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Levels of PCBs, Mercury and Other Contaminants in Surface Water Sediment from the Yahara Monona Watershed

Wisconsin Department of Natural Resources
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Contents

Executive Summary

Sediment in Monona Bay, deep water areas of Lake Monona and two Lake Monona tributaries contain a variety of pollutants originating from nonpoint source pollution, former wastewater discharges, and application of inorganic aquatic herbicides. Detectable levels of PCBs were found along the City of Madison side of Lake Monona, Starkweather Creek and in Wingra Creek, indicating widespread contamination. The level of PCB contamination is low compared to PCB "hot spots" around the state. High arsenic and copper concentrations in Lake Monona sediment reflect extensive historic use of inorganic herbicides. Of several contaminants tested, high levels of mercury pose the greatest problem because of bioaccumulation in large walleyes. Large walleyes in Lake Monona and Lake Waubesa contain levels of mercury exceeding the health standard (0.5 ppm) and have been added to the Wisconsin Fish Consumption Health Advisory. Sediment core sampling indicate reduced mercury deposition following diversion of municipal wastewater from the Madison Chain of Lakes.

Future Monitoring Recommendations

1. Sediment cores should be taken from Lake Monona and Lake Waubesa to identify possible trends of PCB contamination.
2. For a more complete assessment of in-place pollutants in Monona Bay, sediment core sampling should be expanded to areas not previously sampled.
3. Because of the potential for bioaccumulation of PCBs in fish and the human health implications, WDNR's Fish Contaminant Program should continue to monitor PCB levels in Yahara Monona Watershed carp.
4. Measuring levels of mercury in predator fish should continue as part of WDNR's Fish Contaminant monitoring strategy.
5. Bioassay's should be performed to determine if Starkweather Creek sediment is toxic to aquatic life.

Introduction

Levels of toxic substances in lakes are often measured in deep water sediment, where heavy metals and organic compounds accumulate. For substances that bioaccumulate in fish and pose a human health threat, such as mercury and PCBs, sediment sampling can dovetail with fish contaminant testing to better define the source and extent of the problem. Sediment grab samples can be used to identify contaminant "hot spots" and total area of contamination. Sediment core sampling can measure toxic contamination from a historical perspective since the deeper sediments are older than surface sediments. While most contaminants occur in upper sediment layers deposited during the 20th century, background levels of naturally occurring heavy metals can be measured in deep sediment layers.

Since 1946, at least eight sediment surveys were conducted in the Yahara Monona Watershed, mostly to assess heavy metal accumulation in the lakes. Early studies focused on accumulation of arsenic and copper following extensive use of inorganic aquatic herbicides (Nichols, 1946, Antonie, 1963 and Ball, 1973) and mercury deposition associated with municipal wastewater discharges (Syers, 1973). More recent sediment sampling (Lathrop, 1989 and Marshall, 1988) also focused on mercury contamination because mercury resurfaced as a major public health and water quality concern. Lake Monona and Lake Waubesa were added to the Wis. Fish Consumption Health Advisory in 1987 and 1988 respectively, because large walleyes contained mercury concentrations higher than state health standard (0.5 ppm).

The most recent sediment sampling was performed in October, 1988, to measure levels of PCBs, mercury and other contaminants in Lake Monona and its tributaries. Sampling for PCBs became a high priority when two Lake Monona carp were found to contain PCB concentrations at 1.1 and 1.7 ppm. The PCB levels did not exceed the health standard of 2.0 ppm, but were higher than expected and indicated potential source(s) of PCB contamination. To complete the contaminant survey, heavy metals and pesticides were measured from Lake Monona tributaries to assess impacts of industry and urban nonpoint source pollution.

This report briefly discusses the 1988 sediment survey along with previous contaminant studies to provide an updated look at in-place pollutants in the Yahara Monona Watershed. The watershed was selected as a nonpoint source pollution abatement project in 1987. Identifying in-place pollutants is an element of the NPS Priority Watershed Project appraisal. No attempt is made to speculate on specific sources of contamination in this report except to mention sources identified in previous studies.

Sampling Locations and Methods

Figure 1 is a map of the Yahara Monona Watershed identifying 1988 sample locations in Lake Monona and its tributaries. For most of Lake Monona, sediment grab samples were taken with a stainless steel Ekman dredge. A piston core sampler was used to collect sediment cores in Monona Bay, Starkweather Creek, West Branch Starkweather Creek, East Branch Starkweather Creek, Wingra Creek, and Ninesprings Creek. Sediment samples were analyzed at the State Lab of Hygiene Inorganic Chemistry Section and Organic Chemistry Section. Results are listed in Table 1 and data from previous sediment surveys are contained as appendices, starting with the most recent.

Lake Monona

PCB levels in Lake Monona sediment were higher than the laboratory detection limit of 0.05 ppm at all but one location, indicating widespread contamination along the City of Madison side of Lake Monona. The west side of Monona Bay was the only location sampled where PCBs were below detection, while the highest PCB concentration (0.77 ppm) was found along the north side of Monona Bay.

Although PCBs are widely distributed in Lake Monona sediment, the level of contamination is relatively low compared to PCB "hot spots" around the state. Little Lake Butte Des Morts, in Winnebago County, contained PCB concentrations exceeding 200 ppm. The Madison Metropolitan Sewage District sludge lagoons contain PCB concentrations up to 36 ppm. By comparison, PCB concentrations in fifteen Lake Monona sediment samples were all below 1.0 ppm (PCB Range: 0.05-0.77).

Compared with 42 other inland lakes sampled by Lathrop (1989), deep water sediment in Lake Monona exhibit a high degree of mercury contamination. In most lakes tested, atmospheric deposition and low pH appear to influence mercury contamination and bioaccumulation. For Lake Monona (including Lake Waubesa), Syers (1973) demonstrated that peak mercury levels coincided with sewage discharge into the Madison Chain of Lakes. Peak mercury levels (1.9 ppm) were found in deeper sediment, deposited 50-60 years ago, when Lake Monona received municipal wastewater. Compared with deeper sediment, surface layers sampled in 1972 contained lower mercury concentrations (1.1 ppm), indicating reduced mercury deposition following diversion of wastewater from the lake. Recent sediment sampling indicated a continued trend of decreased mercury deposition with even lower concentrations (.38-.79Hg) in surface sediment layers.

The north side of Monona Bay appears to be a mercury "hot spot", which is the same site where the highest PCB concentrations were found. A possible source for the contaminants is a large storm sewer outfall located about 200 feet from the site.

Several sediment surveys focused on the accumulation of copper and arsenic to assess long term impacts of inorganic aquatic herbicide use. Both copper and arsenic compounds were used extensively for aquatic plant management in the Madison Chain of Lakes. Lake Monona was the first lake in Wisconsin treated with copper compounds for the control of planktonic algae. Between 1925 and 1978, 1,688,000 pounds of $CuSO_4$ were applied to the lake. Recent applications of copper compounds are generally less than 200 pounds per season. During the 1930's, as much as 100,000 pounds were applied in a single season. Prior to its ban in 1964, Sodium arsenite was used extensively in Lake Monona between 1926 and 1964 for rooted aquatic plant control. Records from 1947 to 1964 showed that 36,000 pounds were used in Monona Bay.

Early sediment surveys found very high copper concentrations in deep water sediment. Maximum copper levels in surface layer sediment exceeded 800 ppm in 1946 (Nichols) and 500 ppm in 1963(Antonie). Recent sampling indicate reduced levels of copper in surface sediments with maximum level of 200 ppm. A sediment core taken in 1987 had the highest arsenic and copper concentrations in deeper (older) sediment, reflecting decreasing Copper sulfate use and the Sodium arsenite ban.

Although recent sediment sampling in Lake Monona focused on levels of PCB's, mercury, arsenic, and copper, Iskandar and Keeney (1974) characterized vertical distribution of lead, copper, cadmium, chromium, nickel and zinc. A sediment core collected at that time contained the highest levels of lead, copper, chromium and zinc in surface layer sediment, indicating a build-up of these heavy metals during the 20th century. No observed trends of deposition were evident for cadmium and nickel.

