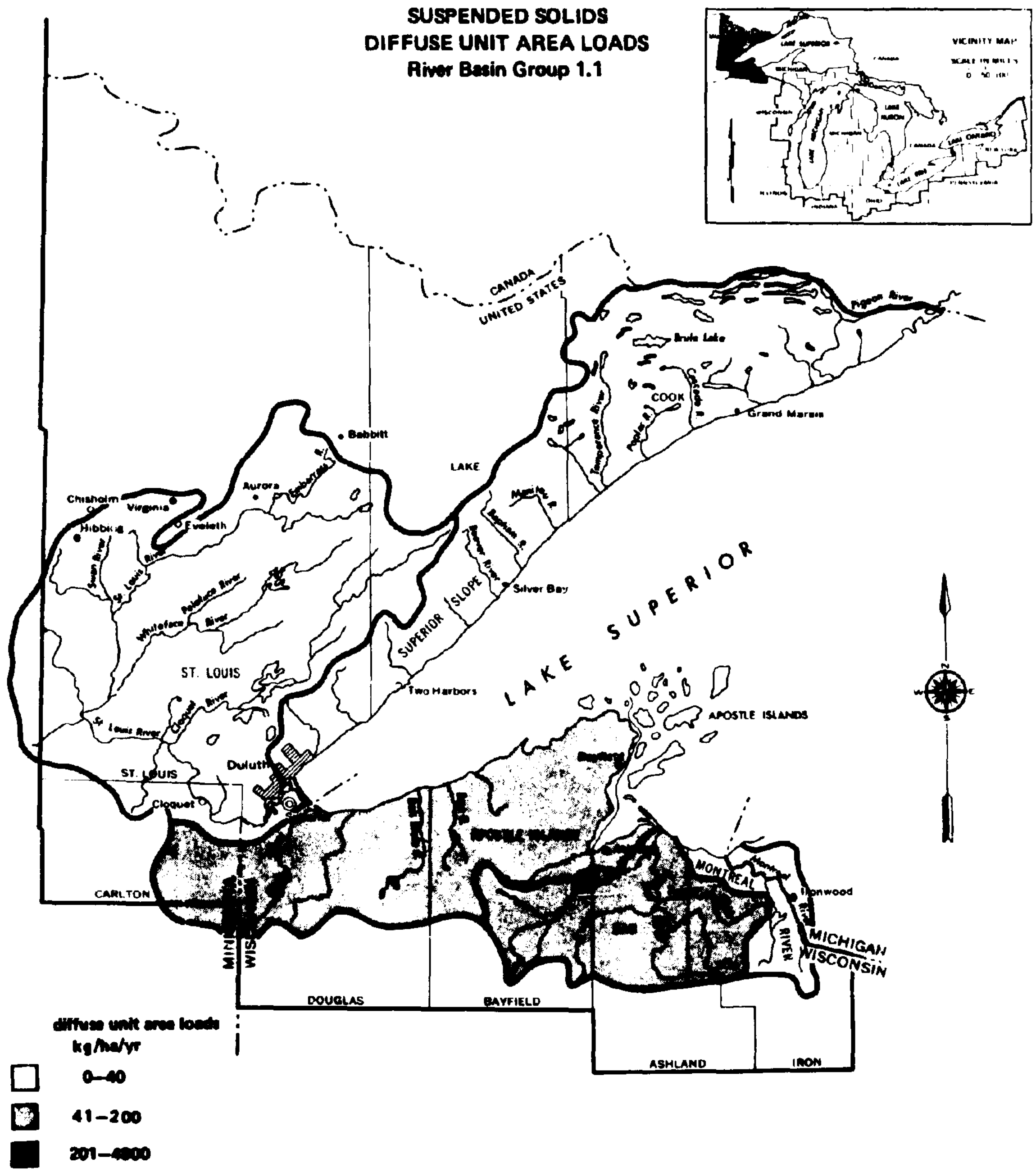
TOTAL PHOSPHORUS
DIFFUSE UNIT AREA LOADS
River Basin Group 5.3



