Inland Lakes Sediment Trends: Sediment Analysis Results for Five Michigan Lakes

Report Number: MI/DEQ/WB-07/078

Yearly report: 2004-2005
Crystal (Montcalm County) Lake
George Lake
Hackert Lake
Otter Lake
Round (Delta County) Lake

Project Team:
Matthew J. Parsons[1]
Sharon S. Yohn[1]
David T. Long[1]
John P. Giesy[2]
Lina C. Patino[1]

[1]Aqueous & Environmental Geochemical Laboratories
Department of Geological Sciences
Michigan State University
East Lansing, Michigan 48824-1115
long@msu.edu

[2]Aquatic Toxicology Laboratory
Department of Zoology
Michigan State University
East Lansing, Michigan 48824-1115
jgiesy@aol.com

Inland Lakes Sediment Trends: Sediment Analysis Results for Five Michigan Lakes

Table of Contents

Acknowledgements

This study was made possible by a grant from the Michigan Department of Environmental Quality, and through the assistance of Glen Schmitt, Sarah Holden, Roxanne Ramirez and Bill Taft.

Introduction

Contaminated sediments can directly impact bottom-dwelling organisms and represent a continuing source of toxic substances in aquatic environments that may impact wildlife and humans through food or water consumption (Catallo *et al.*, 1995). Therefore, an understanding of the trends of toxic chemical (e.g., polychlorinated biphenyls (PCBs), lead) accumulation in the environment is necessary to assess the current state of Michigan's surface water quality and to identify potential future problems. A common fate of chemicals in a lake is to associate with fine-grained particulate matter and settle to the bottom (Evans and Rigler, 1983). As this deposition occurs over time, sediments in lakes become a chemical tape recorder of the temporal trends of toxic chemicals in the environment as well as of general environmental change over time (von Guten *et al.*, 1997). Sediment trend monitoring is consistent with the framework for statewide surface water quality monitoring outlined in the January 1997 report prepared by the Michigan Department of Environmental Quality entitled, "A Strategic Environmental Quality Monitoring Program for Michigan's Surface Waters". A key goal of the monitoring program is to measure trends in the quality of Michigan's surface waters, and one activity designed to examine these trends is the collection and analysis of high-quality sediment cores. This report details the activities and findings of the fifth year of the sediment trend component of the Strategy, and builds upon the results from the five lakes sampled in 1999 (Year 1)(Simpson *et al.*, 2000), two lakes sampled in 2000 (Year 2) (Yohn *et al.*, 2001), five lakes sampled in 2001 (Year 3) (Yohn *et al.*, 2002b), six lakes sampled in 2002 (Yohn *et al.*, 2003), and five lakes sampled in 2003 (Parsons *et al.*, 2004).

Summary

Sediment cores were collected from five lakes in 2004 to evaluate the spatial and temporal variations in lake sediment quality in Michigan, and as a continuation of the trend monitoring component of the monitoring program (Simpson *et al.*, 2000). Lakes include: Crystal M04 (Montcalm County), George (Ogemaw County), Hackert (Mason County), Otter (Tuscola County), and Round (Delta County) lakes. Lakes with similar names will include an abbreviation of the county in which it is located (e.g., Round D, D for Delta County). Lakes that have been revisited will include the year of resampling (e.g. Crystal M04 is Crystal Lake in Montcalm County sampled in 2004). Sediment cores were collected from a single location in each lake, dated with 210-lead (^{210}Pb) and 137-cesium (^{137}Cs), and analyzed for a suite of metals and organic compounds. Analysis for a suite of metals rather than just target anthropogenic metals (e.g., Pb, Cu) allows for interpretations about the sources of different chemicals. Additionally, porewater was collected from each of the lakes and analyzed for a similar suite of metals. Key findings include:

- George and Otter lakes exhibited very high sedimentation rates and did not contain sediment of adequate age to determine geochemical background.
- The total concentration of PCBs, polycyclic aromatic hydrocarbons (PAHs) and pesticides in Otter Lake were amongst the highest of all 2004-2005 study lakes.
- George Lake had the highest total PAHs concentration amongst all study lakes.
- Total pesticide levels in the surficial sediment of Otter Lake were great, compared to all Michigan study lakes only Round Lake had greater total pesticide concentration.
- In some lakes, the total concentration of PCBs, PAHs, and pesticides was higher in the surficial sediment than the sediment below suggesting increased loading to the lake. However, complete profiles were not available and therefore the increases may not reflect an overall trend.
- Surface concentration of arsenic was greater than the Probable Effect Concentration (PEC) in Otter and Round D lakes.
- Surface concentration of copper, lead and zinc was greater than the Threshold Effect Concentration (TEC) in all 2004-2005 lakes.
- Focusing-corrected anthropogenic accumulation rates of cadmium, copper and zinc increased to present day in Crystal M04 and Round D lakes.
- Historic anthropogenic loading of lead to Hackert Lake occurred as three distinct events, the most recent occurring in the late 1980s.

Methods

Sediment cores were collected from Crystal M04 Lake (Montcalm County), George Lake (Ogemaw County), Hackert Lake (Mason County), Otter Lake (Lapeer County), and Round D Lake (Delta County) (Figure 1, Table 1). Sediment cores were collected from the deepest portion of each lake using a MC-400 Lake/Shelf Multi-corer deployed from the Monitoring Vessel Nibi. The M/V Nibi was designed, and has successfully provided access, to both major and remote inland lakes throughout Michigan. Collected sediment cores were described and examined for color, texture, and signs of zoobenthos. Cores were then extruded and sectioned at 0.5 cm intervals for the top 8 cm, and at 1 cm intervals for the remainder of the core.

Table 1. Physical characteristics of study lakes. Lakes sampled in 2004-2005 are highlighted.

Lake	Sampling year	Counties of watershed	Lake area (km^2)	Sampling depth (m)	Watershed area (km^2)
Avalon	2003	Montmorency	1.5	21.3	2
Birch	2003	Cass	1.2	29.6	2.2
Cadillac	2001	Wexford, Missaukee	4.7	8.2	48
Cass	1999	Oakland	5.2	36.6	9.1
Crystal B	2001	Benzie	39.3	49.7	106
Crystal M	2000,2004	Montcalm	2.9	16.8	12
Elk	1999	Grand Traverse, Antrim, Kalkaska	31.3	58.8	217
George	2004	Ogemaw	0.7	26.2	5.1
Gratiot	1999	Keweenaw	5.8	23.8	31
Gull	1999	Kalamazoo, Barry	8.2	33.5	61
Hackert	2004	Mason	0.5	15.5	1.5
Higgins	1999	Roscommon, Missaukee, Crawford	38.9	41.5	108
Houghton	2002	Roscommon	81.2	5.5	450
Hubbard*	2001	Alcona	37.9	29.3	
Imp	2002	Gogebic	0.3	28.0	2.1
Littlefield	2000	Isabella	0.7	21.3	17
Mullett	2001	Cheboygan, Otsego	70.3	35.7	718
Muskegon	2003	Muskegon, Newaygo	16.8	14.5	53
Otter	2004	Genesee, Lapeer, Tuscola	0.3	36.9	3.4
Paw Paw	2001	Berrien, VanBuren	3.7	27.7	30
Round	2002	Luce	7.0	13.7	22
Round D	2004	Delta	1.8	16.0	2.0
Sand	2003	Lenawee	1.8	17.3	24.5
Shupac	2003	Crawford	0.4	30.4	2.2
Torch	2002	Antrim, Kalkaska	76.0	86.0	198
Whitmore	2001	Washtenaw, Livingston	2.7	20.4	5.6
Witch	2002	Marquette	0.9	31.1	13

* A watershed was not delineated for Hubbard Lake.

^{210}Pb was measured on one sub-core from each lake to determine porosity, accumulated dry mass, sedimentation rates, sediment ages and focusing factors (Freshwater Institute in Winnipeg, Manitoba, Canada). Dating models were verified using ^{137}Cs, stable Pb peak and presence of excess ^{210}Pb.

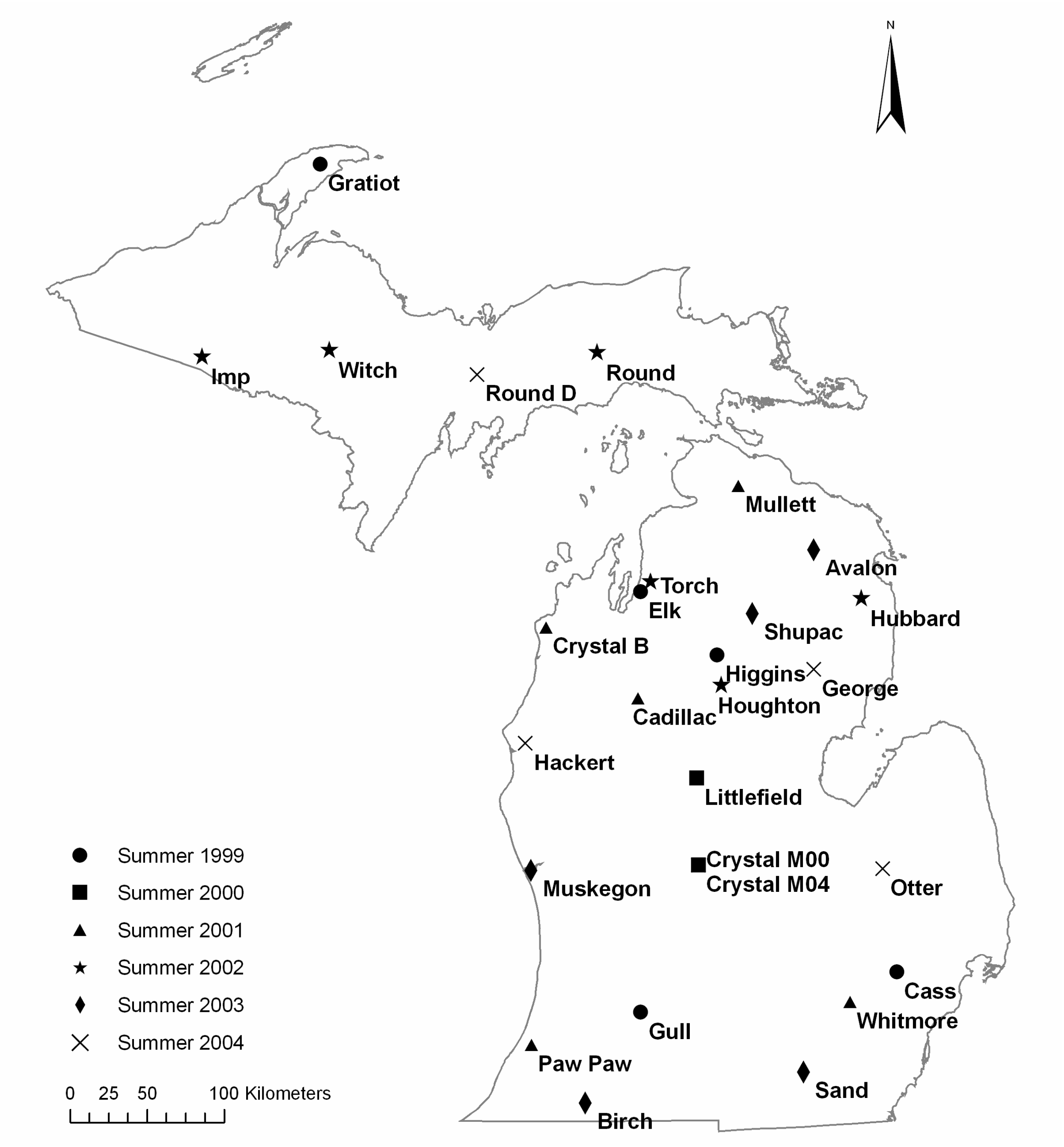
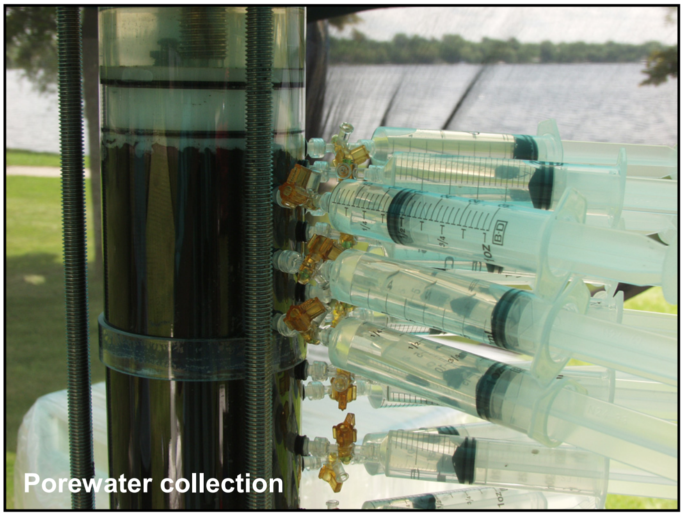


Figure 1. Sampling locations for 1999-2004 study lakes.

Sediments were frozen, freeze-dried and digested by nitric acid in a CEM-MDS-81D microwave (Hewitt and Renyolds, 1990). Standard reference material (NIST RM 8704 Buffalo River Sediment) and procedural blanks were processed to test for accuracy and contamination. The concentrated-acid digests were filtered through an acid-washed, e-pure (Barnstead) rinsed 0.40 µm polycarbonate filter. Samples were then analyzed using a Micromass Platform inductively coupled, plasma, mass spectrometer with hexapole technology (ICP-MS-HEX). Sediments were analyzed for a suite of metals and metalloids including Mg, Al, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Sr, Mo, Cd, Ba, Pb, and U.

Another sub-core was sectioned and used for analysis of organic contaminants. Unlike the metals and ^{210}Pb sub-cores the organics core was sectioned at 1 cm increments for the entire core length. There was insufficient material for analysis in the topmost sediments, so the first two sections were combined, and the third and fourth sections were combined. The combined samples were analyzed for PCBs, PAHs, and pesticides (Khim *et al.*, 1999a, Khim *et al.*, 1999b). A portion of the sediment was dried at 100°C to determine moisture content.

The fourth sub-core was used for the collection of porewater. The sediment core was squeezed 5-6 cm, forcing water through 70 µm Porex™ into syringes placed every 1 cm (10 samples) then 2 cm (18 samples) from the top. The collected water was filtered through an acid washed, DDW rinsed 0.45 µm filter and preserved with Optima™ nitric acid and gold (for mercury analysis). These solutions were analyzed on the ICP-MS-HEX in a similar fashion as the digested sediments.


Porewater collection

Descriptions of the calculations for data analysis follow this section.

^{210}Pb and sedimentation rates

The radioactive isotope ^{210}Pb was used to date sediments from each lake. Several models exist to determine sediment ages from ^{210}Pb activities, and sediments were dated using the constant flux: constant sedimentation rate model (CF:CS) (Golden *et al.*, 1993), segmented CF:CS (SCF:CS) (Heyvaert *et al.*, 2000), rapid steady state mixing model (RSSM) (Robbins, 1982), and the constant rate of supply model (CRS) (Sanchez-Cabeza *et al.*, 2000). The CF:CS model assumes a constant sedimentation rate throughout the core. The RSSM model also assumes a constant sedimentation rate, but also allows for a mixed zone. The SCF:CS model allows for more than one sedimentation rate, and accounts for a mixed zone. The CRS model determines a different sedimentation rate for each sample. Further description of each of the models may be found in the 2001-2002 year end report (Yohn *et al.*, 2002b).

For all models, only sediment layers containing excess ^{210}Pb could be dated. The age of sediment slices not containing excess ^{210}Pb were estimated. This occurred in Hackert (4 slices), Crystal M04(14) and Round D (3). The age of these slices was determined by extrapolation using the assumption that sedimentation rates remain constant below the existence of excess ^{210}Pb. For the RSSM, CF:CS, and SCF:CS model, the sedimentation rate in the lower portion of the core was used to extrapolate dates. For the CRS model, the average sedimentation rate in the last five samples containing excess ^{210}Pb was used. The sedimentation rate used for extrapolation has a significant effect on the resulting dates, and all dates prior to 1850 should be considered estimations that are reported primarily for graphing purposes.

Sedimentation rates in each lake were determined using all models possible for that lake, and then the models were evaluated to ascertain which was the most appropriate for determining sediment ages. There is no consensus as to which model is more appropriate in all cases (Oldfield and Appleby, 1984), and several factors were considered when choosing a model. Visual examination of the ^{210}Pb profile gave some insight into the most appropriate model to be used. The RSSM or CRS models are more appropriate for lakes with large mixing zones, and the SCF:CS or CRS models are more appropriate for lakes with clear changes in sedimentation. Additionally, this study uses two other indicators to determine the most appropriate model to use: profiles of ^{137}Cs activity and stable lead concentration profiles. ^{137}Cs is an artificial radionuclide that was produced by atmospheric testing of nuclear weapons in the late 1950s and early 1960s. The peak level of fallout occurred in 1963, and therefore the peak activity in the sediment should occur in the early 1960s (Walling and Qingping, 1992). The second indicator is the stable lead peak. Stable lead has an historical pattern of deposition that is very consistent among lakes, with lead concentrations increasing from the mid-1800s to the early to mid-1970s, and decreasing to the present. The peak in lead concentrations in the mid-1970s is consistent enough to use for dating verification (Alfaro-De la Torre and Tessier, 2002, Callender and vanMetre, 1997). Excess ^{210}Pb should not be present in sediment slices older than ca. 1850, therefore, dating models that place sediment slices, containing excess ^{210}Pb, older than ca. 1850 are suspect. The dating model with the most appropriate date for both the ^{137}Cs peak (1963-64), stable lead peak (early to mid-1970s), and assigned appropriate dates to the presence of excess ^{210}Pb is chosen.

Focusing factors were also determined from ^{210}Pb analysis. Sediment focusing occurs when fine-grained sediments in a lake are eroded from higher energy erosional zones near the shore of the lake, transported through transitional zones (where deposition and erosion occur episodically) and deposited in depositional zones (Downing and Rath, 1988, Hakanson, 1977). This process of focusing occurs to different extents among lakes, and must be accounted for using the focusing factor before comparing inventories and accumulation rates among lakes. A complete explanation of the focusing factor can be found in the 2001-2002 year end report (Yohn *et al.*, 2002b). Focusing factors and sedimentation rates are summarized in Table 2.

Table 2. Select data from ^{210}Pb analysis, including the model used for dating, mixed depth, sedimentation rate (g/m^2/y), focusing factor (FF) and the age of the oldest section in the sediment core. Lakes from the 2004-2005 sampling year are highlighted

Lake	Model	Approximate mixed depth (cm)	Sedimentation rate (g/m^2/y)	FF	Oldest section	Report#
Avalon	CRS	4	296	1.5	1790[a]	MI/DEQ/WB-06/003
Birch	CRS	3	540	1.7	1824[a]	MI/DEQ/WB-06/003
Cadillac	CRS	14	117	1.7	1829[a]	MI/DEQ/SWQ-03/052
Cass	CF:CS	3	3480	6.0[c]	1971	MI/DEQ/SWQ-01/030
Crystal B	CRS	4	624	2.9	1516[a]	MI/DEQ/SWQ-03/052
Crystal M00	CRS	6	465	1.7	1732[a]	MI/DEQ/WD-02/115
Crystal M04	CRS	0	559	1.6	1804	This report
Elk	SCF:CS	1	337	2.1	1279[a]	MI/DEQ/SWQ-01/030
George	CF:CS	9	417	2.1	1932	This report
Gratiot	CF:CS	5	255	2.5	1823[a]	MI/DEQ/SWQ-01/030
Gull	SCF:CS	3	404	1.8	1496[a]	MI/DEQ/SWQ-01/030
Hackert	CRS	0	451	1.9	1840	This report
Higgins	CF:CS	3	232	2.0	1729[a]	MI/DEQ/SWQ-01/030
Houghton	SCF:CS	8	165	1.2	1715[a]	MI/DEQ/WB-04/066
Hubbard	NA	NA	NA	NA	NA	MI/DEQ/WB-04/066
Imp	CRS	3	119	1.5	1745[a]	MI/DEQ/WB-04/066
Littlefield	Pb	NA	444	2.0[b]	1732[a]	MI/DEQ/WD-02/115
Mullett	SCF:CS	4	801	3.6	1708[a]	MI/DEQ/SWQ-03/052
Muskegon	CF:CS	3	1711	2.8[c]	1956	MI/DEQ/WB-06/003
Otter	CF:CS	8	933	3.5	1945	This report
Paw Paw	CF:CS	3	828	2.7[c]	1923	MI/DEQ/SWQ-03/052
Round	CRS	7	317	2.3	1851	MI/DEQ/WB-04/066
Round D	CRS	9	270	2.4	1852	This report
Sand	CRS	0	441	1.8	1864	MI/DEQ/WB-06/003
Shupac	CRS	1	261	2.0	1829[a]	MI/DEQ/WB-06/003
Torch	Pb	0	365	2.4	1493[a]	MI/DEQ/WB-04/066
Whitmore	SCF:CS	6	556	2.8[c]	1887	MI/DEQ/SWQ-03/052
Witch	CRS	6	269	1.7	1767[a]	MI/DEQ/WB-04/066

a. Estimated dates based on extrapolation
b. A focusing factor could not be calculated for Littlefield Lake, so the average focusing factor of all lakes sampled previously (except Cass Lake) was used
c. Estimated focusing factor based on extrapolation

Results

Radiometric Dating

Crystal (Montcalm County) Lake 2004

Crystal M04 Lake did not appear to have a mixing zone, suggesting minimal disturbance of the sediment water interface by sediment dwelling aquatic organisms (Figure 2). The CF:CS and SCF:CS models placed the ^{137}Cs peak in the mid 1970s; the CRS model placed the ^{137}Cs peak in 1970. These dates were more recent than expected since ^{137}Cs should peak in the early 1960s. The CF:CS and SCF:CS models assigned dates that were too old for the existence of excess ^{210}Pb. The CRS model assigns the date of excess ^{210}Pb more appropriately and placed the maximum concentration of stable Pb in the first half of the 1970s and was used to date the core.

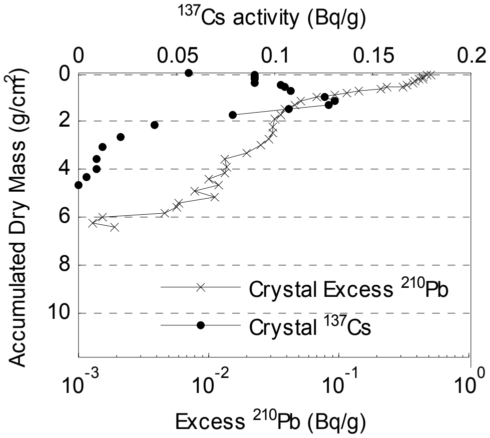


Figure 2. Crystal Lake radiochemical dating results.

George Lake

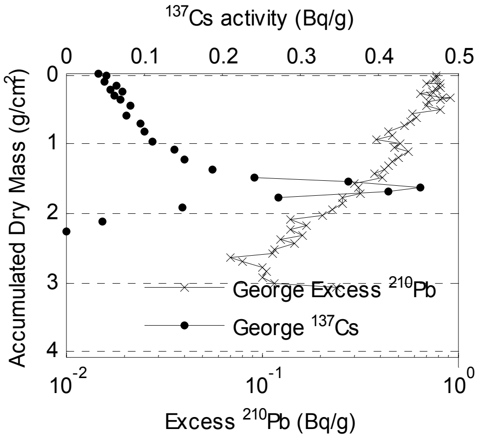


Figure 3. George Lake radiochemical dating results.

Excess ^{210}Pb was found in every sample of the George Lake core making the CRS model inappropriate to use for dating (Figure 3). In addition, the lake had a relatively large mixing zone spanning the top 9 cm of the core, evidence of extensive bioturbation. Worms and other dead invertebrates were identified in the top sections of the core (Appendix B). The CF:CS model places the ^{137}Cs peak in 1968 which agrees with the expected behavior of this particular radionuclide. Stable Pb results from George Lake show two concentration maxima, in 1965 and 1971. Although the bimodal profile is difficult to interpret, the timing of the most recent peak is consistent with the behavior of Pb in the Great Lakes region and confirms the appropriateness of the CF:CS model for this lake.

Hackert Lake

Radiochemical dating results from Hackert Lake show a curvi-log-linear excess ^{210}Pb profile (Figure 4). No mixing zone was apparent in the top sections of the core. Modeling results using the CF:CS model placed the ^{137}Cs peak much more recent than expected whereas the CRS model placed the peak in the mid-1960s. Peak stable Pb concentration was placed in the early 1980s using the CRS model. Although this is more recent than expected (enactment of environmental legislation resulted in the removal Pb from gasoline in the mid-1970s), results do not differ greatly from other study lakes reported in previous years (e.g., Higgins and Torch lakes).

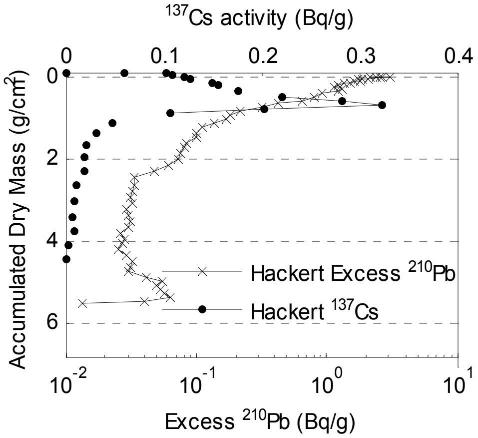


Figure 4. Hackert Lake radiochemical dating results.

Otter Lake

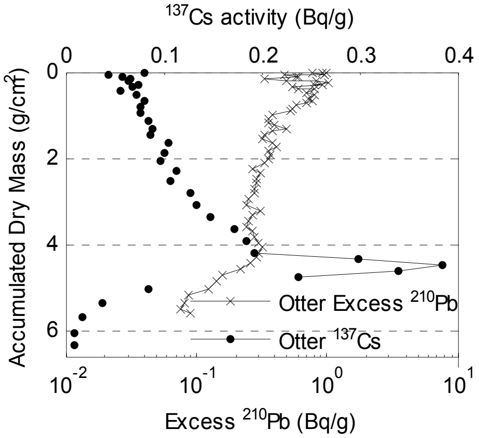


Figure 5. Otter Lake radiochemical dating results.

Similar to George Lake, excess ^{210}Pb was found in each core section of the Otter Lake core making it inappropriate to date using the CRS model (Figure 5). Otter Lake has a relatively large mixing zone, approximately 8 cm, and a log-linear ^{210}Pb decay rate. Dating the core using the CF:CS model placed the ^{137}Cs and stable Pb peaks in the early 1960s. This is consistent with the peak of nuclear fallout, the source of ^{137}Cs, but places the stable Pb peak too early. Although the stable Pb peak was too early, the CF:CS model was used to date the Otter Lake sediment core. Otter Lake lies close to the urban center of Flint and may have other more local sources that attributed to the more recent stable Pb peak.

Round (Delta County) Lake

Excess ^{210}Pb activities in the top 8-9 cm of the Round D Lake sediment core did not vary significantly suggesting either 1) extensive mixing in the top section of the core or 2) extremely high rates of sedimentation (Figure 6). Aluminum concentrations in the top section of the core were variable but tended to be declining sharply in the top 10 cm of the core. This suggests that

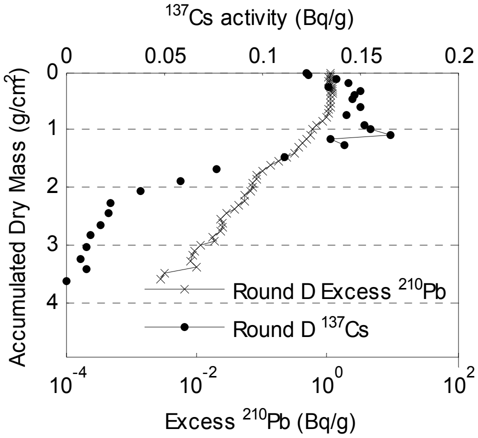


Figure 6. Round (Delta County) Lake radiochemical dating results.

the top sediments in Round D Lake were highly mixed. Both the CF:CS and the CRS models place the ^{137}Cs peak in the mid to early 1960s which is appropriate. Both models placed the peak concentration of stable Pb in the late 1930s suggesting that neither model is appropriate for dating the Round D Lake core. However, a second stable Pb peak was observed in the late 1970s. This would imply that the 1930s peak of stable lead was due to a local scale source of Pb to the watershed. This seems more appropriate because stable Pb concentrations in the lower sections of the core were similar to background concentrations observed in other Upper Peninsula lakes. As further evidence for dating model selection, excess ^{210}Pb activities were measured in all but the last four sections of the sediment core. Excess ^{210}Pb should be evident in core sections that are less than 150 years old, indicating that the bottom core sections from Round D Lake should date in the mid to late 1850s (^{210}Pb dating provides accurate dates for approximately the last 150 years). The CF:CS model placed the last slice containing excess ^{210}Pb in the early 1800s whereas the CRS model placed this slice in the early 1950s, suggesting that the CRS model is more appropriate for the dating of the Round D Lake core.

Organics

Analyses of organic contaminants in the lakes sampled during the 2004-2005 season did not reveal a single lake with high concentrations of PAH, PCBs, and pesticides. However, 2004-2005 lakes organic concentrations were generally higher than previous sampling seasons. All lakes contained PCBs, PAHs and pesticides in one or both samples. In nearly all cases surficial sediments had higher concentrations of organic contaminants than the sample below. This suggests new sources, or an increased loading rate from present sources may be emerging; however, contaminant levels observed in these lakes are consistent with known atmospheric deposition rates (Bradley *et al.*, 2005).

Care should be taken when comparing concentrations of organic contaminants among lakes. Due to the low amount of sediment in the top-most sections of the core, the top two slices were combined, and slices 3 and 4 were combined, to create two samples. As a result of combination and variable sedimentation rates among lakes, each sample represents a range of deposition years. For example, Torch Lake (sampled in 2002), had a low sedimentation rate, therefore a sediment slice represents a broader range of sediment ages and might be expected to have higher concentrations of organic contaminants.

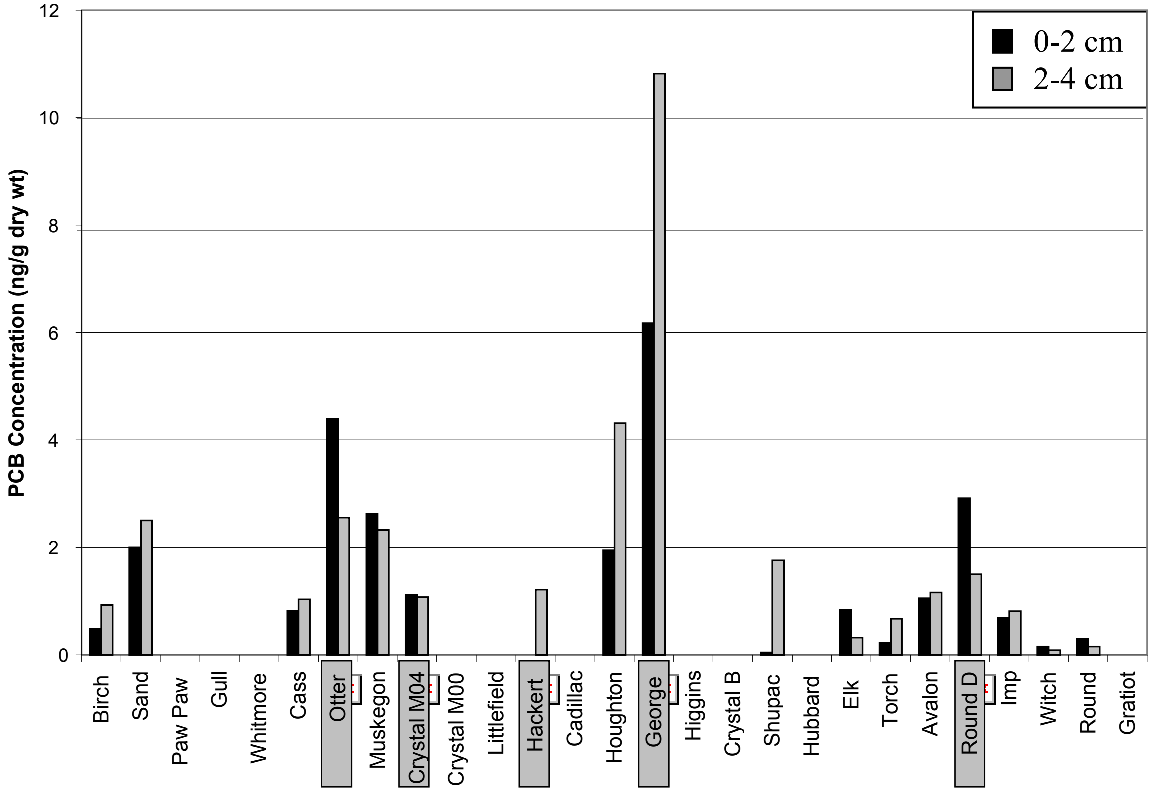


Figure 7. Total PCBs concentrations (ng/g dry wt) for Michigan lakes. Lakes sampled during the 2004-2005 reporting year are highlighted. Slices 1 and 2 (black bars) were combined and 3 and 4 (gray bars) were combined.

