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DISTRIBUTION OF SELECTED TRACE METALS IN SOUTHERN
LAKE MICHIGAN AND LOWER GREEN BAY

by

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F I N A L R E P O R T

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ABSTRACT

DISTRIBUTION OF SELECTED TRACE METALS IN SOUTHERN LAKE MICHIGAN AND LOWER GREEN BAY

This report considers the distribution of selected trace metals in water, suspended matter and sediments of southern Lake Michigan and in surficial sediments of lower Green Bay. Accumulations of As, Br, Cr, Cu, Hg, Pb and Zn in fine-grained surficial sediments of southern Lake Michigan, apparently determined by patterns of sediment deposition, correlate closely with sediment concentrations of organic carbon and iron. Organic carbon concentrations of surficial sediments are more highly correlated with concentrations of Cu, Pb and Zn in surficial sediments of lower Green Bay than are either Fe or Mn contents. Mean concentrations of trace metals in suspended matter near the sediment-water interface of southern Lake Michigan equal or exceed amounts in surficial sediments.

Horizontal (geographic) and vertical distributions of concentrations of nine trace metals (Cd, Cr, Co, Cu, Fe, Pb, Mn, Ni and Zn) in waters of southern Lake Michigan were examined during the period June - October, 1971. Distributions of Cu, Fe, Pb and Zn in filtered lake water are presented. Metal concentrations are typically highest near areas of industrialization and major tributary enbouchment. Concentrations of Cu, Fe, Pb and Zn in nearshore areas of southern Lake Michigan are typically higher than concentrations in offshore waters, but this trend is inconsistent. Horizontal distributions of trace metals in the epilimnion appear to be primarily determined by current patterns. No consistent variations of concentration with depth were observed for the trace metals investigated.

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KEYWORDS--trace elements/*Lake Michigan/*metal transport/*heavy metals/
water-sample storage/*sediment-water interaction

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INTRODUCTION

Lake Michigan is a major source of water and a major recipient of pollution in the North Central region of the United States. During the last decade it has been increasingly apparent that accelerated changes are occurring in certain areas of the lake, most notably lower Green Bay and extreme southern Lake Michigan (Beeton, 1969).

Recognizing the need for an evaluation of the distribution and possible accumulation of trace metals in southern Lake Michigan, a cooperative study was initiated by the principal investigators. These studies initially involved the determination of accumulated trace elements in sediments to provide an estimate of long-term additions of trace elements to Lake Michigan and to establish natural base-line concentrations against which present additions could be evaluated. Water sampling was begun the following year with the purpose of determining geographic (horizontal) and vertical distributions of selected trace metals, particularly those known to be accumulating in sediments of southern Lake Michigan. An evaluation of several possible procedures for storage of samples was conducted before water sampling was initiated because of difficulties experienced by other investigators.

Lower Green Bay, Lake Michigan was selected as an additional site to study factors affecting trace metal distributions in sediments. In lower Green Bay, trace metals are derived from a single main source, the Fox River, and distributed into a confined area.

PRESERVATION AND STORAGE OF WATER SAMPLES FOR TRACE METAL DETERMINATIONS

Publications on trace metals in natural waters only infrequently include a description of the sample storage procedure used despite a potential for significant change in concentrations of trace constituents during storage. Prior to sampling and analyzing Lake Michigan waters for trace metals, assessment of several possible procedures for storage and preservation of samples was conducted. Lake water was analyzed after storage at different time intervals (maximum of 184 days) in linear polyethylene, conventional polyethylene and glass containers. The value of acidification of water samples at the time of collection in significantly reducing adsorption of trace metals to containers was demonstrated, as was the value of storing frozen samples.

Literature pertinent to the subject of sample storage indicates that the principal factors affecting adsorption of metal ions to surfaces are temperature, hydrogen-ion activity and time (Healy et al., 1968; Long and Willard, 1952; Hensley et al., 1949). Hydrogen-ion activity is the most important factor (Strijker and Matievic, 1968). Trace metal exchanges with the walls of sample containers are significantly reduced by the addition of small amounts of acid, which

provide an abundance of hydrogen-ions that preferentially occupy available sites for adsorption.

The rates of adsorption of trace elements to container surfaces apparently decrease with time elapsed between collection and analysis, and an equilibrium is eventually obtained between the concentration of an element in water and its concentration on container surfaces. Eicholz et al. (1964) found the rates of adsorption of trace metals to decrease continuously with time at pH 1.5, but at pH 7.5, dissolved metal concentrations typically increased for several weeks and then decreased until an equilibrium was achieved. Results of the present study do not support the findings of Eicholz et al. (1964). The rates of adsorption of trace metals to polyethylene surfaces either decreased continuously during the 184-day course of the experiment or an equilibrium was achieved earlier.

The choice of container material is an important consideration in storing natural waters for trace metal analysis. Considerable changes in standard solutions (10 mg/l) of Ni, Mn, Mo, V, Au, Pt, Ru, and Ti stored in glass were reported by Luetwein (1940). Concentrations of these elements decreased by a factor of ten in 75 days if stored in 6 percent mineral acid. Only nickel and precious metal concentrations decreased if samples were stored in fused quartz. Contamination of water samples occurs if the water is stored in soft glass but this problem is almost absent if polyethylene is used (Dozer and Dole, 1952). Contamination of acidic solutions after one year of storage occurred with 11 elements (Al, B, Ca, Fe, Pb, Li, Mg, Na, Si and Sr) in Pyrex 774, with 9 elements (Al, B, Ca, Pb, Li, Mg, Na, Si and Sr)

in soft glass (Kimble) and with none of the above elements in polyethylene (Yoe and Koch, 1957). Results of the present investigation also illustrate the high purity of suitable polyethylene containers. No traces of Cu, Cd, Mn, or Zn were found in demineralized, distilled water stored 100 days in conventional or linear polyethylene containers.

A significant difference was noted between the adsorptive properties of linear and conventional polyethylene for trace metals during storage at pH 1.0 and 22° C (Figures 1-3). Adsorption of Cu, Mn, and Zn was significantly greater in linear polyethylene than in conventional polyethylene, although the former is generally considered superior to conventional polyethylene in this respect. The conventional polyethylene containers were previously used for storage of water samples. The linear polyethylene containers were new and were rinsed for one week with 5 percent hydrochloric acid prior to use. Irregardless of the type of container employed, adsorption of Cu, Cd, Mn, and Zn to polyethylene surfaces occurred from low $\mu\text{g/l}$ solutions at pH 1.0 and 22° C during storage of water samples.