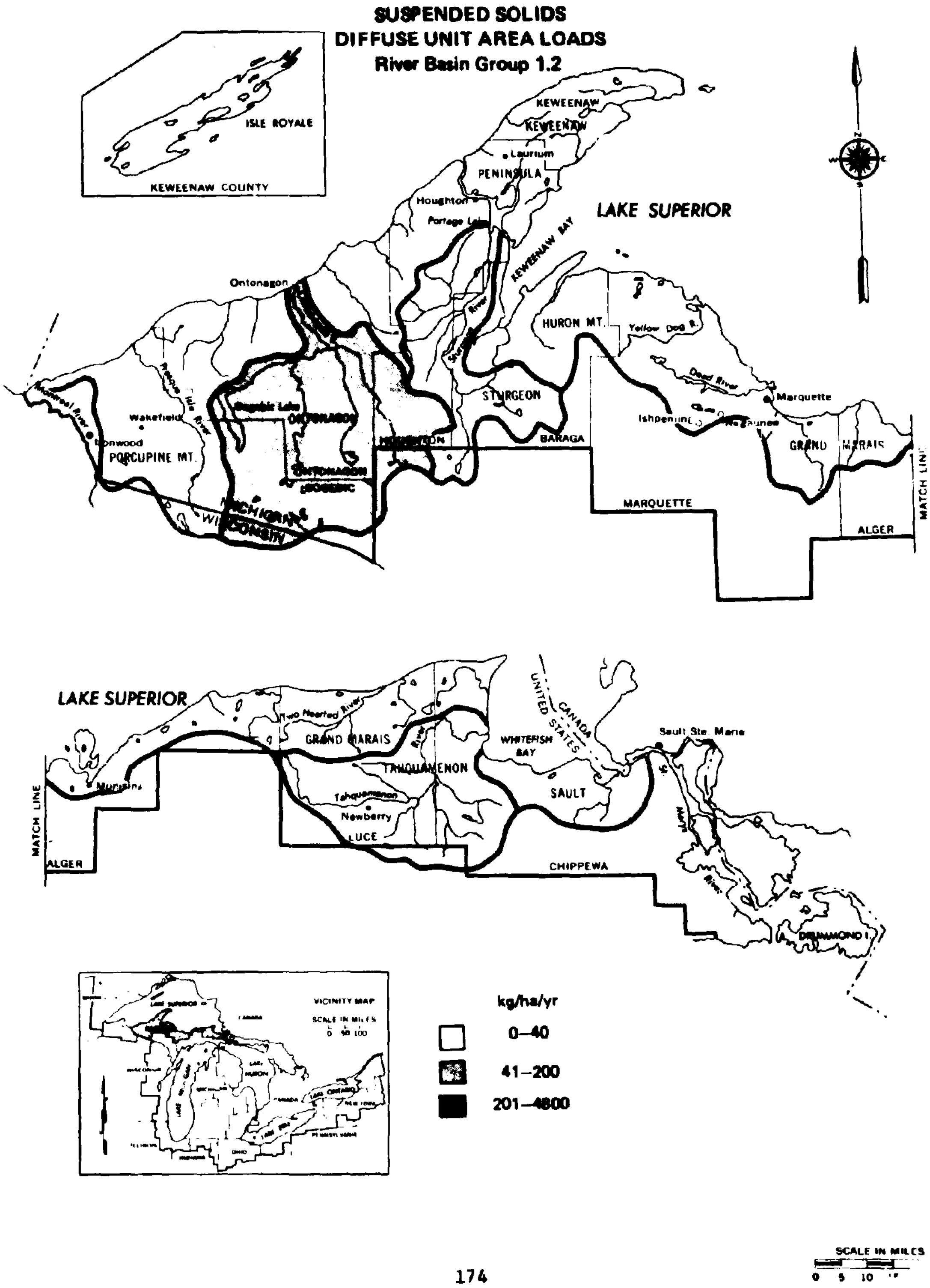


SCALE IN MILES
0 5 10 15

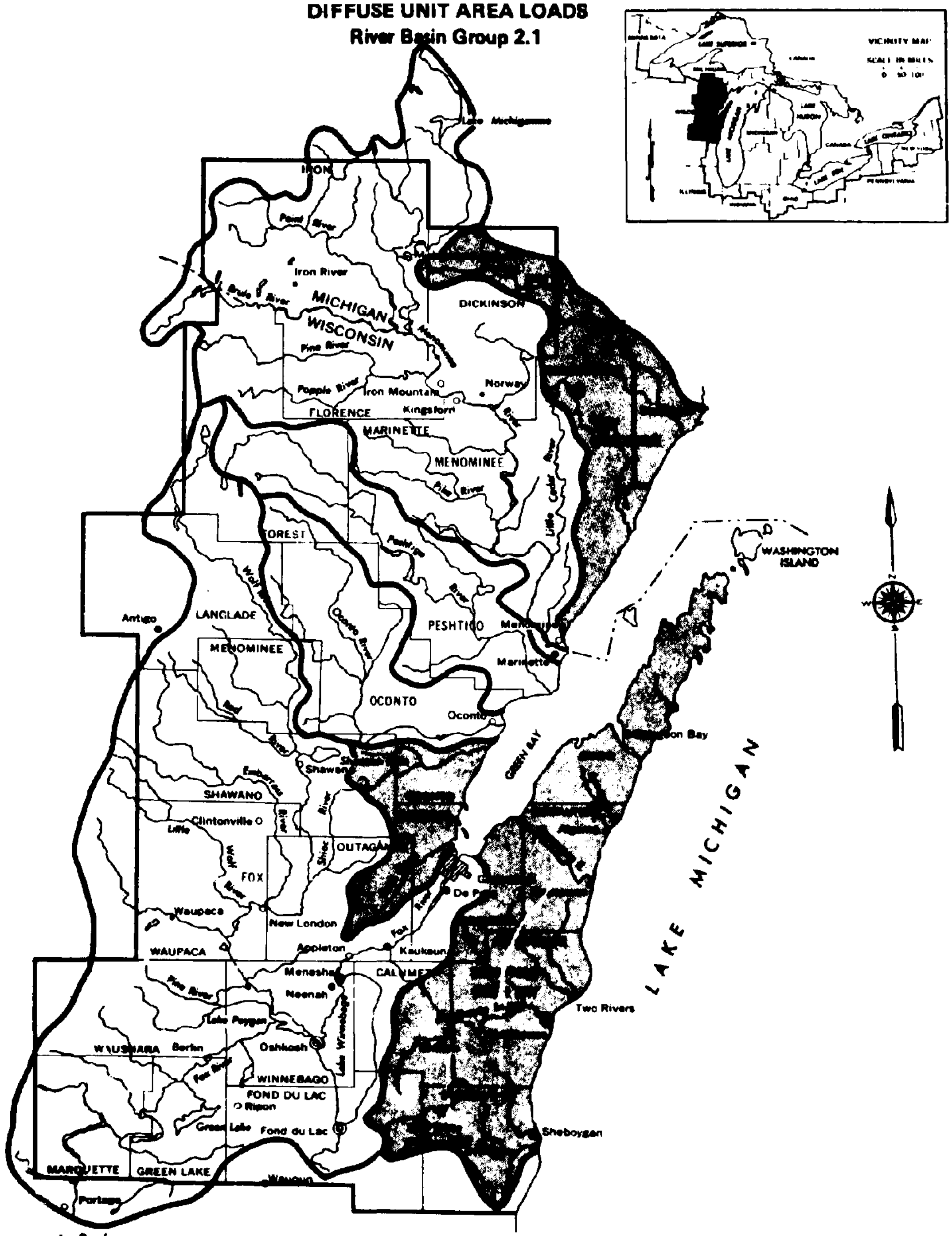
5.3



SCALE IN MILES
0 5 10 15 20 25


SUSPENDED SOLIDS
DIFFUSE UNIT AREA LOADS
River Basin Group 1.2
ISLE ROYALE
KEWEENAW COUNTY
KEWEENAW
PENINSULA
Laurium
Houghton
Portage Lake
KEWEENAW BAY
LAKE SUPERIOR
Ontonagon
HURON MT.
Yellow Dog R.
Dead River
Marquette
Ishpeming
Negaunee
STURGEON
BARAGA
Wakefield
Ironwood
PORCUPINE MT.
ONTONAGON
GOGEBIC
MICHIGAN
WISCONSIN
MARQUETTE
ALGER
GRAND MARAIS
MATCH LINE
LAKE SUPERIOR
Two Hearted River
GRAND MARAIS
TAHQUAMENON
Tahquamenon
Newberry
LUCE
WHITEFISH BAY
UNITED STATES
CANADA
Sault Ste. Marie
SAULT
CHIPPEWA
DRUMMOND I.
MATCH LINE
ALGER
VICINITY MAP
kg/ha/yr
0–40
41–200
201–4800
SCALE IN MILES
0 5 10

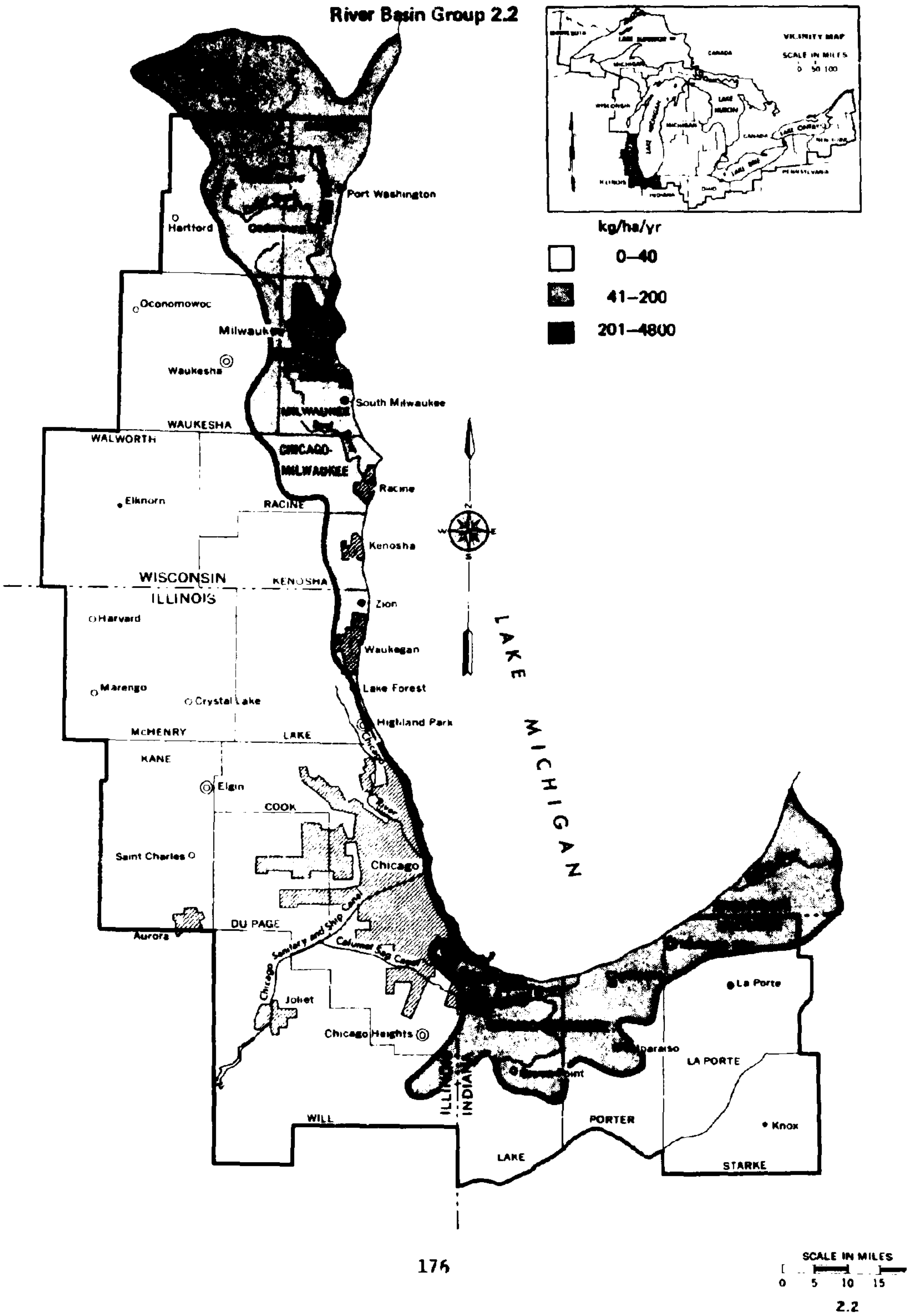
DIFFUSE UNIT AREA LOADS
River Basin Group 2.1