Concentration (ng/g dry wt) of total PCBs (sum of all PCB congeners) for the 2004-2005 study lakes were generally higher than those for previous sample lakes in both the Lower and Upper Peninsulas (Figure 7). Crystal M04, Otter, and Round D lakes had higher concentrations in the surficial sediment compared to the lower sediment suggesting a recent source of PCBs to these lakes. Among all study lakes, George Lake had the highest concentrations of PCBs. Compared to the Crystal M Lake sampling performed in 2000, sediment PCB concentrations in 2004 were higher; this implies a new source for PCBs has emerged. However, total PCBs in 2000 were below detection limits and the increase may only reflect improved analytical capability.

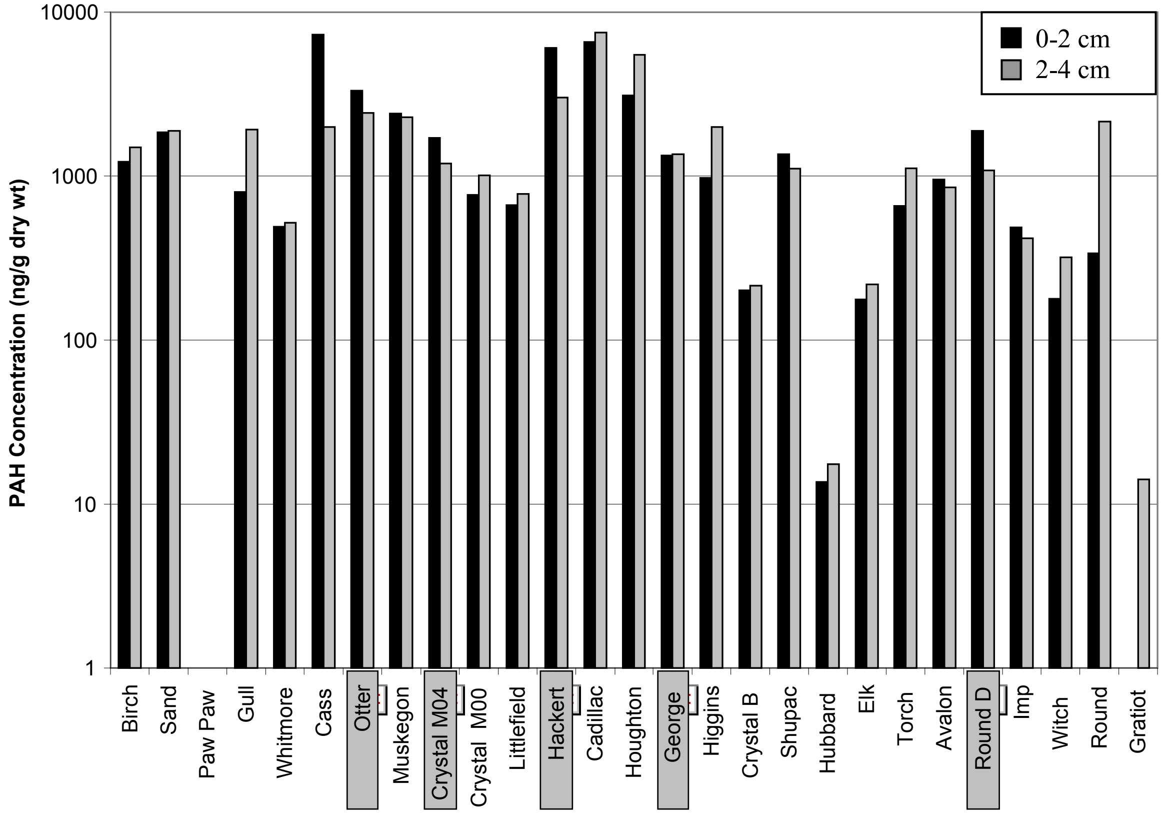


Figure 8. Total PAH (ng/g) in surficial sediments of Michigan lakes. Lakes sampled during the 2004-2005 reporting year are highlighted. Slices 1 and 2 (black bars) were combined and 3 and 4 (gray bars) were combined.

Concentrations (ng/g dry wt) of total PAHs (sum of 14 compounds) from 2004-2005 study lakes were consistent with those from previous sampling years (Figure 8). However, Round D Lake has higher total PAHs than most Upper Peninsula lakes. With the exception of George Lake, all lakes sampled during 2004-2005 had higher concentrations in the surficial sediment than in the sample below, whereas this trend was only observed in five of the lakes sampled previously (Cass, Muskegon, Shupac, Avalon, and Imp).

Concentrations (ng/g dry wt) of total pesticides (sum of 13 compounds) from the 2004-2005 study lakes were higher than those from lakes sampled previously (Figure 9). Higher total pesticide concentrations in the surficial sediment sections were observed in all 2004-2005 lakes; except for George Lake this was also observed for total PAHs. Total pesticide concentration higher in the surficial sediment than in the sediment below was only observed in three lakes studied previously (Houghton, Sand, and Witch). This may reflect an increase in the use of pesticides in Michigan. Excluding Round Lake, total pesticides in Otter Lake were the highest among all study lakes. Due to differences in the reporting of total pesticides only those lakes with analytes that were consistent among reporting years are presented. Results of all organic contaminant concentrations for the 2004-2005 lakes are shown in Table 3a-c.

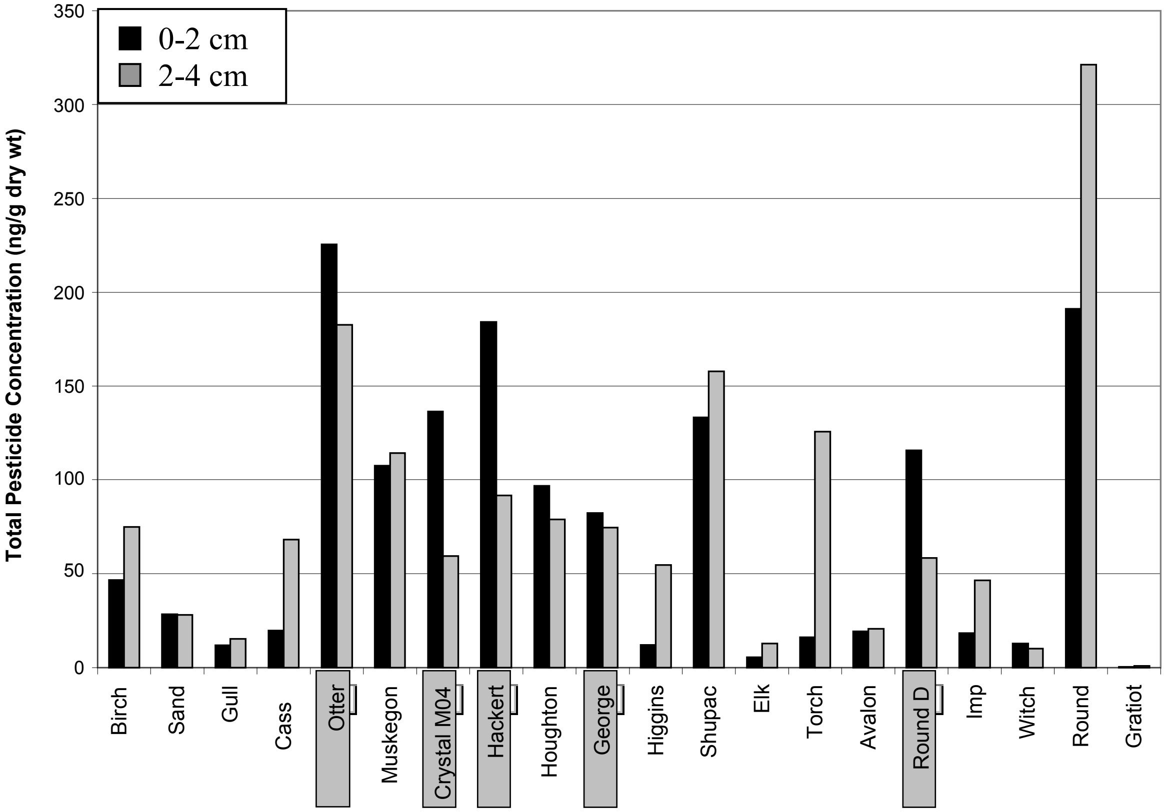


Figure 9. Total pesticide concentration (ng/g dry wt) in surficial sediments of Michigan lakes. Lakes sampled during the 2004-2005 reporting year are highlighted. Slices 1 and 2 (black bars) were combined, and 3 and 4 (gray bars) were combined.

Table 3a. Pesticide concentrations (ng/g dry wt) for 2004-2005 lakes. C1+C2 is the combined sample mass of the first and second 1 cm slices for Crystal M04 Lake, C3+C4 is the combined sampled for the third and fourth 1 cm slices. This naming and sample combination convention was used for all lakes.

Sample	Total Pesticides	α BHC	β BHC	Lindane	γ BHC	Heptachlor	Aldrin	Heptachlor	cis Chlordane	trans Chlordane	DDE	DDD	DDT	Methoxychlor
Crystal M04														
Cr1+ Cr2	136.44	9.09	13.52	31.62	5.98	**BDL**	**BDL**	**BDL**	2.41	1.55	35.12	12.28	16.63	8.24
Cr3+ Cr4	59.52	5.14	1.92	**BDL**	4.47	6.65	**BDL**	**BDL**	1.14	0.78	23.63	5.97	8.00	1.82
George														
G1+ G2	82.39	19.39	3.88	5.82	21.00	**BDL**	1.94	18.09	2.26	3.23	4.52	2.26	**BDL**	**BDL**
G3+ G4	74.59	24.64	**BDL**	2.86	11.44	**BDL**	2.64	16.72	1.98	3.74	6.38	4.18	**BDL**	**BDL**
Hackert														
HA1+HA2	184.19	*NR*	15.02	*NR*	**BDL**	32.41	27.67	26.48	4.35	3.56	54.94	19.76	**BDL**	**BDL**
HA3+HA4	91.75	*NR*	3.04	*NR*	**BDL**	10.96	**BDL**	22.05	**BDL**	2.11	33.66	10.56	6.60	2.77
Otter														
O1+ O2	225.37	32.94	20.18	**BDL**	13.80	46.29	**BDL**	*NR*	3.56	2.37	56.08	30.56	19.58	**BDL**
O3+ O4	182.54	57.85	**BDL**	**BDL**	8.30	33.03	**BDL**	*NR*	1.03	1.03	28.58	45.01	7.70	**BDL**
Round D														
R1+R2	115.72	66.10	**BDL**	**BDL**	5.30	**BDL**	**BDL**	28.41	2.27	**BDL**	7.39	3.60	2.65	**BDL**
R3+R4	58.28	30.09	**BDL**	**BDL**	5.68	3.12	**BDL**	10.79	**BDL**	**BDL**	5.01	**BDL**	3.60	**BDL**

BDL indicates concentration below detection limit

NR indicates analyte not reported

Table 3b. PCB congener concentrations (ng/g dry wt) for 2004-2005 lakes. C1+C2 is the combined sample mass of the first and second 1 cm slices for Crystal M04 Lake, C3+C4 is the combined sampled for the third and fourth 1 cm slices. This naming and sample combination convention was used for all lakes.

	Total	**PCB Congener**																			
Sample	**PCBs**	**5+8**	**18**	**28**	**52**	**44**	**66+95**	**77+110**	**90+101**	**118**	**105+132**	**178+129+126**	**153**	**138**	**128**	**187+159**	**180**	**170**	**195**	**206**	**209**
Crystal M04																					
Cr1+ Cr2	11.19	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	1.40	1.24	**BDL**	1.55	1.79	1.94	**BDL**	1.63	1.71	**BDL**	**BDL**	**BDL**	**BDL**
Cr3+ Cr4	10.70	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	1.09	1.09	**BDL**	1.51	**BDL**	1.97	**BDL**	1.19	1.14	1.14	**BDL**	**BDL**	**BDL**
George																					
G1+ G2	61.71	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	3.88	**BDL**	**BDL**	6.79	17.45	18.42	**BDL**	7.11	8.08	0.00	**BDL**	**BDL**	**BDL**
G3+ G4	108.25	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	7.48	5.28	**BDL**	5.94	23.54	23.54	**BDL**	14.52	19.58	8.14	**BDL**	**BDL**	**BDL**
Hackert																					
HA1+HA2	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**
HA3+HA4	12.15	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	0.92	1.32	**BDL**	**BDL**	4.36	3.17	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	2.38	**BDL**
Otter																					
O1+ O2	43.92	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	3.12	4.01	**BDL**	8.46	5.64	6.97	**BDL**	5.04	5.79	4.90	**BDL**	**BDL**	**BDL**
O3+ O4	25.59	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	0.43	**BDL**	1.54	1.37	**BDL**	6.33	3.77	4.54	**BDL**	3.34	4.28	**BDL**	**BDL**	**BDL**	**BDL**
Round D																					
R1+R2	29.17	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	1.33	**BDL**	1.70	19.32	2.65	4.17	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**
R3+R4	15.04	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	1.04	0.95	0.76	8.33	0.57	1.80	**BDL**	0.66	0.95	**BDL**	**BDL**	**BDL**	**BDL**

BDL indicates concentration below detection limit

Table 3c. PAH concentrations (ng/g dry wt) from 2004-2005 lakes. C1+C2 is the combined sample mass of the first and second 1 cm slices for Crystal M04 Lake, C3+C4 is the combined sampled for the third and fourth 1 cm slices. This naming and sample combination convention was used for all lakes.

Sample	Total PAH	Acena-phthylene	Acena-phthene	Fluo-rene	Phenan-threne	Anthra-cene	Fluor-anthene	Pyrene	Benzo-A-anthracene	Chrysene	Benzo-B-fluoranthene	Benzo-K-fluoranthene	Indeno-1,2,3,-CD-pyrene	Dibenz-a,h-anthracene	Benzo-G,H,I-perylene
Crystal M04															
C1+ C2	1707	12.59	4.97	19.66	142.74	17.09	265.27	247.55	90.75	225.72	209.63	209.63	287.96	**BDL**	**BDL**
C3+ C4	1190	8.67	3.17	12.31	83.72	9.71	163.07	147.65	51.73	148.69	136.22	136.22	155.44	**BDL**	182.55
George															
G1+ G2	1331	11.63	**BDL**	11.63	102.75	21.32	242.65	195.15	58.16	128.92	176.09	176.09	102.10	9.69	132.15
G3+ G4	1358	9.02	**BDL**	16.72	84.05	13.42	224.20	188.34	73.05	131.57	201.10	201.10	115.07	13.20	146.09
Hackert															
H1+H2	6038	36.76	28.85	65.61	505.53	70.36	921.34	**BDL**	218.58	493.68	1027.67	1027.67	726.88	77.08	632.81
H3+H4	3001	18.35	14.52	34.85	221.25	31.82	441.98	**BDL**	143.89	212.41	509.31	509.31	448.84	33.80	328.84
Otter															
O1+ O2	3323	39.17	21.22	37.69	290.65	46.74	491.84	425.07	179.08	279.23	425.37	425.37	426.56	44.96	384.87
O3+ O4	2427	50.66	18.66	42.96	242.02	49.47	359.35	308.77	141.89	194.95	299.10	299.10	275.31	36.46	256.05
Round D															
R1+R2	1887	9.09	7.01	24.24	127.46	16.48	256.63	207.39	57.77	191.48	269.32	269.32	268.56	19.70	230.11
R3+R4	1085	6.34	3.69	17.60	82.21	11.07	152.70	114.95	32.45	125.54	135.29	135.29	120.44	18.26	155.06

BDL incdicates concentration below detection limit

Inorganic chemical sediment chronologies

There are multiple ways to examine and interpret sediment chronologies, and the most appropriate approach is dependant on objectives of the study. In this report, total concentration profiles will be presented, followed by surface concentrations, and focusing corrected anthropogenic accumulation rates. The concentration profile for each of the elements analyzed were compared within each lake, and grouped by similar profiles to determine the major influences on that element (Yohn *et al.*, 2002a). Surface concentrations of arsenic, cadmium, copper, lead and zinc were compared among lakes and to sediment quality guidelines (MacDonald *et al.*, 2000) to determine potential toxicity. Finally, focusing corrected anthropogenic accumulation rates were calculated and compared among all lakes. These rates provide the best possible estimate of the rate of input of a metal to the lake sediments due to humans.

Total concentration and focusing-corrected accumulation rate profiles

Many different sources and processes influence the patterns of metal deposition in a sediment core, making it a challenge to interpret the historical records. The multi-element approach, which includes the analysis of more elements than just those of anthropogenic concern, helps provide insight into the history of the lake and assists in the interpretation of anthropogenic inputs. The first step to understanding multi-element data is grouping the elements that are influenced by similar sources and processes. Elements that have similar profiles in the sediment were grouped for each lake using cluster analysis (Table 4) (Yohn *et al.*, 2002b). Principle components analysis (PCA) can also reduce or classify data. When cluster analysis was not interpretable, PCA was used. Elements classified using PCA are identified in Table 4. In general, cluster analysis and PCA provide similar interpretations of the data. Four classes of elements were usually identified: terrestrial, calcium carbonate, diagenetic, and anthropogenic.

The first class includes the terrestrial elements, which are those that are influenced by the amount of allochthonous (material from outside the lake) non-organic material entering the lake. Changes in the input of terrestrial materials may be caused by increased erosion due to natural (e.g., forest fires) or human (e.g., land use changes) processes (Davis, 1976). Elements that may be primarily influenced by these processes include aluminum, titanium and sometimes iron, potassium, cobalt, nickel, magnesium, sodium, scandium, and the rare earth elements (Boyle *et al.*, 1999, Bruland *et al.*, 1974, Johnson and Nicholls, 1988, Kemp and Thomas, 1976, Kerfoot and Robbins, 1999, Qu *et al.*, 2001, Sanei *et al.*, 2001).

Table 4. Classification of elements into terrestrial (T1, T2), carbonate (C), diagenetic (D, D1,D2), and anthropogenic (A, A1, A2). Use of A2 indicates there was more than one group of anthropogenic elements in the lake, likewise for other element groups. Unclassified elements did not fit clearly into a group, and elements classified twice appeared to be influenced by both classes. A (–) indicates that data were not collected for this element. OR indicates that outliers were removed. Lakes sampled for this report are highlighted.

	Mg	Al	K	Ca	Ti	V	Cr	Mn	Fe	Cu	Zn	As	Sr	Mo	Cd	Ba	Pb	U
Avalon	T1	A,T2	A,T2	A,T2	T1	D	D	A,T2	T1	A,T2	A,T2	D		D	A,T2	A,T2	A,T2	D
Birch	--	T2	T1	T2	T1	T1	D2,T2	D1	--	A	A	D1	--	D1	A	D1	A	D2,T2
Cadillac		T		C	T	T		D	D	A	A	D	C		A	C	A	T
Crystal B		T	T	C		T	T		T	A	A		C		A	C	A	
Crystal M 2000		T	T	C		T	T	D1			A	D1	C	D2	A		A	D2
Crystal M 2004	T	T	T	C	T	T	T	D1	T,D2	A	A	D2	C	D3	A	D2	A	D3
Elk	T	T	T	C	T	T		D	D	A	A	D	--	D	A	D	A	T
Elk OR	T	T	T	C	T	T			T	A	A	A	--		A	T	A	T
George (OR)	C	T		C	C	T	T	C	A	C	A	A2	C	A2	T	T	A	A
Gratiot	T	T	D	T	T	T	T	D	A	A	A	A	T		A	D	A	T
Gull	C	T	T	C	T	T	T	D1	D1	A	A	A,D2	--	D2		C	A	D2
Hackert	C1	T1	T2	C2	T2	T1	T1	C1	T1	T1	A	A	C2	T2	A		A	T2
Higgins	T	T	T	C				D2		A	A	D1	C	D1	A	D2	A	D1
Houghton		T	T	C	T	T	T		D1	A	A	D1	C	D2	A	T	A	D2
Hubbard	T	T		C	T	T	T			T			C		A		A	
Imp		T					T		A	A	A	A	T		A		A	
Littlefield	C, T	T	T	C	T			D2	D1	T		D1	C	D1	A	D2	A	D1
Mullett	T	T	--	C	T	T	T	D	D	A	A	D	C		A	D	A	
Muskegon	T	T	T	C	T	T	A	C	T	A	A	T	C	A	A	C	A	T
Otter	T	T	T	C		T	T			C	A				A		A	A
Paw Paw		T	--	C	T	T	A			A	A	D2	C	D2	A		A	
Round		T		C	T	T	T		T		A		C	D	A		A	D
Round D	T1	T2	T1	C		T2	T2	D	D	A	A	C			A	A	A	T2
Sand	C	T		C		T	T		A	A	A			D	A	T	A	
Shupac	C	T2	T1	C	T1	T1	T2	D	T2	T1	A	T2		D	A	D	A	D
Torch	T	T	T	C		T	T		T	A	A		C		A		A	
Whitmore		T	--	C	T	T	T			A2	A1		C	D	A1	T	A1	D
Witch	T	T			T		T	D			A					D	A	

The second class includes calcium and strontium, which may be influenced by deposition of calcium carbonate. Soils, glacial material, and bedrock in most of the Great Lakes region contain abundant limestone ($CaCO_3$). Thus, lakes become enriched in dissolved Ca and HCO_3 that can precipitate in the lake as a consequence of evaporation or photosynthesis (photosynthesis consumes CO_2, which raises the pH of the water). This portion of the sediment tends to have low concentrations of most metals and therefore acts as a diluting phase (Auer *et al.*, 1996). The presence of carbonates may increase the concentration of calcium and strontium, and sometimes magnesium and barium (Auer *et al.*, 1996, Sanei *et al.*, 2001).

A third class includes those elements influenced by diagenesis. Early diagenesis is the alteration of sediment chemistry after deposition, and will obscure the depositional record. In the top few centimeters of sediment, there are major geochemical changes that occur. Organic matter is decomposed, which uses the oxygen in the sediment, and changes the sediment from an oxidizing to a reducing environment. This will change the mobility of many metals, and metals may mobilize from the sediment into the porewater (remobilization). For example, those metals that are associated with organic matter in the sediment can be released to the porewater as decomposition progresses. Those metals associated with iron and manganese oxyhydroxides would be released to the porewater when these oxyhydroxides dissolve because of the reducing conditions. Once in the porewater, metals may move from areas of high concentration to lower concentrations through diffusive flux and/or be readsorbed to other sediments phases (Brown *et al.*, 2000, Cooper and Morse, 1998, Douglas and Adeney, 2000, Harrington *et al.*, 1998, McKee *et al.*, 1989, Urban *et al.*, 1990). In particular, arsenic is strongly adsorbed to iron oxyhydroxides, and profiles in the sediment may not reflect the historical record of arsenic deposition. For arsenic, which is influenced by both diagenesis and anthropogenic inputs, it is essential to be able to differentiate patterns caused by diagenesis from those caused by changes in anthropogenic inputs (Harrington *et al.*, 1998). Another complication is that elements respond to changing redox conditions in different manners. While iron oxyhydroxides mobilize in reducing conditions, uranium and molybdenum remobilize in oxidizing environments (Brown *et al.*, 2000). Therefore, it may be possible to have more than one group of diagenetic elements.

The final class is the anthropogenic elements. These elements have accumulated in lake sediments due to human actions, and may enter lakes from atmospheric deposition, or from inputs within the watershed. Humans may influence the geochemical cycle of any element, but the arsenic, cadmium, copper, chromium, mercury, lead, and zinc cycles have been modified on the global scale (Bruland *et al.*, 1974, Evans and Dillon, 1982, Iskander and Keeney, 1974, Spiethoff and Hemond, 1996). Since the sources of each metal may be different (e.g., copper from copper smelting emissions, or lead from leaded gasoline), anthropogenic elements may follow similar trends or the trends may vary among elements, depending on the dominant sources and processes. Therefore, while elements in the terrestrial class should have very similar profiles, profiles of anthropogenic elements may vary. The profiles of the anthropogenically-influenced elements listed above were examined closely and compared to profiles of terrestrial elements to determine for each lake if deposition of that element was influenced by human activities. Although terrestrial elements are also influenced by human activities, we will consider the anthropogenic elements as those elements with sources due to humans in addition to increased erosion.

The interpretation of sediment chronologies can be improved by comparing accumulation rates and total concentration, where the accumulation rate is the product of total metal concentration and the sedimentation rate. Sedimentation rates are derived from the ^{210}Pb dating model and may vary depending upon human and natural processes within the watershed. Total metal concentrations are critical and provide knowledge of potential exposure for benthic organisms. However, due to variations in sedimentation rate, total metal concentration may not reflect the true nature of metal loading to a lake. For example, a steady-state concentration profile may be interpreted differently when analyzing the accumulation rate profile if sedimentation rates were variable. Therefore, this analysis will include both total metal concentrations and focusing-corrected accumulation rates (FCAR). When sedimentation rates do not vary with time, concentration and FCAR profiles will be identical, but are still presented here for consistency

Crystal (Montcalm County) 2004 Lake

Terrestrial elements in Crystal M04 Lake included magnesium, aluminum, potassium, titanium, vanadium, chromium, and iron (Table 4). Concentrations of these elements were greatest in the oldest sections of the core then declined until the 1900s (Figure 10). After 1900, terrestrial metal concentrations increased until 1950. After 1950 terrestrial metal concentrations appeared to have reached steady state except for perturbations occurring after 1980. The FCAR profile is similar to the concentration profile before 1900. After 1900 the FCAR increased to local maxima (ca 1935), decreased until 1960, and then appeared to be in steady state. The steady state accumulation rate in the last 40 years suggests that pseudo-equilibrium was established between the lake and the watershed for terrestrial element loading to Crystal M04 Lake.

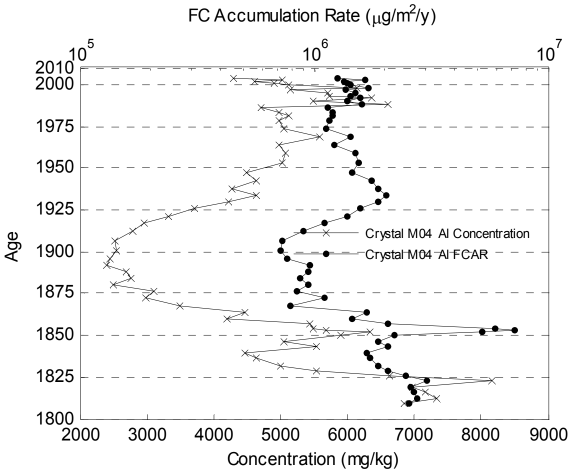


Figure 10. Crystal M04 Lake total concentration and FCAR profiles for aluminum. Note the log scale on the upper abscissa.

Cluster analysis for Crystal M04 Lake showed three groups of diagenetic elements 1) iron and arsenic, 2) manganese, and 3) uranium and molybdenum. Care should be taken when interpreting FCAR profiles for diagenetically influenced elements and are only presented here for consistency. Only concentration profiles for these elements will be discussed. Arsenic (Figure 11) and iron have similar profiles and these element profiles are known to be redox sensitive (e.g., iron) or influenced by diagenetic processes (e.g., arsenic). Manganese profiles in lake sediments are also known to be redox sensitive but the reasons for manganese not clustering with iron and arsenic are unclear because their concentration profiles are quite similar (Figure 12). Notable differences between the manganese and arsenic profiles are that two arsenic concentration maxima occur between 1900 and 1980 while manganese concentrations only reach a local maximum once during that period.

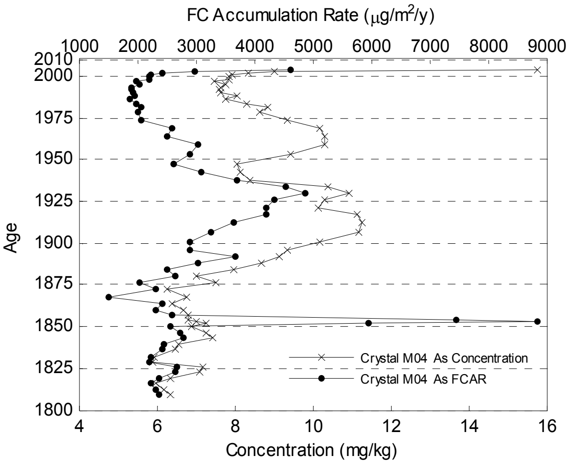


Figure 11. Crystal M04 Lake total concentration and FCAR profiles for arsenic.

However, the reason for the clustering of iron and arsenic, and not manganese, may be indicative of the correlation between iron and arsenic in lake sediment. The sharp increase in arsenic concentration at the top-most portion of the core is indicative of diagenetic reworking of the arsenic profile. Arsenic species in sediment are strongly adsorbed to mineral and amorphous iron oxides in the sediment. When oxygen becomes depleted, mineral and amorphous forms of iron in the sediment can dissolve. This also results in a release of iron-associated arsenic from the sediment to the porewater. If porewater concentrations gradients are appropriate (i.e., porewater iron and arsenic concentrations are high in the lower portions of the core and low in the top portions), dissolved iron and arsenic species can diffuse through the sediment from lower portions of the core towards the top sections. When dissolved iron and arsenic encounter oxygen enriched sediment layers in the top portion of the core they will precipitate. Manganese oxides also undergo diagenetic reworking but arsenic is not as strongly sorbed to these species.

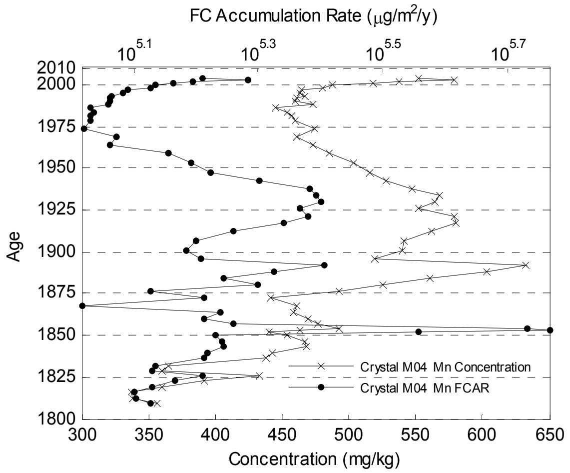


Figure 12. Crystal M04 Lake total concentration and FCAR profiles for manganese, note the log-scale on the upper abscissa.

Unlike sediment iron and manganese species, which are more soluble under reducing (i.e., oxygen poor) conditions, sediment molybdenum and uranium species are more soluble under more oxygen rich conditions. The molybdenum profile showed a great concentration peak in the late 1800s (Figure 13). It is unlikely that the source of molybdenum during that period would have been anthropogenic, but may be a result of diagenetic remobilization of molybdenum from the top sections of the core.

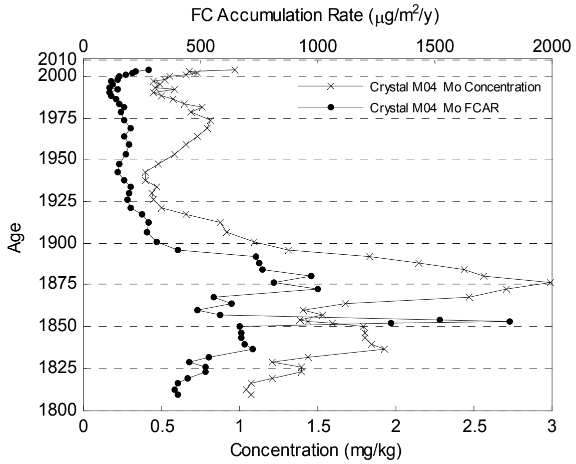


Figure 13. Crystal M04 Lake total concentration and FCAR profiles for molybdenum.

Calcium and strontium were classified as carbonate elements. The calcium profile is shown as a representative element for this group (Figure 14). Calcium concentrations were least in the bottom sections of the core, peaked in the early 1900s then declined to the present. However, the FCAR differs from total concentration profile. In general, calcium FCAR steadily increased after 1800 followed by decreasing FCAR until the late 1950s. An apparent pseudo-equilibrium was established with the watershed, characterized by steady-state FCAR between 1960 and 1990. After about 1990, FCAR had once again increased followed by a most recent decrease.

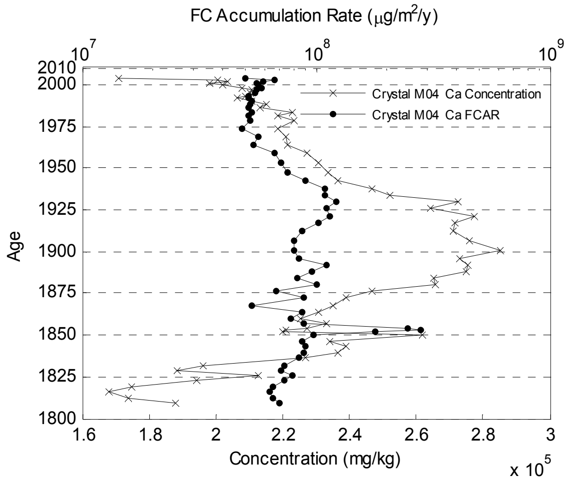


Figure 14. Crystal M04 Lake total concentration and FCAR profiles for calcium. Note the log scale on the upper abscissa.