In general, sediment cores reveal a build-up of several heavy metals above background levels in Lake Monona sediment. Except for mercury, heavy metals found in Lake Monona have a low potential for bioaccumulation in fish (USEPA, 1978), and do not pose a human health threat by consuming fish. On the other hand, deposition of heavy metals and other contaminants in sediment can limit future lake management options, particularly dredging.

Lake Monona Tributaries

Wingra Creek and both branches of Starkweather Creek are sluggish ditched streams with heavy deposition of sediment. Sediment in these streams contain moderate to high levels of heavy metals and reflect impacts of local industry and urban nonpoint source pollution. Lead exceeded 100 ppm at all locations sampled but were highest in the Starkweather Creek East Branch above Milwaukee Street. The highest mercury (3.5 ppm) and zinc (1000 ppm) concentrations in the watershed were found in deeper sediment from the West Branch Starkweather Creek, which indicate a past source of contamination. Other heavy metals measured from Starkweather Creek sediment include arsenic, barium, cadmium, chromium, copper, nickel, selenium, and silver.

Organic compounds tested from stream sediment were PCBs, DDT (and metabolites), Dieldrin and Chlordane. Detectable levels of PCBs were found in Starkweather Creek but the highest concentration was found in Wingra Creek (0.77 ppm). Detectable levels of DDT metabolites were found in both branches of Starkweather Creek and in Wingra Creek.

In general, the tributaries of Lake Monona have accumulated deep sediments contaminated with a variety of pollutants from industry and urban nonpoint source pollution. Land use activities in the watershed can disturb and redistribute contaminated sediment. Physically altering the streams can re-suspend and deposit contaminants in other locations. Construction and development without regard to surface runoff may increase peak flows, which ultimately scour contaminated sediment into Lake Monona.

TABLE 1 (cont.): STARKWEATHER CREEK SEDIMENT CORE SAMPLING
October, 1989

Sta. No.		Arochlor ug/g	CIS-Chlordane ug/g	TRANS-Chlordane ug/g	op DDT ug/g	pp DDT ug/g	op DDD ug/g	pp DDD ug/g	op DDE ug/g	pp DDE ug/g	Dieldrin ug/g	As mg/kg	Ba mg/kg	Cd mg/kg	Cr mg/kg	Cu mg/kg	Pb mg/kg	Hg mg/kg	Ni mg/kg	Se mg/kg	Ag mg/kg	Zn mg/kg
1	Main Stem																					
	Obrich																					
	0-10 cm	<.10	<.01	<.01	<.01	<.01	.19	.79	<.07	.18	<.01	7	81	1	17	32	110	1.6	12	<5	<2.5	510
2	W. Br.																					
	Fair Oaks																					
	0-13 cm											5	64	1	22	37	180	.39	8	<5	<2.5	360
	13-25 cm	<.10	<.01	<.01	<.01	<.01	.13	.74	<.03	.09	<.01	4	34	<1	9	12	80	.38	<.5	<5	<2.5	210
	25-32 cm											7	74	1	12	68	150	3.0	9	<5	<2.5	1000
3	W. Br.	(1260)																				
	Milw. ST.																					
	0-13 cm	.10	<.01	<.01	<.01	.03	.09	.46	<.01	.08	<.01	6	57	1	22	19	130	.15	8	<5	<2.5	180
	13-25 cm	<.10	<.10	<.01	<.01	<.01	.05	.33	<.01	.05	<.01	9	98	1	14	20	93	.43	11	<5	<2.5	320
	25-37 cm	<.05	<.01	<.01	<.01	<.01	<.01	.01	<.01	<.01	<.01	13	130	1	15	21	37	1.9	13	<5	<2.5	790
4	W. Br.																					
	Hoard St.	(1260)																				
	0-13 cm	<.05	<.01	<.01	<.01	<.01	.02	.12	<.01	.03	<.01	3	33	<1	9	14	120	.05	5	<5	<2.5	96
	13-25 cm	.13	<.01	<.01	<.01	.06	.54	2.6	<.04	.26	<.01	7	72	2	10	17	160	.23	9	<5	<2.5	170
	25-37 cm	.06	<.01	<.01	<.01	<.01	.08	.34	<.01	.04	<.01	9	50	<1	9	13	85	.11	7	<5	<2.5	100
5	E. Br.																					
	Ivy St.																					
	0-14 cm											6	130	2	28	36	200	.17	17	<5	<2.5	220
	14-26 cm	<.25	.02	.02	<.01	<.01	.06	.24	<.02	.15	<.01	5	140	1	30	31	120	.15	16	<5	<2.5	170
	26-38 cm	<.15	<.01	.01	<.01	<.01	.09	.41	<.02	.13	<.01	4	120	1	31	22	52	.14	16	<5	<2.5	97
6	Below	(1254-1260)																				
	Hwy. 51																					
	0-13 cm	.27	.01	.01	<.01	<.01	<.01	.02	<.01	<.02	<.01	6	110	2	27	49	320	.20	17	<5	<2.5	400
	13-25 cm	.12	<.01	<.01	<.01	<.01	<.01	.04	<.01	.04	<.01	5	120	1	29	25	90	.15	16	<5	<2.5	150
	25-41 cm	<.10	<.01	<.01	<.01	<.01	.01	.05	<.01	.05	<.01	4	120	<1	26	20	33	.08	14	<5	<2.5	84

TABLE 1 (cont.): STARKWEATHER CREEK SEDIMENT CORE SAMPLING
October, 1989

Sta. No.		Arochlor ug/g	CIS-Chlordane ug/g	TRANS-Chlordane ug/g	op DDT ug/g	pp DDT ug/g	op DDD ug/g	pp DDD ug/g	op DDE ug/g	pp DDE ug/g	Dieldrin ug/g	As mg/kg	Ba mg/kg	Cd mg/kg	Cr mg/kg	Cu mg/kg	Pb mg/kg	Hs mg/kg	Ni mg/kg	Se mg/kg	Ag mg/kg	Zn mg/kg
7	RR Trestle Midwest Steel	(1254-1260)																				
	0-8 cm	.19	<.01	<.01	<.01	<.01	<.01	.01	<.01	.03	<.01	15	110	2	26	52	180	.14	14	<5	<2.5	400
	8-20 cm	.22	<.01	.01	<.01	<.01	<.01	<.01	<.01	.03	<.01	14	120	2	26	59	370	.12	15	<5	<2.5	380
	20-32 cm	.19	<.01	.01	<.01	<.01	<.01	.01	<.01	.04	<.01	9	140	2	27	46	340	.09	15	<5	<2.5	280
8	Above Midwest Steel	(1254-2360)																				
	0-8 cm	.15	<.01	.01	<.01	<.01	<.01	.01	<.01	<.02	<.01	15	100	2	25	39	400	.10	16	<5	<2.5	240
	13-25 cm	.13	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	21	120	1	26	23	180	.07	16	<5	<2.5	140

Lake Waubesa

Lake Waubesa received municipal wastewater via Ninesprings Creek from 1926 until 1958. High mercury concentrations in deep water sediment were one impact of the discharge. Syers(1973) found 1.1 ppm mercury in the surface layer of a core sample. In 1987, sediment cores displayed significantly lower mercury levels (.3 and .4 ppm) in surface sediment layers, indicating reduced mercury deposition nearly thirty years after diversion of wastewater to Badfish Creek. Although mercury levels decreased substantially since 1972, Lake Waubesa contains the second highest mercury levels (behind Lake Monona) in surface sediment compared to 42 other inland lakes tested (Lathrop, 1989).

In addition to mercury sampling, levels of lead, cadmium, chromium, copper, nickel and zinc were measured in Lake Waubesa sediment (Iskandar and Keeney, 1974). At that time, a sediment core displayed the highest concentrations of lead, chromium, copper and zinc in younger sediment, indicating recent build-up of these metals.