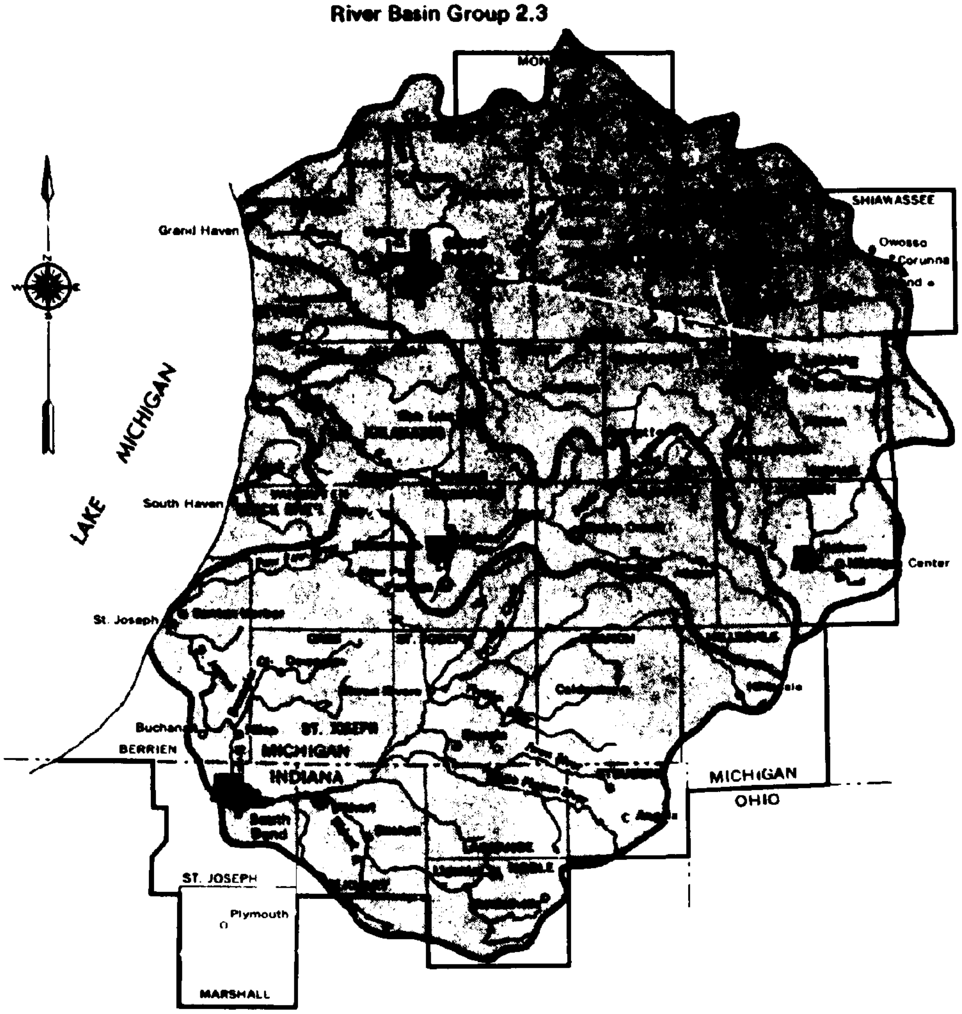
kg/ha/yr

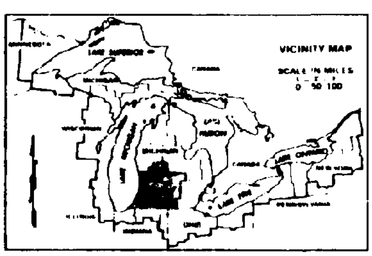
- 0–40
- 41–200
- 201–4800

DIFFUSE UNIT AREA LOADS
River Basin Group 2.2



DIFFUSE UNIT AREA LOADS
River Basin Group 2.3





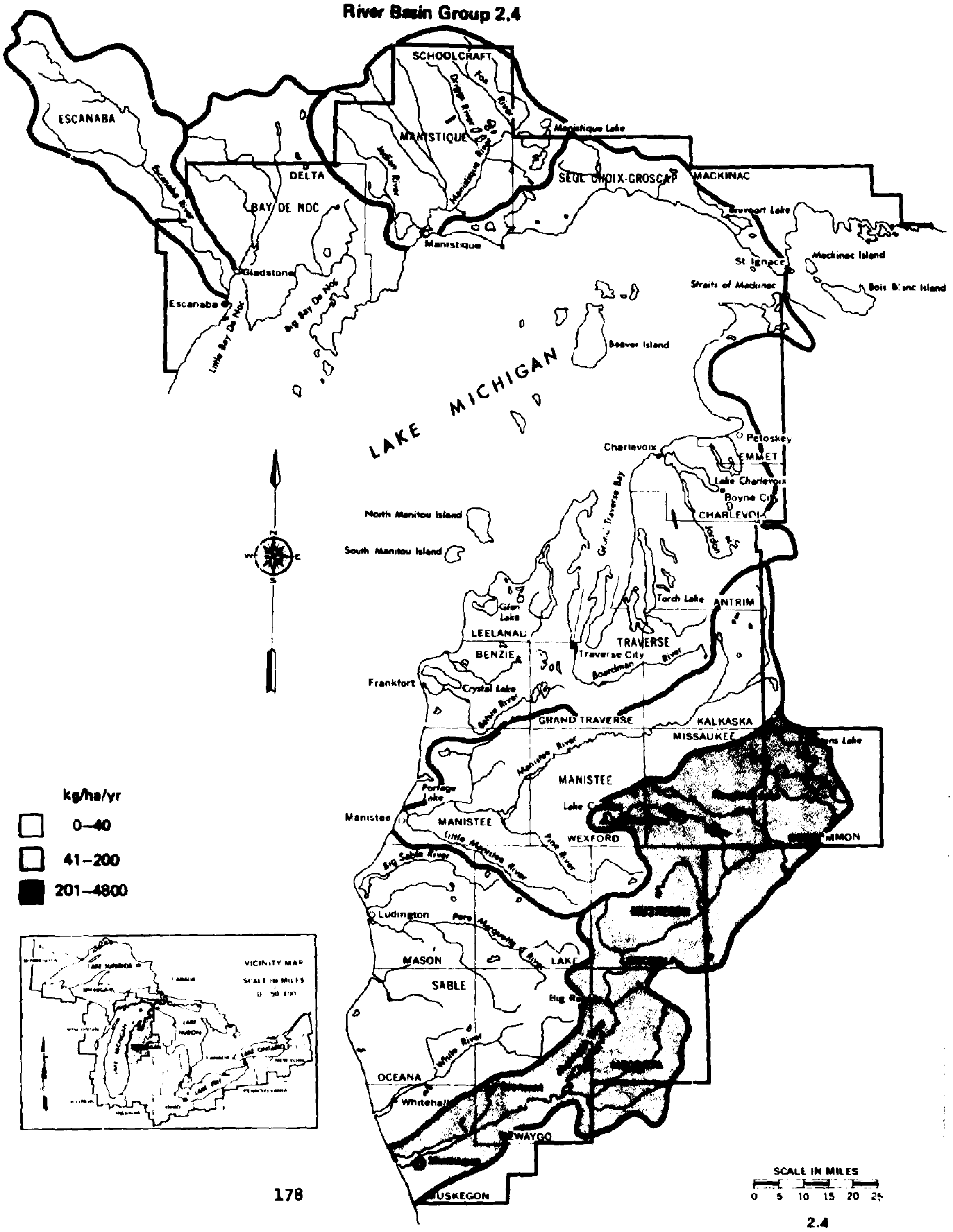