Anthropogenic elements in Crystal M04 Lake included cadmium, copper, lead and zinc (Figure 15). None of the anthropogenic elements show a return to background, pre-European, concentration or accumulation rate. Lead and cadmium concentration were least in the bottom sections of the core and remained relatively constant until the 1900s. On the other hand, copper and zinc concentrations were greater in the bottom sections of the core and then declined to the 1900s. After 1900, concentration profiles of all anthropogenic elements showed a great increase until the mid-1950s. After 1950, lead and cadmium profiles were similar whereas zinc and copper profiles were unique. Lead and cadmium concentrations peaked in the late 1960s or mid-1970s and had declined more recently. Copper concentrations had increased toward the present, whereas zinc concentrations reached a local maximum in the 1960s and had declined more recently. With the exception of lead, anthropogenic element FCAR profiles differed from concentration profiles (Figure 15). Focusing-corrected accumulation rates for copper were similar to the concentration profile but revealed a change in the trajectory of loading. Between 1925 and 1975 FCAR increased slightly; however, after 1975 loadings increased greatly to the present. Changes in FCAR trajectory suggest either a new source of copper to the lake or an increased consumption of copper by previous sources. Although the zinc concentration profile suggests that zinc loading had decreased since the 1960s, FCAR indicates that loading rates had increased since the 1970s to the present. The cadmium FCAR profile showed that peak loading occurred in the early 1930s and declined until 1975. Since 1975, an apparent steady state loading of cadmium had occurred.

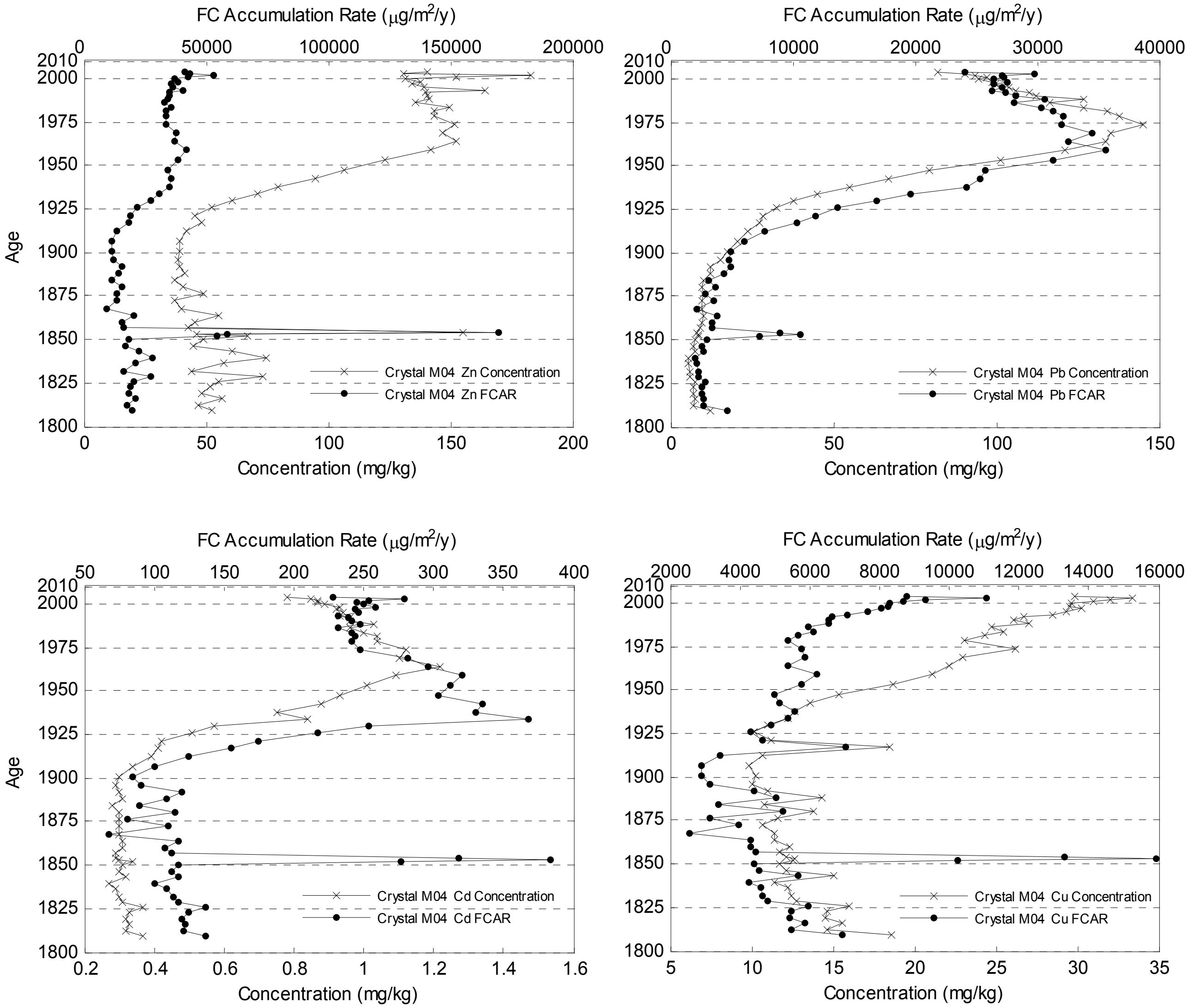


Figure 15. Crystal M04 Lake total concentration and FCAR profiles for zinc, lead, cadmium, and copper.

George Lake

Classification of elements in the sediment core from George Lake was difficult. Several iterations of cluster analysis and PCA were used in an attempt to classify elements. However, no single procedure provided results that were consistent with previous years. For example, cadmium and copper were not identified as anthropogenic elements and titanium was grouped with typically carbonate elements.

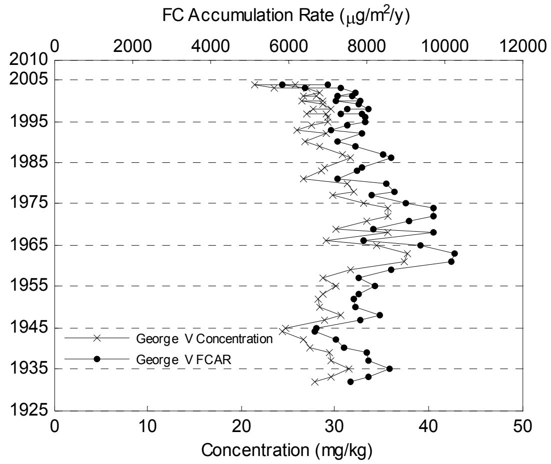


Figure 16. George Lake total concentration and FCAR profiles for vanadium.

Elements characterized as terrestrial in George Lake were aluminum, cadmium, vanadium and chromium. Sedimentation rates in George Lake did not vary over the length of the sediment core and therefore FCAR and concentration profile interpretations were identical. Terrestrial element concentration profiles showed great variability over time. Vanadium concentration and FCAR profiles are shown to represent the terrestrial elements (Figure 16). Generally, concentrations increased from the 1930s until the early 1960s and then declined to present day. Temporal variability in the terrestrial element concentration and FCAR profiles suggests that contribution of watershed bound material has had significant impact on George Lake and that the rate of contribution has varied. This may have implications if watershed soils contain great amounts of anthropogenic metals.

Magnesium, calcium, titanium, manganese, copper and strontium were classified as carbonate elements in George Lake. Typically, titanium, manganese and copper are not identified as carbonate elements in sediment cores from Michigan lakes (Table 4). Although these non-traditional carbonate elements are classified as such in George Lake sediments, similarities among the calcium profile (Figure 17) and these other elements do exist. The profiles for titanium are shown to represent the non-traditional elements (Figure 18). In general, carbonate group element concentrations were least in the bottom sections of the core and increased until the early 1960s. After the early 1960s, concentrations sharply decreased and then continued to increase until present day. During several periods, concentrations had increased episodically, such as increases in the early and late 1990s.

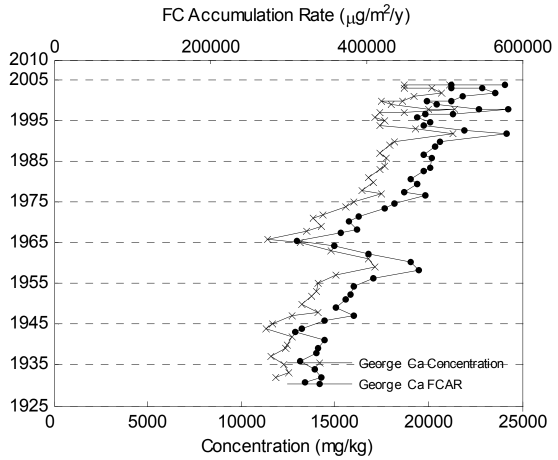


Figure 17. George Lake total concentration and FCAR profiles for calcium.

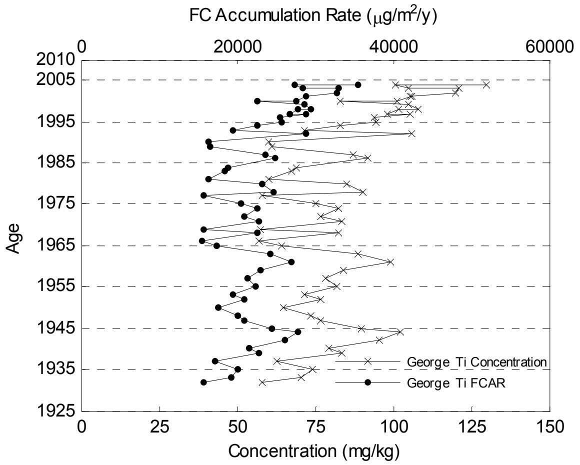


Figure 18. George Lake total concentration and FCAR profiles for titanium.

Cluster analysis of the elements in the sediments of George Lake did not reveal a clearly diagenetic group of elements. This is not unusual. Elk Lake (OR), Crystal B Lake, Torch Lake, and Imp Lake also did not show a diagenetic group of elements. Elk, Crystal B and Torch lakes would be defined as oligotrophic and the absence of the influence of diagenesis in these lakes may be expected. However, it is unusual that an organic-sediment-rich lake such as George Lake does not contain a group of diagenetic elements.

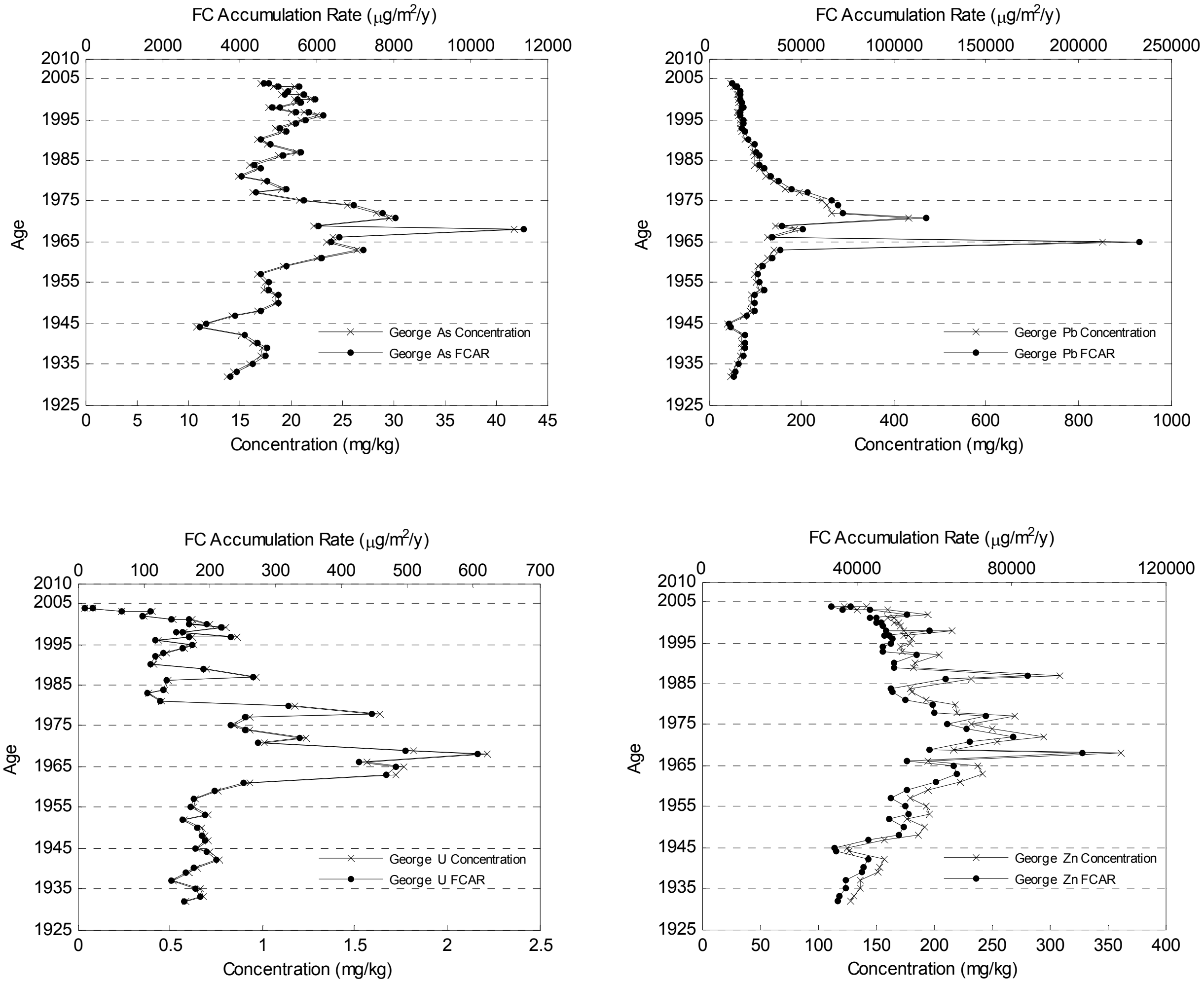


Figure 19. George Lake total concentration and FCAR profiles for arsenic, lead, uranium and zinc.

Elements classified as anthropogenic in George Lake included iron, zinc, arsenic, molybdenum, lead and uranium. The grouping of these elements is unusual and profiles for arsenic, lead, uranium and zinc are shown (Figure 19). In general, concentrations of these elements are least in the bottom sections of the core and reached local maxima between 1960 and 1975, followed by a decline in concentration to present day for zinc, iron, uranium and lead. On the other hand, arsenic and molybdenum concentrations increased after 1975, a deviation from the general trend. Loading of anthropogenic elements appeared to be episodic and may be due to delivery of terrestrial material from the watershed. This is supported by the episodic profile of the terrestrial elements (Figure 16).

Hackert Lake

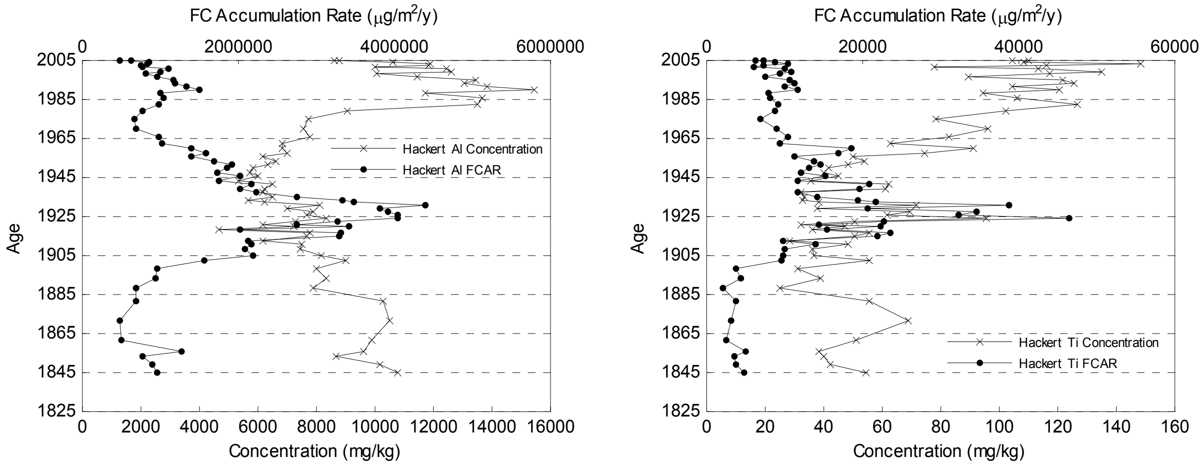


Figure 20. Hackert Lake total concentration and FCAR profiles for aluminum (primary terrestrial) and titatnium (secondary terrestrial).

Two groups of terrestrial elements were identified in Hackert Lake. The primary group contains aluminum, vanadium, chromium, iron, and copper. The secondary group contains potassium, titanium, molybdenum, and uranium. The profiles for primary (aluminum) and secondary (titanium) terrestrial elements are shown (Figure 20). Concentrations of primary terrestrial metals steadily decreased starting in the mid-1840s until the mid-1940s then increased until the late 1980s. After the late 1980s, concentrations again decreased until the present. Primary terrestrial element FCAR are least near the bottom sections of the core and increased until the late 1920s followed by decreased loadings until the early 1970s. After 1970, FCAR increased slightly until 1990 followed by a more recent decrease in loadings. Primary terrestrial FCAR appeared to be nearing background values in recent times. Secondary concentration and FCAR profiles were similar to primary terrestrial elements; however, recent concentrations are increasing to present day and FCAR had reached steady-state loading in the last 25 years. The presence of two terrestrial groups suggests that different watershed materials are being loaded to the lake sediments. This is supported by the distinct trends of the two groups

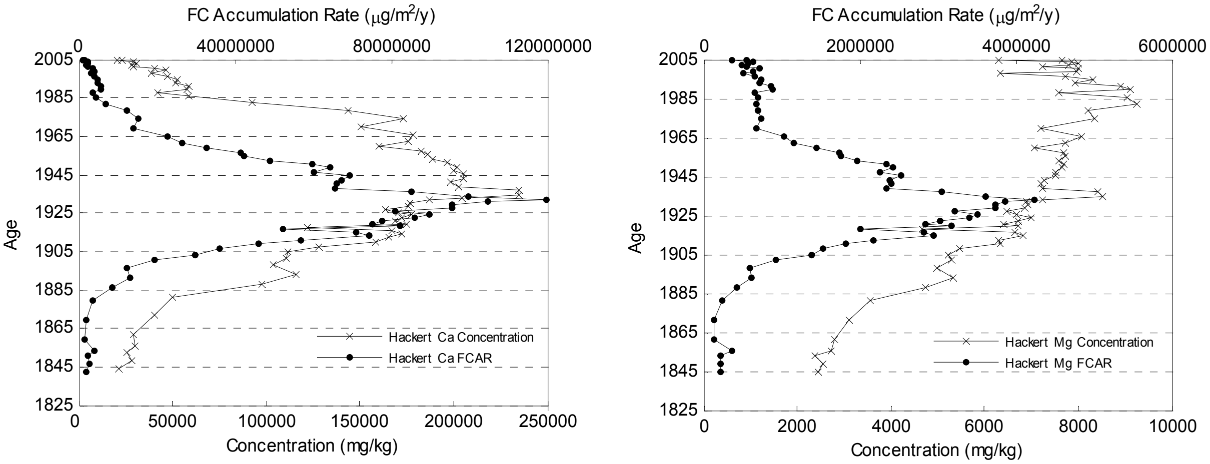


Figure 21. Hackert Lake total concentration and FCAR profiles for calcium (primary carbonate) and magnesium (secondary carbonate).

Similar to the terrestrial elements, two carbonate element groups were identified. The primary carbonate group included calcium and strontium while the secondary group included magnesium and manganese. Calcium and magnesium profiles are shown as representative elements for the two primary and secondary carbonate groups respectively (Figure 21). Primary carbonate element concentrations were least in the bottom sections of the core followed by increased concentrations until the 1930s. After the 1930s concentrations decreased until present day. The primary carbonate FCAR profile was similar to the concentration profile. FCAR values in the top sections of the core were similar to pre-industrial period values in the bottom sections of the core. Secondary carbonate metal concentrations were least in the bottom sections and increased until the late-1980s, since then concentrations have decreased. Secondary carbonate group FCAR increased from lesser values in the bottom sections of the core to maximum values during the 1930s, followed by a sharp loading decrease until the 1970s. Since 1970, loadings of secondary carbonate elements were still decreasing but at a slower rate, illustrated by the change in profile trajectory. The distinct differences between the groups suggests that two sources of carbonate material may exist, such as primary productivity and weathering of terrestrial carbonate sources (i.e., glacial drift).

Metals classified as anthropogenic elements include arsenic, cadmium, lead, and zinc. Concentrations of these elements were least in the bottom sections of the core and increased to maximum concentration during the 1980s (Figure 22). However, the pattern of concentration increase was slightly different for each element. It is not clear if the concentration of anthropogenic elements had reached background values, determined graphically, at the bottom of the core. Profiles of anthropogenic element FCAR for Hackert Lake were least around the 1860s and then increased significantly until the 1930s, FCAR then declined until the 1970s. The increased concentration during the 1980s was also shown in the FCAR profile. Since the 1980s, both concentration and FCAR had declined to present day.

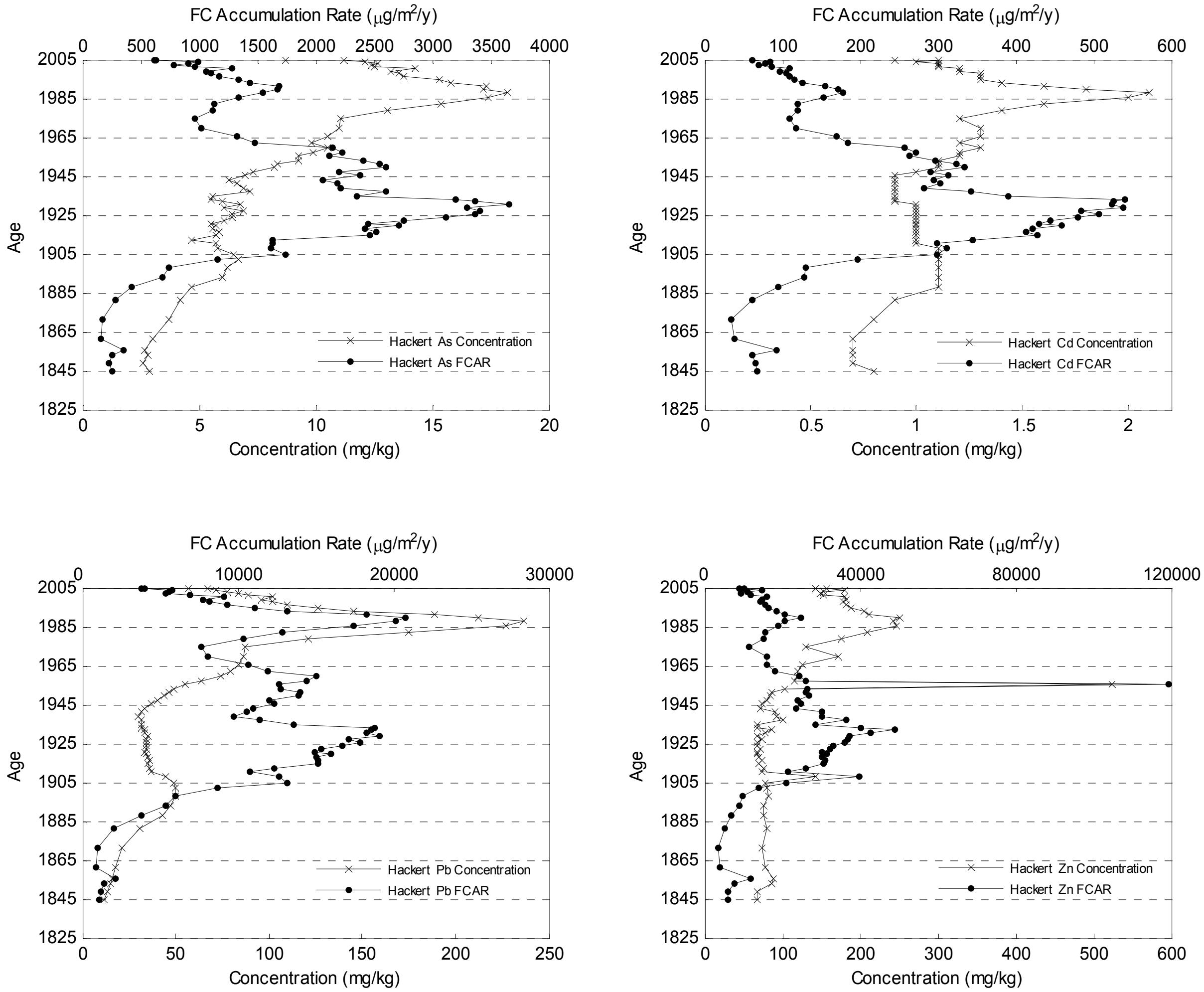


Figure 22. Hackert Lake total concentration and FCAR profiles for arsenic, cadmium, lead, and zinc.

Otter Lake

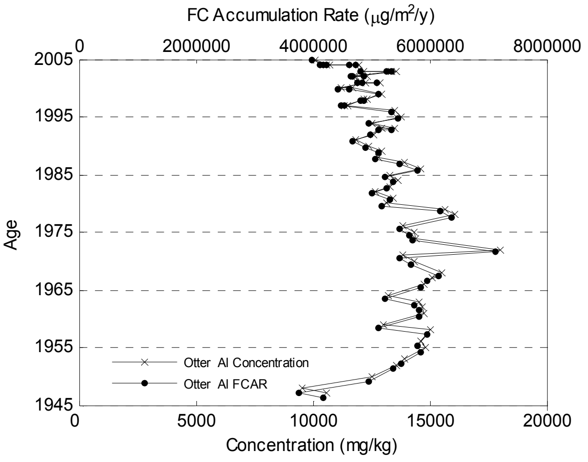


Figure 23. Otter Lake total concentration and FCAR profiles for aluminum.

Similar to George Lake, sedimentation rates in Otter Lake did not appear to vary considerably over time. Therefore, the interpretation of concentration and FCAR profiles are identical. Only concentration profiles will be discussed.

Terrestrial elements in Otter Lake included magnesium, aluminum, potassium, vanadium and chromium. Aluminum concentration and FCAR profiles are shown (Figure 23). Concentrations of terrestrial elements were least in the bottom sections of the core quickly increased until about the late 1950s and then declined slowly. Variability in terrestrial element concentration over time suggests that watershed disturbance has been episodic, but variability in the terrestrial element profile is not unusual. The presence of chromium in the terrestrial element group suggests a watershed source to the lake.

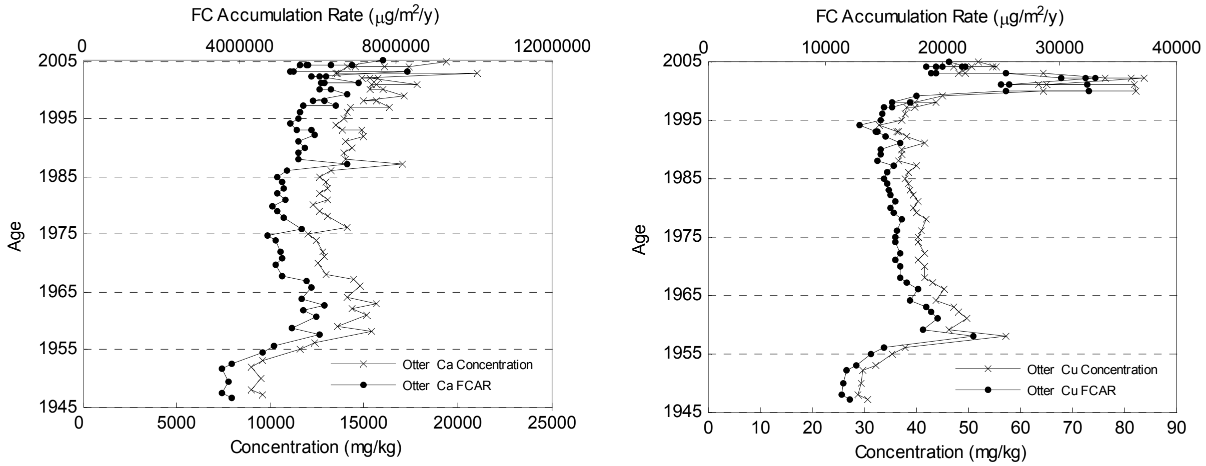


Figure 24. Otter Lake total concentration and FCAR profiles for calcium and copper.

Calcium and copper were classified as carbonate group elements (Figure 24). Copper is generally classified as an anthropogenic element and the inclusion in the carbonate group elements is unusual. However, copper had been associated with element groupings other than anthropogenic in previous study lakes (Table 4). Initially the profiles for these two elements did not seem correlated; however, several general observations could be made. In general, concentration profiles had increased since the late 1940s until the 1960s and then declined until the 1980s or 1990s. After 1995, concentrations had increased and become highly variable.

Otter Lake anthropogenic elements included cadmium, lead, uranium, and zinc (Figure 25). In general, concentrations had increased after 1945 to maximums during the late 1950s to 1960s. Since this time concentrations had decreased until present day. As discussed above copper was included in the carbonate group elements rather than the anthropogenic class. However, the copper profiles are similar to the anthropogenic profiles except for the perturbation during the late 1990s. This suggests a source unique for copper to Otter Lake. The inclusion of copper with the carbonate group may indicate that the source of copper was calcium-rich watershed material. Of the anthropogenic class elements, only uranium showed a similar perturbation after 1995. Uranium has been suggested as an indicator element for terrestrial material to Michigan lakes (Benedict, 2006). This evidence supports a watershed source of copper to Otter Lake during the late 1990s.

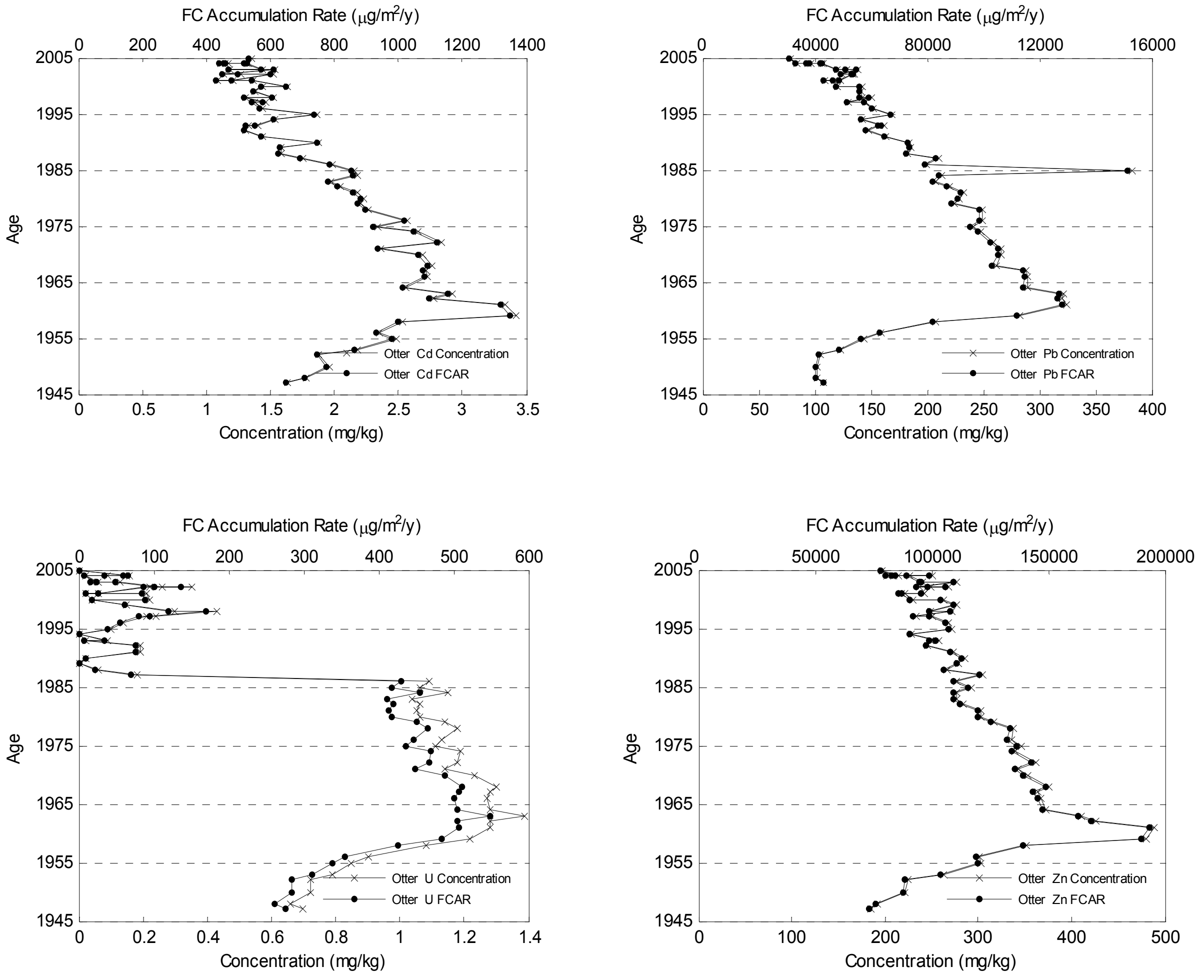


Figure 25. Otter Lake total concentration and FCAR profiles for cadmium, lead, uranium and zinc.

Round (Delta County) Lake

Two classes of terrestrial elements were identified in Round D Lake. The first terrestrial group included magnesium and potassium while the second group contained aluminum, vanadium, chromium, and uranium. Magnesium and aluminum profiles are shown as representative primary and secondary terrestrial elements, respectively (Figure 26).

Profiles of primary and secondary terrestrial elements differ slightly in sediments of Round D Lake. Primary terrestrial element concentration profiles increased gradually from the bottom sections of the core and reached local maxima around 1930 and had since decreased to present day. Secondary terrestrial elements increased more sharply in the bottom-half of the core, when compared to primary terrestrial metals. However, secondary-terrestrial local maxima appeared to coincide with those of the primary-terrestrial elements. After 1930, secondary-terrestrial concentrations gradually decreased to present day. Unlike the concentration profiles, FCAR profiles of primary and secondary terrestrial metals are remarkably similar. This suggests that both groups of terrestrial elements represent the watershed as the source of these metals.