Wastewater Implications

The principle sources of high mercury levels in Lake Monona and Lake Waubesa sediment are attributed to municipal and industrial wastewater (Syers, 1973), even though direct effluent testing was not performed. Peak concentrations of mercury occur in sediment layers that coincide with periods of wastewater discharge in the watershed. Substantially lower concentrations are found in surface sediment, indicating reduced mercury deposition following diversion of wastewater away from each lake.

Even though municipal wastewater was diverted away from the Yahara Monona Watershed to Badfish Creek in 1958, concern for the potential discharge of toxic substances is a current issue. Recent rule development reflects this concern by establishing surface water quality criteria for toxic substances (Wisconsin Administrative Code NR 105). As part of this new toxics package, monitoring for toxics is a requirement of the Wisconsin Pollution Discharge Elimination System (WPDES) permit issuance. The Madison Metropolitan Sewage District (MMSD) routinely samples its effluent for mercury and other toxic substances.

In 1989, concentrations of mercury in the effluent were at or below the standard detection limit of 0.2 ppb. Prior to 1958, when municipal wastewater was discharged to the Yahara lakes, mercury concentrations were probably much greater than today even though direct comparisons cannot be made. Factors that contribute to lower mercury concentrations today include advanced wastewater treatment technologies, industrial pretreatment requirements and reduced reliance on toxic inorganic compounds by our society. Table 2 contains MMSD influent, effluent, and sludge concentrations of mercury from 1972, 1988, and 1989.

Table 2.

Madison Metropolitan Sewage District
Mercury Levels

Date	Influent ug/l	Effluent ug/l	Sludge mg/kg
1972	13.0	<0.5	17.5
*1988	0.3 - 1.3	<0.2 - 0.3	7.37 - 7.9
*1989	0.6 - 1.2	<0.2 - 0.2	7.0

*Range of monthly values

Lake Wingra

Lake Wingra was not targeted for recent sediment sampling because previous studies demonstrated relatively low levels of heavy metals compared to Lake Monona and Lake Waubesa sediment. Lake Wingra does not have a history of inorganic herbicide treatments, municipal wastewater discharge, and is <u>not</u> on the Wisconsin Fish Consumption Health Advisory. Relatively, "clean" sediment in Lake Wingra reflect these factors. During the early seventies, sediment core samples were measured for mercury (Syers, 1973), cadmium, chromium, copper, lead, nickel and zinc (Iskandar and Keeney, 1974). Although concentrations of most metals in Lake Wingra are substantially less than the other Yahara lakes affected by sewage effluents, higher concentrations were found in "younger" sediment, indicating urban nonpoint source pollution and atmospheric deposition (USEPA, 1978 and Sellers, 1986).

Ninesprings Creek and Upper Mud Lake

In 1988, levels of PCBs and organic pesticides were below the detection limit in Ninespring Creek sediment at Moorland Road. Ninesprings Creek displays unnatural stream conditions because of channel ditching and nonpoint source pollution contributing sediment to the stream. At the Moorland Road location, mercury concentrations were .13 and .24 ppm. Downstream in Upper Mud Lake, sediment samples were tested as requirement of the South Beltline dredging project in 1986. PCB concentrations were below the detection limit and mercury reached 0.12 ppm in one of four samples.

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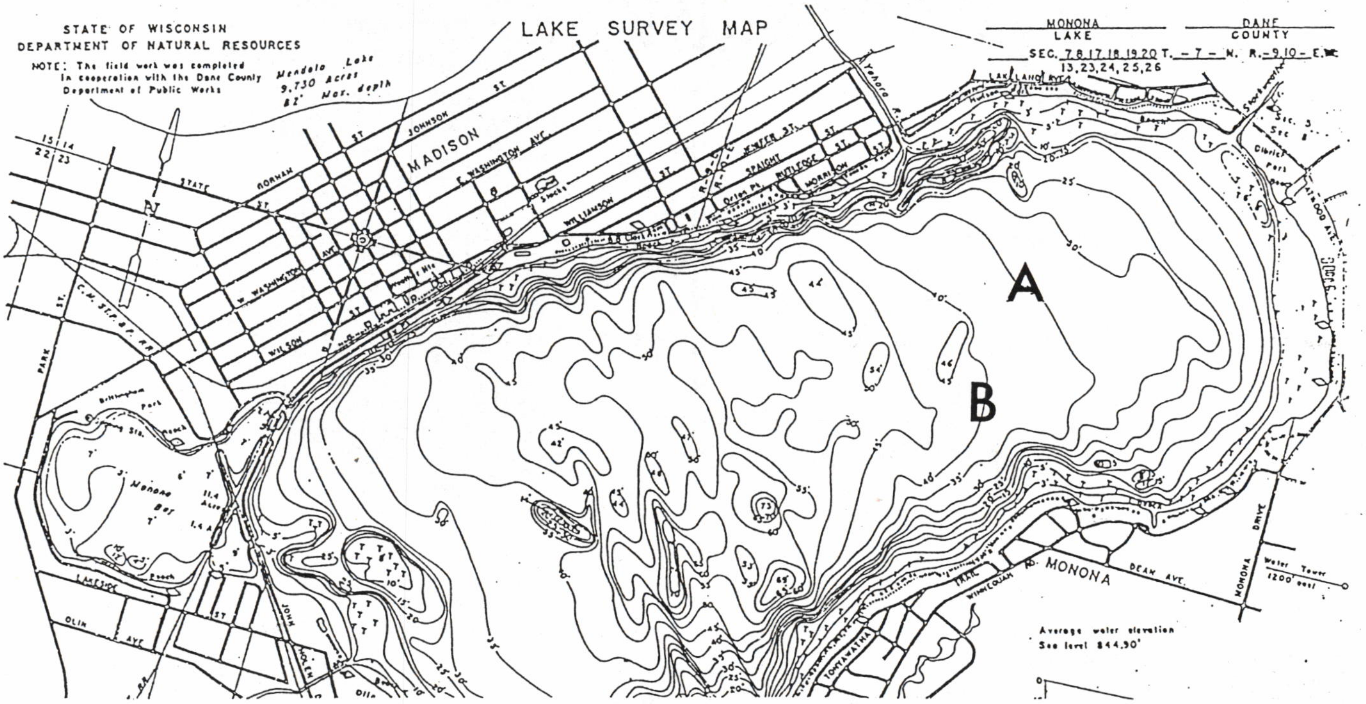
app. A

Lake Monona Sediment Core
Mercury, Arsenic and Copper Concentrations

Sediment Depth (cm)	Site A (1987)** Hg	Site A (1987)** As (mg/kg)	Site A (1987)** Cu	Site B (1987) Hg (mg/kg)	(Lathrop 1985)* Kg (mg/kg)	(Syers et al. 1973)** Hg (mg/kg)
0- 2.5				0.4	0.6	
2.5- 5.0	0.6	14	180	0.5		1.1
5.0- 7.5				0.5		
7.5-10.0	0.6	17	200	0.5		.9
10.0-12.5				0.5		
12.5-15.0	0.6	18	200	0.6		1.3
15.0-17.5				0.7		
17.5-20.0	0.6	21	220	1.0		1.3
20.0-22.5				1.4		
22.5-25.0	0.7	30	250	0.6		1.9
25.0-27.5				0.3		
27.5-30.0	1.4	45	500			1.6
30.0-35.0	1.5	79	600			0.8
35.0-40.0						0.4
45.0-50.0						0.3
55.0-60.0						0.2
60.0-65.0						