kg/ha/yr

☐	0–40
☐	41–200
■	201–4800

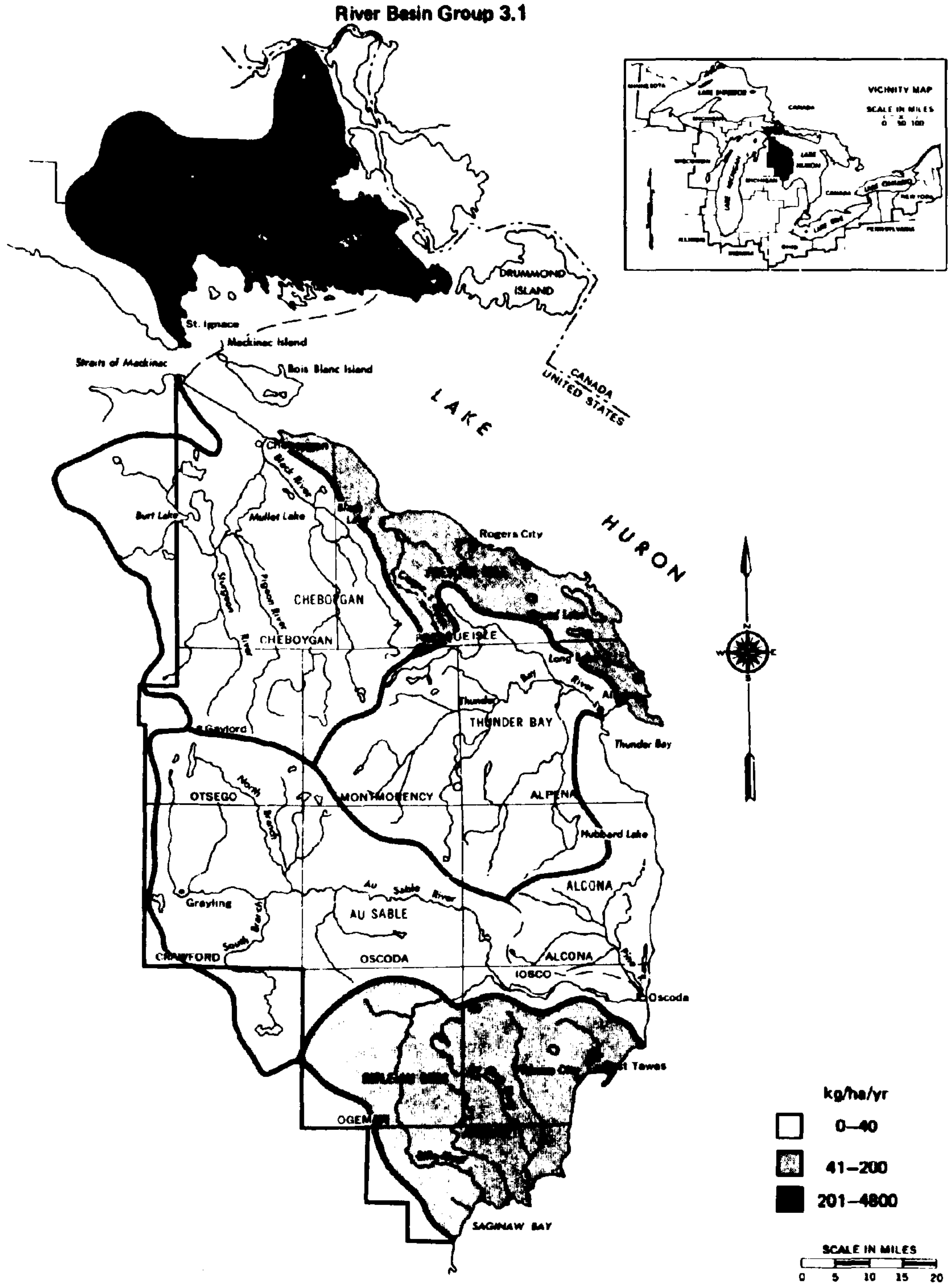
SCALE IN MILES
0 5 10 15 20 25

2.3

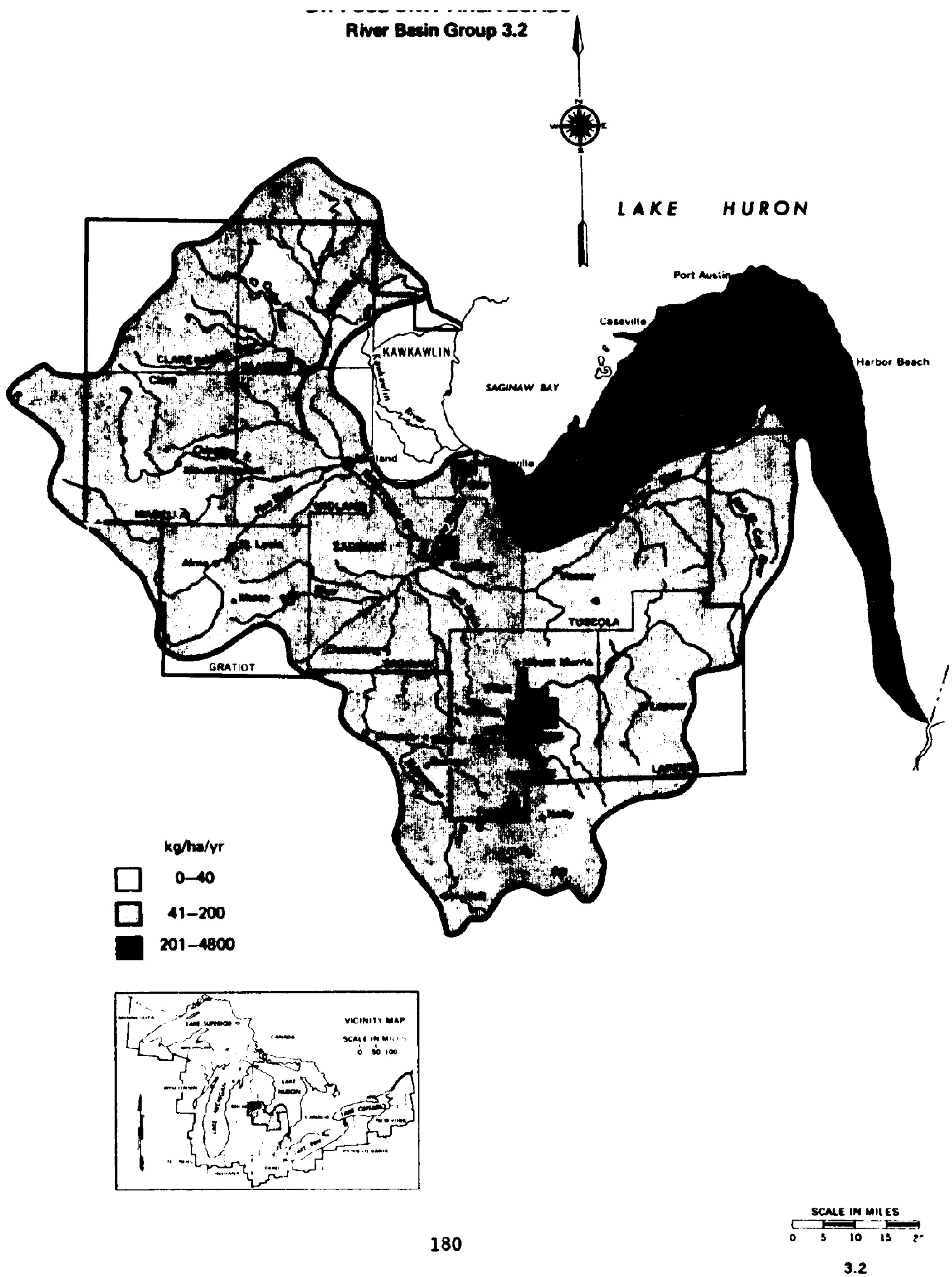
SUSPENDED SOLIDS
DIFFUSE UNIT AREA LOADS
River Basin Group 2.4