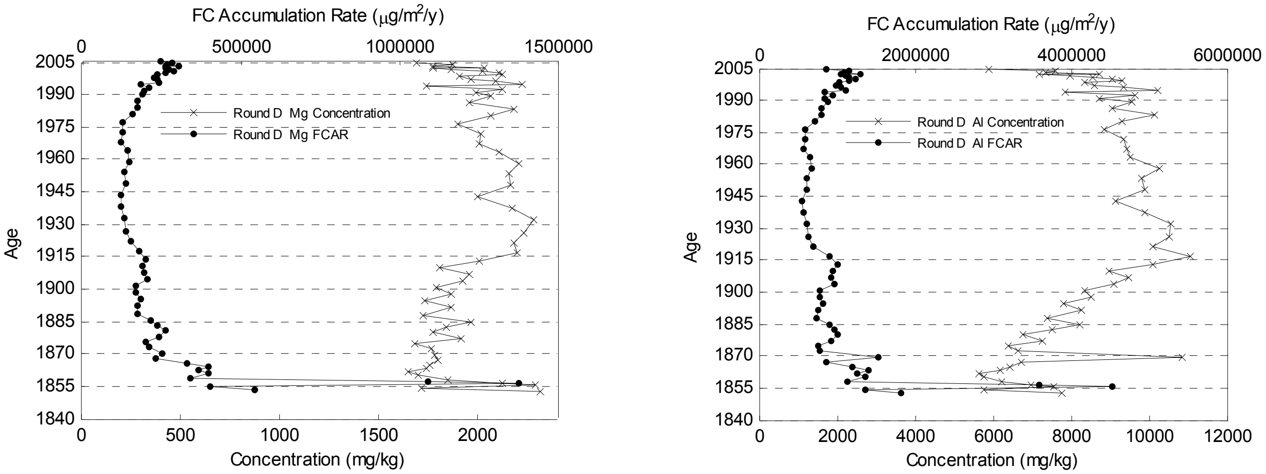


Figure 26. Round D Lake total concentration and FCAR profiles for magnesium (primary terrestrial) and aluminum (secondary terrestrial).

Carbonate group elements in Round D Lake included calcium and arsenic. Arsenic is generally not classified as a carbonate group element. Upon inspection of the arsenic concentration profile it was unclear why this element was classified as such because the two profiles are unique (Figure 27). Hierarchical clustering only grouped calcium and arsenic and they were linked at a relatively great distance. A great distance separating the two elements would suggest that the concentration profiles were only slightly similar. However, the increase in concentration during the past 25 years most likely led to arsenic clustering with calcium. Early diagenesis of arsenic in lacustrine sediments usually results in a profile similar to what was observed in Round D Lake during the last 25 years. Therefore, arsenic will not be considered as a carbonate group element.

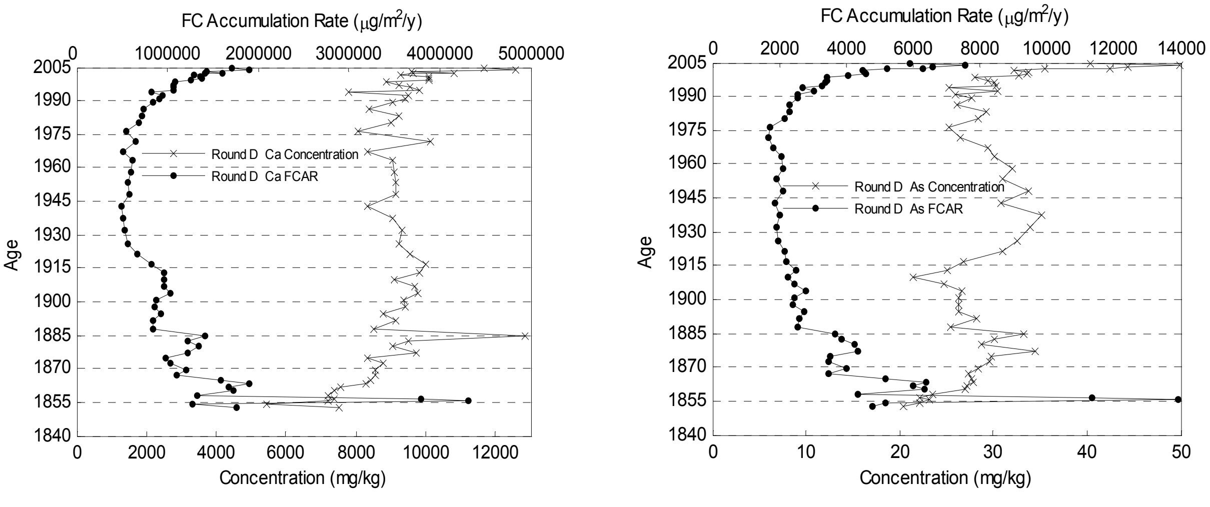


Figure 27. Round D Lake total concentration and FCAR profiles for calcium and arsenic.

Calcium concentrations did not vary considerably in the sediments of Round D Lake. Concentrations were least in the bottom sections of the core, increased until the late 1800s and then remained relatively constant until 1975. After 1975, calcium concentrations have increased until present day.

Focusing-corrected accumulation rates were greatest in the bottom sections of the core and gradually declined until the 1930s. Since 1930, calcium FCAR had increased until present day.

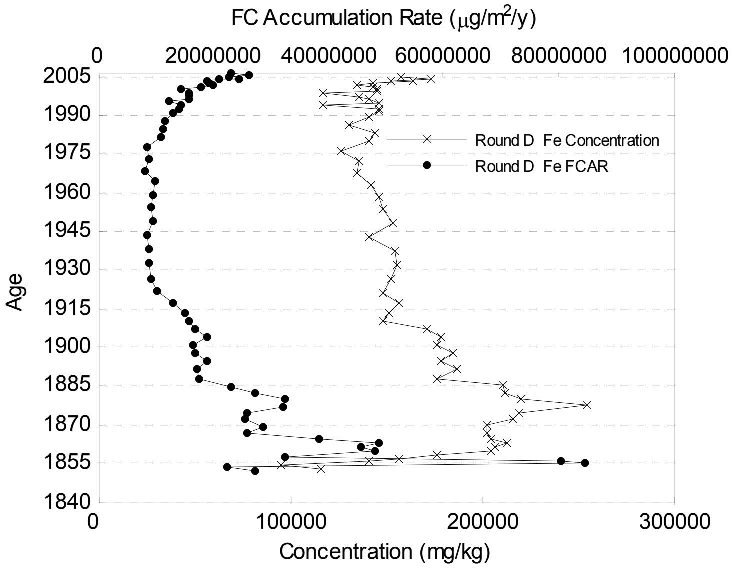


Figure 28. **Round D Lake total concentration and FCAR profiles for iron.**

Diagenetic group elements in Round D Lake included iron and manganese, the iron profile is shown (Figure 28). Starting in the 1850s, diagenetic element concentrations increased until the late 1870s followed by a gradual decline until the late 1970s, since then concentrations increased until present day. Conversely, FCAR were greatest in the bottom sections of the core and sharply decreased until the early 1910s. This was followed by a gradual increase until the mid-1970s after which FCAR sharply increased. In the top sections of the core, concentration profiles for the diagenetic elements possess the diagnostic shape of diagenetic influence.

Two groups of anthropogenic elements were classified in Round D Lake sediments. The primary group included cadmium, lead, and zinc whereas the secondary group contained barium and copper. Hierarchical clustering grouped barium and copper with the cadmium, lead and zinc, but at a greater join distance. A greater join distance may suggest two dissimilar anthropogenic pathways of copper and barium to Round D Lake. In general, sediment concentrations of the primary anthropogenic elements were least in the bottom sections of the core and then sharply increased after the 1900s (Figure 29). After maximum concentrations were reached in the 1930s, concentrations had declined until present day. Secondary anthropogenic elements followed a similar trend but did not reach peak concentrations until the early 1990s. In contrast to the primary anthropogenic elements, secondary anthropogenic element concentrations had not declined since the late 1970s. Focusing-corrected accumulation rate profiles were similar for cadmium, copper and zinc. However, the lead FCAR profile was unique. Cadmium, copper and zinc FCAR profiles declined from the 1850s until the late 1880s, followed by a gradual increase until the 1970s, and then sharply increased until the early 2000s. Lead was near constant background FCAR values in the bottom sections of the core until about 1885. Lead FCAR then gradually increased until the 1900s when a sharp increase in lead loadings occurred until the 1920s. Lead FCAR then remained at steady-state for about 40 years. Following a short decline in lead FCAR during the 1960s and 1970s, lead FCAR again increased until the early 2000s. Recent sediments show that all anthropogenic element FCAR had declined.

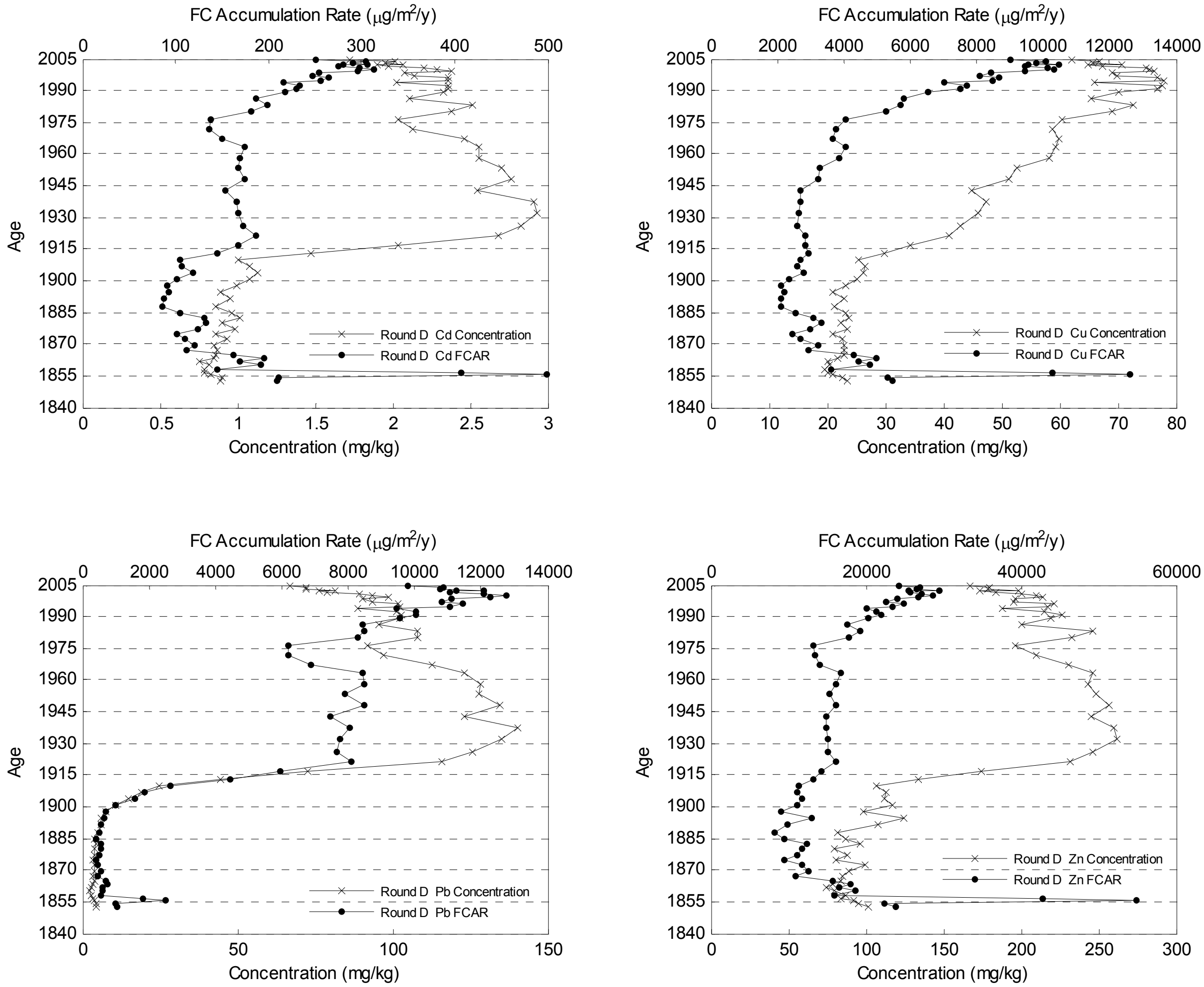


Figure 29. Round D Lake total concentration and FCAR profiles for cadmium, lead, zinc (primary anthropogenic elements) and copper (secondary anthropogenic elements).

Surface concentrations

While high concentrations of some contaminants may exist in sediments deposited in the 1960s and 70s, the concentrations in the surface sediments are of more concern to the health of aquatic organisms. We have averaged the top three samples, 1.5 cm, to represent the surface samples. Three samples were averaged to reduce the possible effects of one anomalous sample. These concentrations were compared among lakes, and compared to sediment quality guidelines (Table 5) (MacDonald *et al.*, 2000). MacDonald et al. (2000) define a threshold effect concentration (TEC) and a probable effect concentration (PEC). The TEC is the concentration below which harmful effects on sediment dwelling organisms are unlikely to be observed, while the PEC is the concentration above which harmful effects are likely to be observed. Surface concentrations of arsenic, cadmium, copper, lead and zinc are presented. These are considered the critical inorganic contaminants (except for mercury) in the Great Lakes (US EPA, 1995) . Only 2004-2005 study lakes will be discussed, but data from all study lakes are presented for comparison. Discussion of previous lakes can be found in previous year-end reports (Parsons *et al.*, 2004, Yohn *et al.*, 2002b). The concentrations reported are total concentrations, and represent both the human-influence and natural component.

Table 5. Surface (1.5 cm) concentrations (mg/kg) of five elements for 23 lakes in Michigan, threshold effect concentrations (TEC) and probable effect concentrations (PEC) (MacDonald et al., 2000). Italics indicates values greater than TEC, bold indicates concentrations greater than PEC. The 2004-2005 study lakes are highlighted, previous study lakes are listed for reference.

	As	Cd	Cu	Pb	Zn
Avalon	4.2	*1.1*	**606.7**	*70.9*	93.5
Birch	8.0	0.3	11.2	22.5	68.2
Cadillac	*16.0*	*2.2*	**417.2**	**190.5**	*265.7*
Cass	*30.8*	0.3	15.4	*53.7*	85.4
Crystal B	4.4	*1.1*	18.0	*56.1*	106.7
Crystal M00	7.3	0.9	21.9	*78.9*	106.5
Crystal M04	*11.0*	0.8	*31.8*	*88.6*	*151.7*
Elk	*23.9*	0.3	8.8	29.9	38.4
George	*17.7*	0.5	*39.7*	*47.9*	*132.8*
Gratiot	6.6	0.8	*60.9*	*39.5*	82.4
Gull	7.6	0.1	11.6	32.4	52.4
Hackert	*10.7*	1.0	*45.4*	*65.1*	*160.3*
Higgins	*10.5*	*1.2*	21.1	*109.1*	*122.1*
Houghton	*23.9*	*1.2*	**175.0**	*67.9*	*159.6*
Hubbard	4.3	0.6	9.1	19.3	49.8
Imp	*10.6*	*1.8*	*61.3*	*102.1*	*137.4*
Littlefield	*11.5*	0.5	12.2	30.1	49.0
Mullett	4.9	0.4	12.7	26.6	57.9
Muskegon	*15.7*	*2.0*	*52.7*	*58.0*	*146.9*
Otter	**42.2**	*1.3*	*54.2*	*85.3*	*207.0*
Paw Paw	*19.2*	0.6	*43.7*	*49.7*	*151.8*
Round	4.7	1.0	15.1	*68.4*	98.0
Round D	**44.9**	*1.9*	*64.8*	*70.5*	*174.9*
Sand	*16.9*	*1.7*	*43.0*	*126.4*	*185.4*
Shupac	9.5	0.3	15.8	26.6	65.4
Torch	3.9	0.6	13.1	*43.3*	57.9
Whitmore	*16.1*	*1.5*	*49.7*	**143.9**	*229.0*
Witch	**51.9**	0.7	22.7	23.4	106.2
TEC	9.8	1.0	31.6	35.8	121
PEC	33	5.0	111	128	459

Surface sediment concentrations were generally greatest in Otter and Round D lakes. Arsenic, cadmium and copper concentrations were greatest in Round D Lake whereas zinc concentration was greatest in Otter Lake. Lead concentration was greatest in Crystal M04 Lake. Arsenic sediment concentrations in Otter and Round D lakes exceeded the PEC; Witch Lake, cored in the summer of 2002, was the only other lake where this was observed (Table 5, Figure 30-Figure 34). All of the other 2004-2005 study lakes exceeded the arsenic TEC; however, this is not uncommon. All 2004-2005 study lakes exceeded the TEC for copper, lead and zinc. Cadmium concentration exceeded TEC in Otter and Round D lakes.

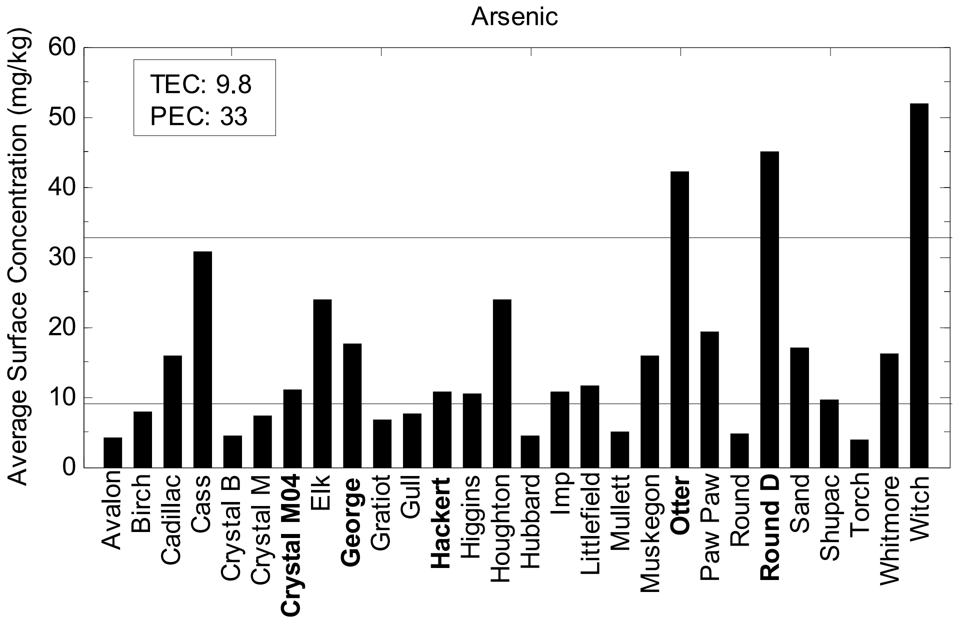


Figure 30. Average surface concentration (average of top 1.5 cm, mg/kg dry wt) for arsenic. Upper lines indicate the PEC, lower lines indicate the TEC. *Data suggest that the surface sediments of Hubbard Lake have been eroded, therefore the top 1.5 cm will represent a different period than lakes sampled during the 2002 reporting year.

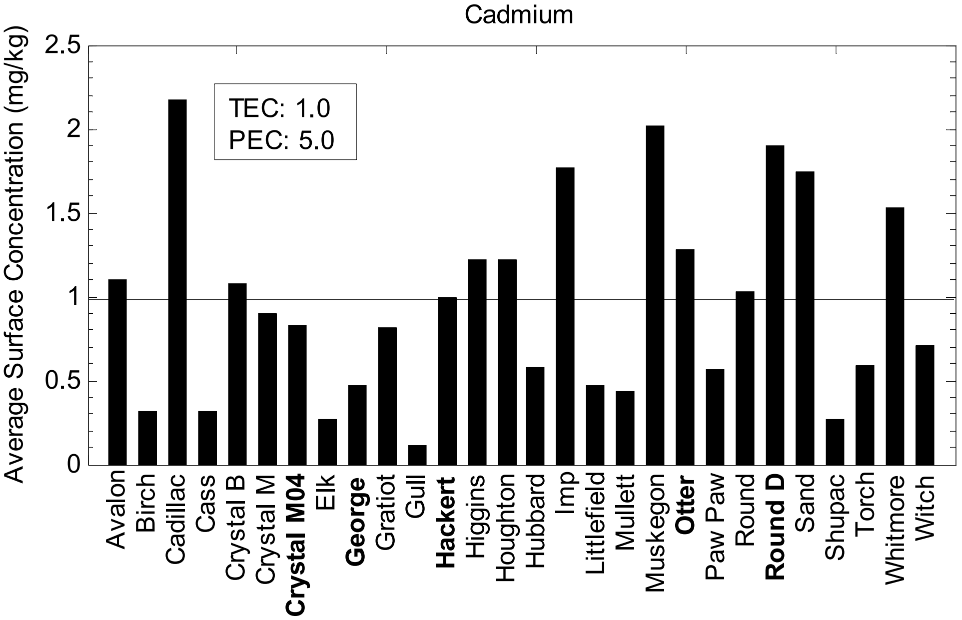


Figure 31. Average surface concentration (average of top 1.5 cm, mg/kg dry wt) for cadmium. The line indicates the TEC, PEC is not shown. *Data suggest that the surface sediments of Hubbard Lake have been eroded, therefore the top 1.5 cm will represent a different period than lakes sampled during the 2002 reporting year..

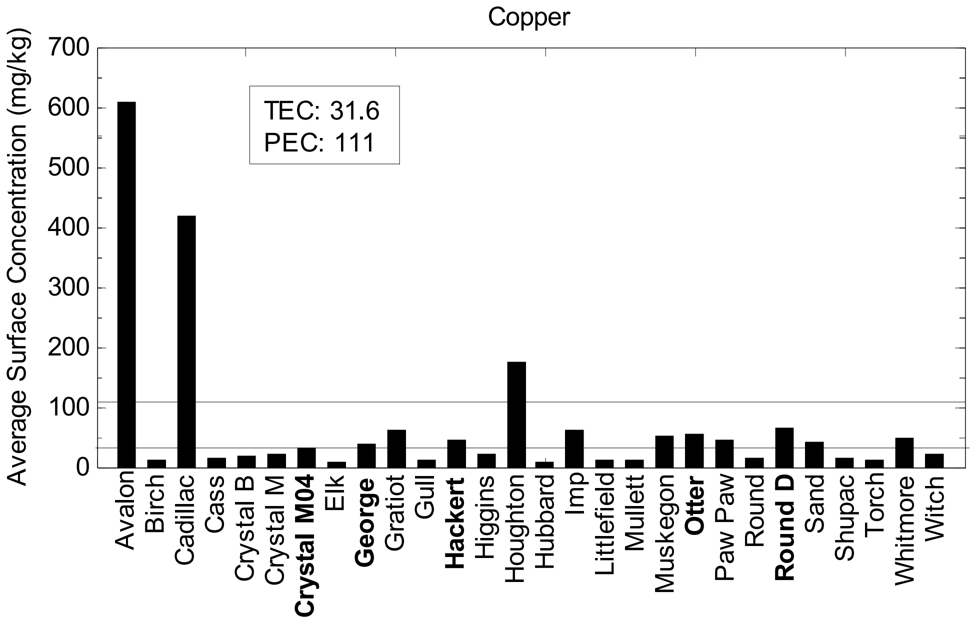


Figure 32. Average surface concentration (average of top 1.5 cm, mg/kg dry wt) for copper. Upper line indicates the PEC, lower line indicates the TEC. *Data suggest that the surface sediments of Hubbard Lake have been eroded, therefore the top 1.5 cm will represent a different period than lakes sampled during the 2002 reporting year.

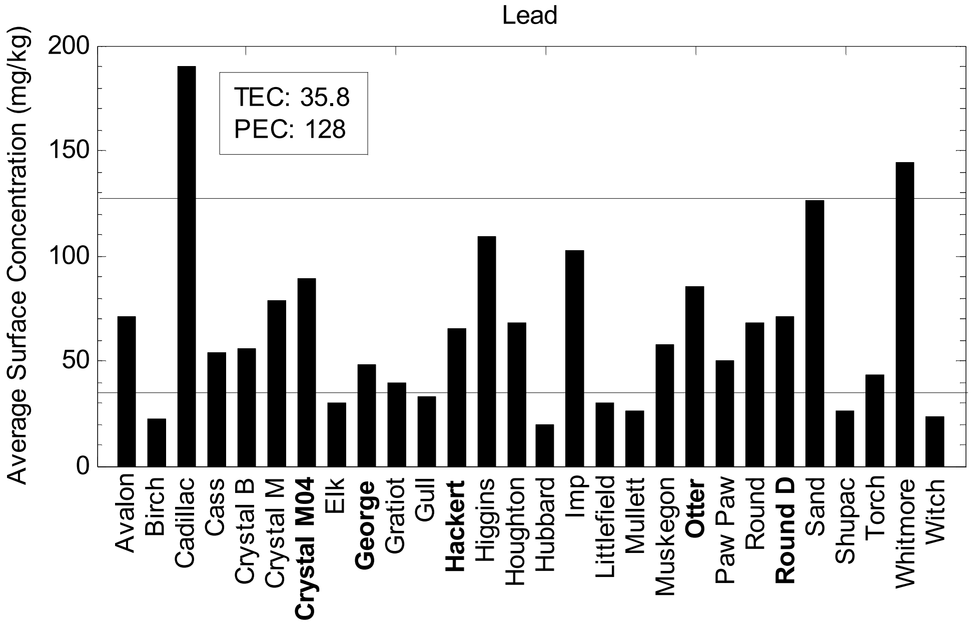


Figure 33. Average surface concentration (average of top 1.5 cm, mg/kg dry wt) for lead. Upper line indicates the PEC, lower line indicates the TEC. *Data suggest that the surface sediments of Hubbard Lake have been eroded, therefore the top 1.5 cm will represent a different period than lakes sampled during the 2002 reporting year.

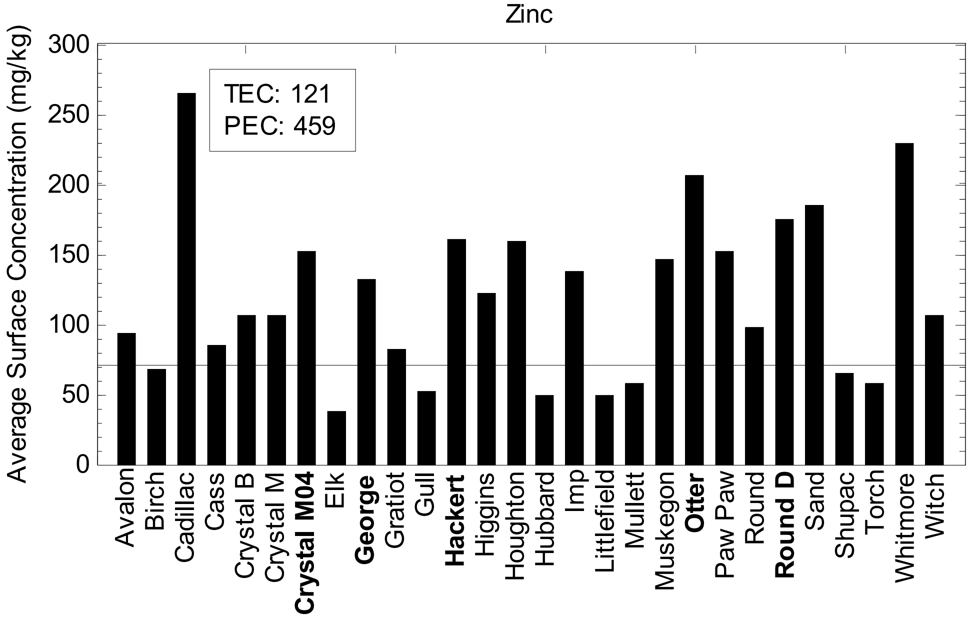


Figure 34. Average surface concentration (average of top 1.5 cm, mg/kg dry wt) for zinc. The line indicates the TEC, PEC is not shown. *Data suggest that the surface sediments of Hubbard Lake have been eroded, therefore the top 1.5 cm will represent a different period than lakes sampled during the 2002 reporting year.

Focusing corrected anthropogenic accumulation rates

Concentrations of metals in the sediment have important implications on bottom-dwelling organisms; however, they do not provide insight into how much of the element is present due to human actions. For example, Gratiot Lake has high copper concentrations even in deep sediments because the lake is located in an area that is naturally rich in copper. Therefore, in addition to the interpretation of the total concentration profiles, focusing corrected anthropogenic accumulation rates (FCAAR) were calculated and compared among lakes. These calculations take into account the natural inputs of elements of interest as well as the process of sediment focusing, and provide the best estimate of the actual rate of input of that element to the lake due to human actions. The calculations are described further in the 2001-2002 year end report (Yohn *et al.*, 2002b).

George and Otter lakes did not have sediment of adequate age to determine geochemical background; therefore only FCAR profiles are shown. Since FCAR does not provide information about the contribution of human activities, comparisons between values of FCAR and FCAAR should be avoided. Loading trends and comparisons of trends among 2004-2005 lakes will be presented.

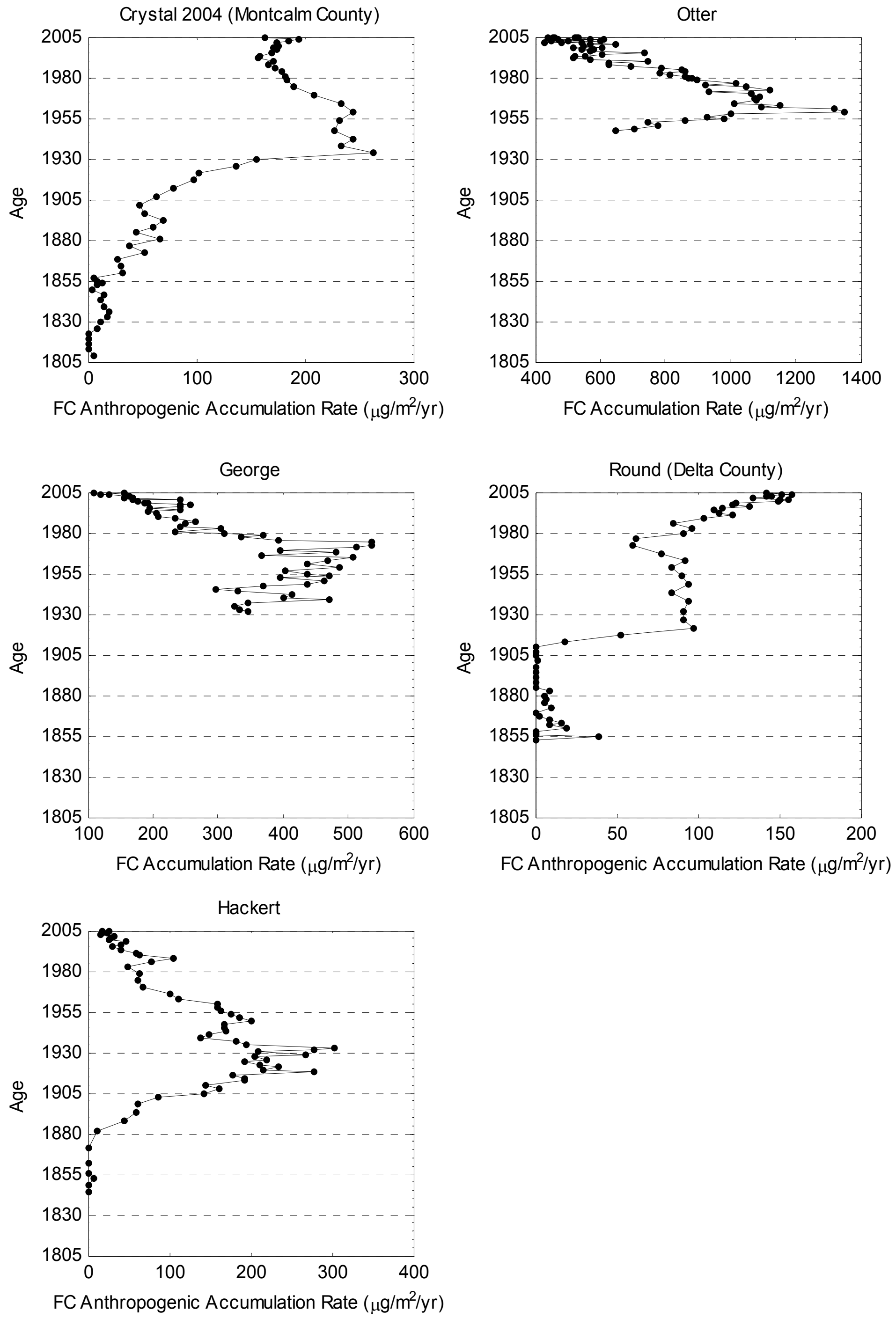


Figure 35. Focusing-corrected anthropogenic accumulation rates (µg/m2/yr) for cadmium in the sediments of 2004-2005 study lakes. George and Otter lakes did not have sediment of adequate age to determine geochemical background, therefore only FCAR profiles are shown. Note the change in the abscissa for each lake.