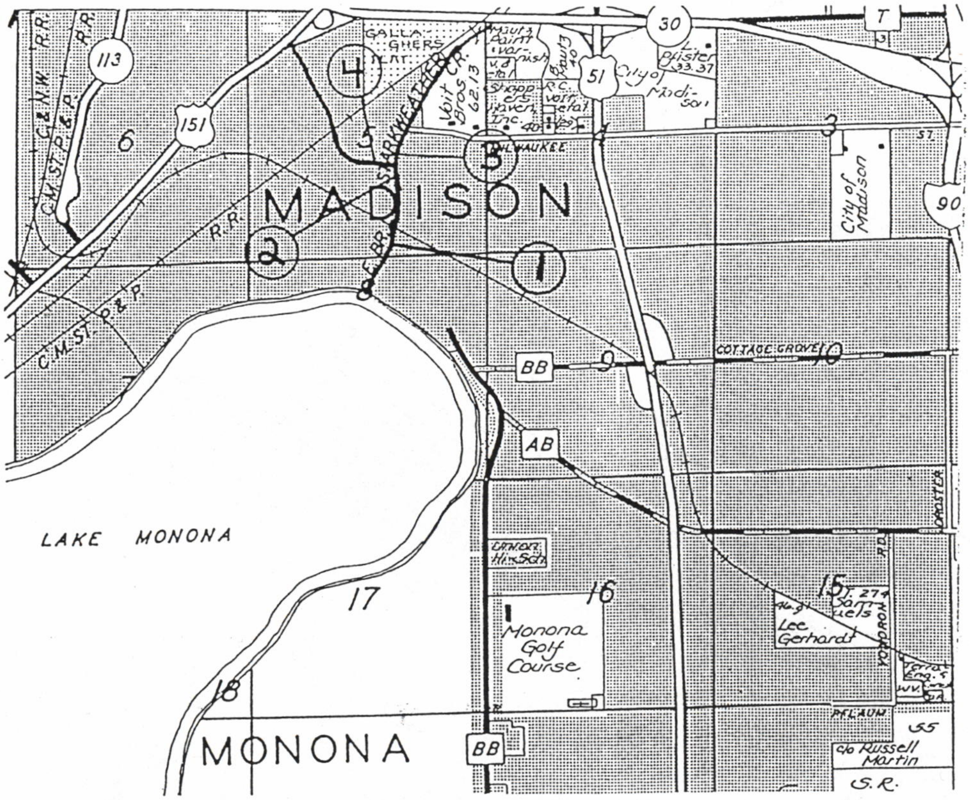
*Mean of seven samples ranging from .4-.8 collected at sediment surface
**5 cm intervals



app. B

Starkweather Creek Sediment Core
Mercury, Lead and Zinc Concentrations
June, 1987

Sediment Depth (cm)	#1 Hg (mg/kg)	#2 Hg (mg/kg)	#3 Hg (mg/kg)	#3 Pb (mg/kg)	#3 Zn (mg/kg)	#4 Hg (mg/kg)	#4 Pb (mg/kg)	#4 Zn (mg/kg)
0- 4	<0.1	0.1	<0.1	280	180	0.2	120	230
4- 8	<0.1	0.3	0.1	270	190	0.2	110	190
8-12	<0.1	0.6	0.1	120	150	0.7	270	560
12-16	<0.1	1.0	<0.1	130	69	2.2	220	1400
16-20	<0.1	1.8	0.1	180	62	2.8	290	1900
20-24	0.2	1.8	0.1	53	120	3.5	310	1900
24-28	0.2	1.6	0.1	51	130	2.5	220	1200
28-32	0.3	0.3						
32-36	0.2							

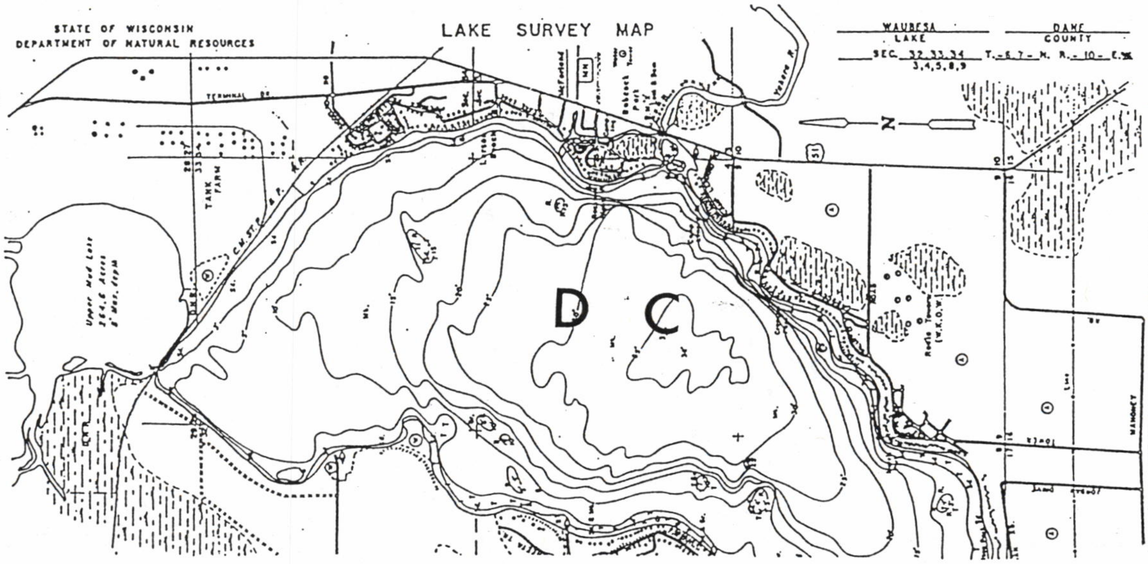


app. C

Lake Waubesa Sediment Core
Mercury Concentrations

Sediment Depth (cm)	Site C (1987) Hg (mg/kg)	Site D (1987) Hg (mg/kg)	(Lathrop 1985)* Hg (mg/kg)	(Syers et al. 1973)** Hg (mg/kg)
0.0- 2.5	0.3	0.4	0.4-0.5	
2.5- 5.0	0.3	0.4		1.1
5.0- 7.5	0.4	0.5		
7.5-10.0	0.4	0.5		0.9
10.0-12.5	0.5	0.6		
12.5-15.0	0.5	0.5		0.7
15.0-17.5	0.5	0.6		
17.5-20.0	0.5	0.6		0.7
20.0-22.5	0.5	0.7		
22.5-25.0	0.7	0.7		1.0
25.0-27.5	1.0	0.8		
27.5-30.0	1.0	1.0		1.0
30.0-32.5	1.3	1.1		
32.5-35.0		1.1		0.9
35.0-40.0				0.8
40.0-45.0				0.8
45.0-50.0				0.7
50.0-55.0				0.7
55.0-60.0				0.2