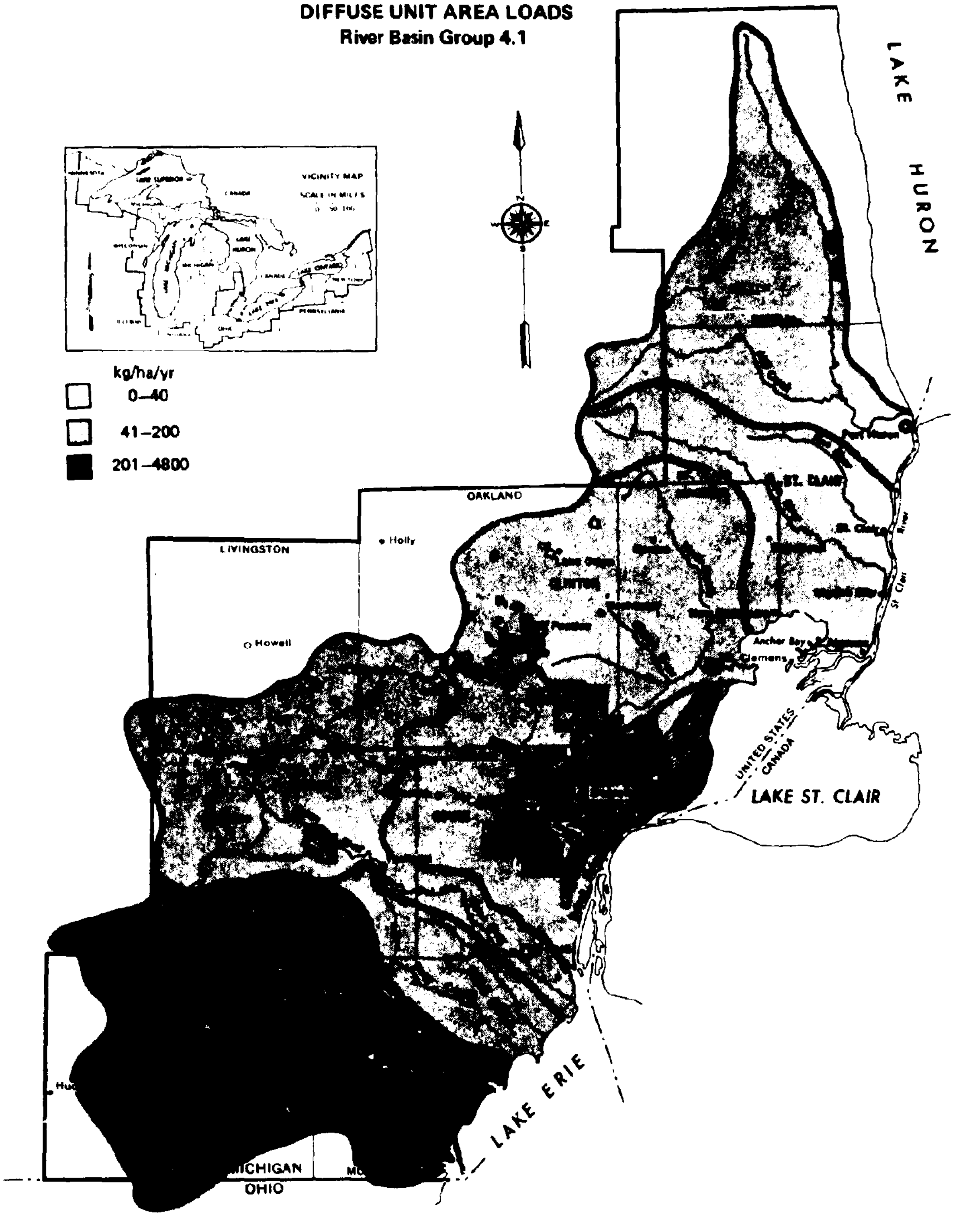
DIFFUSE UNIT AREA LOADS
River Basin Group 3.1



3.1

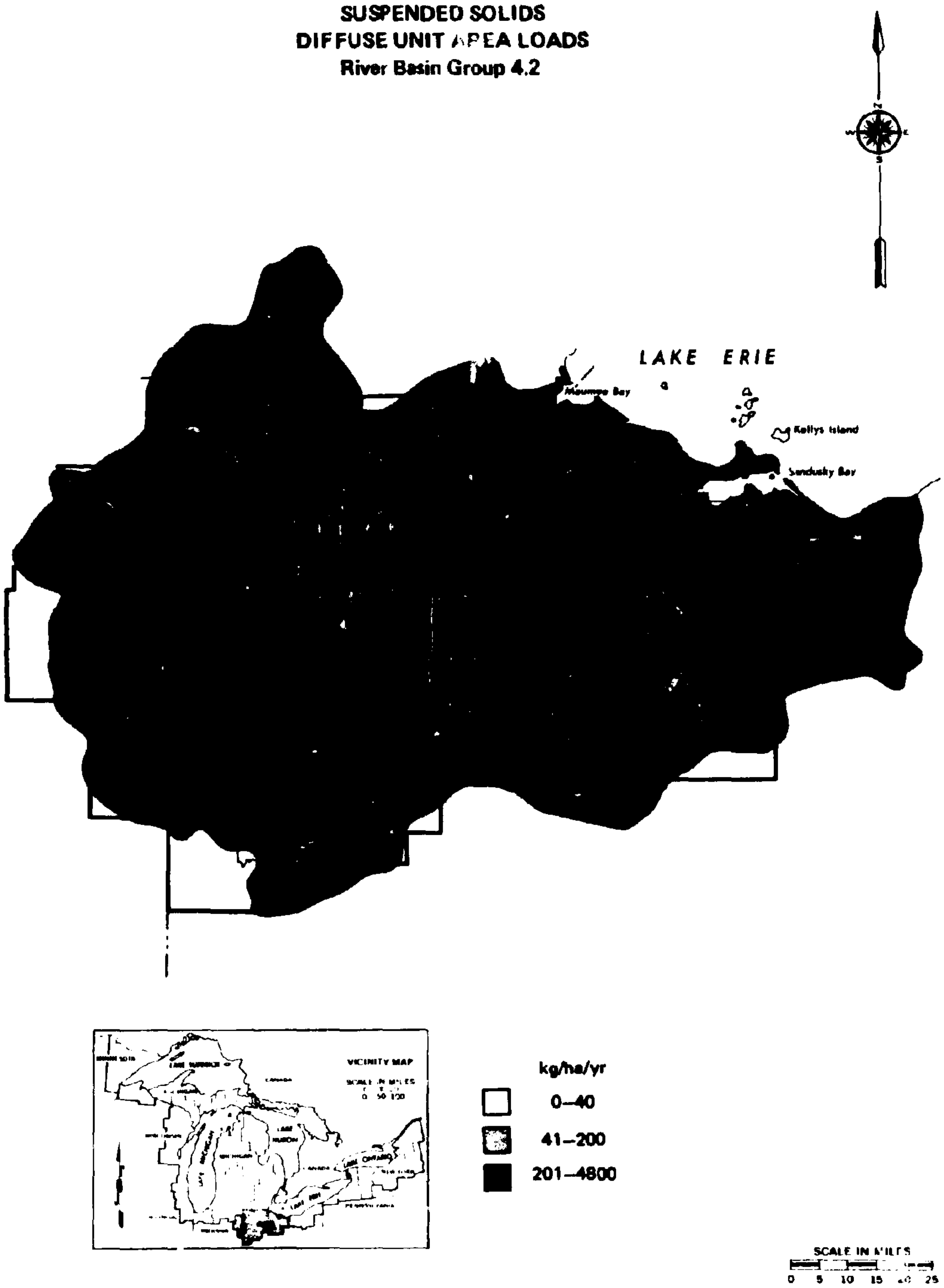

River Basin Group 3.2
LAKE HURON
Caseville
Harbor Beach
KAWKAWLIN
SAGINAW BAY
TUSCOLA
GRATIOT
kg/ha/yr
0–40
41–200
201–4800
VICINITY MAP
SCALE IN MILES
3.2