The single most effective procedure to eliminate changes in trace metal composition of water samples during storage is to keep samples frozen. Freezing eliminated adsorption of trace metals (Cu, Cd, Mn and Zn) to container surfaces and permitted quantitative recoveries following storage. Recoveries of 85 to 105 percent after 184-days storage were obtained for the above elements. Acidification of water samples at the time of collection is recommended to avoid adsorption of trace metals to container surfaces during periods when

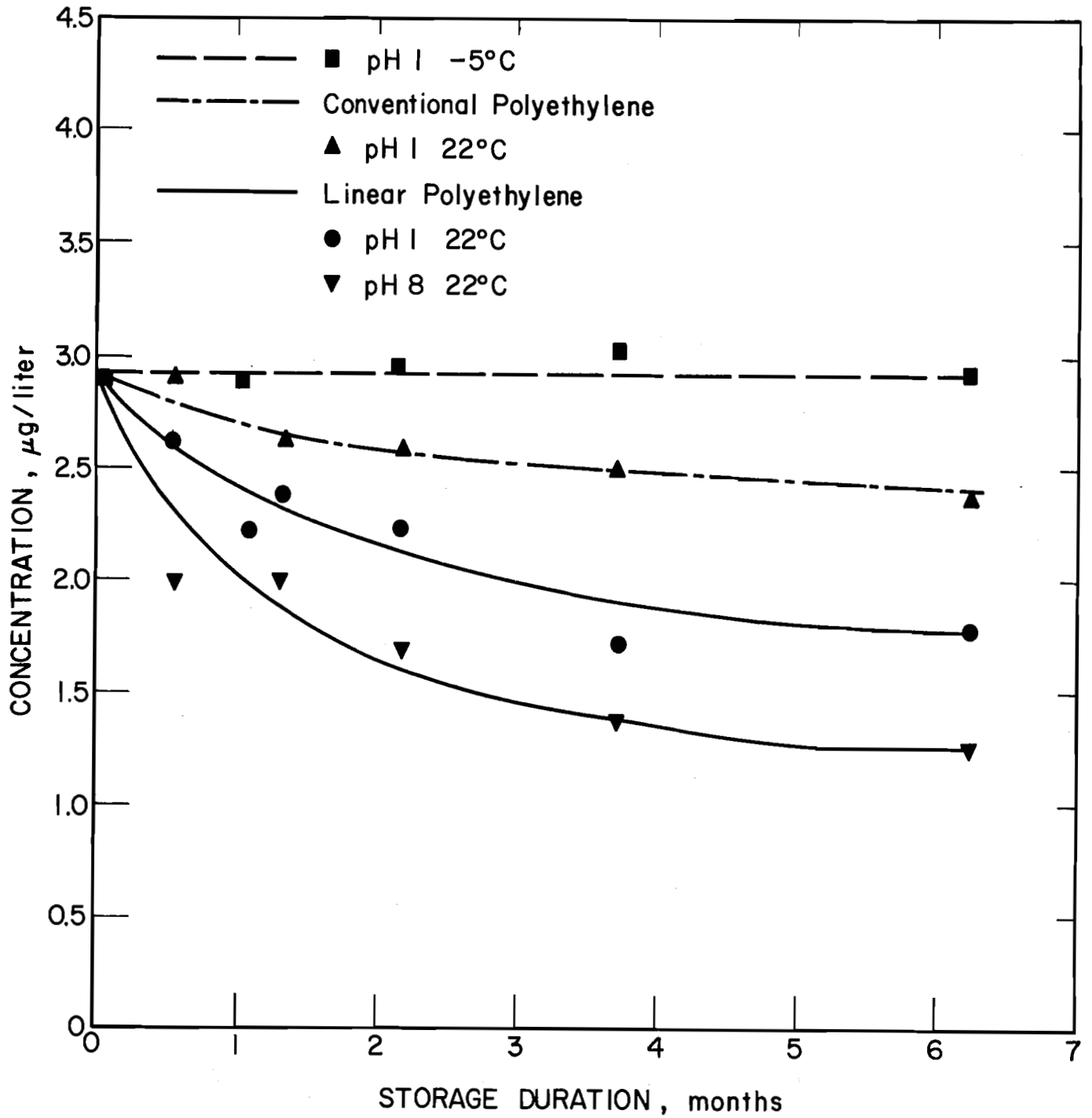


Figure 1. Influences of Storage Duration, Temperature and Hydrogen-Ion Activity on the Concentration of Copper in Lake Water Samples

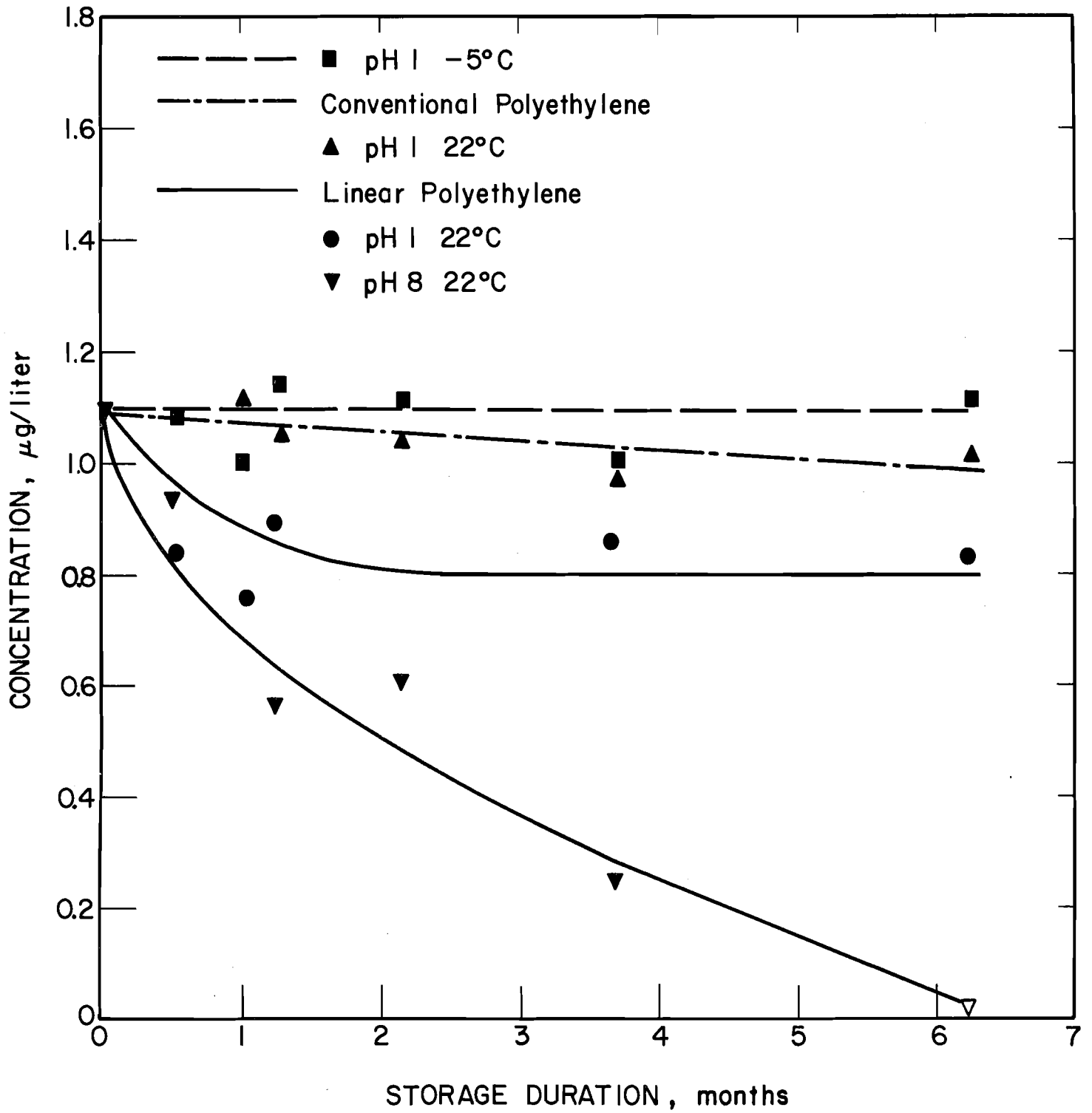


Figure 2. Influences of Storage Duration, Temperature and Hydrogen-Ion Activity on the Concentration of Manganese in Lake Water Samples