*Based on two surface sediment samples
**5 cm intervals

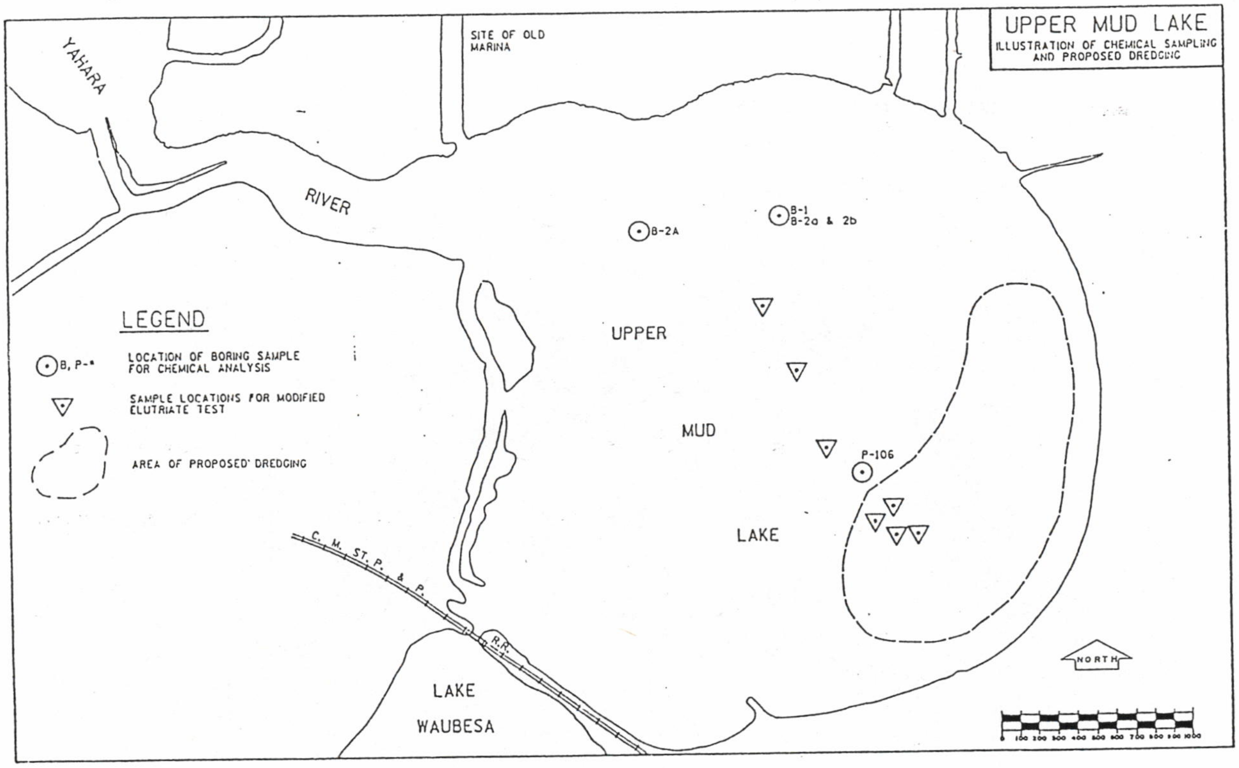


app. D

CHEMICAL ANALYSIS OF MUD LAKE BORINGS

Sample Identification	B-2A	P-106	B-1	B-2a	B-2b
Station	10+00	27+00			
Offset (ft.)	0	200 RT			
Sample Date	3/85	3/85	1/85	1/85	1/85
Depth (ft.)	0-3	0-3	0-1	1-2	2-3
Lab Sample #	4112	4113	3691	3692	3693
PARAMETERS	mg/kg *				
pH (S.U.)	7.8	7.8	7.4	7.4	7.6
% Total Solids	61.7	70.4	48.6	37.0	56.3
% Total Volatile Solids	2.68	1.94	6.3	6.5	3.5
Total Kjeldahl Nitrogen	1170	544	2720	3190	1400
Ammonia Nitrogen	94	84	191	161	102
Total Phosphorus	185	464	395	245	128
Cadmium	<0.22	0.41	<1.00	<1.00	<1.00
Total Chromium	---	---	8.62	3.64	4.58
Copper	<11.0	13.6	<10	8.5	8.6
Arsenic	3.55	19.0	3.92	4.85	7.16
Lead	<2.00	8.15	3.72	1.58	1.58
Zinc	15.5	40.8	25.5	17.0	20.1
Mercury	<0.08	<0.08	0.12	<0.14	<0.09
PCB's (Total)	<0.02	<0.02	---	---	---
PCB 1016	---	---	<0.010	<0.010	<0.010
PCB 1221	---	---	<0.010	<0.010	<0.010
PCB 1232	---	---	<0.010	<0.010	<0.010
PCB 1242	---	---	<0.010	<0.010	<0.010
PCB 1248	---	---	<0.010	<0.010	<0.010
PCB 1254	---	---	<0.010	<0.010	<0.010
PCB 1260	---	---	<0.010	<0.010	<0.010
PCB 1262	---	---	<0.010	<0.010	<0.010
Aldrin	<0.0006	<0.0006	<0.0004	<0.0004	<0.0004
Dieldrin	<0.0005	<0.0005	<0.0003	<0.0003	<0.0003
Chlordane	<0.003	<0.003	<0.002	<0.002	<0.002
Endrin	<0.0010	<0.0010	<0.0008	<0.0008	<0.0008
Heptachlor	<0.0015	<0.0015	<0.009	<0.009	<0.009
Lindane	<0.0010	<0.0010	<0.0006	<0.0006	<0.0006
Toxaphene	<0.006	<0.006	<0.03	<0.03	<0.03
4,4-DDT	<0.003	<0.003	---	---	---

* unless otherwise stated



app. E

Table III. Heavy Metal Concentration (μG/G of Sediment) in Sediment Cores of Wisconsin Lakes

Depth, cm	Southern lakes					
	Cu	Zn	Cd	Pb	Cr	Ni
			Monona			
0–5	268	92	4.6	124	49	50
5–10	294	101	5.5	167	46	60
10–15	363	95	4.6	94	38	52
15–20	434	92	5.1	85	28	50
20–25	510	101	3.6	69	10	48
25–50	90	38	2.4	40	8	43
>50	22	15	2.5	14	7	34
			Waubesa			
0–5	438	182	2.8	44	33	37
5–10	340	175	2.5	40	24	38
10–15	340	179	2.5	38	35	36
15–20	354	177	1.8	37	36	38
20–25	531	195	2.1	37	30	39
25–50	455	162	1.4	27	22	36
>50	108	73	0.7	18	17	32
			Kegonsa			
0–5	229	83	2.7	28	17	28
5–10	286	82	3.0	24	13	28
10–15	328	82	2.5	24	16	24
15–20	297	76	2.0	24	18	25
20–25	255	77	2.0	21	18	25
25–50	76	63	2.0	19	15	24
>50	40	60	1.6	20	15	20
			Wingra			
0–5	18	62	3.0	40	17	33
5–10	16	57	3.0	42	23	32
10–15	18	71	3.2	41	21	32
15–25	17	50	3.0	37	19	33
25–50	12	31	2.9	24	23	31
>50	7	13	2.7	16	18	25

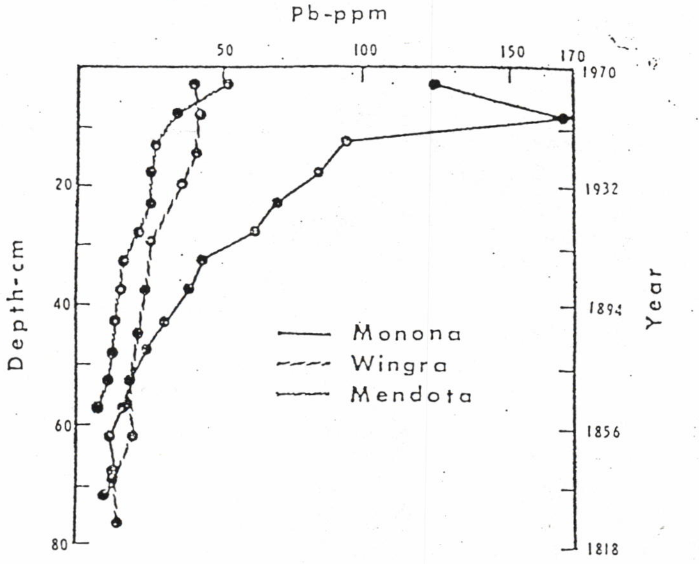


Figure 5. Vertical distribution of Pb in selected Wisconsin lake sediments

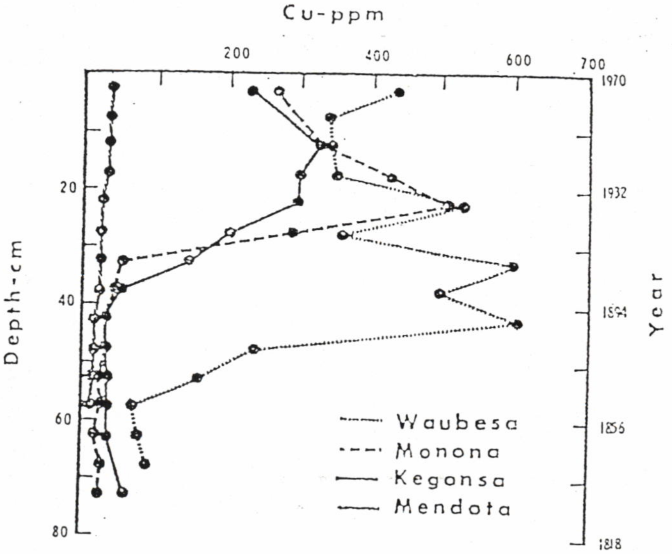


Figure 2. Vertical distribution of Cu in selected southern Wisconsin lake sediments