Anthropogenic loadings of cadmium to the 2004-2005 study lakes varied by location (Figure 35). Cadmium loading to George and Otter lakes increased from the bottom sections of the core and had maxima in the mid-1970s and late 1950s respectively. Since then, cadmium loadings to both lakes had decreased until present day. Crystal M04 and Hackert lakes had maximum anthropogenic loadings in the 1930s and had since declined. Although Hackert Lake FCAAR had declined to present day, cadmium loadings to Crystal M04 had appeared to increase in the last 10 years. Increased FCAAR in most recent sediment was also observed in Round D Lake; however, increases in Round D Lake began about 1980. Round D Lake had an extensive mixing zone in the top 8-9 cm of the core and the increased FCAAR extends to the bottom of this mixing zone. Cadmium concentrations in Round D Lake were decreasing during this period (Figure 29) while mass sedimentation rates were increasing according to the CRS ^{210}Pb dating model. This evidence suggests that the increased mass sedimentation rate resulted in the greater FCAAR. Most recent anthropogenic contribution of cadmium was greatest in Crystal M04 Lake followed by Round D Lake. Hackert Lake appeared to be near historic background loadings in most recent sediments.

Similar to cadmium, copper profiles from the 2004-2005 study lakes suggest unique histories of loading to each lake (Figure 36). Unique profiles imply that the source of copper to the lake was local in scale (e.g., watershed). Crystal M04 and Round D lakes had copper FCAAR that increased toward present day. Although the increase in Round D Lake appeared to be monotonic the increase in Crystal M04 Lake appeared to break after 1990. A break in the loading profile suggests a change in source or an increased loading rate from a continuous source. In general, copper attributed to human disturbance occurred during the turn of the 20th century in Round D and Hackert lakes. However, human attributed copper loading occurred much earlier in Crystal M04 Lake. Hackert and Round D lakes are in the northern Lower Peninsula and Upper Peninsula, respectively, and earlier occurrence of anthropogenic copper in Crystal M04 Lake may be a reflection of its geographical position in the southern Lower Peninsula. Copper loading to Hackert Lake peaked in the late 1980s and had since decreased to present day. Profiles of FCAR for George and Otter lakes were unique suggesting local sources of copper to these lakes. In general, George Lake copper loadings were least in the bottom sections of the core and increased steadily until the 1970s; this was followed by a short-lived decrease in copper loadings. Copper loadings again increased after 1980 reaching a maximum in the late 1980s. In most recent sediments, loadings appeared to be in balance with the watershed but did not show a clear increasing or decreasing trend. Otter Lake copper loadings increased quickly in the 1950s reaching local maxima then steadily decreased until the mid-1990s. Maximum loading of copper was recorded in the last 10 years; however, most recent sediments recorded a decline in loadings.

Profiles of lead FCAAR were, in general, similar to previous study lakes (Figure 37). Anthropogenic loadings began to increase above background in the mid- to late-1800s and peaked between the 1960s and 1970s. The first occurrence of anthropogenic lead additions followed the expected south-to-north trend of population or industrial activity, with earliest occurrence in Crystal M04 Lake. Other than peak lead loadings, similarities among the 2004-2005 lakes were few. After peaking in the late 1950s, anthropogenic lead contributions to Crystal M04 Lake declined until the early 1990s. Since then, it appeared that lead loading had reached a steady-state until present day. George and Otter lakes, after peak lead loading was reached, had declined until present day. Anthropogenic lead loadings declined in Round D Lake after local maxima in the early-1960s. However, after 1975 FCAAR increased sharply until 2000 and had since declined until present day. Anthropogenic lead loading to Hackert Lake was the most unique. Lead loadings to Hackert Lake showed distinct maxima in the early-1930s, early-1960s and late-1980s. Recent sediments in Hackert Lake showed that lead FCAAR had declined.

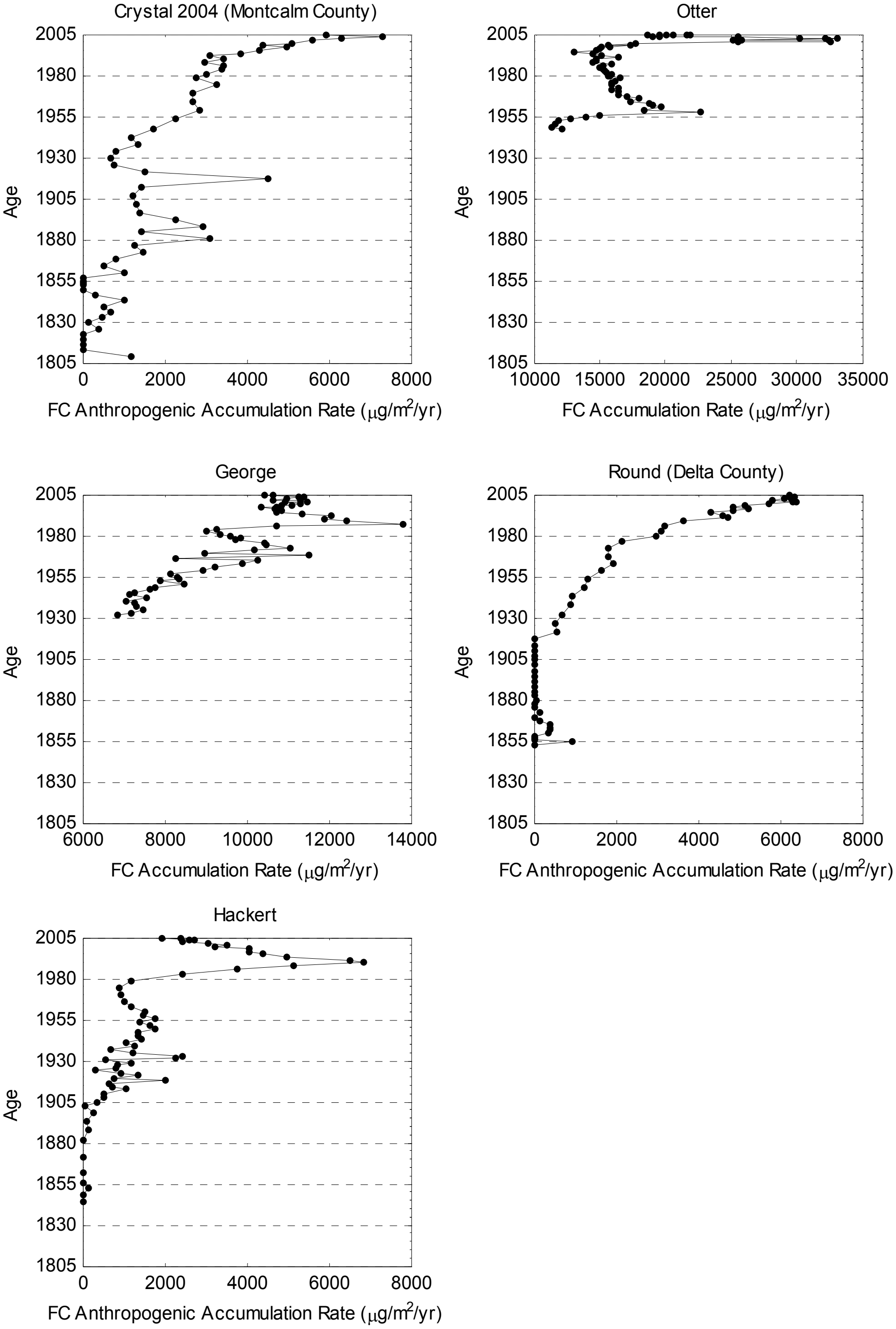


Figure 36. Focusing-corrected anthropogenic accumulation rates (μg/m^2/yr) for copper in the sediments of 2004-2005 study lakes. George and Otter lakes did not have sediment of adequate age to determine geochemical background, therefore only FCAR profiles are shown. Note the change in the abscissa for each lake.

Profiles of anthropogenic zinc loading were similar among Crystal M04 and Round D lakes (Figure 38). However, Hackert Lake's profile of zinc FCAAR was unique. Crystal M04 and Round D lakes zinc FCAAR increased above background after 1850 and 1905 respectively. Both lakes showed local maxima during the mid- to late-1950s followed by FCAAR that decreased until the late-1970s for

Round D Lake and early-1990s for Crystal M04 Lake. After the period of decline, both lakes had FCAAR that increased until present day. Similar to lead, Hackert Lake zinc FCAAR show maxima in the 1930s, 1950s and 1990s. The similarity among the zinc and lead profiles suggest a common

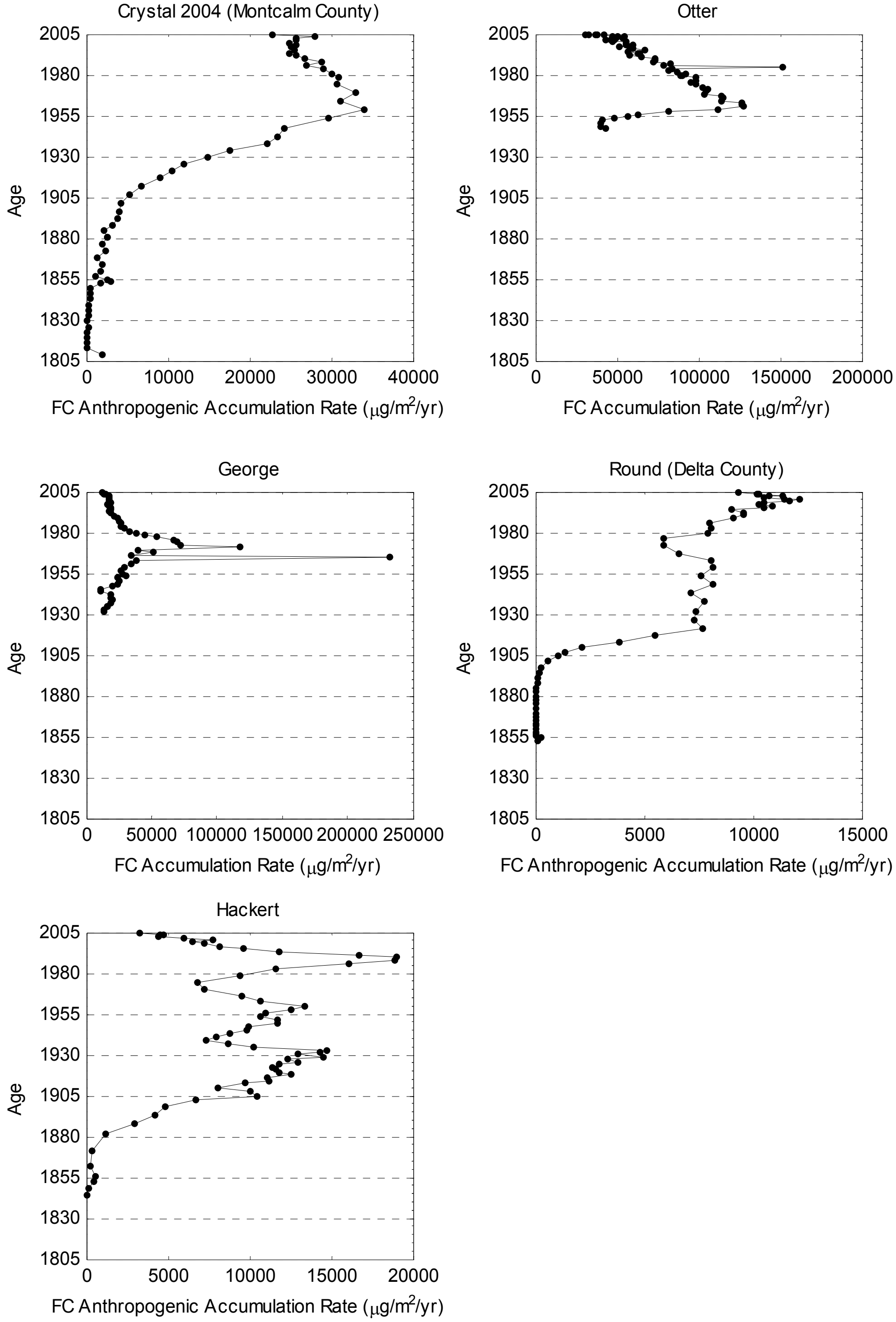


Figure 37. Focusing-corrected anthropogenic accumulation rates (μg/m^2/yr) for lead in the sediments of 2004-2005 study lakes. George and Otter lakes did not have sediment of adequate age to determine geochemical background therefore only FCAR profiles are shown. Note the change in the abscissa for each lake.

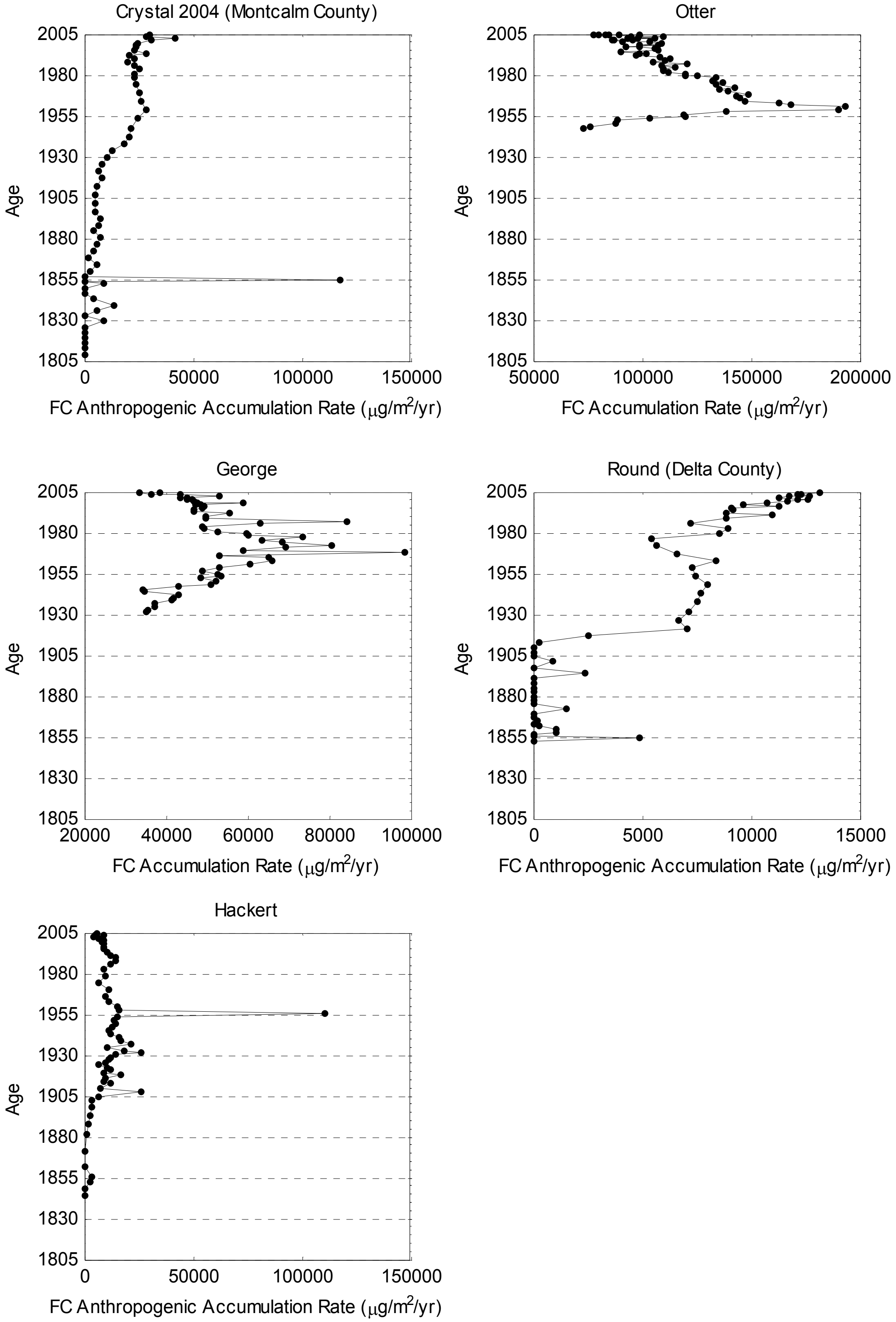


Figure 38. Focusing-corrected anthropogenic accumulation rates (μg/m^2/yr) for zinc in the sediments of the 2004-2005 study lakes. George and Otter lakes did not have sediment of adequate age to determine geochemical background therefore only FCAR profiles are shown. Note the change in the abscissa for each lake.

source for these contaminants. Hackert Lake zinc FCAAR in most recent sediments appeared to decline. Profiles of FCAR from George and Otter lakes resembled the lead FCAR profiles suggesting a common source of lead and zinc to the respective lake. Lead and zinc FCAR in the top sections of the cores from George Lake were near those observed in the bottom sections of the core. The same can be said for lead and zinc FCAR from Otter Lake. Although the anthropogenic contribution cannot be calculated, the reduction of loading does indicate a recovery to at least late-1940s FCAR.

Recommendations of a lake monitoring strategy

Designing a monitoring strategy should include the determination of two different things: (1) which lakes to monitor, and (2) how often to sample those lakes.

Several factors should be considered when determining which lakes to monitor. One important consideration is the quality of the core. The sediment core from Littlefield Lake has evidence that the sediment record has been disturbed. Given the historical uses of the lake, this is not unexpected, but the sediment cannot be accurately dated. If this lake is to be resampled, ^{210}Pb dates can not be used to determine when such sampling should be done. It would be possible to match element profiles to differentiate the depth of new deposition, however, unless there are particular contaminant concerns, resampling this lake is not recommended. Because of the sand layers, dating of the sediments collected from Hubbard Lake was problematic. This lake could be resampled, but should only be analyzed and ^{210}Pb dated if the core visually does not contain any sand layers or appear disturbed in any way.

An overall monitoring strategy should include:

1. Lakes of concern: lakes with increasing levels of contaminants to the surface, or concentrations of contaminants higher than most other Michigan lakes
2. Background lakes: lakes with low concentrations of contaminants with few point sources in the watershed. These lakes would provide background data on atmospheric deposition and provide a comparison for the lakes of concern. Ideally, these lakes would be spatially dispersed throughout Michigan.

The lakes that have been most affected by anthropogenic activities are classified as lakes of concern. Cass Lake has clearly been influenced by human activities and has relatively high concentrations of anthropogenic elements near the surface. Concentrations of anthropogenic elements are also higher than most lakes in Otter, Muskegon, Sand, Whitmore, Paw Paw and Cadillac lakes. Additionally, Avalon, Cadillac, Crystal B, Crystal M, Round, Round D and Imp lakes have FCAAR that increase to the present. Crystal B, Imp, Round and Round D lakes are particularly interesting, because they do not have high rates of metal inputs, but the cause of the increasing FCAAR trend is not clear.

Elk Lake has consistently low concentrations of contaminants. Gratiot, Mullett, Imp and Round lakes also have low anthropogenic accumulation rates. These lakes appear to be the “cleanest” of the lakes sampled (i.e., they have low anthropogenic accumulation rates). Imp Lake would be particularly useful to sample, as it has little development in the watershed, generally low anthropogenic accumulation rates; however FCAAR are increasing in the past decade.

The second determination is the frequency of lake sampling. The intent of monitoring is to be able to detect change from when the last sample was taken. Change can be in the concentration of a chemical or a change in the trend of the environmental loading of a chemical. In the first case only the very surface sediment sample would need to be taken. However, given the complexities of lake dynamics (e.g., bioturbation), a single sample would not be informative, since it would not determine the change in the trend of the chemical inputs. Therefore, one might consider a minimum of four samples that reflect new sediment input from the last sampling as necessary to define a trend.

Our current sampling protocol involves taking 0.5 cm samples from the top sediments. Therefore, the accumulation of 2.0 cm of new sediment would be needed to obtain the four samples. The time to deposit 2.0 cm of sediment can be determined from the sedimentation rate (Table 6).

Table 6. Minimum number of years needed to deposit approximately 2 cm of new sediment for Michigan study lakes. Lakes are grouped by years required to accumulate 2 cm of new sediment. *Littlefield estimated.

Years required to accumulate 2 cm of sediment								
1	2	3	4	5	6	7	10	13
Cass	Cadillac	Hackert	Crystal B	Birch	Avalon	Shupac	Elk	Torch
Otter	George	Mullett	Crystal M	Imp	Higgins			
Paw Paw	Gratiot	Round	Gull	Littlefield				
	Muskegon	Round D	Houghton					
	Witch	Sand						

In addition to the issues described above, other factors to consider when determining a monitoring plan could include the usage of the lake for recreation (e.g., Houghton Lake), and spatial distribution of the monitoring lakes.

A possible suite of lakes to sample could include: Gratiot, Imp, and Round lakes in the Upper Peninsula. Gratiot Lake would represent a “clean” lake, while Imp and Round lakes represent relatively undeveloped lakes, but also show a trend of increasing FCAAR in the last decade . In the Lower Peninsula, Paw Paw, Whitmore and/or Cass, and Cadillac lakes could be monitored as lakes of concern, while Elk Lake could be sampled as a more pristine lake. Crystal B Lake would be useful to monitor, as FCAAR are also increasing in this lake.

References

Alfaro-De la Torre, M.C., Tessier, A., 2002. Cadmium deposition and mobility in the sediments of an acidic oligotrophic lake. Geochimica et Cosmochimica Acta 66, 3549-3562.

Auer, M.T., Johnson, N.A., Penn, M.R., Effler, S.W., 1996. Pollutant sources, depositional environment, and the surficial sediments of Onondaga Lake, New York. Journal of Environmental Quality 25, 46-55.

Benedict, M. 2006. Lead Isotopic Chronologies from Inland Lakes: Watershed vs. Regional Scale Sources of Lead in the Great Lakes Region. Thesis, Michigan State University, East Lansing, MI.

Boyle, J.F., Rose, N.L., Bennion, H., Yang, H., Appleby, P.G., 1999. Environmental impacts in the Jianghan Plain: evidence from lake sediments. Water, Air, and Soil Pollution 112, 21-40.

Bradley, P.W., Jones, P.D., Giesy, J.P., 2005. Organics in sediment cores from inland lakes in Michigan - samples collected in 2004, *unpublished work*, Michigan State University

Brown, E.T., Callonnec, L.L., German, C.R., 2000. Geochemical cycling of redox-sensitive metals in sediments from Lake Malawi: A diagnostic paleotracer for episodic changes in mixing depth. Geochimica et Cosmochimica Acta 64, 3515-3523.

Bruland, K.W., Bertine, K., Koide, M., Goldberg, E.D., 1974. History of metal pollution in Southern California costal zone. Environmental Science and Technology 8, 425-432.

Callender, E., vanMetre, P.C., 1997. Reservoir sediment cores show US lead declines. Environmental Science and Technology 31, A424-A428.

Catallo, W.J., Schlenker, M., Gambrell, R.P., Shane, B.S., 1995. Toxic chemicals and trace metals from urban and rural Louisiana lakes: recent historical profiles and toxicological significance. Environmental Science and Technology 29, 1439-1446.

Cooper, D.C., Morse, J.W., 1998. Biogeochemical controls on trace metal cycling in anoxic marine sediments. Environmental Science and Technology 32, 327-330.

Davis, B.M., 1976. Erosional rates and land use history in southern Michigan. Environmental Conservation 3, 139-148.

Douglas, G.B., Adeney, J.A., 2000. Diagenetic cycling of trace elements in the bottom sediments of the Swan River Estuary, Western Australia. Applied Geochemistry 15, 551-566.

Downing, J.A., Rath, L.C., 1988. Spatial patchiness in the lacustrine sedimentary environment. Limnology and Oceanography 33, 447-458.

Evans, R.D., Dillon, P.J., 1982. Historical changes in anthropogenic lead fallout in southern Ontario, Canada. Hydrobiologia 91, 131-137.

Evans, R.D., Rigler, F.H., 1983. A test of lead-210 dating for the measurement of whole lake soft sediment accumulation. Canadian Journal of Fisheries and Aquatic Sciences 40, 506-515.

Golden, K.A., Wong, C.S., Jeremiason, J.D., Eisenreich, S.J., Sanders, M.G., Hallgren, J., Swackhammer, D.L., Engstrom, D.R., Long, D.T., 1993. Accumulation and preliminary inventory of organochlorines in Great Lakes sediments. Water Science and Technology 28, 19-31.

Hakanson, L., 1977. The influence of wind, fetch, and water depth on the distribution of sediments in Lake Vanern, Sweden. Canadian Journal of Earth Science 14, 397-412.

Harrington, J.M., Laforce, M.J., Rember, W.C., Fendorf, S.E., Rosenzweig, R.F., 1998. Phase associations and mobilization of iron and trace elements in Coeur d'Alene Lake, Idaho. Environmental Science and Technology 650-656.

Hewitt, A.D., Renyolds, C.M., 1990. Dissolution of metals from soils and sediments with a microwave-nitric acid digestion technique. Atomic Spectroscopy 11, 1425-1436.

Heyvaert, A.C., Reuter, J.E., Slotton, D.G., Goldman, C.R., 2000. Paleolimnological reconstruction of historical atmospheric lead and mercury deposition at Lake Tahoe, California-Nevada. Environmental Science and Technology 34, 3588-3597.

Iskander, I.K., Keeney, D.R., 1974. Concentration of heavy metals in sediment cores from selected Wisconsin Lakes. Environmental Science and Technology 8, 165-170.

Johnson, M.G., Nicholls, K.H., 1988. Temporal and spatial trends in metal loads to sediments of Lake Simcoe, Ontario. Water, Air and Soil Pollution 39, 337-354.

Kemp, A.L.W., Thomas, R.L., 1976. Cultural impacts on the geochemistry of the sediments of Lakes Ontario, Erie and Huron. Water, Air and Soil Pollution 5, 469-490.

Kerfoot, W.C., Robbins, J.A., 1999. Nearshore regions of Lake Superior: Multi-element signatures of mining discharges and a test of Pb-210 deposition under conditions of variable sediment mass flux. Journal of Great Lakes Research 25, 697-720.

Khim, J., Kannan, K., Villeneuve, D., Koh, C., Giesy, J., 1999a. Characterization and distribution of trace organic contaminants in sediment from Masan Bay, Korea: 1. Instrumental analysis. Environmental Science and Technology 33, 4199-4205.

Khim, J., Villeneuve, D., Kannan, K., Lee, K., Snyder, S., Koh, C., Giesy, J., 1999b. Alkylphenols, polycyclic aromatic hydrocarbons (PAHs), and organochlorines in sediment from Lake Shihwa, Korea: Instrumental and bioanalytical characterization. Environ Toxicol Chem 8, 2424-2432.

MacDonald, D.D., Ingersoll, C.G., Berger, T.A., 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology 39, 20-31.

McKee, J.D., Wilson, T.P., Long, D.T., Owen, R.M., 1989. Pore water profiles and early diagenesis of Mn, Cu and Pb in sediments from large lakes. Journal of Great Lakes Research 15, 68-83.

Oldfield, F., Appleby, P.G., 1984. Empirical testing of 210Pb-dating models for lake sediments. In: Haworth, E.Y., Lund, J.W.G. (Eds.), Lake Sediments and Environmental History. University of Minnesota Press, Minneapolis, pp. 93-124.

Parsons, M.J., Yohn, S.S., Long, D.T., Giesy, J.P., Bradley, P.W., 2004. Inland Lakes Sediment Trends: Sediment Analysis Results for Five Michigan Lakes. Available from: <http://www.michigan.gov/waterquality>.

Qu, W.C., Dickman, M., Wang, S.M., 2001. Multivariate analysis of heavy metal and nutrient concentrations in sediments of Taihu Lake, China. Hydrobiologia 450, 83-89.

Robbins, J.A., 1982. Stratigraphic and dynamic effects of sediment reworking by Great Lakes zoobenthos. Hydrobiologia 92, 611-622.

Sanchez-Cabeza, J.A., Ani-Ragolta, I., Masque, P., 2000. Some considerations of the Pb-210 constant rate of supply (CRS) dating model. Limnology and Oceanography 45, 990-995.

Sanei, H., Goodarzi, F., Van der Flier-Keller, E., 2001. Historical variation of elements with respect to different geochemical fractions in recent sediments from Pigeon Lake, Alberta, Canada? Journal of Environmental Monitoring 3, 27-36.

Simpson, S.J., Long, D.T., Geisey, J.P., Fett, J.D., 2000. Inland lakes sediment trends: sediment analysis results for five Michigan Lakes. Available from: <http://www.michigan.gov/waterquality>.

Spiethoff, H.M., Hemond, H.F., 1996. History of toxic metal discharge to surface waters of the Aberjona Watershed. Environmental Science and Technology 30, 121-128.

Urban, N.R., Gorham, E., Underwood, J.K., Martin, F.B., Ogden, J.G., 1990. Geochemical processes controlling concentrations of Al, Fe, and Mn in Nova Scotia lakes. Limnology and Oceanography 35, 1516-1534.

US EPA, 1995. Final Water Quality Guidance for the Great Lakes System. Available from:

von Guten, H.R., Sturm, M., Moser, R.N., 1997. 200-year record of metals in lake sediments and natural background concentrations. Environmental Science and Technology 31, 2193-2197.

Walling, D.E., Qingping, H., 1992. Interpretation of caesium-137 profiles in lacustrine and other sediments: the role of catchment-derived inputs. Hydrobiologia 235, 219-230.

Yohn, S.S., Long, D.T., Fett, J.D., Patino, L., Giesy, J.P., Kannan, K., 2002a. Assessing environmental change through chemical-sediment chronologies from inland lakes. Lakes Reserv Res Manage 7, 217-230.

Yohn, S.S., Long, D.T., Giesy, J.P., Fett, J.D., Kannan, K., 2001. Inland lakes sediment trends: sediment analysis results for two Michigan Lakes. Available from: <http://www.michigan.gov/waterquality>.

Yohn, S.S., Long, D.T., Giesy, J.P., Scholle, L.K., Patino, L.C., Fett, J.D., Kannan, K., 2002b. Inland lakes sediment trends: sediment analysis results for five Michigan Lakes. Available from: <http://www.michigan.gov/waterquality>.

Yohn, S.S., Long, D.T., Giesy, J.P., Scholle, L.K., Patino, L.C., Parsons, M., Kannan, K., 2003. Inland Lakes Sediment Trends: sediment analysis results for six Michigan Lakes. Available from: <http://www.michigan.gov/waterquality>.