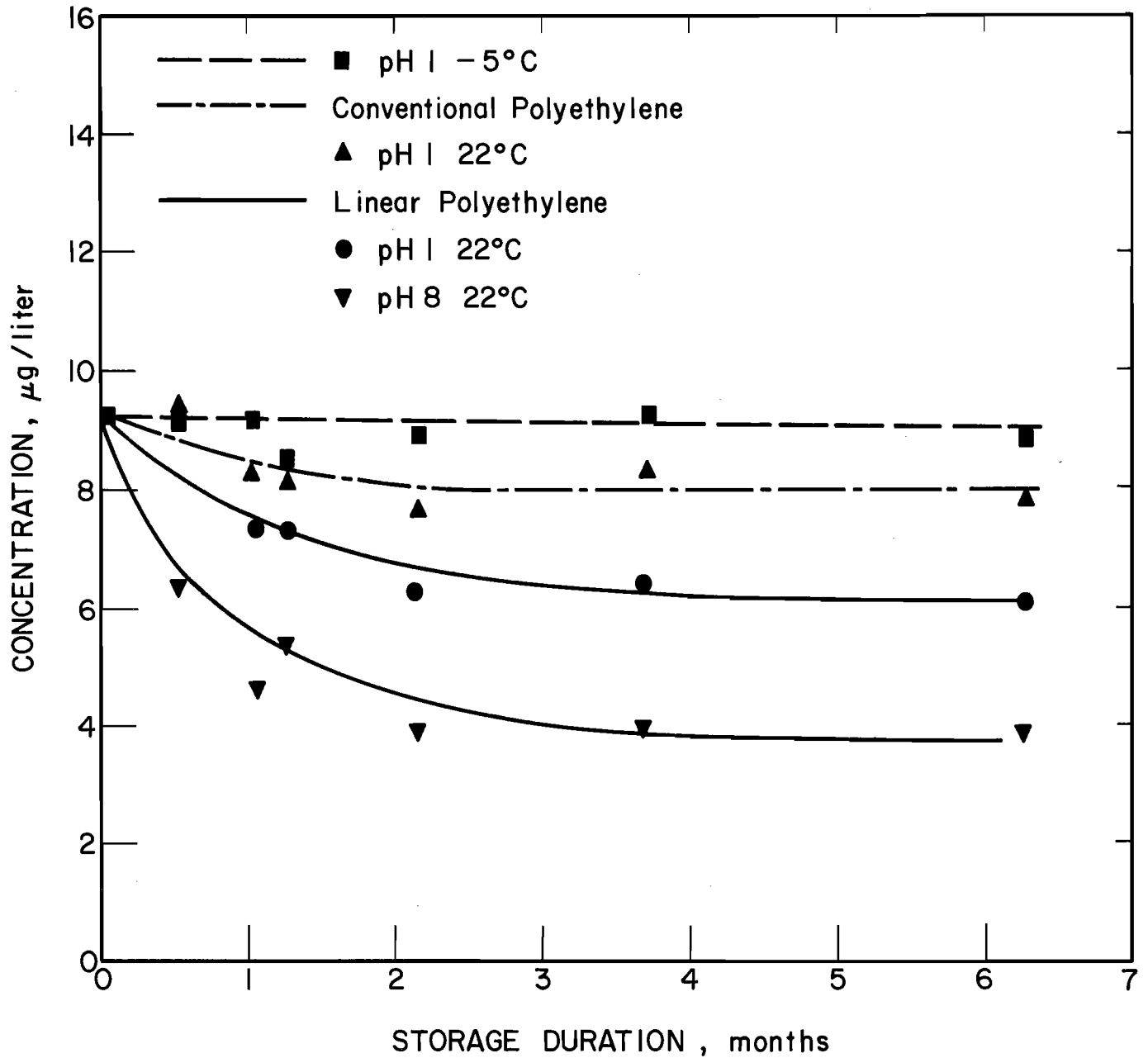


Figure 3. Influences of Storage Duration, Temperature and Hydrogen-Ion Activity on the Concentration of Zinc in Lake Water Samples

the sample cannot be kept frozen.

Lake Michigan water samples obtained for trace metal analysis by atomic absorption spectrophotometry were acidified (0.5 percent double-distilled hydrochloric acid) and stored frozen. Trace metals were concentrated 50-fold by sublimation of water samples at reduced temperature and pressure (freeze-drying). This procedure is acceptable for reducing sample volume and concentrating the elements of interest. An average 94 percent recovery of Cu, Zn, Cd, and Mn (range of 86 to 102 percent) was obtained.

DISTRIBUTIONS OF TRACE METALS IN WATERS OF SOUTHERN LAKE MICHIGAN

Several recent reports contain information on trace metals in Lake Michigan waters (Copeland and Ayers, 1972; Michigan Water Resources Commission, 1973). Higher concentrations of Cd, Cr, Ni and Zn were reported in waters at nearshore stations in the vicinity of the Grand and St. Joseph Rivers than in offshore waters. These rivers, the second and third largest in drainage area and mean annual discharge of Lake Michigan tributaries, drain into the southern lake basin. Robbins *et al.* (1972) provide a preliminary estimate of mean daily loadings of Ca, Mg, Na, K, Fe, Mn, Cu, Ni, Cr, Mo, Zn, Sr and Ba to Lake Michigan via tributaries. The Grand River, the largest tributary source of 10 of the 13 elements analyzed, is singularly high as a source of Cu, Ni and Cr. The St. Joseph River is the tributary with the second largest trace metal loading to Lake Michigan.

Geographic and seasonal variations in trace metal concentrations

of Lake Michigan waters are poorly characterized. To permit examination of these variations, concentrations of nine elements (Cd, Cr, Co, Cu, Fe, Pb, Mn, Ni and Zn) in nearshore and offshore waters of southern Lake Michigan (Figure 4) were determined for the period June - October, 1971. At approximately six-week intervals, samples were taken at the lake surface, directly above and below the thermocline and one meter above the sediment. Only surface and near-sediment waters were sampled at shallow (<10 meters depth) water stations. To facilitate data interpretations, stations are assigned to one of eleven areas, designated regions A through L. The nearshore regions include stations one-quarter, one-half, and one mile from shore; intermediate stations are four miles, eight miles and sixteen miles from shore; and the offshore regions are greater than 16 miles from shore. Locations sampled in this program are not in the vicinity of major tributaries. A broader area of southern Lake Michigan which includes locations near major tributaries, (Figure 5) was sampled on separate cruises during 1971. On these latter cruises, determinations of Cu and Pb were made by anodic-stripping voltammetry immediately after sample collection.

Results reported herein are Cu, Fe, Pb and Zn concentrations in filtered lake water. Precautions taken to avoid sample contamination included pre-rinsing the all-glass filter apparatus and cellulose acetate membrane filters (0.45 μ pore size) with double-distilled hydrochloric acid (5 percent) and offshore hypolimnion water. Anodic-stripping voltammetric analyses were conducted without pre-concentration of metals in the water before (pH 8) and after (pH 3) acidification.