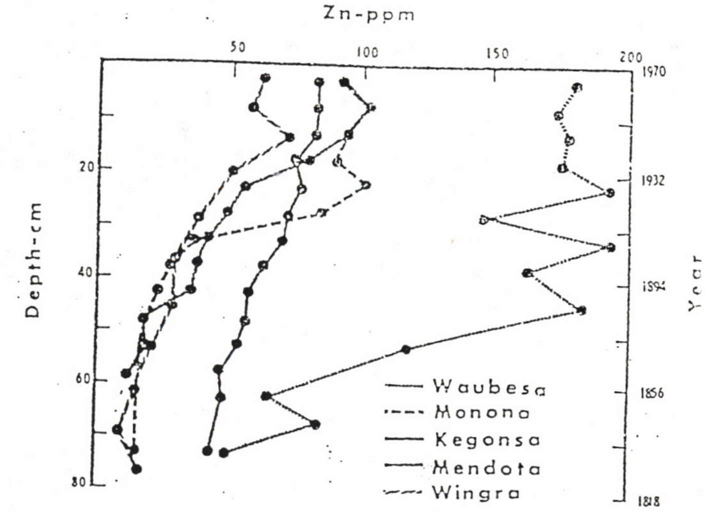


Figure 3. Vertical distribution of Zn in selected southern Wisconsin lake sediments

Concentration of Heavy Metals in Sediment Cores from Selected Wisconsin Lakes

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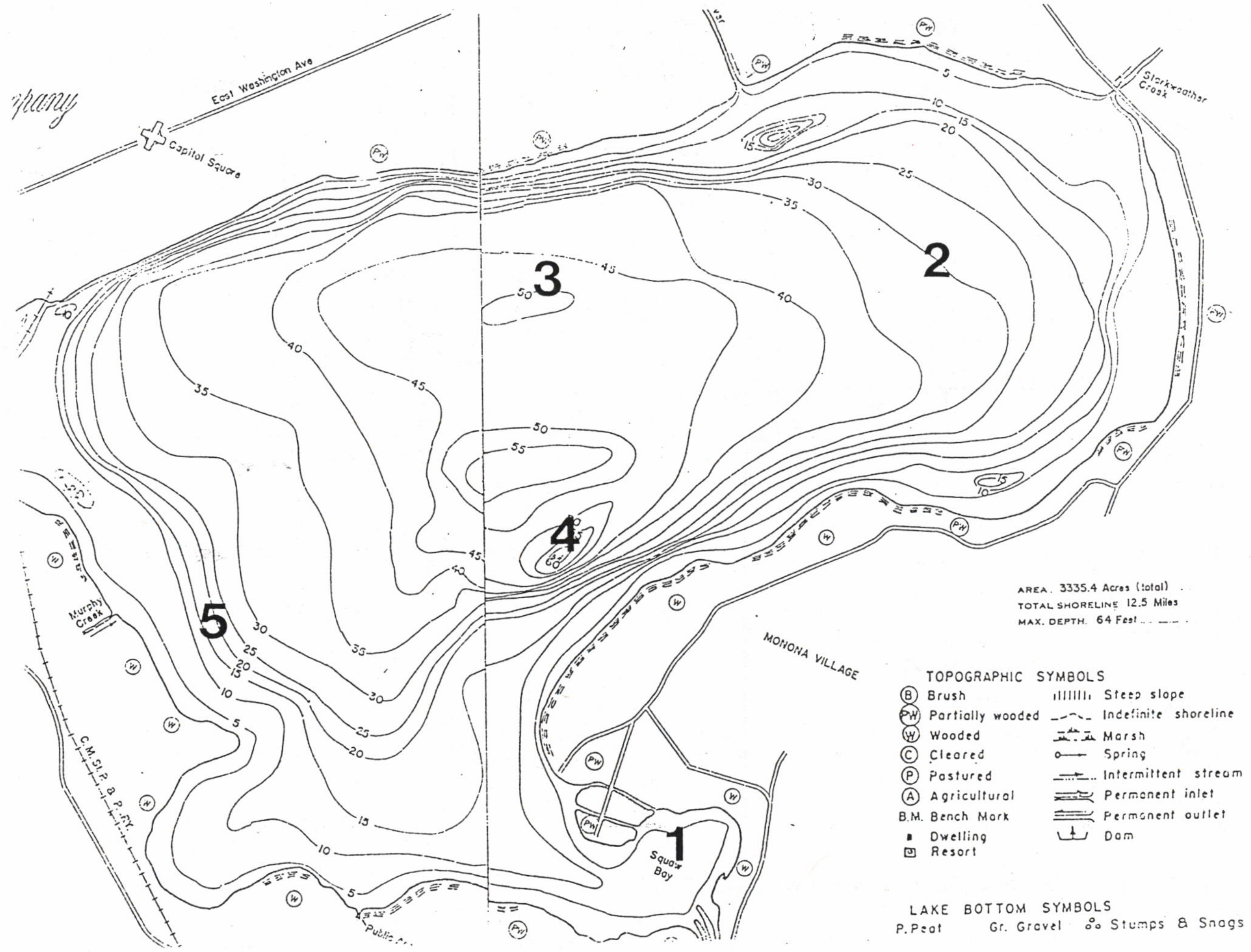
app. F

COPPER AND ARSENIC CONCENTRATIONS IN CORE SAMPLES FROM LAKE MONONA, 1972

Core depth (inches)	Station 1 ppm Copper	Station 1 ppm Arsenic	Station 2 ppm Copper	Station 2 ppm Arsenic	Station 3 ppm Copper	Station 3 ppm Arsenic	Station 4 ppm Copper	Station 4 ppm Arsenic	Station 5 ppm Copper	Station 5 ppm Arsenic
0-1	5	1	230	37.4	260	19.6	220	7.0	7	2.2
2-3	5	1.2	230	34.4	300	25.2	220	6.8	5	2.2
4-5	5	1.4	250	17.8	330	25.6	220	14.4	5	1.2
6-7	5	7.4	330	15.6	350	24.2	330	23.4	5	1.2
8-9	5	1.2	460	6.6	430	24.8	430	13.4	5	3.6
10-11	5	2.6	300	17.6	250	37.0	500	15.2	5	1.2
12-13	5	2.6	45	23.8	40	13.0	570	39.2	5	2.6