Inland Lakes Sediment Trends: Sediment Analysis Results for Five Michigan Lakes 2004-2005

Appendix A

Background Concentrations
Focusing Factors and Sedimentation Rates
Anthropogenic Inventories
Watershed Characteristics

DEQ

MICHIGAN STATE UNIVERSITY

Aqueous & Environmental Geochemical Laboratory
Geological Sciences
Michigan State University

Background Concentrations

Concentrations in mg/kg dry weight

Lake	Cadmium	Copper	Lead	Zinc
Avalon	-	-	-	-
Birch	-	-	-	-
Cadillac	1.0	19.9	8.0	108.9
Cass	-	-	-	-
Crystal B	-	-	-	-
Crystal M	0.2	8.1	3.6	-
Crystal M	0.3	14.1	6.7	54.0
Elk	BDL	3.0	0.3	4.4
George	-	-	-	-
Gratiot	0.6	46.0	3.0	53.0
Gull	BDL	1.3	0.2	4.6
Hackert	0.7	13.0	12.7	68.2
Higgins	0.3	15.0	8.2	48.0
Houghton	0.6	14.6	7.4	99.9
Imp	0.8	-	6.1	-
Littlefield	0.2	-	0.1	-
Mullett	0.2	8.6	3.2	27.9
Muskegon	-	-	-	-
Otter	-	-	-	-
Paw Paw	-	-	-	-
Round	0.4	-	4.4	-
Round D	0.9	21.6	3.6	87.0
Sand	-	-	-	-
Shupac	-	-	-	-
Torch	0.1	-	1.6	-
Whitmore	-	23.2	-	-
Witch	-	13.5	-	-

\- indicates that background levels could not be determined
BDL indicates that values were below detection limits

Focusing Factors and Sedimentation Rates

Lake	Focusing Factor	Sedimentation Rates (g/sq. meter/y)				Pb-210 Flux (Bq/sq. meter//y)
		CF:CS	SCF:CS	RSSM	CRS	
Avalon	1.5	406	458	326	340	278
Birch	1.7	384		367	445	302
Cadillac	1.7			91	117	307
Cass	6.0	3480				1160
Crystal B	2.9	572		588	624	166
Crystal M	1.7	529			465	297
Crystal M04	1.6	455			559	280
Elk	2.1	415	337		364	367
George	2.1	417				350
Gratiot	2.5	255			287	446
Gull	1.8	499	404		498	318
Hackert	1.9	398			451	344
Higgins	2.0	232			257	362
Houghton	1.2	143	165	111	208	208
Imp	1.5	75		78	119	268
Mullett	3.6	920	801	1084	926	639
Muskegon	3.2	1711				600
Otter	3.5	933				672
Paw Paw	2.7	828		754		484
Round	2.3	312		350	317	418
Round D	2.4	188			270	413
Sand	1.8				441	323
Shupac	2.0	213		188	261	353
Torch	2.4	932	944	542	1470	427
Whitmore	2.8	463	556	517		522
Witch	1.7	318		289	269	301

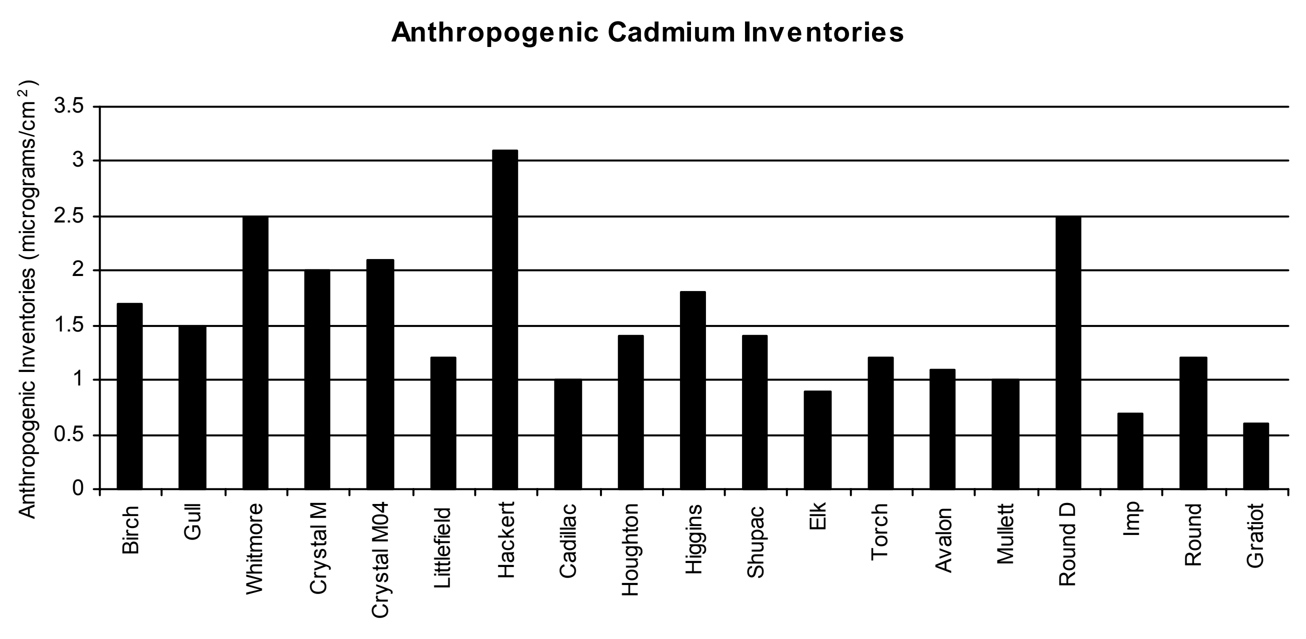
CF:CS: constant sedimentation model sedimentation rate
SCF:CS: average sedimentation rate for the segmented CF:CS model
RSSM: rapid steady state mixing model sedimentation rate
CRS: Average sedimentation rate for the constant rate of supply model
Pb-210 fluxes are calculated values
Focusing factors for Paw Paw and Whitmore lakes are estimated

Anthropogenic Cadmium Inventories

Cadmium (microgram/sq. centimeter)

Lake	Constant BG	Constant BG FC	Wshed	Wshed FC
Birch	3.2	1.9	2.9	1.7
Gull	2.7	1.5	2.7	1.5
Whitmore	7.2	2.6	7	2.5
Crystal M	3.2	1.9	3.3	2
Littlefield	3	1.5	2.4	1.2
Cadillac	1.6	1	1.7	1
Houghton	1.5	1.3	1.6	1.4
Higgins	3.4	1.7	3.5	1.8
Shupac	3.2	1.6	2.8	1.4
Elk	1.8	0.9	1.8	0.9
Torch	3.1	1.3	2.8	1.2
Avalon			1.6	1.1
Mullett	4	1.1	3.4	1
Round	2.8	1.2	2.8	1.2
Imp	1.2	0.8	1.1	0.7
Gratiot	1.3	0.5	1.5	0.6
Round D	2.8	1.2	6	2.5
Hackert	1.7	0.9	5.9	3.1
Crystal M04	2.4	1.5	3.2	2.1

Inventories and focusing corrected anthropogenic inventories were calculated with a constant background concentration (Constant BG and Constant BG FC), and watershed correction technique (Wshed, Wshed FC). Some inventories from earlier years are slightly different than reported previously. Data were recalculated to correct errors and improve the consistency of the calculation. The watershed focusing corrected inventories (Wshed FC) are the best estimation of true anthropogenic inputs, and are graphed below. Inventories are plotted from south to north, starting from the left. If lakes did not contain sediment of adequate age to determine the contribution of human-activities, an anthropogenic inventory could not be calculated.

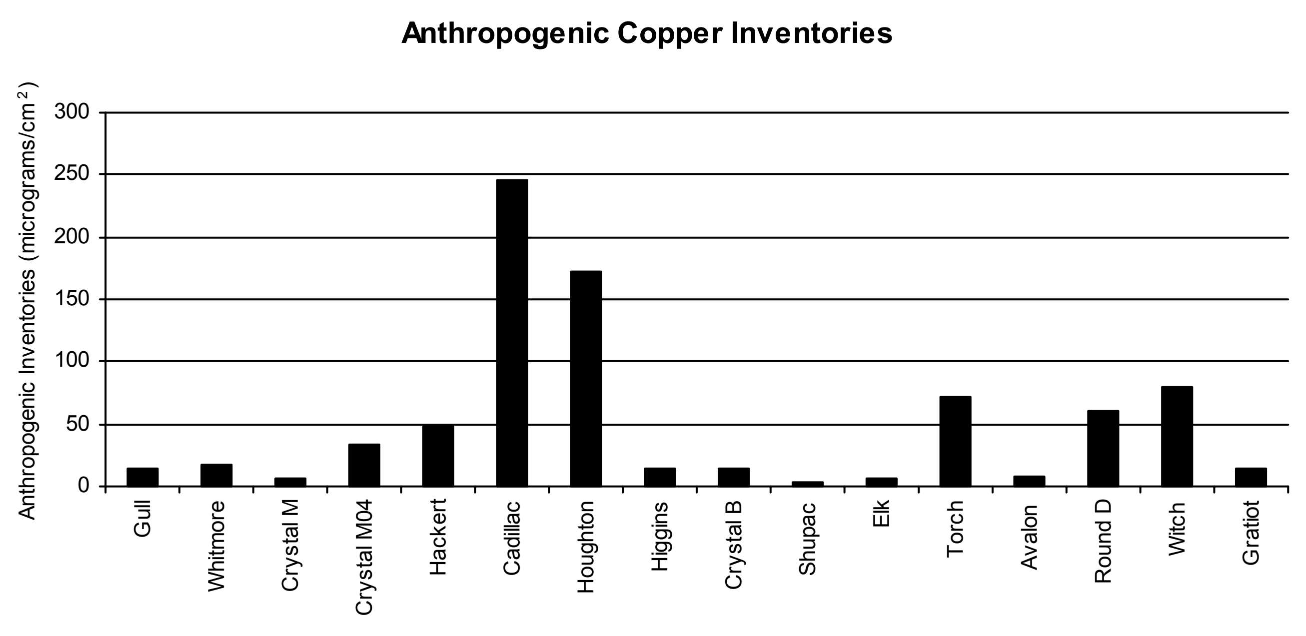


Anthropogenic Copper Inventories

Copper (microgram/sq. centimeter)

Lake	Constant BG	Constant BG FC	Wshed	Wshed FC
Gull	49	27	25	14
Whitmore	68	24	46	17
Crystal M	13	8	11	6
Cadillac	419	245	421	246
Houghton	197	171	199	173
Higgins	17	8	29	14
Crystal B			40	14
Shupac	19	9.7	5.5	2.8
Elk	27	13	14	7
Torch			110.2	72
Avalon	52	15	30	8.5
Gratiot	57	23	38	15
Witch	214	129	133	80
Round D	63.2	26.3	144.7	60.3
Hackert	22.8	12	89.8	47.2
Crystal M04	26.8	17.3	53	34.2

Inventories and focusing corrected anthropogenic inventories were calculated with a constant background concentration (Constant BG and Constant BG FC), and watershed correction technique (Wshed, Wshed FC). Some inventories from earlier years are slightly different than reported previously. Data were recalculated to correct errors and improve the consistency of the calculation. The watershed focusing corrected inventories (Wshed FC) are the best estimation of true anthropogenic inputs, and are graphed below. Inventories are plotted from south to north, starting from the left. If lakes did not contain sediment of adequate age to determine the contribution of human-activities, an anthropogenic inventory could not be calculated..

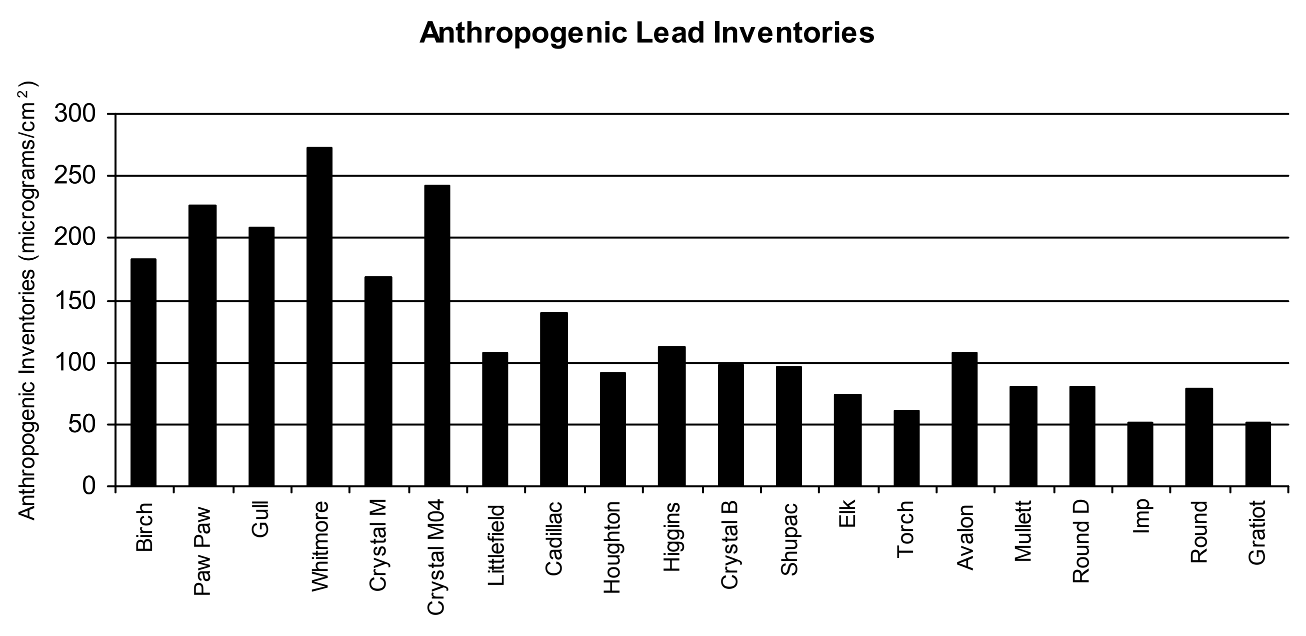


Anthropogenic Lead Inventories

Lead (microgram/sq. centimeter)

Lake	Constant BG	Constant BG FC	Wshed	Wshed FC
Birch	305	182.6	304.6	182.4
Paw Paw	597	221	613	227
Gull	378	210	375	208
Whitmore	760	272	763	272
Crystal M	286	168	288	169
Littlefield	216	108	215	108
Cadillac	238	139	239	140
Houghton	105	91	106	92
Higgins	219	108	225	112
Crystal B			279	98
Shupac	194.2	99.6	188	96.4
Elk	153	75	152	74
Torch	152	64	145	61
Avalon			164.2	107.3
Mullett	297	83	288	81
Round	179	78	179	78
Imp	76	51	75	51
Gratiot	128	51	128	51
Round D	179.8	74.9	193.2	80.5
Crystal M04	355.9	229.6	374.7	241.7

Inventories and focusing corrected anthropogenic inventories were calculated with a constant background concentration (Constant BG and Constant BG FC), and watershed correction technique (Wshed, Wshed FC). Some inventories from earlier years are slightly different than reported previously. Data were recalculated to correct errors and improve the consistency of the calculation. The watershed focusing corrected inventories (Wshed FC) are the best estimation of true anthropogenic inputs, and are graphed below. Inventories are plotted from south to north, starting from the left. If lakes did not contain sediment of adequate age to determine the contribution of human-activities, an anthropogenic inventory could not be calculated..

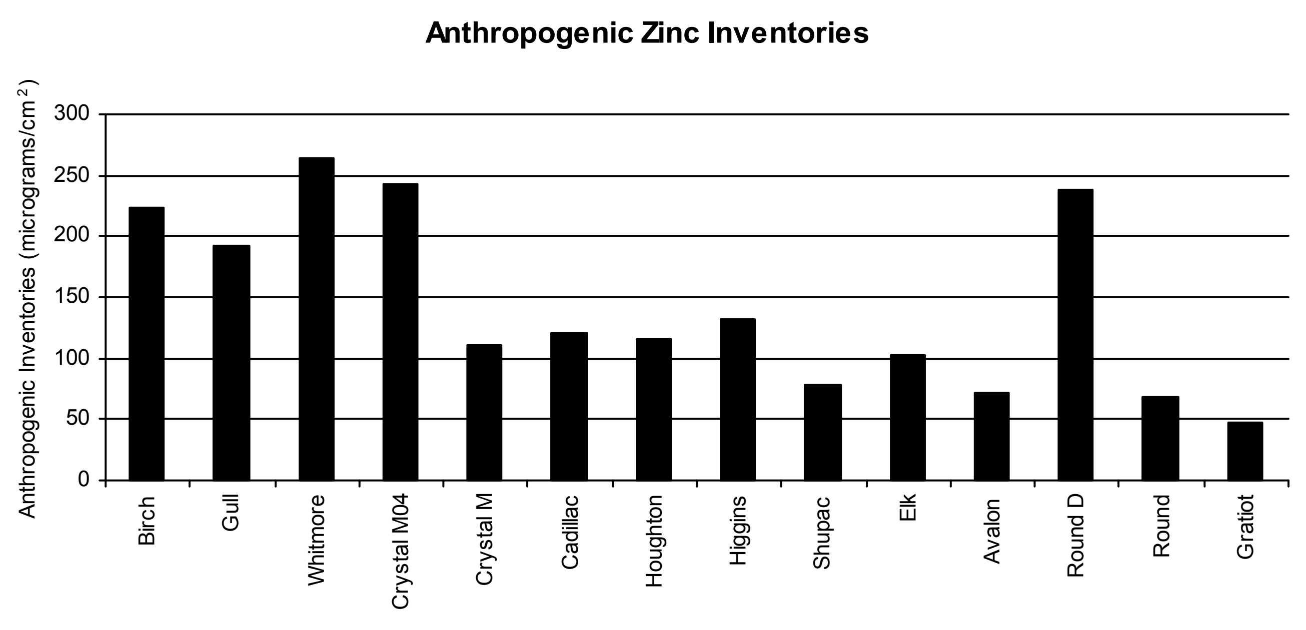


Anthropogenic Zinc Inventories

Inventories and focusing corrected anthropogenic inventories were calculated with a constant background concentration (Constant BG and Constant BG FC), and watershed correction technique (Wshed, Wshed FC). Some inventories from earlier years are slightly different than reported previously. Data were recalculated to correct errors and improve the consistency of the calculation. The watershed focusing corrected inventories (Wshed FC) are the best estimation of true anthropogenic inputs, and are graphed below. Inventories are plotted from south to north, starting from the left. If lakes did not contain sediment of adequate age to determine the contribution of human-activities, an anthropogenic inventory could not be calculated.

Zinc (microgram/sq. centimeter)

Lake	Constant BG	Constant BG FC	Wshed	Wshed FC
Birch			372.2	222.9
Gull	435	241	348	193
Whitmore	757	270	740	264
Crystal M			189	111
Cadillac	199	116	207	121
Houghton	116	100	133	116
Higgins	227	113	266	132
Shupac	206.8	106	152.3	78.1
Elk	237	115	210	103
Avalon			110.7	72.4
Round			159	69
Gratiot	105	42	121	48
Round D	245.6	102.3	571.8	238.2
Crystal M04	268.5	173.2	375.4	242.2



Watershed Characteristics

Lake	Watershed County/Counties	Watershed Area (km2)	Lake Area (km2)	WA:LA	Sulfate Deposition (kg/ha/y)	k-factor	k-factor slope corrected	Slope (degrees)
Avalon	Montmorency	3.10	1.51	2.0	13.3	0.13	0.05	1.92
Birch	Cass	2.70	1.19	2.2	19.1	0.17	0.09	3.74
Cadillac	Wexford, Missaukee	47.60	4.7	10.2	16.7	0.15	0.14	2.62
Cass	Oakland	46.80	5.2	9.0	16.2	0.22	0.11	0.96
Crystal B	Benzie	106.20	39.3	2.7	15.7	0.16	0.18	4.82
Crystal M	Montcalm	12.10	2.9	4.1	16.4	0.25	0.15	2.11
Elk	Grand Traverse, Antrim, Kalkaska	130.90	31.3	4.2	14.7	0.19	0.27	3.38
George	Ogemaw	5.10	0.8	6.7	14.5	0.22	0.04	1.95
Gratiot	Keweenaw	27.00	5.8	4.6	8.5	0.16	0.12	5.32
Gull	Kalamazoo, Barry	61.70	8.2	7.5	18.5	0.26	0.12	1.96
Hackert	Mason	1.50	0.5	3.0	16.0	0.26	0.03	3.31
Higgins	Roscommon, Missaukee, Crawford	108.50	38.9	2.8	14.9	0.12	0.08	2.46
Houghton	Roscommon	460.90	81.2	5.7	15.1	0.13	0.06	1.87
Imp	Gogebic	2.10	0.3	6.1	8.8	0.31	0.2	3.77
Littlefield	Isabella	17.00	0.7	23.0	15.8	0.21	0.09	3.20
Mullett	Cheboygan, Otsego	1353.40	70.3	19.3	12.6	0.16	0.14	3.36
Muskegon	Muskegon, Newaygo	884.70	16.8	52.7	16.8	0.21	0.1	2.48
Otter	Genesee, Lapeer, Tuscola	3.40	0.3	12.0	14.8	0.212	0.1	3.33
Paw Paw	Berrien, VanBuren	29.60	3.7	7.9	19.4	0.28	0.08	1.99
Round	Luce	22.40	7	3.2	12.2	0.18	0.12	2.74
Sand	Lenawee	2.70	1.8	1.5	14.0	0.2	0.2	4.50
Shupac	Crawford, Otsego	10.60	0.4	24.5	12.2	0.12	0.04	1.36
Torch	Antrim, Kalkaska	191.50	76	2.5	14.1	0.19	0.29	4.31
Whitmore	Washtenaw, Livingston	11.40	2.7	4.2	16.6	0.23	0.14	1.10
Witch	Marquette	11.90	0.9	14.0	9.3	0.29	0.16	2.90

1970s MIRIS Land Use/Land Cover

Lake	Population Density (people/sq. km)	Population (people)	Urban (%)	Agriculture (%)	Rangeland (%)	Forest (%)	Wetland (%)
Avalon	12.1	37.5	2.9	69.4	1.2	25.4	0.1
Birch	25.1	66.5	2.1	32.2	19.4	41.1	2.7
Cadillac	102.6	4394.7	19.7	40.7	10.2	24.4	4.1
Cass	736.6	30580.5	60.5	2.4	13.9	8.6	12.2
Crystal B	23.5	1572	12.4	12.9	21.2	51.9	1.2
Crystal M	21.9	201.9	11.1	58.3	5.0	16.9	8.2
Elk	20.9	2084.7	6.3	28.0	19.8	41.0	3.9
George	13.1	65.9	9.5	22.9	24.0	39.6	1.3
Gratiot	1.1	24.1	0.8	0.0	0.0	98.1	0.6
Gull	37.9	1998.9	9.7	59.0	7.9	14.1	5.8
Hackert	17.7	89.1	20.7	30.8	15.1	27.4	3.8
Higgins	14.2	981.8	15.0	0.5	3.5	77.4	3.4
Houghton	12.9	4776.6	7.1	1.6	5.3	74.5	9.8
Imp	1.4	2.4	7.3	0.0	0.0	86.8	4.9
Littlefield	8	131.5	1.8	9.3	13.8	69.7	4.2
Mullett	6.6	8474.7	3.0	7.4	15.2	70.8	2.9
Muskegon	97.5	86238.2	8.1	50.3	9.3	2.9	0.2
Otter	45.9	116.3	8.9	7.9	16.7	48.5	3.6
Paw Paw	82.5	2127	17.3	30.1	13.2	35.0	2.1
Round	5.5	84.9	4.8	13.8	11.4	68.5	1.0
Round_D	2	4	9.8	0.0	0.0	87.8	1.1
Sand	31.2	83.4	20.1	11.4	14.9	49.0	2.4
Shupac	3.1	5.9	0.9	0.5	13.9	83.6	1.1
Torch	16.1	1961.6	7.3	23.5	21.9	44.8	1.9
Whitmore	64.3	558.1	22.1	23.5	20.5	23.7	8.7
Witch	4.8	53.3	1.8	2.9	6.7	80.6	6.5

1990s IFMAP Land Use/Land Cover

Lake	Population Density (people/sq. km)	Population (people)	Urban (%)	Agriculture (%)	Upland (%)	Forest (%)	Wetland (%)
Avalon	15.6	48.1	8.8	0.0	15.3	70.5	1.1
Birch	28.9	76.6	9.2	29.5	9.1	44.8	1.8
Cadillac	120.3	5154.5	12.0	33.5	18.7	30.9	2.0
Cass	832.2	34550.5	31.0	0.5	19.1	38.1	10.2
Crystal B	29.8	1989	6.0	10.8	22.3	58.9	0.9
Crystal M	29.5	271.3	11.1	49.4	2.8	21.1	13.5
Elk	36	3588.9	4.7	24.7	17.7	49.6	1.8
George	17.3	86.9	4.7	6.9	19.1	59.8	7.5
Gratiot	1.6	34.8	0.9	0.0	6.2	89.0	3.5
Gull	45.8	2416.5	5.3	57.7	6.3	22.2	5.8
Hackert	26	75.8	6.0	40.2	9.2	36.5	2.9
Higgins	35.3	2434.6	7.0	0.1	15.3	72.9	3.7
Houghton	23.5	8660.2	4.1	0.8	15.3	62.2	15.7
Imp	1.7	2.9	1.7	0.0	0.5	94.9	0.7
Littlefield	11.6	189	2.6	5.1	13.1	73.6	4.2
Mullett	9.8	12600.1	2.8	7.5	17.6	68.0	3.1
Muskegon	95.4	84408.4	7.0	17.5	17.2	48.1	6.8
Otter	50.8	129	2.8	10.9	13.9	55.1	15.4
Paw Paw	101.7	2621	12.4	33.6	14.1	31.9	6.6
Round	4.8	74.1	5.3	8.3	9.3	67.2	9.1
Round_D	2.5	4.8	0.8	0.0	2.0	90.4	1.3
Sand	43.7	116.8	8.4	6.5	12.0	65.1	7.2
Shupac	3.8	11.5	1.6	0.5	23.7	72.6	1.1
Torch	22.1	2682.8	4.1	18.1	19.3	55.3	1.6
Whitmore	144.8	1256.4	12.3	17.0	16.0	41.8	11.7
Witch	3.1	34.6	4.0	0.0	4.9	86.7	2.1

Inland Lakes Sediment Trends: Sediment Analysis Results for Five Michigan Lakes 2004-2005

Appendix B

Fact Sheets
Core logs
^{210}Pb Data
Metals Concentrations
Porewater Metals Concentrations

DEQ

MICHIGAN STATE
UNIVERSITY

Aqueous & Environmental Geochemical Laboratory
NIBI
Geological Sciences
Michigan State University

MICHIGAN STATE
UNIVERSITY

Crystal M04 Lake Sediment Fact Sheet

Date Sampled:	28-Jul-04	Sampling site water depth (m):	16.2
County:	Montcalm	Depth of Core (cm):	53.5
Lake Area (sq. km):	2.9	Watershed Area (sq. km):	12.1
Sampling Site:	43º 15.676 N & 84º 56.230 W	Focusing Factor:	1.6

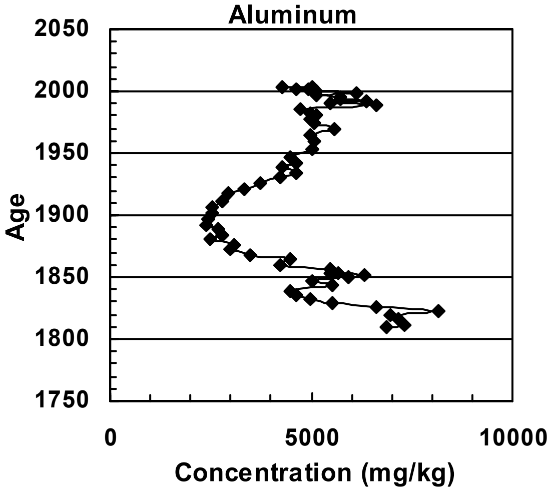
PAHs, PCBs, and Total Pesticides sediment concentrations was greater in the surface sediment than in the sediment below.   However, absolute values were average for lakes in Michigan.

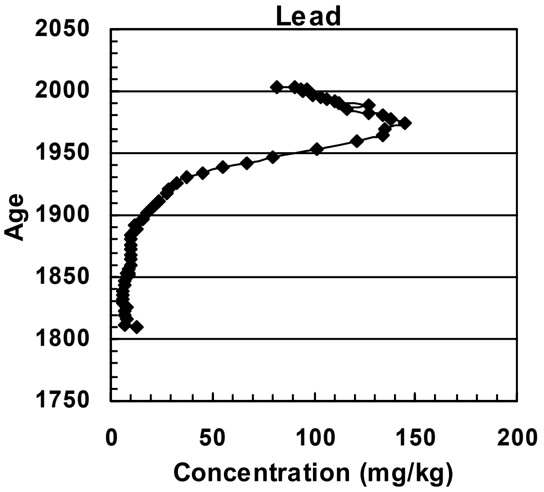
Over the last decade zinc and copper concentrations had increased whereas cadmium and lead decreased. Surface concentrations of arsenic, copper, lead and zinc exceeded the TEC. Copper, lead and zinc FCAAR were increasing in the last decade.

	Surface Concentration	Background Concentration	Trend
Cadmium (mg/kg)	0.83	0.32	Decreasing
Copper (mg/kg)	31.8	14.1	Increasing
Lead (mg/kg)	88.6	6.7	Decreasing
Zinc (mg/kg)	151.7	54.0	Increasing
Total PAHs:	1707.5		Increasing
Total PCBs:	11.2		Increasing
Total Pesticides:	136.4		Increasing

NA indicates that the concentration could not be determined
Trends for organic contaminants are taken from only two data points and should be interpreted with care

Example Profiles





A Strategic Environmental Quality Monitoring Program for Michigan's Surface Waters: Sediments

Lake: Crystal M04 **Water Depth (m):** 16.2

Sampling Date: 7/28/2004 **Latitude (N):** 43.2614 **Longitude (W):** -84.9371

Core Description: Top 0.5-0.75 cm is black, smearing of black material evident down the sides of the core for around 5 cm. Black material transitions to grainy brown and brown/gray material ~25 cm from the top. Core then becomes less grainy and more gray in color to ~33cm. Smearing of gray material down core is evident 31-36 cm. The remainder of the core is brown to light brown in color and finely grained. Worm visible at 1.5 cm moving towards sediment/water interface

Sample Number	Jar Number	Thickness (cm)	Total Thickness (cm)	Description
Crystal M04 1	1	0.5	0.5	grainy black with small amounts of brown
Crystal M04 2	2	0.5	1.0	brown and black coarse grain sediment, watery, shells
Crystal M04 3	3	0.5	1.5	same as 2, more brown
Crystal M04 4	4	0.5	2.0	grayish brown with black specs and worms
Crystal M04 5	5	0.5	2.5	grayish and brown sediment with strings of black material
Crystal M04 6	6	0.5	3.0	grayish and brown sediment with strings of black material
Crystal M04 7	7	0.5	3.5	grayish and brown sediment with strings of black material
Crystal M04 8	8	0.5	4.0	same as 7, becoming more finely grained
Crystal M04 9	9	0.5	4.5	brown and grayish sediment, less black
Crystal M04 10	10	0.5	5.0	same as 10, with red segmented worm
Crystal M04 11	11	0.5	5.5	brown and gray sediment, 5% black material
Crystal M04 12	12	0.5	6.0	brown and gray sediment, 5% black material
Crystal M04 13	13	0.5	6.5	brown and gray sediment, 15% black material
Crystal M04 14	14	0.5	7.0	brown and gray sediment, 15% black material, shells (4)
Crystal M04 15	15	0.5	7.5	brown and gray sediment, 15% black material, shells (3-5)
Crystal M04 16	16	0.5	8.0	brown and gray sediment, 15% black material, shells (3-5)
Crystal M04 17	17	1.0	9.0	gray with small amounts of brown and black
Crystal M04 18	18	1.0	10.0	grayish brown with 30-40% black material and worm
Crystal M04 19	19	1.0	11.0	grayish brown and 10-20% black material, shells
Crystal M04 20	20	1.0	12.0	grayish brown and 10-20% black material, shells, worms, and
Crystal M04 21	21	1.0	13.0	gray sediment with 5-10% black, shells
Crystal M04 22	22	1.0	14.0	gray sediment with 5-10% black, shells
Crystal M04 23	23	1.0	15.0	gray sediment with 5-10% black, shells
Crystal M04 24	24	1.0	16.0	gray sediment with 5-10% black, shells
Crystal M04 25	25	1.0	17.0	gray sediment with 5-10% black, shells
Crystal M04 26	26	1.0	18.0	gray sediment with 0-5% black, shells
Crystal M04 27	27	1.0	19.0	gray sediment with 0-5% black, shells
Crystal M04 28	28	1.0	20.0	gray sediment with 0-5% black, shells
Crystal M04 29	29	1.0	21.0	gray sediment with 0-5% black, shells
Crystal M04 30	30	1.0	22.0	gray sediment with 0-5% black, shells
Crystal M04 31	31	1.0	23.0	gray sediment with 0-5% black, shells
Crystal M04 32	32	1.0	24.0	gray sediment with 0-5% black, shells
Crystal M04 33	33	1.0	25.0	gray sediment with 0-5% black, shells
Crystal M04 34	34	1.0	26.0	gray sediment 0-3% black

Sample Number	Jar Number	Thickness (cm)	Total Thickness (cm)	Description
Crystal M04 35	35	1.0	27.0	gray sediment 0-3% black, no shells
Crystal M04 36	36	1.0	28.0	gray sediemtn, 10-15% black materials, shells
Crystal M04 37	37	1.0	29.0	gray sediemtn, 10-15% black materials, shells
Crystal M04 38	38	1.0	30.0	gray sediemtn, 10-15% black materials, shells and sticks
Crystal M04 39	39	1.0	31.0	gray sediemtn, 10-15% black materials, shells
Crystal M04 40	40	1.0	32.0	brownish gray sediment with black material (30%), shells
Crystal M04 41	41	1.0	33.0	brownish gray sediment with black material (30%), shells
Crystal M04 42	42	1.0	34.0	brownish gray sediment with black material (30%), shells
Crystal M04 43	43	1.0	35.0	brownish gray sediment with black material (30%), shells
Crystal M04 44	44	1.0	36.0	brownish gray sediment with black material (30%), shells
Crystal M04 45	45	1.0	37.0	light brown sedimetn with 20-30% black material, shells
Crystal M04 46	46	1.0	38.0	light brown sedimetn with 20-30% black material, shells
Crystal M04 47	47	1.0	39.0	brown sediment 5-20% black material, lots of shells
Crystal M04 48	48	1.0	40.0	brown sediment 5-20% black material, lots of shells
Crystal M04 49	49	1.0	41.0	brown sediment 5-20% black material, lots of shells
Crystal M04 50	50	1.0	42.0	grayish brown and tan with 10-20% black
Crystal M04 51	51	1.0	43.0	grayish brown and tan with 10-20% black
Crystal M04 52	52	1.0	44.0	grayish brown and tan with 10-20% black
Crystal M04 53	53	1.0	45.0	grayish brown and tan with 10-20% black, lots of shells
Crystal M04 54	54	1.0	46.0	grayish brown with 5-10% black, lots of shells
Crystal M04 55	55	1.0	47.0	grayish brown with 5-10% black, lots of shells
Crystal M04 56	56	1.0	48.0	grayish brown with 5-10% black, lots of shells
Crystal M04 57	57	1.0	49.0	grayish brown with 5-10% black, lots of shells
Crystal M04 58	58	1.0	50.0	grayish brown with 5-10% black, lots of shells, leaf litter
Crystal M04 59	59	1.0	51.0	grayish brown with 5-10% black, lots of shells, leaf litter
Crystal M04 60	60	1.0	52.0	brownish gray sediment , lots of shells, 10-20% black materia