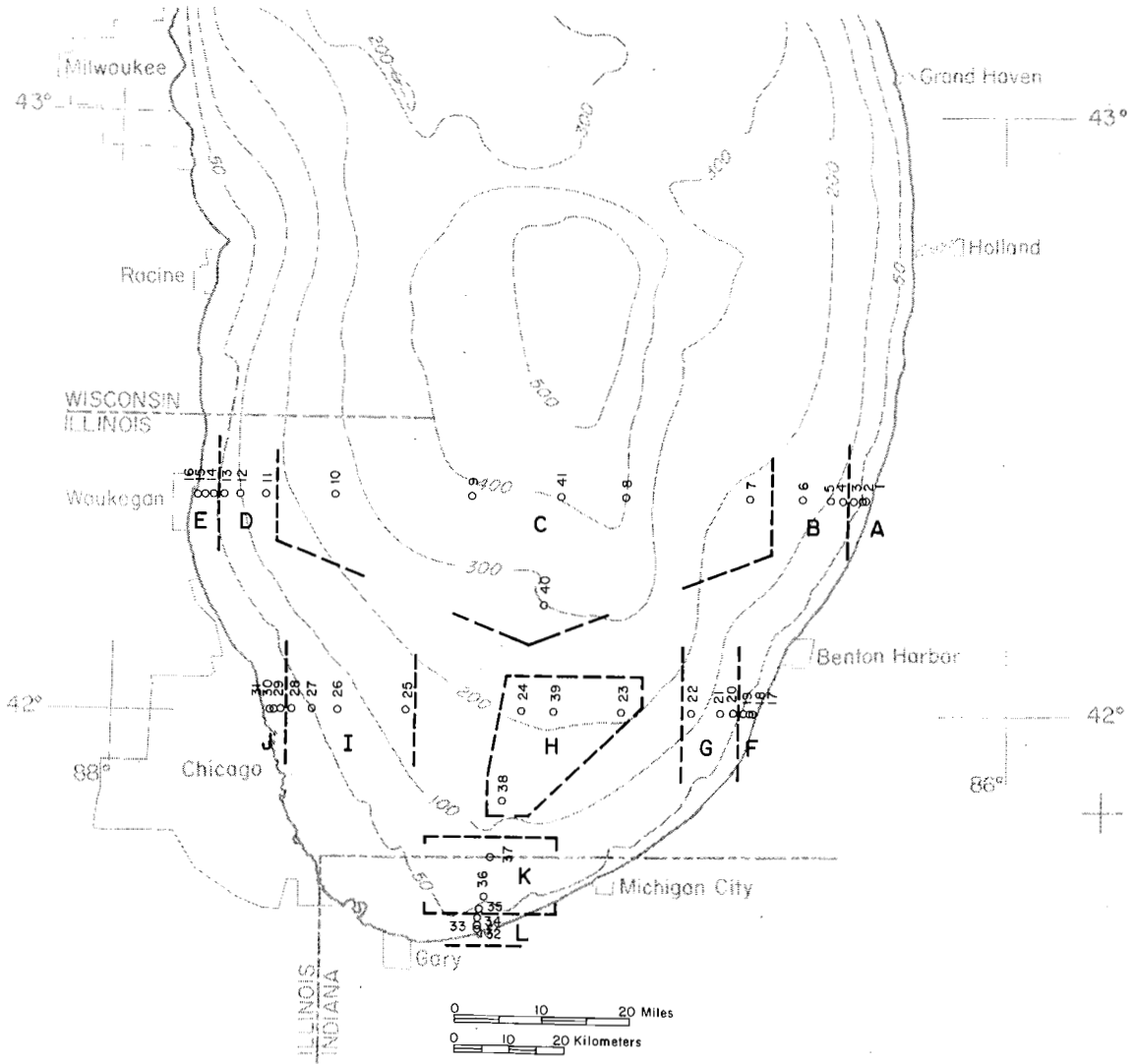


Figure 4. Water-sampling Locations in Southern Lake Michigan. Each Station was Sampled at Two or Four Depths at Approximately Six-week Intervals from June through October, 1971

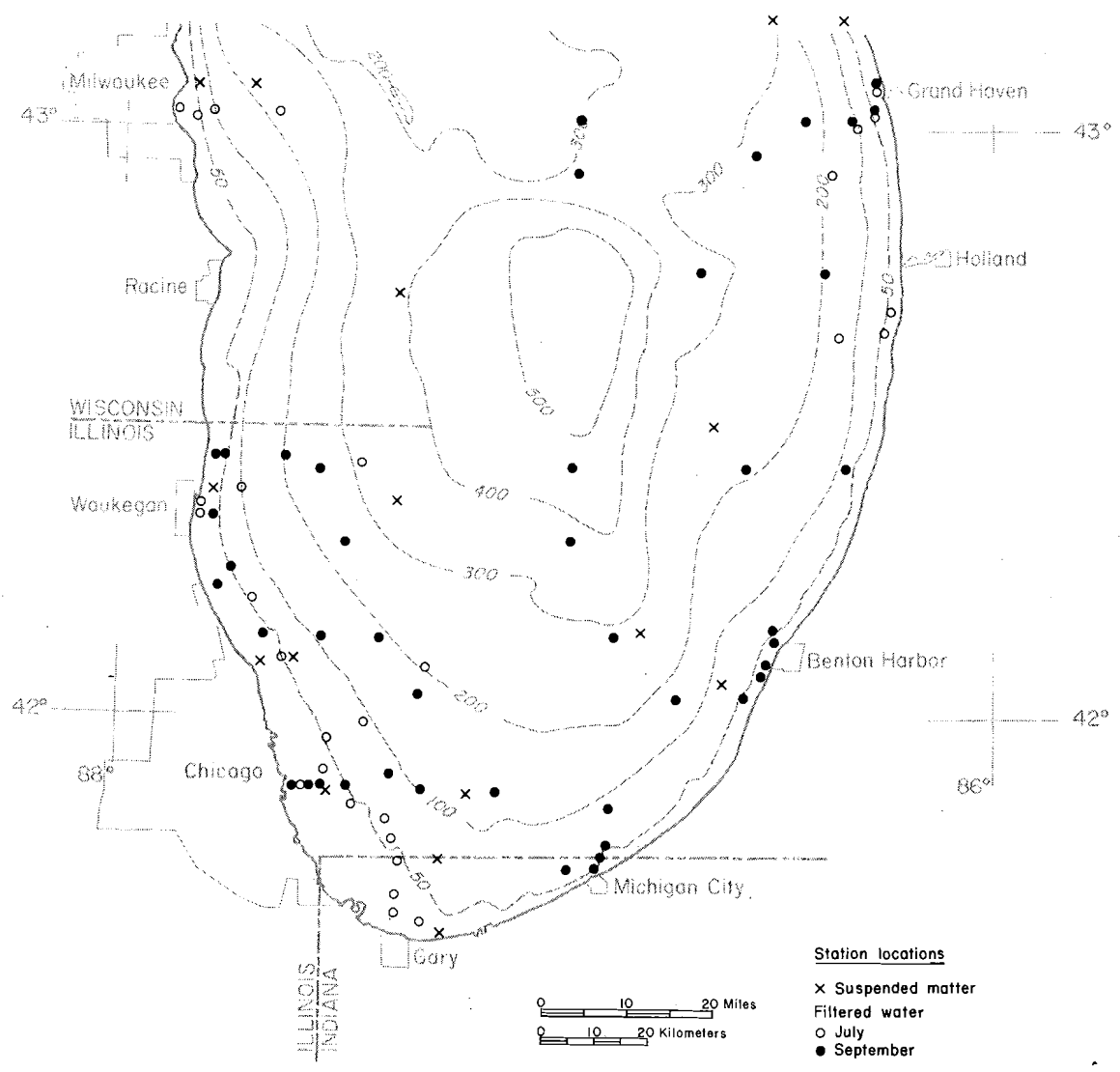


Figure 5. Water and Suspended Matter Sampling Locations in Southern Lake Michigan

Determinations of Pb and Cu reported were conducted at pH 3. Water samples collected for subsequent analysis by atomic absorption spectrophotometry were acidified (1.0 percent hydrochloric acid) and frozen. In the laboratory, one-liter portions of the samples were reduced to dryness by freeze-drying and the residues were redissolved in 20 ml of N hydrochloric acid. Concentrations of trace metals reported were corrected for background and matrix effects.