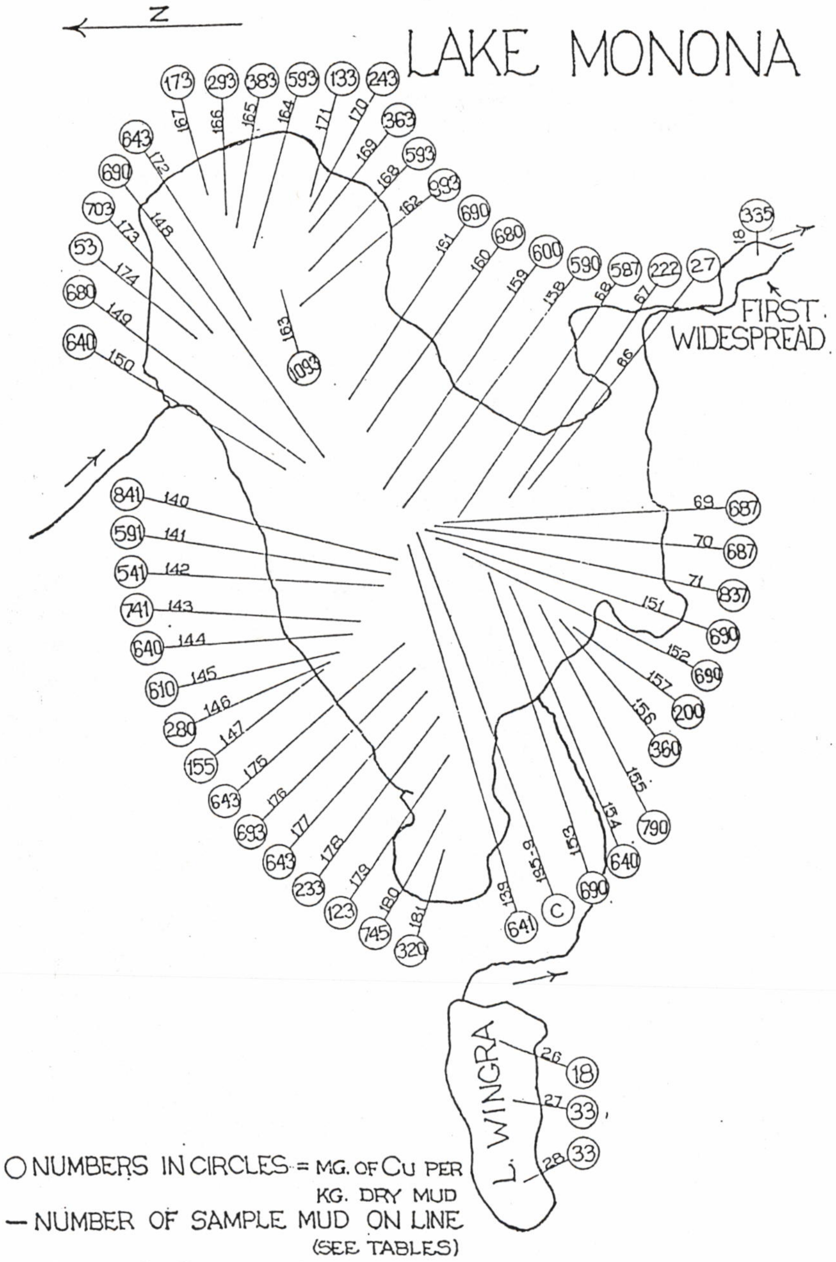


FIG. 4.—Outline map of Lake Monona and Lake Wingra showing location of sampling points, sample numbers corresponding to data in tables at these points, and amount of copper found at the several sampling points. (c) refers to core samples.

app. H

TABLE 4

LAKE MONONA. TOTAL AND SOLUBLE COPPER FOUND IN MUDS FROM BOTTOM OF THIS LAKE FOR VARIOUS DEPTHS

(For location of sampling points consult the map of this lake)

SAMPLE No.	DEPTH IN METERS	COPPER as Cu mg./kg. (dry mud)		SAMPLE No.	DEPTH IN METERS	COPPER as Cu mg./kg. (dry mud)	
		Total	Soluble			Total	Soluble
10	0.91	440	280	147	6	155	122
11	17.2	500	352	148	17	690	400
12	13.0	400	331	149	15	680	400
13	1.1	70	26	150	13	640	343
14	2.7	73	23	151	20	690	317
15	2.7	45	13	152	18	690	308
16	1.8	110	100	153	16	690	343
17	0.5	28	4	154	14	640	336
18	3.3	335	210	155	12	790	360
45	0.9	27	25	156	10	360	185
46	1.2	18	12	157	8	200	18
48	0.6	23	11	158	20	590	380
49	6.0	320	200	159	18	600	337
50	2.7	50	1	160	18	680	355
51	7.3	80	18	161	16	690	360
52	3.3	150	62	162	14	993	360
53	0.97	390	308	163	12	1093	343
54	6.4	50	31	164	10	593	337
55	4.6	55	26	165	8	383	255
56	5.5	260	155	166	6	293	245
57	5.2	130	87	167	4	173	130
58	2.1	110	37	168	12	593	320
66	7.5	27	10	169	10	363	160
67	11	222	150	170	8	243	12
68	16	587	285	171	6	133	35
69	17.5	687	285	172	12	643	360
70	20	687	320	173	10	703	365
71	21.5	837	330	174	8	53	32
139	20	641	317	175	12	643	360
140	18	841	390	176	10	693	337
141	16	591	320	177	8	643	175
142	14	541	305	178	6	233	18
143	14	741	337	179	4	123	43
144	12	640	337	180	2.5	745	320
145	10	610	360	181	2	320	30
146	8	280	190	....	....	....	....

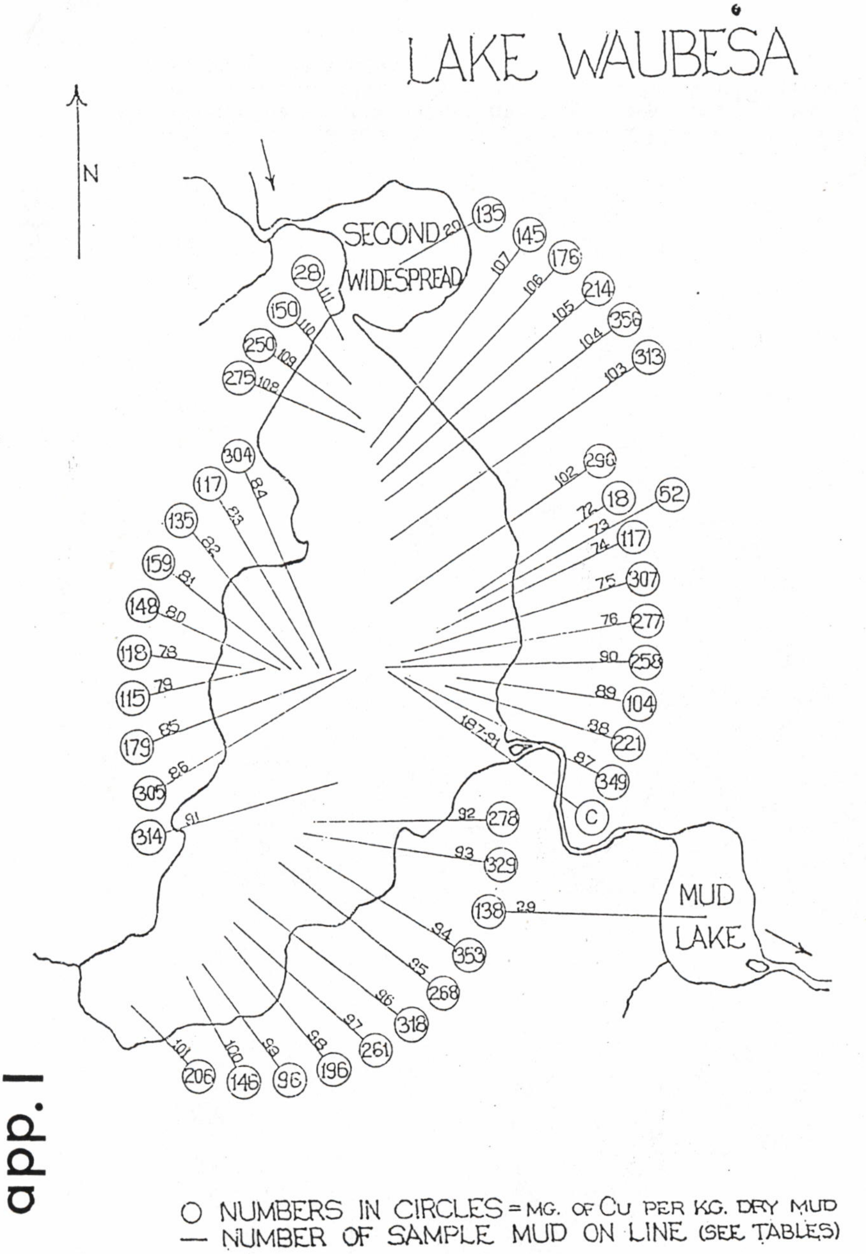


FIG. 5.—Outline map of Lake Waubesa showing location of sampling points, sample numbers corresponding to data in tables at these points, and amount of copper found at the several sampling points. (c) refers to core samples.

app. I

TABLE 5

LAKE WINGRA. TOTAL AND SOLUBLE COPPER FOUND IN MUDS FROM BOTTOM OF THIS LAKE AT VARIOUS DEPTHS

(For location of sampling points consult the map of this lake)

SAMPLE No.	DEPTH IN METERS	COPPER AS Cu mg./kg. (dry mud)		SAMPLE No.	DEPTH IN METERS	COPPER AS Cu mg./kg. (dry mud)	
		Total	Soluble			Total	Soluble
26	1.8	18	2	28	1.5	33	4
27	3.3	33	13	....	....	....	....