SUSPENDED SOLIDS
DIFFUSE UNIT AREA LOADS
River Basin Group 4.1

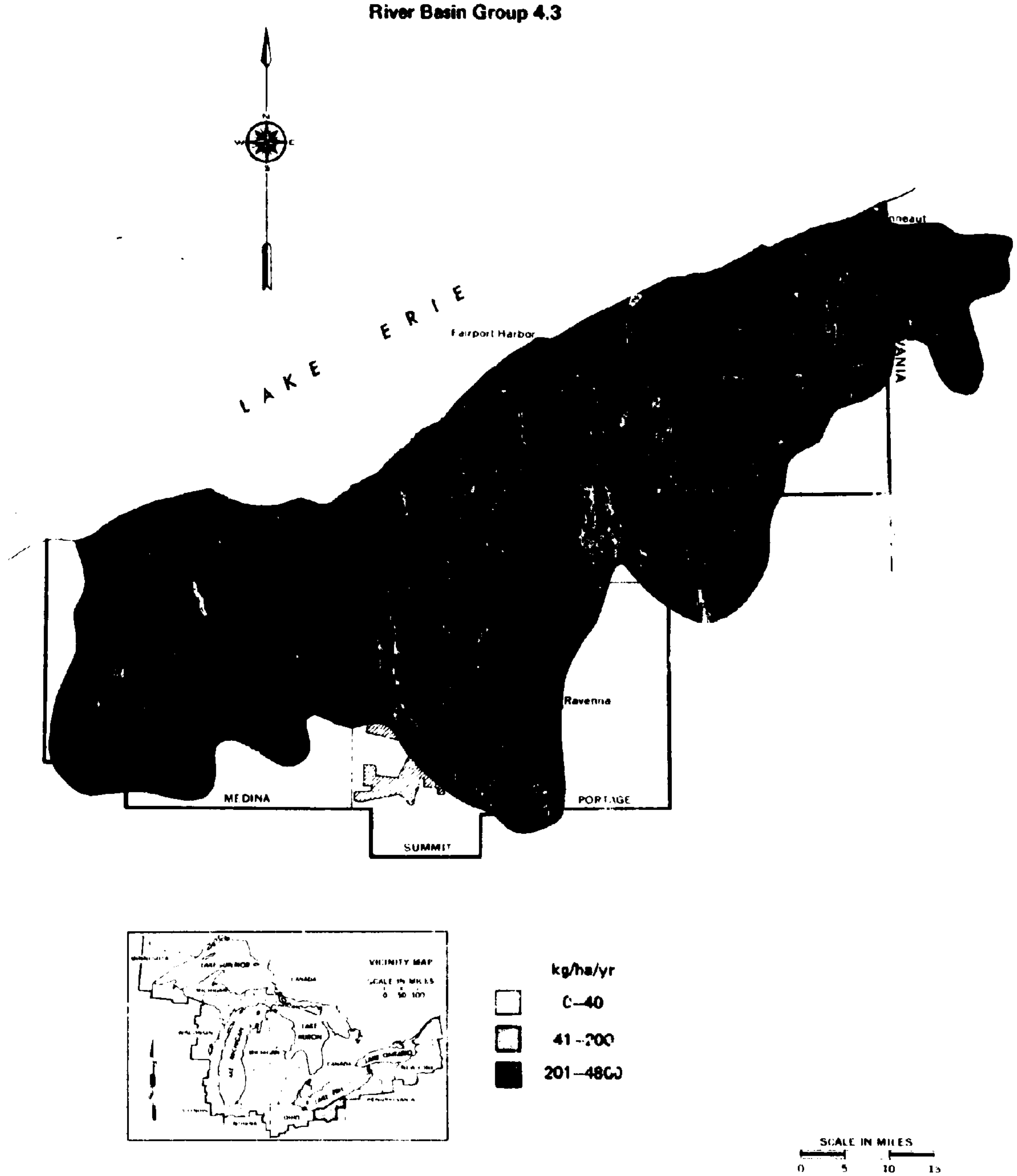


4.1

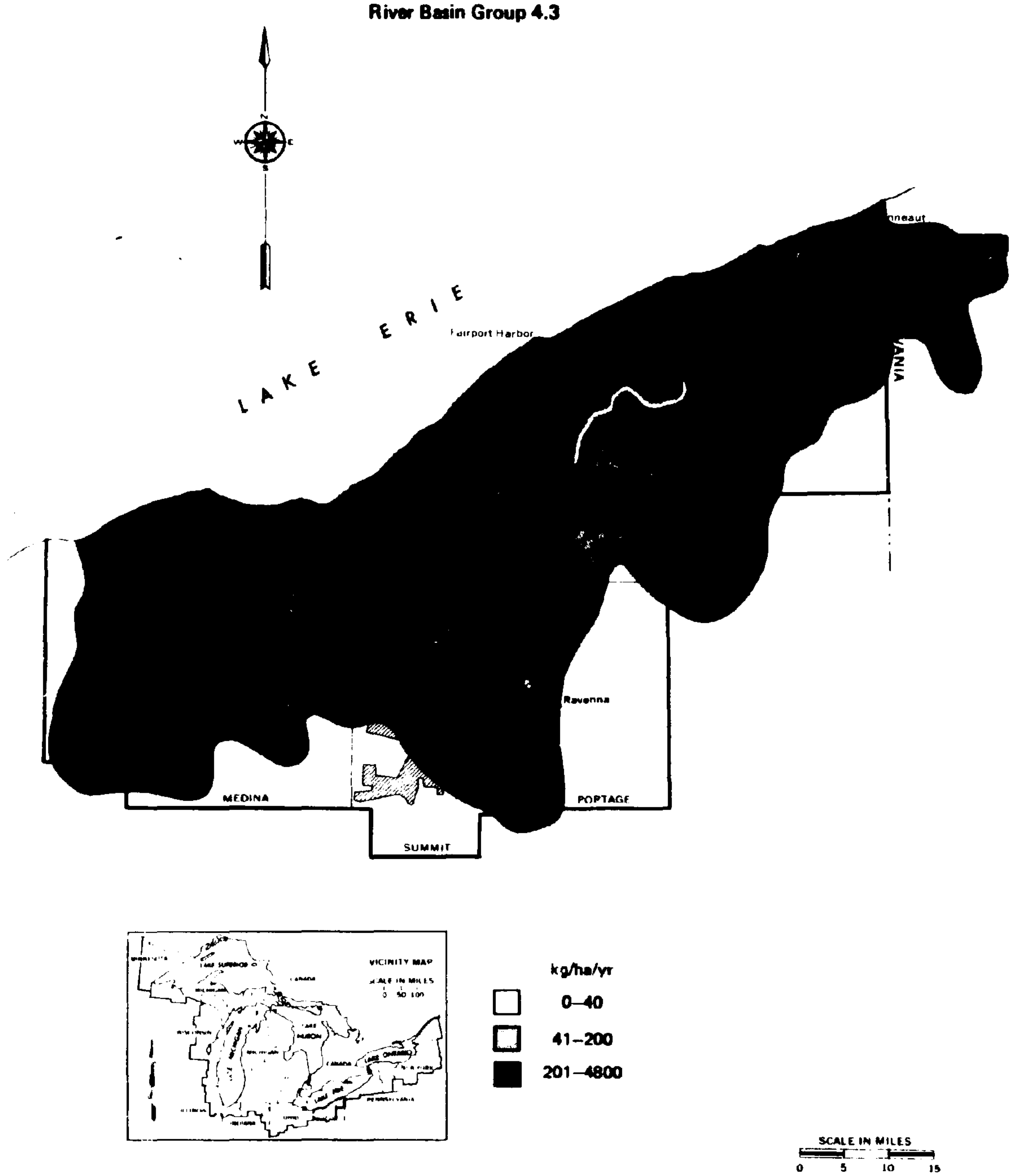
SUSPENDED SOLIDS
DIFFUSE UNIT AREA LOADS
River Basin Group 4.2