An analysis of horizontal (geographic) distributions of trace metals in southern Lake Michigan shows that metal concentrations are typically highest immediately adjacent to areas of high population density, industrialization and major tributaries. Examples are the plumes of the Grand and St. Joseph Rivers and nearshore waters at Milwaukee, Wisconsin, Chicago, Illinois, and Gary, Indiana. Concentrations of Cd and Co in intermediate and offshore regions are near the limits of detection of the analytical method and descriptions of distributions of these elements are not possible. Methods for determining concentrations of Cr, Cu, Fe, Pb, Mn and Zn in filtered lake water are adequate and geographic variations in concentration of these elements are evident. Examples are given for the distributions of lead (Figure 6), copper (Figure 7), iron and zinc (Table 1).

Concentrations of each of the above elements vary geographically and with time of sampling. Increased levels generally occur in near-shore regions and lower concentrations in intermediate and offshore regions. However, this trend is inconsistent. Metal concentrations in many instances are no higher in inshore waters than in offshore or intermediate regions. Surface waters in extreme southern Lake

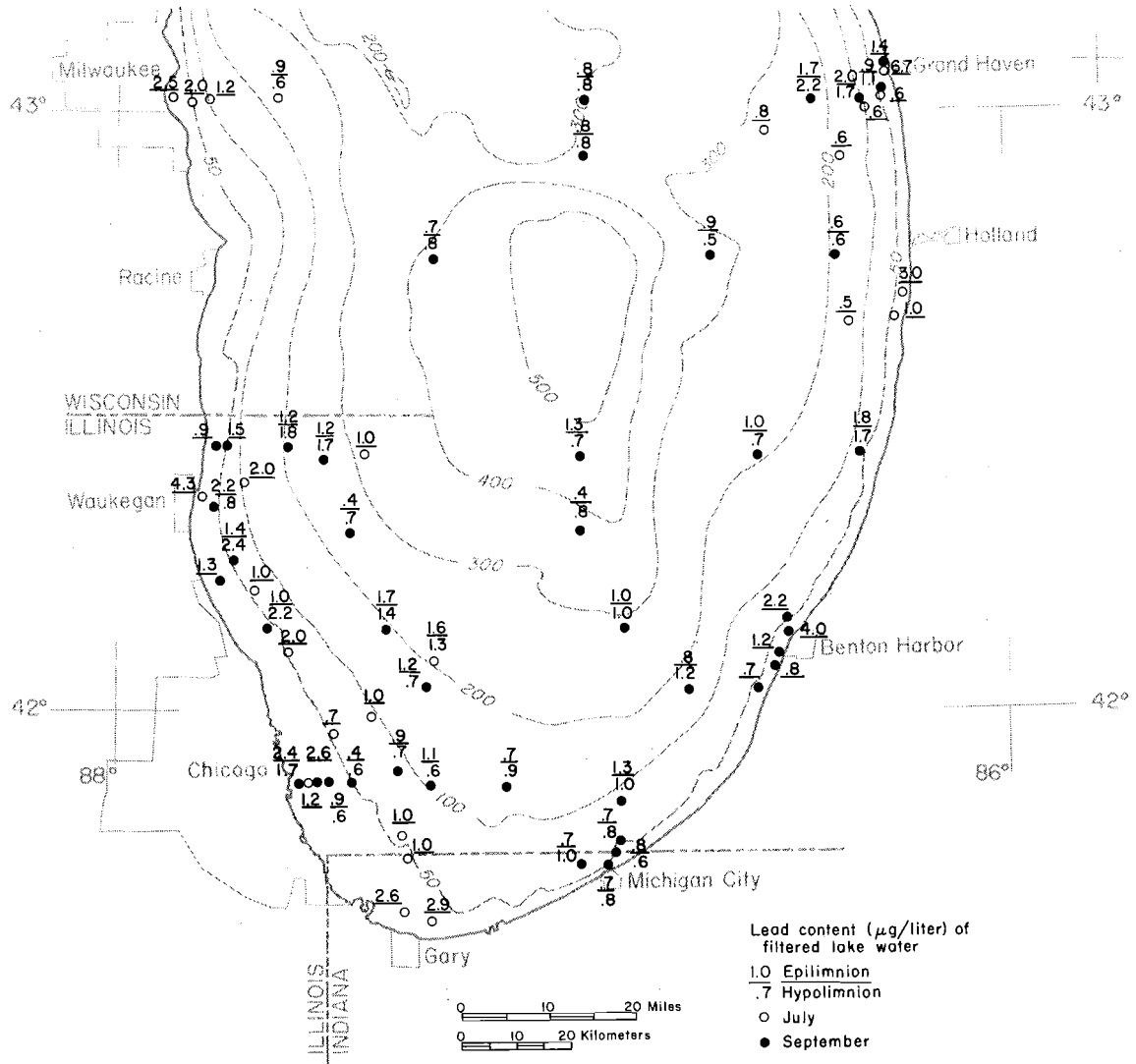


Figure 6. Mean Concentrations of Lead in Waters of Southern Lake Michigan. Data for All Depths Sampled are Included in the Means