TABLE 6

LAKE WAUBESA. TOTAL AND SOLUBLE COPPER FOUND IN MUDS FROM THIS LAKE AT VARIOUS DEPTHS

(For location of sampling points consult the map of this lake)

SAMPLE No.	DEPTH IN METERS	COPPER AS Cu mg./kg. (dry mud)		SAMPLE No.	DEPTH IN METERS	COPPER AS Cu mg./kg. (dry mud)	
		Total	Soluble			Total	Soluble
19	1.5	175	80	88	9	221	62
20	0.91	135	50	89	8	104	6
21	4.3	245	101	90	10.5	258	230
22	10.6	400	251	91	10.5	314	230
23	8.8	415	260	92	10	278	240
24	2.1	145	62	93	9	329	235
25	0.6	22	6	94	8	353	200
29	0.91	138	50	95	7	268	200
72	3	18	15	96	6	318	50
73	6	52	25	97	5	261	62
74	7	117	20	98	4	196	90
75	9	307	110	99	3	96	6
76	10.5	277	140	100	2	146	6
77	bottom	252	16	101	1	206	27
78	2	118	2	102	10	296	165
79	3	115	2	103	9	313	155
80	4	148	37	104	8	356	270
81	5	159	13	105	7	214	37
82	6	135	6	106	6	176	62
83	7	117	51	107	5	145	80
84	8	305	250	108	4	275	130
85	9	179	130	109	3	250	165
86	10	305	200	110	2	150	12
87	10	349	240	111	1	28	12

TABLE I
YAHARA MONONA SEDIMENT CORE SAMPLING
OCTOBER, 1988

Site		Aroclor ug/g	CIS-Chlordane ug/g	TRANS-Chlordane ug/g	op DDT ug/g	pp DDT ug/g	op DDT ug/g	pp DDD ug/g	op DDE ug/g	pp DDE ug/g	Dieldrin ug/g	As mg/kg	Cd mg/kg	Cr mg/kg	Cu mg/kg	Hg mg/kg	Pb mg/kg
M10	Monona Bay (west)	(total)															
	0-10 cm	<.05										5			5	.07	
	10-20 cm	<.05										-			-	-	
	20-30 cm	<.05										2			<2	<.02	
M11	Monona Bay (north)	(1254/1260)															
	0-10 cm	.76										27			140	.84	
	10-20 cm	.77										50			130	1.1	
	20-30 cm	.66										51			120	1.0	
W1	Wingra Cr. (J. Nolan Dr.)	(1242/1254)															
	0-10 cm																
	10-20 cm	.66	.01	.01	<.01	.34	.02	.08	<.02	.05	<.01	7	1	23	28	.16	200
	20-35 cm	.77	<.01	<.01	<.01	<.01	.03	.19	<.03	.08	<.01	10	1	34	30	.28	
N1	Nine Springs Cr. (Moorland Rd.)		(total)														
	0-20 cm	<.05	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01					.13	
	20-35 cm	<.05	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01					.24	

LAKE MONONA EKMAN GRAB SAMPLES
October, 1988

	(1254-1260)			
Site M1	.15	16	160	.53
Site M2	.14	15	150	.54
Site M3	.15	28	200	.79
Site M4	.15	11	120	.38
Site M5	.14	13	130	.42
Site M6	.17	20	160	.62
Site M7	.16	14	140	.53
Site M8	.07	14	97	.62
Site M9	.07	12	110	.43

TABLE 1 (cont.): STARKWEATHER CREEK SEDIMENT CORE SAMPLING
October, 1989

Sta. No.		Arochlor ug/g	CIS-Chlordane ug/g	TRANS-Chlordane ug/g	op DDT ug/g	pp DDT ug/g	op DDD ug/g	pp DDD ug/g	op DDE ug/g	pp DDE ug/g	Dieldrin ug/g	As mg/kg	Ba mg/kg	Cd mg/kg	Cr mg/kg	Cu mg/kg	Pb mg/kg	Hg mg/kg	Ni mg/kg	Se mg/kg	Ag mg/kg	Zn mg/kg
1	Main Stem Obrich 0-10 cm	<.10	<.01	<.01	<.01	<.01	.19	.79	<.07	.18	<.01	7	81	1	17	32	110	1.6	12	<5	<2.5	510
2	W. Br. Fair Oaks 0-13 cm											5	64	1	22	37	180	.39	8	<5	<2.5	360
	13-25 cm	<.10	<.01	<.01	<.01	<.01	.13	.74	<.03	.09	<.01	4	34	<1	9	12	80	.38	<.5	<5	<2.5	210
	25-32 cm											7	74	1	12	68	150	3.0	9	<5	<2.5	1000
3	W. Br. Milw. ST. 0-13 cm	(1260) .10	<.01	<.01	<.01	.03	.09	.46	<.01	.08	<.01	6	57	1	22	19	130	.15	8	<5	<2.5	180
	13-25 cm	<.10	<.10	<.01	<.01	<.01	.05	.33	<.01	.05	<.01	9	98	1	14	20	93	.43	11	<5	<2.5	320
	25-37 cm	<.05	<.01	<.01	<.01	<.01	<.01	.01	<.01	<.01	<.01	13	130	1	15	21	37	1.9	13	<5	<2.5	790
4	W. Br. Hoard St. 0-13 cm	(1260) <.05	<.01	<.01	<.01	<.01	.02	.12	<.01	.03	<.01	3	33	<1	9	14	120	.05	5	<5	<2.5	96
	13-25 cm	.13	<.01	<.01	<.01	.06	.54	2.6	<.04	.26	<.01	7	72	2	10	17	160	.23	9	<5	<2.5	170
	25-37 cm	.06	<.01	<.01	<.01	<.01	.08	.34	<.01	.04	<.01	9	50	<1	9	13	85	.11	7	<5	<2.5	100
5	E. Br. Ivy St. 0-14 cm											6	130	2	28	36	200	.17	17	<5	<2.5	220
	14-26 cm	<.25	.02	.02	<.01	<.01	.06	.24	<.02	.15	<.01	5	140	1	30	31	120	.15	16	<5	<2.5	170
	26-38 cm	<.15	<.01	.01	<.01	<.01	.09	.41	<.02	.13	<.01	4	120	1	31	22	52	.14	16	<5	<2.5	97
6	Below Hwy. 51 0-13 cm	(1254- 1260) .27	.01	.01	<.01	<.01	<.01	.02	<.01	<.02	<.01	6	110	2	27	49	320	.20	17	<5	<2.5	400
	13-25 cm	.12	<.01	<.01	<.01	<.01	<.01	.04	<.01	.04	<.01	5	120	1	29	25	90	.15	16	<5	<2.5	150
	25-41 cm	<.10	<.01	<.01	<.01	<.01	.01	.05	<.01	.05	<.01	4	120	<1	26	20	33	.08	14	<5	<2.5	84