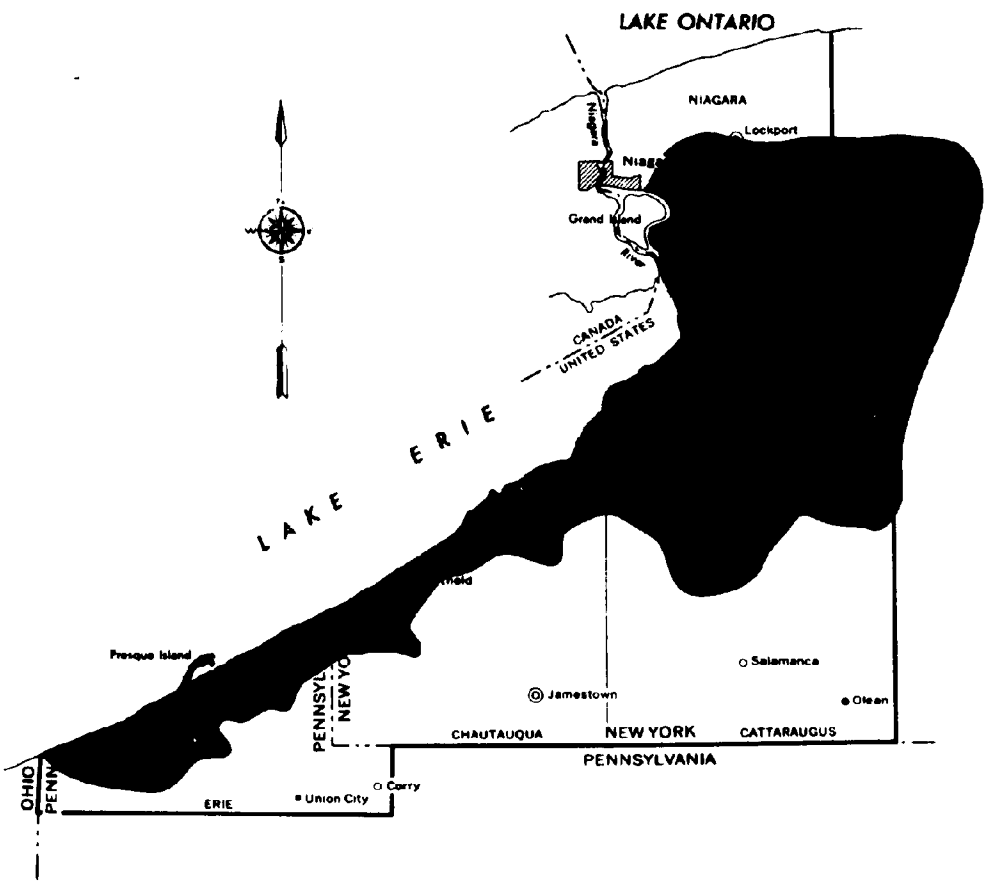
SUSPENDED SOLIDS
DIFFUSE UNIT AREA LOADS
River Basin Group 4.3