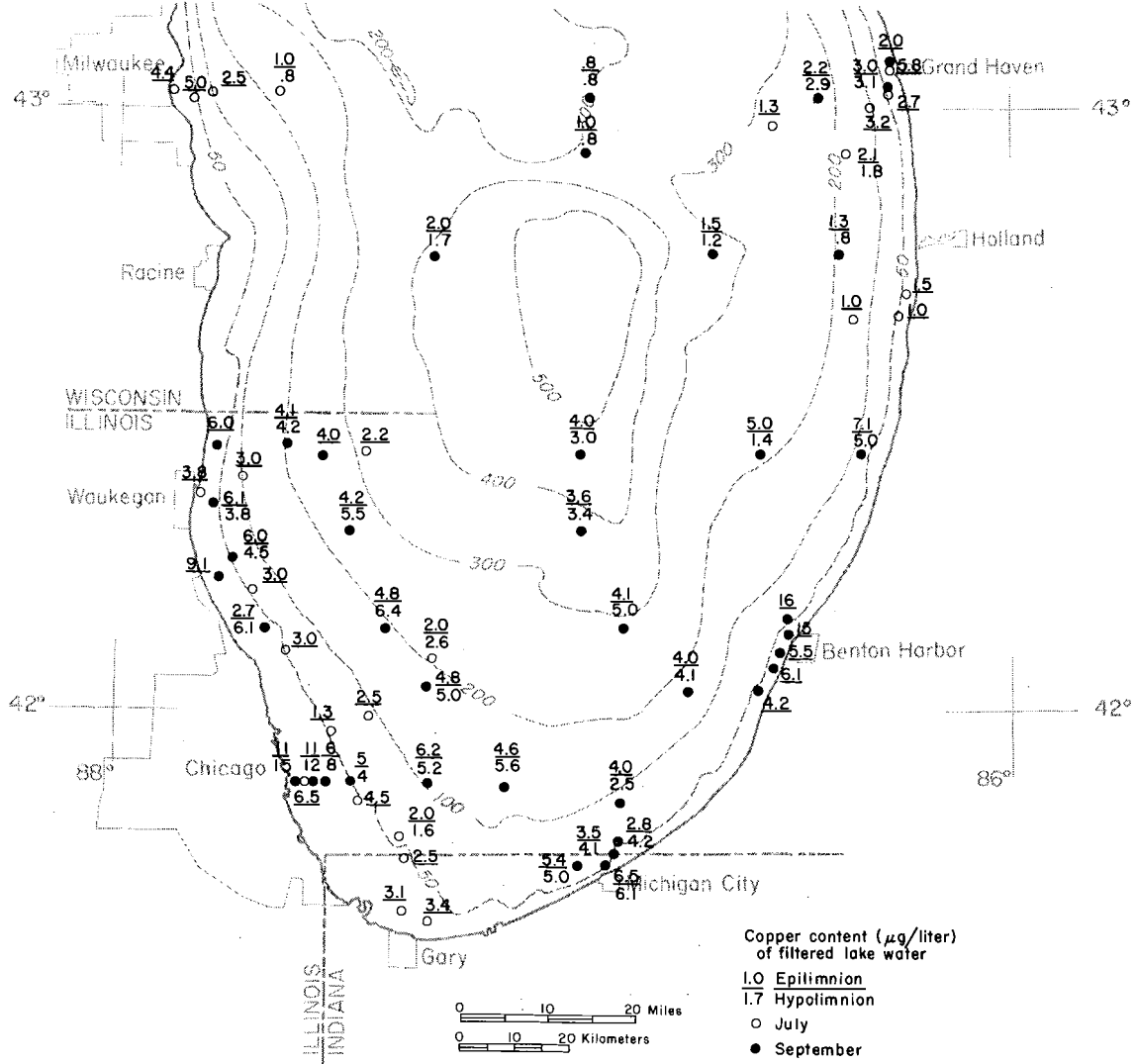


Figure 7. Mean Concentrations of Copper in Waters of Southern Lake Michigan. Data for All Depths Sampled are Included in the Means

TABLE 1
 Concentrations ($\mu\text{g/liter}$) of Iron and Zinc in Waters
 of Southern Lake Michigan (1971)^{a,b}

Region	June		July		August		October	
	Fe	Zn	Fe	Zn	Fe	Zn	Fe	Zn
A	23	26	10	15	9	-	11	14
B	18	19	9	-	8	-	11	18(21)
C	12	15(12)	10(13)	6(16)	13(12)	11(15)	7(11)	13(12)
D	6	7(20)	18(9)	-	15(12)	3(20)	6(10)	7
E	12	-	8	14	5	12	7	16
F	19	8	6	11	5	14	19	4
G	19	11	7	14	18	14	18(17)	-
H	8(8)	11(14)	8(9)	12(17)	13(9)	8	9(13)	-
I	27	21	10	-	22(5)	19	12(13)	19
J	20	6	10	7	13	4	9	-
K	8	-	7	-	16	6	15	-
L	15	11	11	-	7	13	10	9

^aConcentrations are means of at least three separate determinations. Samples were filtered (0.45 μ membrane filter) at the time of collection.

^bConcentrations in parenthesis are for hypolimnion waters. All other values are metal concentrations of epilimnion waters.

Michigan are higher in Pb and Cu than surface waters in the deepest regions of the southern basin. Southward-flowing surface currents in the intermediate region (Region D) on the western side of southern Lake Michigan contain lower concentrations of Pb, Fe and Zn than do northward-flowing surface waters in the intermediate regions (Regions B and G) on the eastern side. Geographic patterns of trace metals in epilimnion waters are apparently related to flows of major lake currents.

Vertical distributions of trace metals are also best interpreted by considering current patterns. Significant variations in trace metal concentrations exist with depth of sampling but concentrations in the epilimnion are higher than in the hypolimnion in some areas and lower in other areas. In general, concentrations of Pb and Cu are higher in epilimnion waters than in the deeper waters of the southern basin. Distribution of trace metals in southern Lake Michigan waters are to be discussed further in a separate report.

TRACE ELEMENTS IN SEDIMENTS AND SUSPENDED MATTER OF SOUTHERN LAKE MICHIGAN

Studies by Shimp et al. (1970, 1971), Kennedy et al. (1971) and Ruch et al. (1970) show that certain trace elements, namely As, Br, Cr, Cu, Hg, Pb and Zn, occur in substantially (up to 20 times) higher concentrations near the sediment-water interface of fine-grained sediments than in underlying sediments of southern Lake Michigan. Leland et al. (1973a) examined the factors affecting trace metal transport and distribution in the lake sediments. These studies were

supported in part by project A-052-ILL.

Accumulation of the above trace elements in sediments near the water interface is evident from an examination of Table 2. The relatively high concentrations of these elements in sediments near the water interface are not a natural phenomenon. The major, minor and trace element composition of underlying (15-100 cm depth interval) fine-grained sediments of southern Lake Michigan is very similar to that of Lake Saline, a Pleistocene lake which received sediments during the time Lake Michigan was occupied by glaciers (Frye and Shimp, 1973). This indicates that the trace element concentrations of underlying sediments probably represent natural levels in southern Lake Michigan.

Significantly higher trace element concentrations occur in fine-grained surficial sediments, particularly where recent sedimentation is most active. Geographic areas of greatest trace element abundance correspond to regions of greatest contamination by organochlorine insecticides (Leland et al., 1973b). Geographic distributions of trace elements in southern Lake Michigan sediments are presented in Leland et al., 1973a; Shimp et al., 1971; Kennedy et al., 1971; and Ruch et al., 1970. Trace elements presently accumulating in sediments of southern Lake Michigan are apparently sorbed, either directly or through biological processes, to suspended particles, which are transported by water and deposited in areas of active sedimentation. Regression analysis of the data on sediment constituents indicates a relationship between accumulating trace element concentrations and contents of organic carbon and iron in the sediments (Shimp et al.,

TABLE 2

Chemical Composition of Sediments and Suspended Matter in Southern Lake Michigan

Major or Minor Constituent (Percent)	Sediments ^{a,b}						Suspended Matter ^c					
	Uppermost Sample Interval		Number of Samples	All Sample Intervals > 75 cm but < 100 cm			One Meter Above Lake Floor			Epilimnion (5-7 meters)		
	Mean	Range		Mean	Range	Number of Samples	Mean	Range	Number of Samples	Mean	Range	Number of Samples
SiO ₂	53.1	40.2-70.2	24	48.4	41.5-58.9	31	33.1	14.3-48.7	12	29.8	2.8-62.7	14
TiO ₂ *	0.36	.13-0.55	24	0.49	0.41-0.57	22	0.23	0.17-0.37	12	0.20	0.08-0.45	14
Al ₂ O ₃ *	7.95	4.72-11.70	24	9.54	8.24-11.60	22	4.90	2.19-9.78	12	3.70	1.23-9.92	14
Fe ₂ O ₃	4.04	2.09-9.99	24	3.56	1.74-5.99	31	4.68	2.47-7.38	12	3.71	1.07-7.22	14
MnO	0.072	0.025-0.212	25	0.05	0.027-0.110	24	0.094	0.012-0.23	6	0.063	0.004-0.19	14
MgO *	5.26	2.55-9.18	24	6.65	4.87-8.11	22						
CaO	7.83	4.37-15.90	24	9.14	3.37-15.00	32	29.2	8.8-71.1	12	9.38	2.2-45.1	14
Na ₂ O *	0.62	0.37-0.88	24	0.63	0.55-0.93	22						
K ₂ O	2.19	0.98-3.51	24	2.73	2.05-3.31	22	1.34	0.83-2.28	12	1.50	0.11-3.61	14
P ₂ O ₅	0.15	<0.01-0.42	56	0.17	<0.01-0.46	73	0.33	0.07-0.60	12	0.19	0.02-0.38	14
S *	0.10	0.02-0.24	23	0.12	0.08-0.20	22	0.18	0.06-0.36	12	0.16	0.02-0.32	14
Ignition Loss	16.10	9.15-20.33	24	17.46	11.09-20.91	32	34.4	19.1-47.2	12	53.8	26.4-94.5	14
Organic Carbon	2.51	0.77-4.73	25	1.40	0.49-2.65	23						
Trace Element (µg per g)												
As	14.	8-30	15	5.	2-8	24						
B	41.	14-71	21	48.	17-71	24						
Be	1.8	0.6-3.0	24	1.7	0.7-3.2	23	1.2	1.0-1.7		0.7	0.6-0.9	3
Br	62.	<20-132	20	35.	<20-72	19	9.7	2-19	12	15.	12-20	14
Co	13.	7-24	22	14.	6-22	23				8.	3-13	3
Cr	77.	35-165	24	52.	32-68	24	98.	64-160		54.	33-79	6
Cu	37.	9-75	22	20.	8-29	24	39.	17-102	12	101.	21-230	14
Hg	0.20	0.06-0.38	21	0.05	0.04-0.08	28						
Ni	34.	18-58	24	35.	12-54	23	47.	26-84	12	33.	7-50	14
Pb	88.	27-172	24	20.	16-48	23	56.	36-97	12	51.	8-73	14
V	48.	7-83	24	62.	26-99	23	56.	26-72	12	69.	15-180	14
Zn	206.	58-519	22	66.	22-129	23						