210-Pb Analysis: Crystal M04 Lake

Data provided by Paul Wilkinson, Freshwater Institute, Manitoba, Canada

Sample	Dry Weight (g)	Accumulated Dry Weight (g/sq. cm)	Porosity	Percent Water	Excess Pb-210 (Bq/g)	Activity Bq/g +/- 2SD Pb-210 +/- Error	Activity Bq/g +/- 2SD Cs-137 +/- Error
Crystal M04 1	1.73	0.0244	0.98	94.8	6.09E-01	6.29E-01 +/- 1.25E-02	5.71E-02 +/- 1.08E-02
Crystal M04 2	3.60	0.0752	0.97	90.8	5.28E-01	5.48E-01 +/- 1.20E-02	
Crystal M04 3	3.45	0.1239	0.94	85.3	5.81E-01	6.01E-01 +/- 1.40E-02	9.07E-02 +/- 3.73E-03
Crystal M04 4	3.89	0.1788	0.95	86.4	5.79E-01	5.99E-01 +/- 1.35E-02	
Crystal M04 5	4.84	0.2470	0.96	88.2	5.57E-01	5.77E-01 +/- 1.26E-02	9.05E-02 +/- 4.46E-03
Crystal M04 6	3.89	0.3019	0.95	86.5	5.34E-01	5.54E-01 +/- 1.34E-02	
Crystal M04 7	4.81	0.3698	0.95	86.6	5.38E-01	5.58E-01 +/- 1.30E-02	8.99E-02 +/- 4.48E-03
Crystal M04 8	4.83	0.4379	0.95	86.2	5.17E-01	5.37E-01 +/- 1.59E-02	
Crystal M04 9	5.32	0.5130	0.95	86.6	5.15E-01	5.35E-01 +/- 1.31E-02	9.08E-02 +/- 3.95E-03
Crystal M04 10	4.45	0.5758	0.95	86.6	4.86E-01	5.06E-01 +/- 1.31E-02	
Crystal M04 11	5.89	0.6589	0.95	85.9	4.54E-01	4.74E-01 +/- 1.16E-02	1.03E-01 +/- 4.22E-03
Crystal M04 12	5.05	0.7301	0.95	85.6	4.43E-01	4.63E-01 +/- 1.02E-02	
Crystal M04 13	6.02	0.8150	0.94	84.9	4.16E-01	4.36E-01 +/- 1.13E-02	1.06E-01 +/- 1.59E-03
Crystal M04 14	5.83	0.8973	0.94	84.3	3.91E-01	4.11E-01 +/- 8.93E-03	
Crystal M04 15	6.76	0.9927	0.94	83.8	3.71E-01	3.91E-01 +/- 1.08E-02	1.08E-01 +/- 4.34E-03
Crystal M04 16	6.76	1.0880	0.94	83.6	3.43E-01	3.63E-01 +/- 1.12E-02	
Crystal M04 17	12.45	1.2637	0.93	83.0	3.21E-01	3.41E-01 +/- 8.50E-03	1.26E-01 +/- 4.18E-03
Crystal M04 18	14.24	1.4646	0.93	82.4	2.37E-01	2.57E-01 +/- 9.88E-03	1.31E-01 +/- 3.94E-03
Crystal M04 19	15.12	1.6779	0.93	81.1	2.11E-01	2.31E-01 +/- 7.29E-03	1.28E-01 +/- 4.35E-03
Crystal M04 20	16.31	1.9080	0.92	79.5	1.47E-01	1.67E-01 +/- 7.39E-03	1.07E-01 +/- 3.94E-03
Crystal M04 21	20.95	2.2036	0.91	78.4	1.18E-01	1.38E-01 +/- 5.72E-03	7.93E-02 +/- 3.56E-03
Crystal M04 22	19.03	2.4721	0.91	77.6	9.37E-02	1.14E-01 +/- 5.47E-03	
Crystal M04 23	18.74	2.7365	0.90	76.5	6.88E-02	8.88E-02 +/- 4.93E-03	3.90E-02 +/- 1.66E-03
Crystal M04 24	19.27	3.0083	0.90	76.1	5.19E-02	7.19E-02 +/- 4.77E-03	
Crystal M04 25	20.54	3.2981	0.90	75.8	4.62E-02	6.62E-02 +/- 3.41E-03	2.22E-02 +/- 2.84E-03
Crystal M04 26	20.03	3.5807	0.90	75.4	3.97E-02	5.97E-02 +/- 4.54E-03	
Crystal M04 27	20.05	3.8636	0.90	75.9	3.67E-02	5.67E-02 +/- 3.09E-03	1.29E-02 +/- 2.35E-03
Crystal M04 28	20.35	4.1507	0.90	76.0	3.25E-02	5.25E-02 +/- 4.34E-03	
Crystal M04 29	18.53	4.4121	0.90	76.1	3.11E-02	5.11E-02 +/- 2.43E-03	9.93E-03 +/- 2.47E-03
Crystal M04 30	19.17	4.6826	0.91	77.5	3.12E-02	5.12E-02 +/- 2.48E-03	
Crystal M04 31	16.84	4.9201	0.92	78.8	2.93E-02	4.93E-02 +/- 2.79E-03	9.53E-03 +/- 1.60E-03
Crystal M04 32	17.42	5.1659	0.92	79.7	2.55E-02	4.55E-02 +/- 3.08E-03	
Crystal M04 33	15.30	5.3818	0.92	80.2	1.99E-02	3.99E-02 +/- 2.75E-03	4.07E-03 +/- 1.94E-03
Crystal M04 34	15.22	5.5965	0.93	81.0	1.35E-02	3.35E-02 +/- 2.35E-03	

Sample	Dry Weight (g)	Accumulated Dry Weight (g/sq. cm)	Porosity	Percent Water	Excess Pb-210 (Bq/g)	Activity Bq/g +/- 2SD Pb-210 +/- Error	Activity Bq/g +/- 2SD Cs-137 +/- Error
Crystal M04 35	15.48	5.8149	0.93	81.1	1.39E-02	3.39E-02 +/- 2.44E-03	0.00E+00 +/- 0.00E+00
Crystal M04 36	14.09	6.0137	0.93	81.2	1.37E-02	3.37E-02 +/- 2.57E-03	
Crystal M04 37	15.42	6.2312	0.93	81.9	1.00E-02	3.00E-02 +/- 2.60E-03	
Crystal M04 38	13.56	6.4225	0.93	82.6	1.23E-02	3.23E-02 +/- 2.38E-03	
Crystal M04 39	12.81	6.6033	0.93	83.2	8.01E-03	2.80E-02 +/- 2.36E-03	
Crystal M04 40	13.89	6.7992	0.93	82.9	1.15E-02	3.15E-02 +/- 2.53E-03	
Crystal M04 41	14.02	6.9970	0.93	82.7	5.95E-03	2.60E-02 +/- 2.12E-03	
Crystal M04 42	13.58	7.1886	0.93	82.8	5.79E-03	2.58E-02 +/- 2.03E-03	
Crystal M04 43	14.10	7.3876	0.93	82.5	4.75E-03	2.48E-02 +/- 2.23E-03	
Crystal M04 44	15.04	7.5997	0.93	82.0	1.54E-03	2.15E-02 +/- 2.06E-03	
Crystal M04 45	12.70	7.7789	0.93	82.3	1.29E-03	2.13E-02 +/- 1.51E-03	
Crystal M04 46	13.31	7.9667	0.93	83.0	1.92E-03	2.19E-02 +/- 1.60E-03	
Crystal M04 47	13.81	8.1615	0.93	82.5		1.96E-02 +/- 1.89E-03	
Crystal M04 48	14.14	8.3610	0.93	81.9		1.92E-02 +/- 1.76E-03	
Crystal M04 49	14.91	8.5714	0.93	81.5		1.84E-02 +/- 1.43E-03	
Crystal M04 50	14.50	8.7760	0.93	81.2		1.45E-02 +/- 1.35E-03	
Crystal M04 51	14.21	8.9764	0.93	81.6		1.79E-02 +/- 1.38E-03	
Crystal M04 52	13.33	9.1645	0.93	82.4		1.82E-02 +/- 1.64E-03	
Crystal M04 53	13.56	9.3558	0.93	83.1		1.86E-02 +/- 1.45E-03	
Crystal M04 54	12.68	9.5347	0.93	83.1		1.81E-02 +/- 1.38E-03	
Crystal M04 55	13.03	9.7185	0.93	82.7		1.98E-02 +/- 1.55E-03	
Crystal M04 56	13.58	9.9101	0.93	82.1		2.32E-02 +/- 1.64E-03	
Crystal M04 57	14.59	10.1160	0.93	81.5		2.34E-02 +/- 1.70E-03	
Crystal M04 58	14.85	10.3255	0.92	80.6		2.29E-02 +/- 1.69E-03	
Crystal M04 59	15.76	10.5478	0.92	79.6		2.35E-02 +/- 1.92E-03	
Crystal M04 60	17.79	10.7988	0.91	77.0		3.18E-02 +/- 2.15E-03	

Metal Concentration in the Sediment: Crystal M04 Lake

Concentration in mg/kg dry weight

Sample	Mg	Al	K	Ca	Fe	Ti	V	Cr	Mn	Ni	Cu	Zn	As	Rb	Sr	Mo	Cd	Sn	Ba	Pb	U
Crystal M04 1	11185	4287	639	170865	25614	47.5	15.2	10.88	552	13.7	29.9	140.8	15.75	6.65	91.7	0.97	0.78	0.25	100.7	82.2	0.95
Crystal M04 2	12681	5021	644	200392	16597	47.7	16.5	12.72	579	15.0	33.4	131.2	9.01	7.53	102.1	0.68	0.85	0.25	101.8	90.3	1.11
Crystal M04 3	12862	4615	571	203615	15924	37.3	15.5	11.77	538	14.9	32.1	183.0	8.35	7.03	103.6	0.73	0.87	0.20	100.1	93.3	1.20
Crystal M04 4	12630	4902	584	198220	15214	40.5	16.1	12.00	518	15.0	31.0	152.3	7.94	7.64	104.7	0.66	0.87	0.23	102.9	96.9	1.17
Crystal M04 5	12552	5115	627	202283	14633	47.5	15.9	12.14	487	14.8	29.7	131.5	7.84	8.05	104.7	0.56	0.89	0.17	100.6	94.7	1.06
Crystal M04 6	12965	6135	783	207831	15148	61.5	17.3	13.48	481	15.6	29.5	138.2	7.87	9.37	108.2	0.53	0.93	0.17	107.9	98.6	1.01
Crystal M04 7	13313	5139	591	210798	14624	40.3	15.8	12.43	465	15.3	30.3	134.3	7.47	7.57	105.5	0.45	0.92	0.16	100.8	99.9	0.96
Crystal M04 8	13309	5713	670	210444	14792	50.6	16.6	13.13	463	15.6	29.3	139.1	7.77	8.61	106.0	0.49	0.94	0.16	104.4	103.8	0.96
Crystal M04 9	13380	5740	690	208676	14721	48.8	16.3	12.97	467	15.5	28.5	164.3	7.64	8.67	106.4	0.46	0.93	0.15	103.9	106.2	0.93
Crystal M04 10	13348	6353	761	206232	14648	58.7	16.7	13.27	461	15.1	26.7	139.8	7.59	9.57	106.1	0.59	0.96	0.18	107.7	110.2	0.96
Crystal M04 11	13319	5489	584	210680	14076	39.7	15.4	11.99	460	14.7	26.1	140.6	7.64	8.30	105.1	0.45	0.96	0.16	105.9	112.5	0.96
Crystal M04 12	13515	6594	467	215274	13887	31.9	15.0	11.58	473	15.2	27.1	141.4	8.05	7.49	108.4	0.51	1.03	0.18	106.8	126.6	1.13
Crystal M04 13	13409	4707	532	213327	13655	31.4	13.9	10.43	445	13.8	24.7	136.0	7.76	7.25	105.4	0.58	0.96	0.19	103.5	116.7	1.13
Crystal M04 14	13953	4984	526	222947	15433	37.7	15.2	10.75	453	14.0	25.4	149.6	8.31	7.09	105.7	0.65	1.00	0.23	103.7	126.9	1.26
Crystal M04 15	13570	5121	530	218753	15610	35.9	14.8	11.28	457	14.4	24.3	143.5	8.87	7.79	107.0	0.77	1.04	0.21	106.3	133.9	1.34
Crystal M04 16	13977	4965	545	223287	15755	30.5	14.2	10.43	459	14.1	23.1	143.6	8.64	7.45	106.4	0.69	1.04	0.19	105.8	137.9	1.26
Crystal M04 17	14075	5062	493	218627	16137	39.4	14.7	11.24	474	15.2	26.2	151.5	9.35	7.71	105.0	0.82	1.12	0.24	106.7	144.8	1.33
Crystal M04 18	14065	5580	594	220836	16972	40.6	15.0	11.71	462	14.7	23.0	147.2	10.17	8.27	103.0	0.80	1.10	0.17	103.5	135.3	1.31
Crystal M04 19	13930	4988	473	221409	16492	41.6	14.2	10.83	474	14.1	22.2	152.4	10.32	7.84	106.1	0.73	1.22	0.24	109.9	133.7	1.26
Crystal M04 20	13756	5083	497	227316	16490	32.4	13.7	10.47	485	13.7	21.1	141.8	10.32	7.74	106.4	0.66	1.09	0.23	109.1	121.0	1.15
Crystal M04 21	13419	5036	498	230847	15495	34.9	13.1	10.91	504	13.4	18.7	123.5	9.43	7.70	108.3	0.59	1.01	0.57	108.2	101.4	1.05
Crystal M04 22	13144	4493	441	233830	13848	31.4	11.2	9.32	516	12.5	15.3	106.6	8.05	7.41	110.2	0.48	0.93	0.29	110.9	79.5	0.85
Crystal M04 23	13079	4644	433	236762	12807	36.4	11.0	9.16	527	12.2	13.6	94.5	8.15	7.75	110.4	0.40	0.88	0.17	111.6	66.7	0.80
Crystal M04 24	13152	4261	381	246588	12431	32.3	10.0	8.79	548	11.3	12.7	79.6	8.38	6.85	111.1	0.40	0.75	0.14	108.2	54.8	0.81
Crystal M04 25	13040	4647	467	251984	12879	47.5	10.6	8.97	568	12.1	12.3	70.9	10.41	7.55	112.9	0.47	0.84	0.14	110.1	45.1	0.91
Crystal M04 26	13661	4234	402	272771	13934	34.1	9.1	7.71	565	11.0	11.0	60.9	10.92	6.41	113.1	0.44	0.57	0.08	109.1	37.7	0.80
Crystal M04 27	12662	3724	335	264241	12417	28.0	8.3	6.88	552	10.1	10.2	52.3	10.30	5.96	112.7	0.45	0.51	0.09	107.7	32.4	0.83
Crystal M04 28	12381	3327	315	277313	11877	32.7	8.3	7.07	578	10.2	11.2	45.7	10.13	5.31	117.0	0.50	0.42	0.08	106.0	28.6	0.93
Crystal M04 29	11149	2953	255	271729	12319	29.8	8.0	6.65	580	10.7	18.5	48.2	11.15	5.02	120.4	0.66	0.41	0.10	106.2	27.2	1.13

Metal Concentration in the Sediment: Crystal M04 Lake

Concentration in mg/kg dry weight

Sample	Mg	Al	K	Ca	Fe	Ti	V	Cr	Mn	Ni	Cu	Zn	As	Rb	Sr	Mo	Cd	Sn	Ba	Pb	U
Crystal M04 30	11016	2789	240	270910	12863	26.7	7.5	5.98	562	10.4	10.6	42.3	11.27	4.73	119.2	0.88	0.39	0.06	106.5	23.8	1.24
Crystal M04 31	10708	2517	201	276041	13462	24.3	7.1	5.12	542	9.7	9.9	39.5	11.18	4.17	120.0	0.92	0.34	0.09	106.6	20.7	1.31
Crystal M04 32	10753	2539	226	285388	13761	22.4	7.1	5.18	540	9.4	10.3	39.4	10.20	4.06	119.1	1.10	0.30	0.04	103.7	17.6	1.29
Crystal M04 33	10229	2456	218	272847	13043	25.9	6.9	5.74	519	10.2	10.0	38.5	9.37	4.24	119.7	1.32	0.29	0.04	105.7	15.4	1.34
Crystal M04 34	10060	2397	288	275586	13804	37.5	8.9	5.80	633	10.6	11.0	39.2	9.14	4.50	131.8	1.84	0.30	0.06	103.9	12.1	1.36
Crystal M04 35	10150	2686	367	274737	14566	42.4	9.3	5.97	603	12.4	14.3	41.5	8.68	5.02	131.7	2.15	0.31	0.02	109.1	12.4	1.43
Crystal M04 36	10096	2769	355	265294	14923	42.0	9.0	5.75	560	9.5	10.7	37.0	7.97	5.08	126.6	2.44	0.28	0.02	107.4	10.0	1.39
Crystal M04 37	10494	2500	276	265583	16172	28.5	8.3	5.27	526	9.5	13.8	40.5	7.02	4.34	120.0	2.57	0.30	0.09	104.1	9.8	1.49
Crystal M04 38	10530	3103	397	246737	18406	36.3	9.5	6.23	493	10.2	11.6	49.0	7.54	5.37	115.7	2.99	0.30	0.02	101.1	10.3	1.62
Crystal M04 39	10896	2979	342	238859	20435	27.0	8.6	5.64	441	8.9	10.7	37.1	6.26	4.84	105.5	2.71	0.30	0.02	96.1	9.6	1.65
Crystal M04 40	11522	3502	417	235136	21501	33.6	10.0	6.61	461	10.1	11.4	40.2	6.77	5.78	107.0	2.47	0.30	0.02	98.6	9.4	1.54
Crystal M04 41	12037	4468	615	230879	20573	49.5	11.1	7.88	459	10.2	11.4	55.0	6.41	7.10	104.2	1.68	0.31	0.21	100.1	10.1	1.27
Crystal M04 42	12349	4212	512	225573	20399	42.4	11.5	7.75	470	11.3	12.4	45.6	6.69	6.82	104.1	1.41	0.31	0.27	97.8	9.8	1.16
Crystal M04 43	12682	5450	836	233236	20705	71.4	13.2	8.80	477	10.9	11.7	42.6	6.80	8.78	105.3	1.54	0.29	0.11	102.1	8.9	1.12
Crystal M04 44	13030	5477	820	227202	20416	68.2	14.0	9.46	493	11.7	12.2	155.4	6.81	8.86	106.6	1.39	0.29	0.10	103.6	8.2	1.01
Crystal M04 45	13247	5677	803	220775	21550	59.5	13.8	9.45	464	12.2	12.6	46.5	7.00	8.92	101.0	1.44	0.30	0.11	100.2	8.4	1.10
Crystal M04 46	12979	6337	993	220116	20413	76.0	14.1	9.89	440	11.6	12.5	66.7	7.26	10.11	100.4	1.60	0.34	0.17	104.2	8.8	1.22
Crystal M04 47	14327	5899	797	261735	20780	60.6	12.1	8.43	454	10.7	11.7	49.1	6.89	8.23	105.9	1.80	0.31	0.17	104.9	7.8	1.19
Crystal M04 48	12178	5049	709	234075	16934	60.3	12.4	8.71	467	11.4	12.2	44.9	7.29	8.35	108.7	1.81	0.30	0.28	105.0	7.0	1.16
Crystal M04 49	12343	5532	828	238971	16533	69.6	13.3	9.23	469	12.1	15.1	60.5	7.44	9.01	109.4	1.81	0.32	0.08	106.1	7.4	1.14
Crystal M04 50	12417	4474	601	236803	16956	41.7	11.1	7.78	442	10.4	11.4	75.0	6.56	7.18	104.2	1.85	0.27	0.08	104.2	5.5	1.14
Crystal M04 51	12606	4636	591	227027	18890	38.8	11.7	8.16	437	11.5	12.3	57.0	6.46	7.39	101.7	1.93	0.29	0.02	100.5	5.7	1.20
Crystal M04 52	12897	4990	588	196219	21151	29.2	11.1	8.12	365	11.4	12.5	43.9	5.95	7.61	86.4	1.44	0.30	0.02	93.3	6.0	1.15
Crystal M04 53	13399	5526	664	188567	22792	31.5	12.0	8.79	360	11.8	12.8	73.0	5.90	8.26	82.7	1.21	0.31	0.02	93.5	6.2	1.13
Crystal M04 54	15434	6637	798	212945	25784	44.7	15.1	11.19	433	15.5	16.0	55.1	7.18	10.15	96.8	1.40	0.37	0.04	108.2	7.7	1.25
Crystal M04 55	14632	8153	1148	194191	24756	67.8	16.6	11.82	392	14.1	14.6	51.7	7.12	12.19	89.0	1.40	0.33	0.10	104.1	6.8	1.15
Crystal M04 56	14669	6966	839	174624	24491	38.6	14.6	10.70	360	14.2	14.5	48.5	6.35	10.19	78.5	1.21	0.32	0.11	92.6	6.8	1.09
Crystal M04 57	15334	7166	832	168220	24379	32.7	14.6	10.96	338	14.6	15.6	56.4	5.97	10.04	74.0	1.08	0.33	0.10	92.6	7.4	1.10
Crystal M04 58	15288	7329	904	173663	23830	37.9	15.2	11.01	338	14.0	14.6	46.8	6.19	10.60	75.9	1.05	0.32	0.02	94.8	7.1	1.08
Crystal M04 59	15236	6849	803	187742	22307	35.1	15.2	11.08	357	16.2	18.6	52.7	6.35	10.02	82.1	1.08	0.37	0.04	96.0	12.3	1.04

MICHIGAN STATE UNIVERSITY

George Lake Sediment Fact Sheet

Date Sampled:	13-Jul-04	**Sampling site water depth (m):**	26.2
County:	Ogemaw	**Depth of Core (cm):**	47.5
Lake Area (sq. km):	0.8	**Watershed Area (sq. km):**	5.1
Sampling Site:	44º 23.982' N & 83º 58.199' W	**Focusing Factor:**	2.1

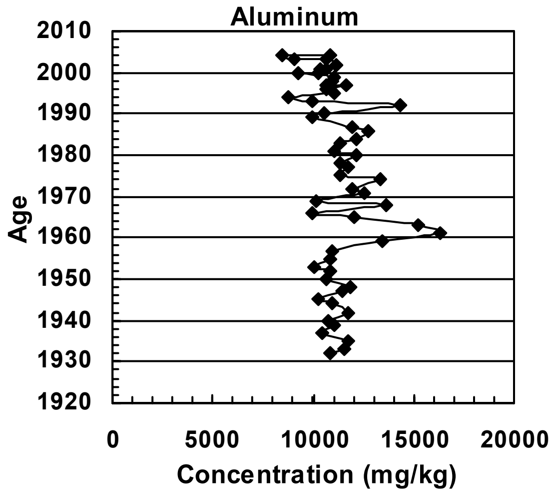
Sediment concentrations of PCBs in George Lake were the greatest among all lakes that have been studied. PAHs and PCBs were declining whereas Total Pesticides were increasing.

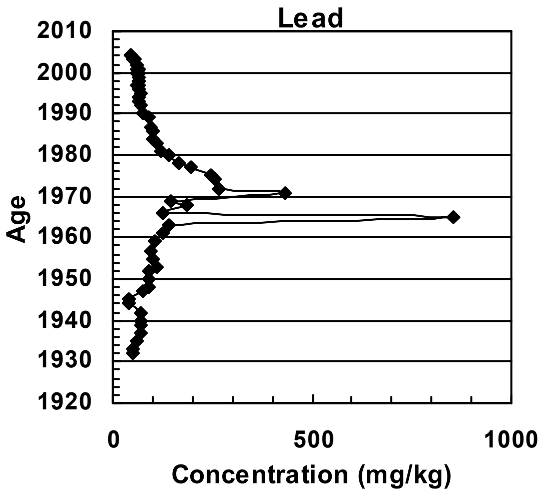
Surface sediment concentration of arsenic, copper, lead and zinc were above the TEC. Cadmium, copper, lead, and zinc concentrations have decreased in the last decade. However, FCAAR were great for cadmium, copper, lead, and zinc when compared to other lakes, other than Otter, in this years' study.

	Surface Concentration	Background Concentration	Trend
Cadmium (mg/kg)	0.47	NA	Decreasing
Copper (mg/kg)	39.7	NA	Decreasing
Lead (mg/kg)	47.9	NA	Decreasing
Zinc (mg/kg)	132.8	NA	Decreasing
Total PAHs:	1331.8		Decreasing
Total PCBs:	61.7		Decreasing
Total Pesticides:	82.4		Increasing

NA indicates that the concentration could not be determined
Trends for organic contaminants are taken from only two data points and should be interpreted with care

Example Profiles





A Strategic Environmental Quality Monitoring Program for Michigan's Surface Waters: Sediments

Lake: George **Water Depth (m):** 26.2

Sampling Date: 7/13/2004 **Latitude (N):** 44.3997 **Longitude (W):** -83.97

Core Description: Topwater has fishy smell, sediment water interface is slanted at 15 degree angle, and the core length is measured from botto to bottom of slant. Core is highly aerated and black in color, with several white translucent worms in core and topwater. Core is black in color throughout its entire length.

Sample Number	Jar Number	Thickness (cm)	Total Thickness (cm)	Description
George 1	1	0.5	0.5	watery, fluff, high in organics
George 2	2	0.5	1.0	watery, fluff, high in organics
George 3	3	0.5	1.5	watery, fluff, high in organics
George 4	4	0.5	2.0	watery, fluff, high in organics
George 5	5	0.5	2.5	dark brown with high organics
George 6	6	0.5	3.0	dark brown with high organics
George 7	7	0.5	3.5	dark brown with high organics
George 8	8	0.5	4.0	dark brown with high organics
George 9	9	0.5	4.5	dark brown with high organics
George 10	10	0.5	5.0	dark brown with high organics
George 11	11	0.5	5.5	dark brown with high organics
George 12	12	0.5	6.0	dark brown with high organics
George 13	13	0.5	6.5	more black than brown
George 14	14	0.5	7.0	more black than brown
George 15	15	0.5	7.5	dark brown with high organics
George 16	16	0.5	8.0	dark brown with high organics
George 17	17	1.0	9.0	more black than brown
George 18	18	1.0	10.0	more black than brown
George 19	19	1.0	11.0	highly organic, big leaf
George 20	20	1.0	12.0	highly organic, big leaf
George 21	21	1.0	13.0	dark brown with high organics
George 22	22	1.0	14.0	dark brown with high organics
George 23	23	1.0	15.0	dark brown with high organics
George 24	24	1.0	16.0	dark brown with high organics
George 25	25	1.0	17.0	continued oragne filaments, more brown than above, lower or
George 26	26	1.0	18.0	brown with high organics
George 27	27	1.0	19.0	brown with high organics
George 28	28	1.0	20.0	brown with high organics
George 29	29	1.0	21.0	brown with high organics
George 30	30	1.0	22.0	brown with high organics
George 31	31	1.0	23.0	brown with high organics
George 32	32	1.0	24.0	brown with high organics
George 34	34	1.0	25.0	brown with high organics
George 35	35	1.0	26.0	brown with high organics

Sample Number	Jar Number	Thickness (cm)	Total Thickness (cm)	Description
George 36	36	1.0	27.0	brown with high organics
George 37	37	1.0	28.0	homogenous, brownish-olive, thicker
George 38	38	1.0	29.0	homogenous, brownish-olive, thicker
George 39	39	1.0	30.0	homogenous, brownish-olive, thicker
George 40	40	1.0	31.0	homogenous, brownish-olive, thicker
George 41	41	1.0	32.0	homogenous, brownish-olive, thicker
George 42	42	1.0	33.0	homogenous, brownish-olive, thicker
George 43	43	1.0	34.0	dark brown with high organics
George 44	44	1.0	35.0	dark brown with high organics
George 45	45	1.0	36.0	dark brown with high organics
George 46	46	1.0	37.0	dark brown with high organics
George 47	47	1.0	38.0	dark brown with high organics
George 48	48	1.0	39.0	dark brown with high organics
George 49	49	1.0	40.0	dark brown with high organics
George 50	50	1.0	41.0	dark brown with lots of filamentous material
George 51	51	1.0	42.0	dark brown with lots of filamentous material
George 52	52	1.0	43.0	dark brown with lots of filamentous material
George 53	53	1.0	44.0	dark brown with lots of filamentous material, some black
George 54	54	1.0	45.0	dark brown with lots of filamentous material
George 55	55	1.0	46.0	grayish black, filamentous material
George 56	56	1.0	47.0	grayish black, filamentous material
George 57	57	1.0	48.0	grayish black, filamentous material (47.5 cm in depth)

210-Pb Analysis: George Lake

Data provided by Paul Wilkinson, Freshwater Institute, Manitoba, Canada

Sample	Dry Weight (g)	Accumulated Dry Weight (g/sq. cm)	Porosity	Percent Water	Excess Pb-210 (Bq/g)	Activity Bq/g +/- 2SD Pb-210 +/- Error	Activity Bq/g +/- 2SD Cs-137 +/- Error
George 1	0.91	0.0128	0.99	97.5	7.74E-01	8.24E-01 +/- 2.12E-02	4.26E-02 +/- 8.05E-03
George 2	1.42	0.0329	0.99	96.2	7.85E-01	8.35E-01 +/- 1.64E-02	
George 3	1.50	0.0540	0.99	95.9	7.82E-01	8.32E-01 +/- 1.61E-02	5.12E-02 +/- 6.20E-03
George 4	1.52	0.0755	0.98	95.3	7.63E-01	8.13E-01 +/- 1.81E-02	
George 5	3.04	0.1184	0.98	94.7	6.93E-01	7.43E-01 +/- 1.70E-02	4.94E-02 +/- 3.42E-03
George 6	1.69	0.1422	0.98	94.6	8.27E-01	8.77E-01 +/- 1.57E-02	
George 7	1.92	0.1693	0.98	94.6	7.96E-01	8.46E-01 +/- 1.18E-02	6.53E-02 +/- 6.60E-03
George 8	1.70	0.1933	0.98	94.5	8.25E-01	8.75E-01 +/- 1.13E-02	
George 9	1.86	0.2195	0.98	94.6	7.73E-01	8.23E-01 +/- 1.18E-02	5.63E-02 +/- 6.40E-03
George 10	1.55	0.2414	0.98	94.5	7.46E-01	7.96E-01 +/- 1.25E-02	
George 11	1.87	0.2678	0.98	94.0	6.44E-01	6.94E-01 +/- 1.40E-02	7.30E-02 +/- 6.27E-03
George 12	1.82	0.2935	0.98	94.5	7.28E-01	7.78E-01 +/- 1.60E-02	
George 13	1.74	0.3180	0.98	94.5	8.29E-01	8.79E-01 +/- 1.63E-02	6.26E-02 +/- 7.38E-03
George 14	1.66	0.3414	0.98	94.4	9.31E-01	9.81E-01 +/- 1.50E-02	
George 15	1.90	0.3682	0.98	94.2	8.24E-01	8.74E-01 +/- 1.91E-02	6.95E-02 +/- 6.30E-03
George 16	2.02	0.3967	0.98	93.6	7.12E-01	7.62E-01 +/- 1.37E-02	
George 17	3.92	0.4520	0.98	93.6	6.90E-01	7.40E-01 +/- 1.35E-02	8.31E-02 +/- 4.68E-03
George 18	4.24	0.5119	0.98	93.3	8.15E-01	8.65E-01 +/- 1.79E-02	
George 19	4.28	0.5722	0.98	93.3	5.93E-01	6.43E-01 +/- 1.55E-02	7.84E-02 +/- 5.57E-03
George 20	4.26	0.6323	0.97	92.9	6.16E-01	6.66E-01 +/- 1.41E-02	
George 21	3.84	0.6865	0.98	93.4	5.82E-01	6.32E-01 +/- 1.20E-02	9.60E-02 +/- 5.85E-03
George 22	4.26	0.7466	0.97	92.8	5.36E-01	5.86E-01 +/- 1.06E-02	
George 23	4.63	0.8119	0.97	92.3	4.41E-01	4.91E-01 +/- 9.70E-03	1.01E-01 +/- 4.56E-03
George 24	4.53	0.8758	0.97	92.7	4.66E-01	5.16E-01 +/- 7.95E-03	
George 25	3.82	0.9297	0.97	93.0	3.82E-01	4.32E-01 +/- 9.38E-03	1.10E-01 +/- 5.67E-03
George 26	4.81	0.9976	0.97	92.3	5.06E-01	5.56E-01 +/- 9.41E-03	
George 27	4.29	1.0581	0.97	92.2	4.73E-01	5.23E-01 +/- 1.22E-02	1.38E-01 +/- 5.43E-03
George 28	4.31	1.1189	0.97	92.9	5.62E-01	6.12E-01 +/- 1.11E-02	
George 29	4.74	1.1858	0.97	92.9	4.95E-01	5.45E-01 +/- 9.59E-03	1.51E-01 +/- 4.74E-03
George 30	4.13	1.2441	0.97	92.8	4.61E-01	5.11E-01 +/- 1.08E-02	
George 31	4.49	1.3074	0.97	92.7	4.41E-01	4.91E-01 +/- 9.35E-03	1.87E-01 +/- 8.63E-03
George 32	4.49	1.3708	0.97	92.7	4.23E-01	4.73E-01 +/- 9.53E-03	
George 34	4.16	1.4927	0.97	92.4	4.13E-01	4.63E-01 +/- 1.19E-02	3.61E-01 +/- 7.21E-03
George 35	4.58	1.5573	0.97	92.6	2.98E-01	3.48E-01 +/- 7.13E-03	4.52E-01 +/- 1.07E-02