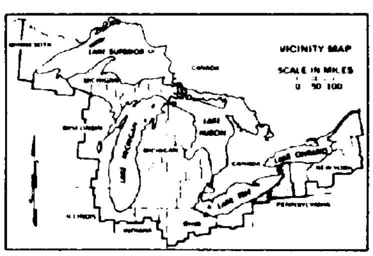


SUSPENDED SOLIDS
DIFFUSE UNIT AREA LOADS
River Basin Group 4.3



SUSPENDED SOLIDS
DIFFUSE UNIT AREA LOADS
River Basin Group 4.4



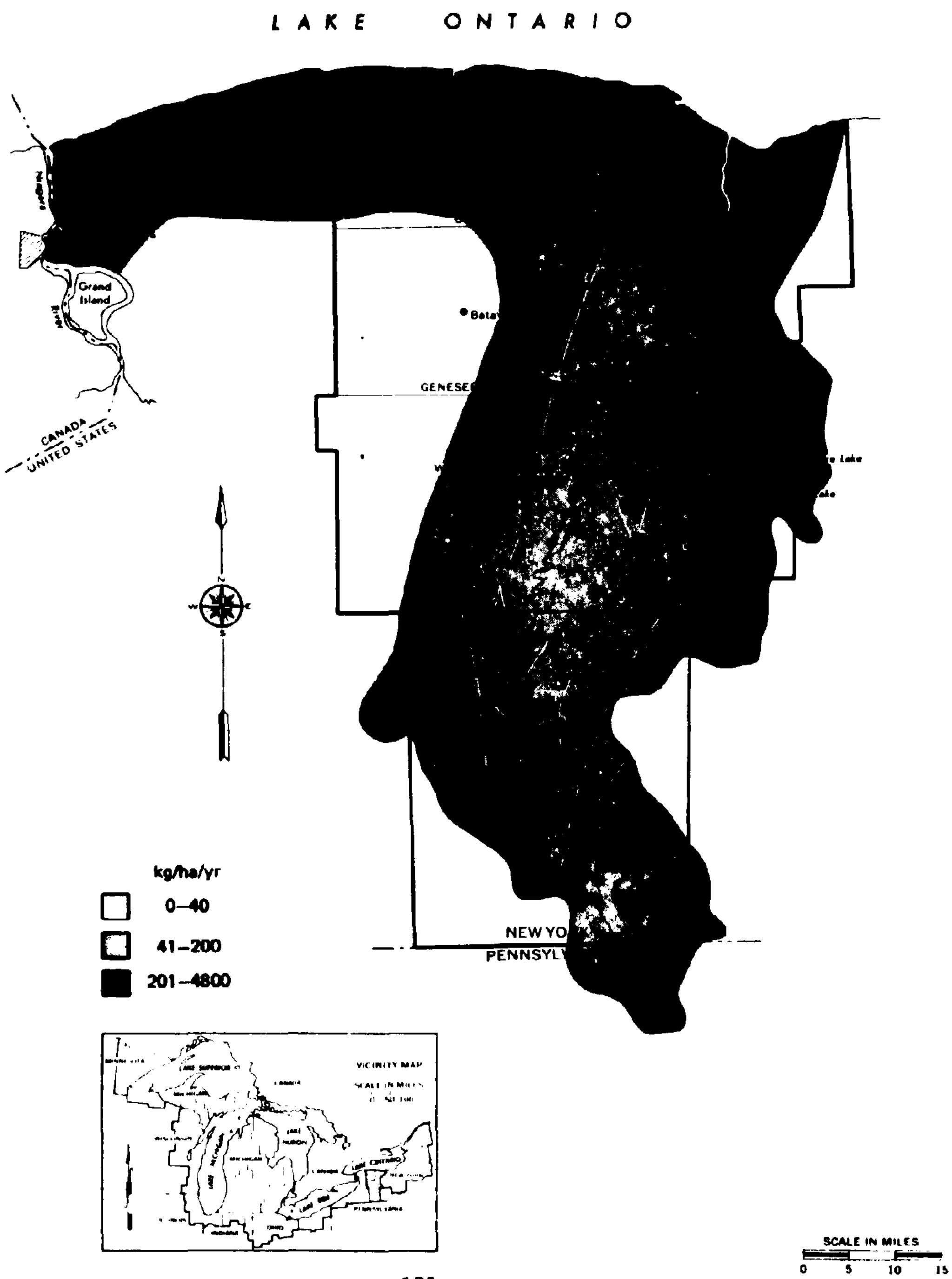


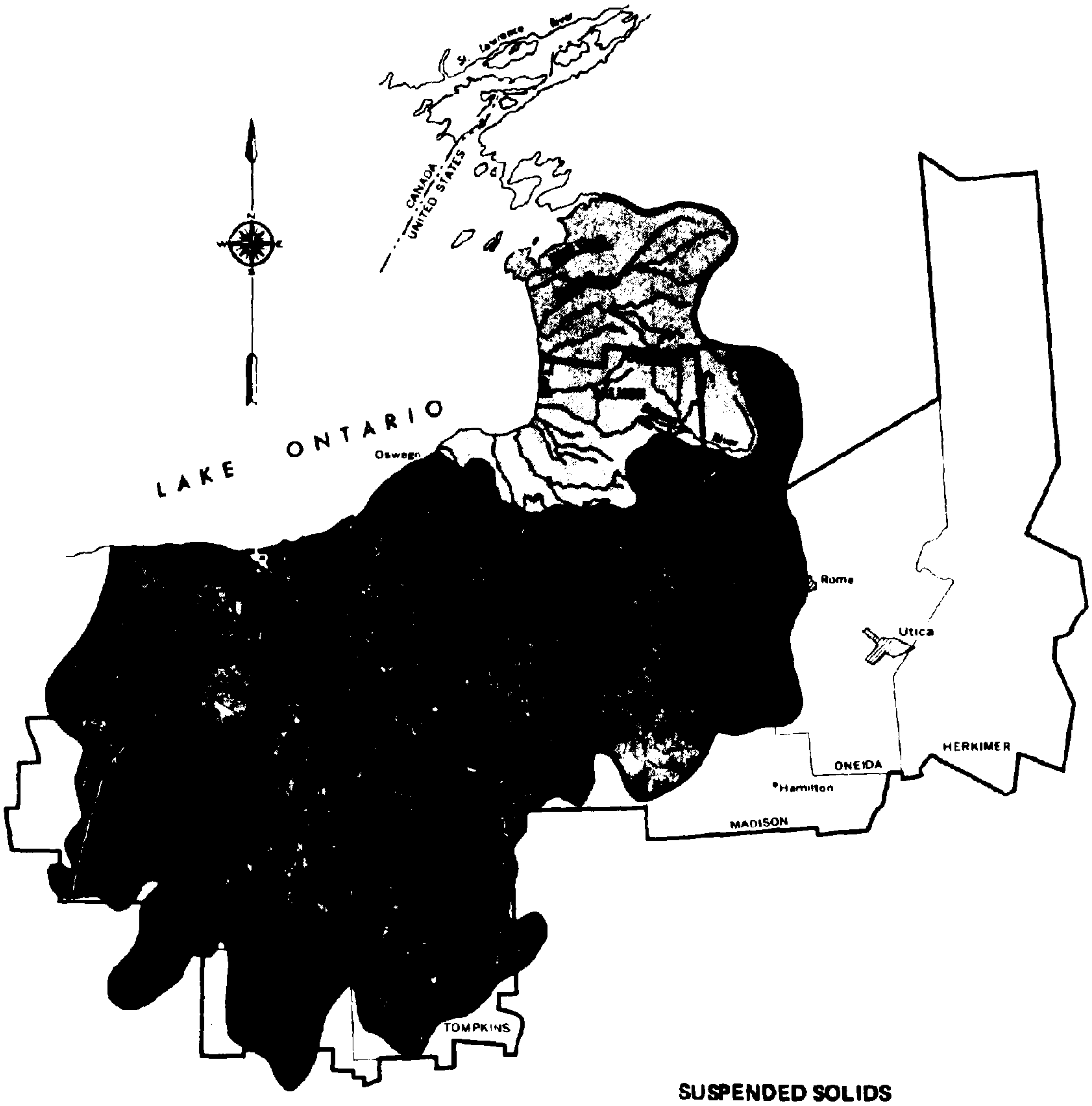
kg/ha/yr

□	0–40
▨	41–200
■	201–4800

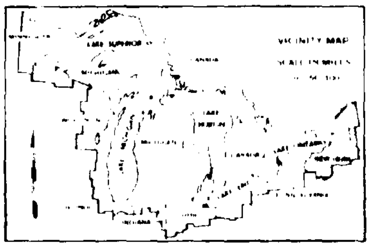
SCALE IN MILES
0 5 10 15

SUSPENDED SOLIDS
DIFFUSE UNIT AREA LOADS
River Basin Group 5.1





SUSPENDED SOLIDS
DIFFUSE UNIT AREA LOADS
River Basin Group 5.2

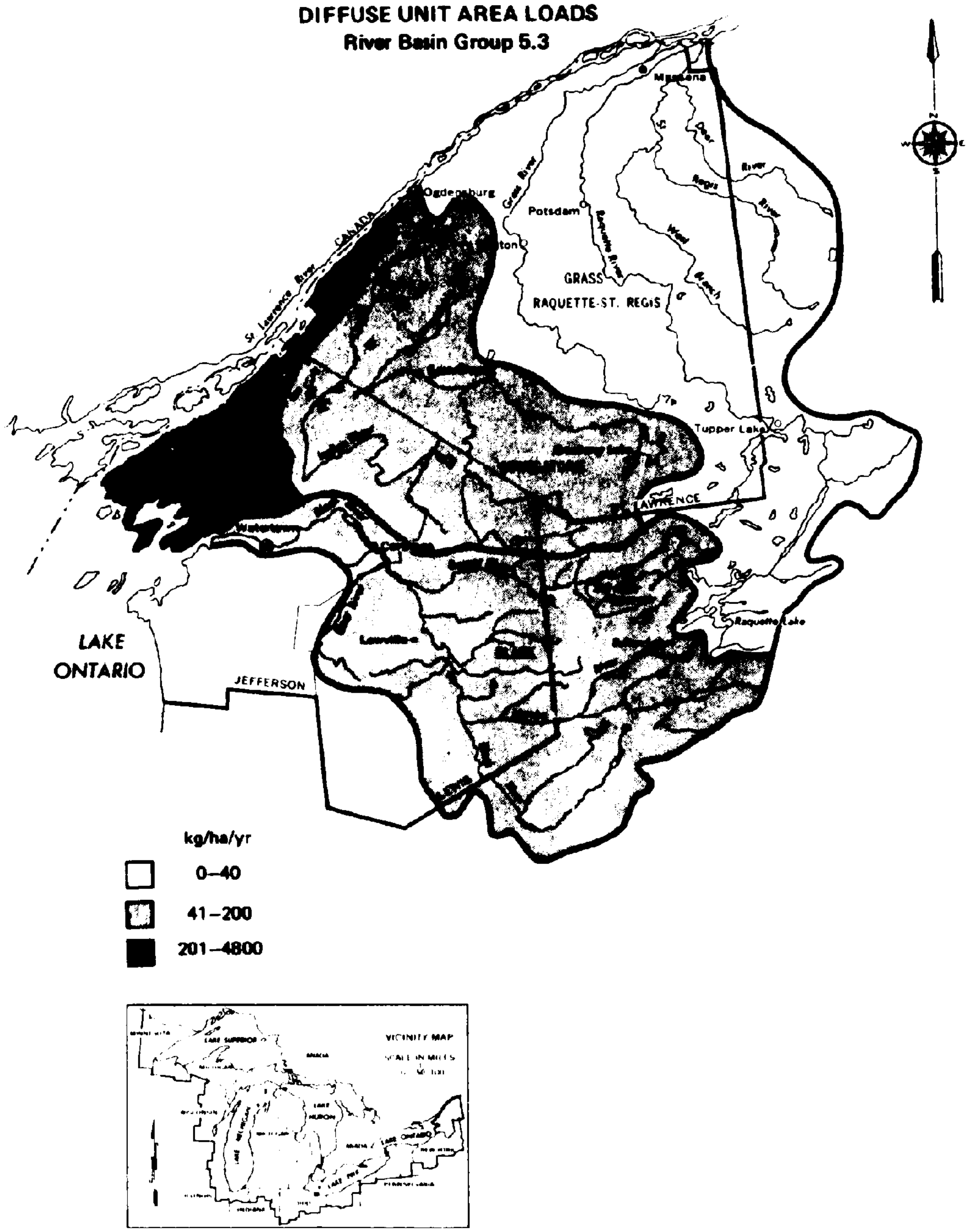


kg/ha/yr

- 0–40
- 41–200
- 201–4800

SCALE IN MILES
0 5 10 15

SUSPENDED SOLIDS
DIFFUSE UNIT AREA LOADS
River Basin Group 5.3



SCALE IN MILES