^a Data on sediments from Shimp, Leland and White (1970); Ruch, Kennedy and Shimp (1970); Schleicher and Kuhn (1970); Shimp et al. (1971); and Kennedy, Ruch and Shimp (1971). The means and ranges for sediment constituents are from Frye and Shimp (1973), with the exception of constituents marked by an asterisk (*).

^b Top interval sediments selected to contain $\geq 0.75\%$ organic carbon and $\geq 10\%$ less than 2μ clay-size material.

^c Suspended matter (particles removed by a 0.45μ membrane filter) selected without regard to organic carbon content or particle size.

1971; Leland et al., 1973a).

Determinations of major, minor and trace constituents in suspended matter of southern Lake Michigan were made to ascertain if deposition of particles satisfactorily accounts for the high trace element concentrations of surficial sediments. A comparison of trace element concentrations of surficial sediments and suspended matter taken one meter from the lake floor (Table 2) is particularly informative. With the exception of bromine, mean trace element concentrations in the suspended matter equal or exceed amounts in surficial sediments. Lead concentrations of suspended particles in the central portions of the basin exceed 80 μg per g, which is equivalent to the mean concentration found in surficial sediments of the basin. The lower concentrations of bromine in suspended matter, as compared to sediments, may be due to the decreased ability of hydrous oxides to sorb bromine at the higher pH (~ 8.2) of Lake Michigan water. Another possible mechanism for bromine enrichment in surficial sediments of southern Lake Michigan is specific incorporation of bromine by aquatic organisms (Leland et al., 1973a).

DISTRIBUTIONS OF Cu, Ni, Pb AND Zn IN LOWER GREEN BAY AS RELATED TO OTHER SEDIMENT COMPONENTS

Several authors have reported previously on trace metals in sediments of Green Bay, Lake Michigan. Edgington et al. (1972) described vertical distributions of trace metals in several sediment cores, but only two were from the present area of study (i.e. Green Bay south of $44^{\circ} 55' \text{ N}$). Surface enrichment of Cu was noted in both cores, Zn was enriched at the surface in only one core and no variation

with sediment depth was reported for concentrations of iron. Moore et al. (1973) found concentrations of Cr, Fe, Cu and Zn in surficial sediments to be correlated with each other in lower Green Bay but not consistently associated in other areas of the bay. These correlations together with the fact that Cu, Zn and Cr are significantly more concentrated in lower Green Bay than in other Green Bay areas led the authors to suggest that the metals may be associated with organic matter in lower Green Bay sediments. Callendar (1972) emphasized the potential enrichment of trace metals in sediments containing ferromanganese nodules. Although nodules are distributed in the central and northern portions of Green Bay, they probably do not occur in lower Green Bay.

Results from the analysis of 27 surficial sediments of lower Green Bay are considered in the present report. An Ekman dredge was used for sampling and the 0-6 cm depth interval was retained. A survey of the benthos of lower Green Bay with distribution maps showing abundances of macroinvertebrates at the same stations was published by Howmiller (1971).

Distribution maps of organic carbon and zinc contents of surficial sediments in lower Green Bay are presented in Figures 8 and 9. Analytical methods employed are discussed by Shimp et al. (1970) and Jackson (1973). The highest organic carbon concentrations occur in sediments of the deeper areas, which are also the regions of finest-grained sediments. The highest concentrations of trace metals generally occur at the same locations. Trace metal contents of fine-grained sediments of lower Green Bay (Table 3) are generally lower

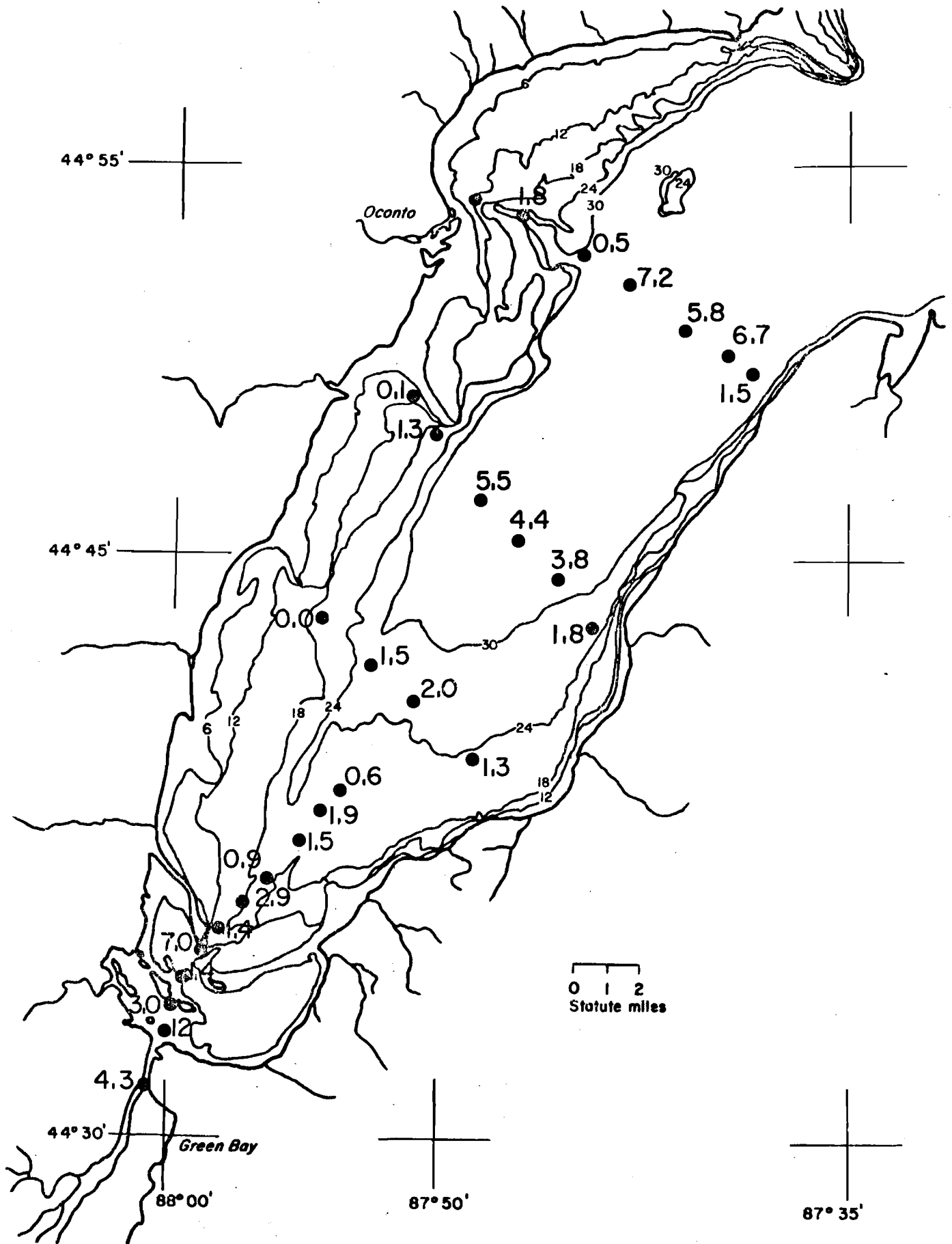


Figure 8. Distribution of Organic Carbon (Percent) in Lower Green Bay Surficial (0-6 cm Depth Interval) Sediments

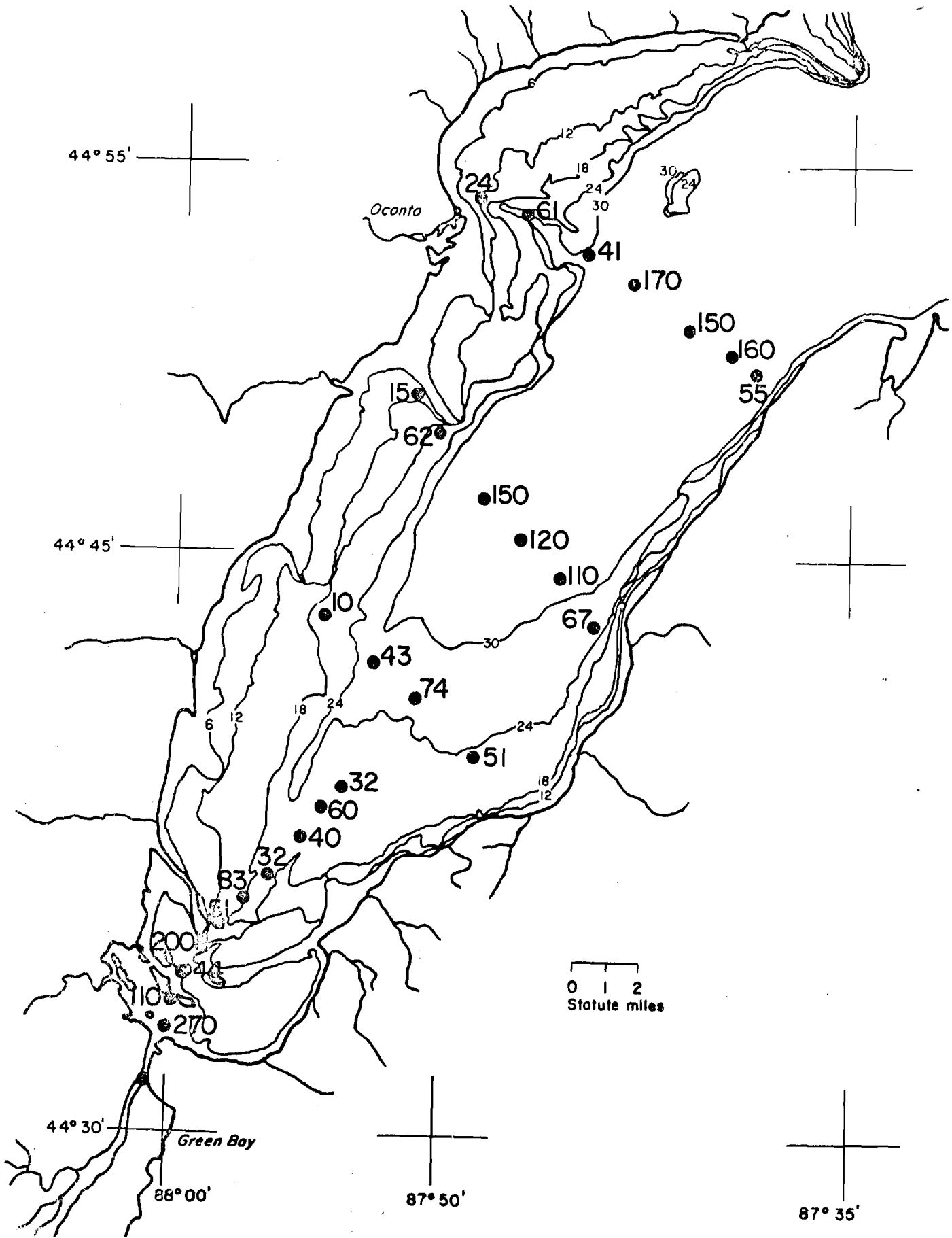


Figure 9. Distribution of Zinc ($\mu\text{g per g}$) in Lower Green Bay Surficial (0-6 cm Depth Interval) Sediments

TABLE 3
 Composition of Surficial (0-6 cm) Sediments
 in Lower Green Bay, Lake Michigan

Sediment Component	Mean	Standard Deviation	Range	Number of Samples
< 2 μ clay-sized material (percent)	19	10	1 - 47	28
Clay and silt-sized material (percent)	70	29	8 - 100	26
Organic carbon (percent)	3.04	2.81	0.03 - 12.1	27
Ignition loss (percent)	5.76	5.50	0.40 - 6.72	27
Fe ₂ O ₃ (percent)	2.94	1.53	0.64 - 6.72	27
MnO (percent)	0.067	0.045	0.045- 0.20	27
Cu (μ g per g)	41	28	10 - 120	28
Pb (μ g per g)	41	31	5 - 140	28
Ni (μ g per g)	52	34	6 - 160	24
Zn (μ g per g)	84	62	10 - 270	27

than the metal contents of fine-grained surficial sediments of southern Lake Michigan. This is probably a consequence of a much more rapid rate of sedimentation in lower Green Bay.

Correlation coefficients were determined for each of eleven parameters against other sediment components. The highest coefficients ($r \sim 0.95$) observed were for Cu, Pb and Zn concentrations versus organic carbon content of lower Green Bay sediments. Highly significant relationships ($r \sim 0.75$) were also observed for Cu, Pb and Zn versus the iron content of sediments. Correlation coefficients for Cu, Pb and Zn concentrations versus manganese content averaged 0.46. Organic matter clearly plays a highly significant role in the transport of Cu, Pb and Zn in sediments of lower Green Bay. The concentration of Ni in the surficial sediments is more highly correlated with the content of iron than with organic carbon.

RELATIONSHIP TO WATER RESOURCES PROBLEMS

The studies summarized in this report have as common objectives the description of trace metal distributions in Lake Michigan waters, suspended matter and sediments and the definition of major trace metal transport parameters. Studies of suspended and surficial sediments showed that the amounts of some trace metals currently being deposited significantly exceed natural rates of deposition. The exchanges of individual elements between suspended matter and water are important to understand.

A program of effective water quality management in any natural body of water depends upon a knowledge of sources of pollutants, changes the pollutant undergoes and the ultimate fate of each substance. Information was obtained on each of these facets for one of our largest and most important water resources, Lake Michigan. Although data sufficient to permit materials-balance studies of Lake Michigan currently do not exist, such information is required for an evaluation of the capacity of the lake to absorb domestic, industrial and agricultural wastes without further deterioration.

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