Sample	Dry Weight (g)	Accumulated Dry Weight (g/sq. cm)	Porosity	Percent Water	Excess Pb-210 (Bq/g)	Activity Bq/g +/- 2SD Pb-210 +/- Error	Activity Bq/g +/- 2SD Cs-137 +/- Error
George 36	4.74	1.6242	0.97	92.2	3.09E-01	3.59E-01 +/- 8.02E-03	4.12E-01 +/- 6.22E-03
George 37	5.49	1.7016	0.97	91.4	3.17E-01	3.67E-01 +/- 7.49E-03	2.71E-01 +/- 4.87E-03
George 38	5.23	1.7754	0.97	91.6	2.60E-01	3.10E-01 +/- 7.66E-03	
George 39	5.06	1.8468	0.97	91.4	2.56E-01	3.06E-01 +/- 5.23E-03	1.48E-01 +/- 6.02E-03
George 40	6.49	1.9383	0.96	90.1	2.29E-01	2.79E-01 +/- 5.59E-03	
George 41	6.36	2.0281	0.96	89.8	2.03E-01	2.53E-01 +/- 5.38E-03	4.76E-02 +/- 4.33E-03
George 42	5.15	2.1007	0.97	90.6	1.40E-01	1.90E-01 +/- 5.69E-03	
George 43	4.81	2.1686	0.97	91.7	1.68E-01	2.18E-01 +/- 6.30E-03	0.00E+00 +/- 0.00E+00
George 44	4.71	2.2350	0.97	91.9	1.40E-01	1.90E-01 +/- 5.28E-03	
George 45	5.01	2.3057	0.97	91.5	1.60E-01	2.10E-01 +/- 4.77E-03	
George 46	4.71	2.3722	0.97	92.0	1.26E-01	1.76E-01 +/- 6.57E-03	
George 47	4.85	2.4406	0.97	92.1	1.47E-01	1.97E-01 +/- 5.52E-03	
George 48	5.17	2.5135	0.97	91.2	1.17E-01	1.67E-01 +/- 5.56E-03	
George 49	4.69	2.5797	0.97	91.9	1.14E-01	1.64E-01 +/- 6.42E-03	
George 50	4.59	2.6445	0.98	93.2	6.92E-02	1.19E-01 +/- 4.88E-03	
George 51	4.25	2.7044	0.97	92.7	7.98E-02	1.30E-01 +/- 4.30E-03	
George 52	4.81	2.7723	0.97	92.0	1.01E-01	1.51E-01 +/- 5.17E-03	
George 53	5.15	2.8449	0.97	91.2	1.07E-01	1.57E-01 +/- 4.61E-03	
George 54	6.20	2.9324	0.97	90.6	1.01E-01	1.51E-01 +/- 5.10E-03	
George 55	6.00	3.0171	0.96	90.4	1.17E-01	1.67E-01 +/- 3.80E-03	
George 56	3.20	3.0622	0.96	89.3	2.40E-01	2.90E-01 +/- 5.10E-03	

Metal Concentration in the Sediment: George Lake

Concentration in mg/kg dry weight

Sample	Mg	Al	K	Ca	Fe	Ti	V	Cr	Mn	Ni	Cu	Zn	As	Rb	Sr	Mo	Cd	Sn	Ba	Pb	U
George 1	9026	10810	2243	21174	21267	130.0	25.7	17.92	715	22.0	39.1	141.8	17.53	15.78	32.6	1.60	0.40	0.21	133.1	46.2	0.08
George 2	7651	8426	1612	18713	18593	100.6	21.5	14.63	712	20.0	38.3	122.6	17.08	12.43	26.1	2.13	0.58	0.43	109.1	45.2	0.04
George 3	8051	9056	1912	18665	20822	104.7	23.6	15.96	834	21.6	41.8	133.9	18.37	13.12	27.2	2.11	0.44	0.20	115.7	52.2	0.24
George 4	8951	10672	1801	20158	23233	121.3	27.0	18.32	956	22.6	41.3	159.7	20.43	15.23	28.4	2.21	0.49	0.26	125.2	56.0	0.40
George 5	9127	11190	1793	20737	22763	120.1	28.3	19.53	1034	24.3	40.3	195.0	19.38	16.39	29.4	1.85	0.60	0.17	130.0	62.8	0.36
George 6	8639	10374	1599	19250	22542	105.6	26.6	18.64	1003	23.9	39.1	159.9	19.09	15.41	27.9	1.94	0.62	0.14	123.8	62.2	0.52
George 7	8490	10614	1583	19239	24685	106.2	28.1	18.71	1061	24.6	41.6	165.8	20.82	15.14	27.5	2.20	0.58	0.16	124.1	62.8	0.62
George 8	8245	10232	1498	18655	24997	101.5	28.8	18.55	1046	25.2	42.2	170.3	21.97	14.77	27.0	2.71	0.89	0.30	124.6	62.7	0.72
George 9	7845	9226	1263	17513	24473	82.9	26.5	17.23	1022	24.1	40.1	166.1	20.32	13.11	24.9	2.22	0.62	0.19	119.0	63.7	0.62
George 10	8182	11029	1610	18011	26829	104.8	28.7	18.99	1005	25.1	41.5	172.0	20.51	15.30	25.8	2.45	0.65	0.17	122.5	64.1	0.80
George 11	8838	10930	1602	20022	25481	107.9	29.6	19.55	1041	25.0	40.7	174.6	18.65	15.94	27.8	2.02	0.69	0.19	126.1	67.4	0.58
George 12	9148	10966	1575	21363	23499	101.8	27.7	19.61	1066	25.6	39.9	216.5	17.82	15.87	28.5	1.69	0.71	0.18	130.4	66.5	0.55
George 13	8094	10635	1505	18740	25886	98.2	27.0	18.71	1032	25.1	39.4	173.7	20.07	14.61	26.3	2.53	0.95	0.35	128.9	63.5	0.86
George 14	7708	11665	1662	17429	27105	105.5	29.0	19.32	1015	24.5	38.0	178.3	21.37	15.49	24.3	2.33	0.89	0.34	127.9	61.4	0.62
George 15	7294	10650	1399	17113	27019	93.9	29.2	18.58	1042	24.6	39.2	181.9	22.64	14.44	23.2	2.24	0.89	0.33	125.9	63.4	0.44
George 16	7678	11025	1461	17706	26667	94.4	29.2	19.46	1030	25.5	39.8	180.1	20.95	15.14	24.2	1.90	0.71	0.20	127.5	68.8	0.63
George 17	7266	8803	1132	17371	20812	82.8	27.5	19.19	940	25.4	39.3	171.4	20.10	14.88	25.5	1.91	0.89	0.35	128.2	67.5	0.58
George 18	8702	9961	1301	19316	25611	71.4	26.0	18.80	938	25.6	41.6	172.3	18.51	13.75	22.9	1.66	0.70	0.17	130.9	66.7	0.48
George 19	9095	14302	1289	21304	25619	105.9	29.0	20.38	1159	26.0	44.2	204.7	19.21	15.37	26.6	1.61	0.75	0.23	168.1	71.4	0.44
George 20	9054	10520	1179	18143	24501	60.3	26.7	20.13	882	26.7	43.7	183.4	16.78	15.18	21.9	1.75	0.77	0.15	147.7	77.6	0.41
George 21	8265	9919	1165	17935	56198	61.1	28.4	18.73	907	25.4	45.6	183.3	17.68	13.63	21.4	2.01	0.86	0.27	132.4	90.5	0.70
George 22	8192	11989	1472	17377	27365	87.1	30.9	20.33	931	28.3	50.6	309.0	20.62	16.18	22.0	2.46	0.97	0.17	136.9	95.0	0.97
George 23	8551	12784	1621	17792	25675	91.7	31.7	21.23	916	26.3	39.3	232.0	18.81	17.81	22.2	1.66	0.92	0.20	140.9	99.5	0.49
George 24	8746	12119	1368	17661	23867	68.8	29.0	20.77	904	26.5	34.1	179.7	16.09	16.40	21.1	1.40	0.89	0.16	147.2	99.1	0.47
George 25	8386	11368	1274	17366	23520	67.7	28.5	20.49	893	27.4	33.2	180.9	16.73	15.81	20.8	1.61	1.12	0.34	145.9	109.9	0.39
George 26	8315	11059	1215	16755	24893	60.2	26.7	20.11	840	26.7	34.3	193.6	14.93	14.46	18.4	1.47	0.86	0.15	138.9	122.1	0.46
George 27	8865	12132	1446	17056	28481	85.0	31.3	20.17	819	26.4	35.2	218.7	17.39	16.97	20.6	2.44	1.13	0.28	140.1	139.6	1.18
George 28	8638	11353	1360	16441	27983	90.5	32.0	20.09	823	27.5	36.2	220.8	19.19	16.46	20.4	2.84	1.35	0.41	135.9	165.5	1.64
George 29	8847	11726	1338	17471	33465	57.9	29.8	19.38	806	26.4	35.7	269.5	16.29	14.38	18.0	2.30	1.23	0.20	132.8	196.2	0.93

Metal Concentration in the Sediment: George Lake

Concentration in mg/kg dry weight

Sample	Mg	Al	K	Ca	Fe	Ti	V	Cr	Mn	Ni	Cu	Zn	As	Rb	Sr	Mo	Cd	Sn	Ba	Pb	U
George 30	7763	11376	1263	16039	32115	75.2	33.1	21.40	896	28.2	38.3	232.6	20.81	16.03	19.9	2.58	1.45	0.37	155.1	244.2	0.85
George 31	7822	13307	1543	15546	31549	82.7	35.7	94.60	860	31.7	38.5	250.8	25.55	18.52	19.7	4.39	1.96	0.46	156.2	256.5	0.93
George 32	7207	11899	1301	14332	33825	76.7	35.7	22.67	832	28.5	40.5	295.4	28.29	16.76	18.5	3.75	1.96	0.45	155.2	267.0	1.24
George 33	6988	12570	1440	13876	32637	83.7	33.5	22.89	812	29.1	37.4	254.5	29.66	18.37	18.4	3.23	1.88	0.45	155.8	431.7	1.01
George 34	6847	10117	1020	14261	27123	57.7	30.0	18.96	777	27.3	32.9	216.7	22.26	14.26	19.2	2.05	1.45	0.00	147.0	144.5	1.82
George 35	7108	13665	1528	13514	35250	82.6	35.8	23.57	787	31.3	42.2	361.2	41.74	20.26	20.7	3.49	1.76	0.00	174.0	186.8	2.22
George 36	5581	9987	1057	11442	25778	57.2	29.1	18.28	672	25.0	30.4	194.8	24.19	15.00	16.8	1.79	1.35	0.00	147.0	127.0	1.57
George 37	6349	11996	1247	13190	27398	64.1	34.5	22.50	822	31.0	37.7	238.8	23.46	18.00	20.3	1.92	1.86	0.00	213.0	854.0	1.77
George 38	8072	15227	1808	14816	31941	89.0	37.7	24.65	782	31.0	36.4	242.3	26.52	22.00	21.5	2.15	1.72	0.00	183.0	141.0	1.72
George 39	9093	16321	1970	16766	28377	99.3	37.4	26.16	760	31.4	33.8	222.6	22.50	25.35	22.2	1.66	1.61	0.26	192.0	127.2	0.93
George 40	9307	13414	1474	17164	27022	84.2	31.7	24.05	770	30.4	32.8	194.7	19.22	21.05	20.4	2.05	1.79	0.44	178.6	107.4	0.76
George 41	7102	10926	1229	15045	24157	78.5	28.7	19.70	769	26.4	29.9	179.3	16.72	17.12	18.9	1.67	1.48	0.30	159.3	97.7	0.64
George 42	6355	10806	1189	14075	24746	81.8	30.2	19.76	825	26.1	30.5	193.1	17.51	16.67	18.6	1.52	1.60	0.28	159.1	101.1	0.63
George 43	6459	10078	1044	13988	26555	71.6	28.7	18.37	770	24.4	30.7	196.4	17.48	14.73	18.0	1.98	1.73	0.33	152.6	110.7	0.71
George 44	6509	10870	1107	13718	25260	76.9	28.2	19.46	784	27.0	28.9	177.4	18.44	16.77	18.1	1.71	1.45	0.24	156.1	90.5	0.58
George 45	6086	10628	1088	13231	25196	64.8	28.3	18.77	761	25.2	31.1	192.4	18.45	15.89	16.9	2.02	1.69	0.40	157.9	91.8	0.67
George 46	6468	11850	1412	14117	23455	73.8	30.7	19.72	756	25.0	28.5	187.4	16.77	17.25	17.9	1.50	1.60	0.32	162.9	90.0	0.69
George 47	5662	11440	1274	12714	21572	76.8	28.9	19.55	774	24.7	28.0	158.2	14.29	17.15	18.1	1.42	1.36	0.24	164.2	74.5	0.71
George 48	4250	10256	1196	11690	18618	89.9	24.7	18.58	841	24.8	26.7	125.6	11.59	15.66	18.6	1.33	1.09	0.15	157.3	40.3	0.65
George 49	4260	10983	1382	11355	18814	102.1	24.5	19.26	810	24.8	26.3	127.5	10.92	17.11	18.8	1.24	1.22	0.18	157.2	42.4	0.72
George 50	5279	11720	1504	12704	23350	95.8	26.6	19.27	794	25.3	27.8	157.6	15.28	17.40	18.6	1.65	1.52	0.26	163.0	71.2	0.77
George 51	5270	10758	1235	12421	23543	79.2	27.3	16.93	720	22.7	26.0	153.0	16.39	15.63	17.2	1.68	1.47	0.23	146.3	71.0	0.65
George 52	5389	11011	1315	12380	24237	83.5	29.4	17.96	712	23.0	26.6	151.9	17.29	17.31	17.2	1.94	1.73	0.42	153.0	72.8	0.60
George 53	5328	10447	1155	11565	24633	62.9	29.7	17.21	700	22.3	26.9	136.5	17.18	17.05	15.8	1.62	1.27	0.37	154.7	68.1	0.52
George 54	5927	11731	1353	12297	25207	74.0	31.6	19.30	702	24.2	27.4	137.5	15.98	19.04	17.3	1.66	1.19	0.18	163.4	59.5	0.66
George 55	6169	11542	1227	12555	23458	70.6	29.6	18.86	685	24.3	26.4	131.4	14.49	17.78	16.6	1.47	1.22	0.17	167.6	51.6	0.68
George 56	5792	10855	1077	11827	22707	58.1	27.8	18.13	658	23.2	25.1	129.0	13.78	16.40	15.3	1.30	1.27	0.22	159.4	48.0	0.59

Hackert Lake Sediment Fact Sheet

Date Sampled:	27-Jul-04	**Sampling site water depth (m):**	15.5
County:	Mason	**Depth of Core (cm):**	57.5
Lake Area (sq. km):	0.5	**Watershed Area (sq. km):**	1.5
Sampling Site:	42° 58.964' N & 86° 19.745' W	**Focusing Factor:**	1.9

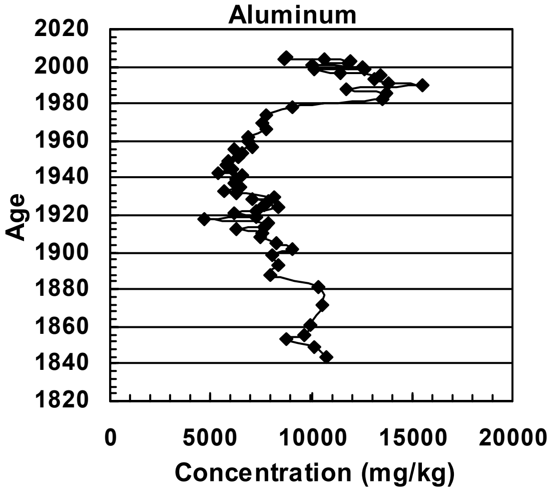
Total PCBs concentration in the surface sediment of Hackert Lake was low. PAHs and Total Pesticides concentrations were similar to other study lakes; although, concentrations had increased in recent years.

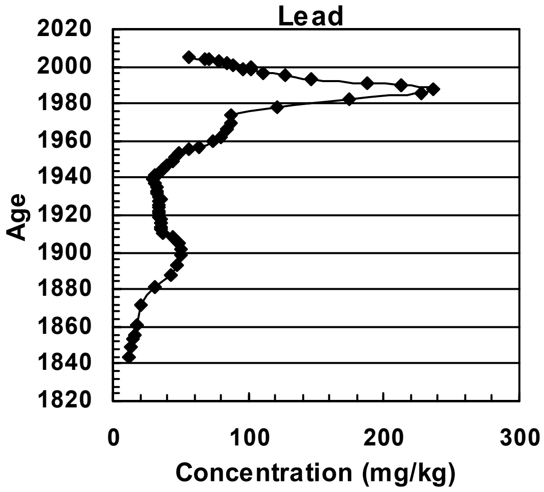
Over the last decade concentrations of cadmium, copper, lead and zinc had decreased. However, surface sediment concentrations of arsenic, copper, lead and zinc exceeded the TEC. Lead FCAAR indicate three distinct anthropogenic loading events.

	Surface Concentration	Background Concentration	Trend
Cadmium (mg/kg)	1.00	0.74	Decreasing
Copper (mg/kg)	45.4	13.0	Decreasing
Lead (mg/kg)	65.1	12.7	Decreasing
Zinc (mg/kg)	160.3	68.2	Decreasing
Total PAHs:	6037.5		Increasing
Total PCBs:	NA		Decreasing
Total Pesticides:	184.2		Increasing

NA indicates that the concentration could not be determined
Trends for organic contaminants are taken from only two data points and should be interpreted with care

Example Profiles





A Strategic Environmental Quality Monitoring Program for Michigan's Surface Waters: Sediments

Lake: Hackert **Water Depth (m):** 15.5

Sampling Date: 7/27/2004 **Latitude (N):** 43.9827 **Longitude (W):** -86.3291

Core Description: Alternating brown and black stratigraphic layers extend through top 10 cm of the core. Pink granules on surface covering approximately 5-10% of surface area.10-26 cm grainy blackish gray, 26-35 cm brownish gray color more homogenous in texture than above. 35-45 cm light gray. 2 cm black sediment material at 46 cm. at 46cm light gray transitions into brown sediment with gas pockets for remainder of the core. Top water has a nematode and smells of lake water.

Sample Number	Jar Number	Thickness (cm)	Total Thickness (cm)	Description
Hackert 1	1	0.5	0.5	very watery; black, brown, tan grains, snails
Hackert 2	2	0.5	1.0	very watery; more black grains, brown and tan still there
Hackert 3	3	0.5	1.5	very watery; more black grains, brown and tan still there
Hackert 4	4	0.5	2.0	watery; mixture of black brown, tan grains
Hackert 5	5	0.5	2.5	watery; mixture of black brown, tan grains
Hackert 6	6	0.5	3.0	watery; mixture of black brown, tan grains
Hackert 7	7	0.5	3.5	becoming less watery, more brown than black
Hackert 8	8	0.5	4.0	becoming less watery, more brown than black; snails (6-7)
Hackert 9	9	0.5	4.5	even less water; brownish black in color
Hackert 10	10	0.5	5.0	brownish black; 2-4 small snails
Hackert 11	11	0.5	5.5	brownish black, no snails
Hackert 12	12	0.5	6.0	brownish black, no snails
Hackert 13	13	0.5	6.5	brownish black, 2 snails
Hackert 14	14	0.5	7.0	brownish black grainy sediment
Hackert 15	15	0.5	7.5	brownish black grainy sediment
Hackert 16	16	0.5	8.0	brownish sediment with black strings
Hackert 17	17	1.0	9.0	brown with strings of black material
Hackert 18	18	1.0	10.0	brown with strings of black material
Hackert 19	19	1.0	11.0	brown with strings of black material
Hackert 20	20	1.0	12.0	brown with strings of black material
Hackert 21	21	1.0	13.0	brown with strings of black material
Hackert 22	22	1.0	14.0	dark brown with 1 mm black spec
Hackert 23	23	1.0	15.0	dark brown with 1 mm black spec; 2 slime molds
Hackert 24	24	1.0	16.0	dark brown with 1 mm black spec
Hackert 25	25	1.0	17.0	grayish brown with specs of black
Hackert 26	26	1.0	18.0	gray sediment specs of black
Hackert 27	27	1.0	19.0	gray sediment specs of black
Hackert 28	28	1.0	20.0	gray sediment specs of black
Hackert 29	29	1.0	21.0	gray sediment specs of black
Hackert 30	30	1.0	22.0	gray sediment specs of black
Hackert 31	31	1.0	23.0	gray sediment specs of black
Hackert 32	32	1.0	24.0	gray sediment specs of black
Hackert 33	33	1.0	25.0	gray sediment specs of black
Hackert 34	34	1.0	26.0	gray sediment specs of black

Sample Number	Jar Number	Thickness (cm)	Total Thickness (cm)	Description
Hackert 35	35	1.0	27.0	grayish thick sediment
Hackert 36	36	1.0	28.0	grayish thick sediment
Hackert 37	37	1.0	29.0	grayish thick sediment
Hackert 38	38	1.0	30.0	grayish thick sediment
Hackert 39	39	1.0	31.0	grayish thick sediment
Hackert 40	40	1.0	32.0	grayish thick sediment
Hackert 41	41	1.0	33.0	grayish thick sediment
Hackert 42	42	1.0	34.0	grayish thick sediment
Hackert 43	43	1.0	35.0	grayish thick sediment
Hackert 44	44	1.0	36.0	grayish thick sediment
Hackert 45	45	1.0	37.0	thick grayish sediment
Hackert 46	46	1.0	38.0	thick grayish sediment
Hackert 47	47	1.0	39.0	thick grayish sediment
Hackert 48	48	1.0	40.0	thick grayish sediment
Hackert 49	49	1.0	41.0	thick grayish sediment
Hackert 50	50	1.0	42.0	thick grayish sediment
Hackert 51	51	1.0	43.0	thick grayish sediment
Hackert 52	52	1.0	44.0	thick grayish sediment
Hackert 53	53	1.0	45.0	dark gray sediment
Hackert 54	54	1.0	46.0	dark gray sediment
Hackert 55	55	1.0	47.0	dark grayish brown sediment
Hackert 56	56	1.0	48.0	dark grayish brown sediment
Hackert 57	57	1.0	49.0	dark brown sediment, leaf litter
Hackert 58	58	1.0	50.0	dark brown sediment, leaf litter
Hackert 59	59	1.0	51.0	dark brown sediment, leaf litter
Hackert 60	60	1.0	52.0	dark brown sediment, leaf litter
Hackert 61	61	1.0	53.0	dark brown sediment, leaf litter
Hackert 62	62	1.0	54.0	dark brown sediment, leaf litter
Hackert 63	63	1.0	55.0	dark brown sediment, leaf litter
Hackert 64	64	1.0	56.0	dark brown sediment, leaf litter

210-Pb Analysis: Hackert Lake

Data provided by Paul Wilkinson, Freshwater Institute, Manitoba, Canada

Sample	Dry Weight (g)	Accumulated Dry Weight (g/sq. cm)	Porosity	Percent Water	Excess Pb-210 (Bq/g)	Activity Bq/g +/- 2SD Pb-210 +/- Error	Activity Bq/g +/- 2SD Cs-137 +/- Error
Hackert 1	0.08	0.0011	1.00	99.6	2.53E+00	2.56E+00 +/- 5.96E-02	0.00E+00 +/- 0.00E+00
Hackert 2	0.35	0.0061	1.00	98.8	3.12E+00	3.15E+00 +/- 4.16E-02	
Hackert 3	0.56	0.0140	0.99	98.4	2.16E+00	2.19E+00 +/- 3.25E-02	6.11E-02 +/- 1.46E-02
Hackert 4	0.74	0.0244	0.99	97.9	2.41E+00	2.45E+00 +/- 3.88E-02	
Hackert 5	0.86	0.0365	0.99	97.5	2.64E+00	2.68E+00 +/- 4.97E-02	1.03E-01 +/- 1.44E-02
Hackert 6	1.06	0.0515	0.99	97.0	2.10E+00	2.13E+00 +/- 3.19E-02	
Hackert 7	1.31	0.0700	0.99	96.8	1.75E+00	1.79E+00 +/- 3.36E-02	1.10E-01 +/- 8.89E-03
Hackert 8	1.22	0.0872	0.99	96.3	1.88E+00	1.92E+00 +/- 4.26E-02	
Hackert 9	1.49	0.1082	0.99	95.8	1.81E+00	1.84E+00 +/- 3.03E-02	1.22E-01 +/- 2.67E-03
Hackert 10	1.95	0.1357	0.98	95.3	1.64E+00	1.67E+00 +/- 2.90E-02	
Hackert 11	1.90	0.1625	0.98	94.8	1.51E+00	1.54E+00 +/- 3.59E-02	1.28E-01 +/- 7.76E-03
Hackert 12	2.18	0.1933	0.98	94.2	1.38E+00	1.42E+00 +/- 4.39E-02	
Hackert 13	2.10	0.2229	0.98	94.0	1.23E+00	1.26E+00 +/- 3.49E-02	1.49E-01 +/- 7.31E-03
Hackert 14	2.05	0.2518	0.98	93.8	1.16E+00	1.19E+00 +/- 3.31E-02	
Hackert 15	2.25	0.2836	0.98	93.3	1.26E+00	1.30E+00 +/- 2.44E-02	1.57E-01 +/- 7.55E-03
Hackert 16	2.31	0.3162	0.98	93.5	1.31E+00	1.35E+00 +/- 3.77E-02	
Hackert 17	4.65	0.3818	0.97	92.9	1.23E+00	1.26E+00 +/- 2.16E-02	1.76E-01 +/- 5.24E-03
Hackert 18	3.53	0.4316	0.97	92.9	9.35E-01	9.70E-01 +/- 1.60E-02	
Hackert 19	5.87	0.5144	0.97	92.2	8.05E-01	8.40E-01 +/- 1.67E-02	2.21E-01 +/- 3.22E-03
Hackert 20	6.02	0.5993	0.97	91.4	6.51E-01	6.86E-01 +/- 1.82E-02	2.83E-01 +/- 3.03E-03
Hackert 21	5.48	0.6766	0.97	91.1	4.20E-01	4.55E-01 +/- 9.83E-03	3.24E-01 +/- 5.50E-03
Hackert 22	6.54	0.7689	0.97	90.8	3.22E-01	3.57E-01 +/- 7.89E-03	2.03E-01 +/- 4.36E-03
Hackert 23	6.19	0.8562	0.96	90.3	2.18E-01	2.53E-01 +/- 6.90E-03	1.07E-01 +/- 3.96E-03
Hackert 24	6.62	0.9496	0.96	90.1	1.84E-01	2.19E-01 +/- 6.45E-03	
Hackert 25	6.76	1.0450	0.96	89.6	1.70E-01	2.05E-01 +/- 5.56E-03	4.88E-02 +/- 2.00E-03
Hackert 26	7.39	1.1493	0.96	89.6	1.40E-01	1.75E-01 +/- 5.61E-03	
Hackert 27	7.40	1.2537	0.96	88.9	1.12E-01	1.47E-01 +/- 5.53E-03	3.19E-02 +/- 1.88E-03
Hackert 28	8.31	1.3709	0.96	88.5	1.01E-01	1.36E-01 +/- 5.66E-03	
Hackert 29	8.25	1.4873	0.96	88.2	1.01E-01	1.36E-01 +/- 4.18E-03	2.11E-02 +/- 2.60E-03
Hackert 30	9.34	1.6191	0.95	87.8	8.41E-02	1.19E-01 +/- 3.86E-03	
Hackert 31	8.57	1.7400	0.95	87.5	8.12E-02	1.16E-01 +/- 5.76E-03	2.02E-02 +/- 2.78E-03
Hackert 32	9.25	1.8705	0.95	86.9	7.54E-02	1.10E-01 +/- 4.18E-03	
Hackert 33	9.89	2.0100	0.95	86.3	7.24E-02	1.07E-01 +/- 2.74E-03	1.84E-02 +/- 1.88E-03
Hackert 34	10.64	2.1601	0.95	85.7	6.04E-02	9.54E-02 +/- 3.22E-03	

Sample	Dry Weight (g)	Accumulated Dry Weight (g/sq. cm)	Porosity	Percent Water	Excess Pb-210 (Bq/g)	Activity Bq/g +/- 2SD Pb-210 +/- Error	Activity Bq/g +/- 2SD Cs-137 +/- Error
Hackert 35	10.63	2.3101	0.94	84.9	4.83E-02	8.33E-02 +/- 4.14E-03	1.18E-02 +/- 1.45E-03
Hackert 36	11.36	2.4704	0.94	84.7	3.32E-02	6.82E-02 +/- 2.99E-03	
Hackert 37	10.92	2.6244	0.94	84.6	3.33E-02	6.83E-02 +/- 3.49E-03	8.55E-03 +/- 2.06E-03
Hackert 38	11.48	2.7864	0.94	84.6	3.28E-02	6.78E-02 +/- 3.51E-03	
Hackert 39	11.46	2.9481	0.94	84.5	3.11E-02	6.61E-02 +/- 4.59E-03	6.68E-03 +/- 1.48E-03
Hackert 40	10.77	3.1000	0.94	85.0	3.24E-02	6.74E-02 +/- 4.09E-03	
Hackert 41	10.30	3.2453	0.95	85.8	2.92E-02	6.42E-02 +/- 3.30E-03	8.33E-03 +/- 2.87E-03
Hackert 42	9.46	3.3788	0.95	86.1	3.02E-02	6.52E-02 +/- 3.55E-03	
Hackert 43	9.99	3.5198	0.95	86.2	3.10E-02	6.60E-02 +/- 3.98E-03	2.79E-03 +/- 1.80E-03
Hackert 44	10.05	3.6615	0.95	86.1	2.99E-02	6.49E-02 +/- 4.28E-03	
Hackert 45	9.84	3.8004	0.95	86.0	2.68E-02	6.18E-02 +/- 3.76E-03	0.00E+00 +/- 0.00E+00
Hackert 46	9.94	3.9406	0.95	86.2	2.79E-02	6.29E-02 +/- 3.37E-03	
Hackert 47	9.15	4.0697	0.95	86.1	2.69E-02	6.19E-02 +/- 3.81E-03	
Hackert 48	10.23	4.2140	0.95	86.0	2.51E-02	6.01E-02 +/- 3.19E-03	
Hackert 49	9.71	4.3510	0.95	86.5	2.96E-02	6.46E-02 +/- 2.62E-03	
Hackert 50	9.49	4.4849	0.95	86.5	3.29E-02	6.79E-02 +/- 2.86E-03	
Hackert 51	9.63	4.6208	0.95	86.5	3.13E-02	6.63E-02 +/- 3.91E-03	
Hackert 52	9.62	4.7565	0.95	86.5	3.04E-02	6.54E-02 +/- 3.34E-03	
Hackert 53	8.07	4.8703	0.96	88.2	4.24E-02	7.74E-02 +/- 3.53E-03	
Hackert 54	7.44	4.9753	0.96	89.4	5.44E-02	8.94E-02 +/- 3.49E-03	
Hackert 55	7.16	5.0763	0.96	89.4	4.93E-02	8.43E-02 +/- 3.64E-03	
Hackert 56	7.16	5.1773	0.96	89.9	5.36E-02	8.86E-02 +/- 3.60E-03	
Hackert 57	6.93	5.2751	0.96	89.5	5.73E-02	9.23E-02 +/- 3.57E-03	
Hackert 58	7.03	5.3743	0.96	89.4	6.33E-02	9.83E-02 +/- 4.11E-03	
Hackert 59	6.18	5.4615	0.97	90.8	4.03E-02	7.53E-02 +/- 3.79E-03	
Hackert 60	4.66	5.5272	0.97	93.0	1.33E-02	4.83E-02 +/- 3.09E-03	
Hackert 61	4.35	5.5886	0.98	93.1		3.56E-02 +/- 2.49E-03	
Hackert 62	5.31	5.6635	0.97	92.6		3.40E-02 +/- 2.37E-03	
Hackert 63	5.04	5.7346	0.97	92.8		3.87E-02 +/- 2.70E-03	
Hackert 64	4.87	5.8033	0.97	92.7		4.35E-02 +/- 2.96E-03	

Metal Concentration in the Sediment: Hackert Lake

Concentration in mg/kg dry weight

Sample	Mg	Al	K	Ca	Fe	Ti	V	Cr	Mn	Ni	Cu	Zn	As	Rb	Sr	Mo	Cd	Sn	Ba	Pb	U
Hackert 1	7671	8805	2364	23321	15770	104.9	18.0	12.60	278	15.4	44.4	143.5	8.70	13.50	17.1	3.00	0.90	0.70	107.6	56.5	1.60
Hackert 2	6296	8661	1703	20266	13436	110.5	20.7	13.70	273	11.0	44.9	157.2	11.20	15.10	19.1	2.70	1.10	0.50	119.1	67.3	1.80
Hackert 3	7861	10644	1923	29239	17110	108.4	19.4	13.50	268	10.9	46.9	180.3	12.10	14.70	20.1	3.00	1.00	0.40	127.7	71.5	1.90
Hackert 4	7995	11922	2087	31103	18849	148.4	21.4	15.20	275	12.4	51.3	153.4	12.70	16.60	21.4	3.00	1.10	0.60	82.5	77.8	1.90
Hackert 5	7812	11881	1851	28496	19422	116.2	21.3	14.90	275	12.9	53.1	149.4	12.40	15.70	18.0	2.70	1.10	0.50	76.2	83.8	1.90
Hackert 6	7230	10002	1461	29445	19628	78.1	21.3	14.40	274	12.7	51.9	152.6	12.50	13.50	17.4	2.50	1.10	0.40	69.1	88.8	1.90
Hackert 7	8002	12499	1851	39932	22694	113.7	25.8	16.90	297	15.7	54.8	179.9	14.30	16.00	22.0	2.60	1.20	0.50	75.3	101.8	2.10
Hackert 8	7955	12650	1927	46783	21069	135.0	26.0	17.20	312	15.5	55.6	182.4	13.20	17.00	25.0	2.50	1.20	0.50	75.1	96.0	2.00
Hackert 9	6333	10105	1458	38933	18016	117.3	26.5	17.60	319	16.5	62.8	177.4	13.60	16.70	25.2	2.30	1.30	0.50	76.8	101.7	2.00
Hackert 10	7725	11489	1560	47224	22629	89.6	26.7	16.80	314	17.6	62.1	181.9	13.80	15.10	24.3	2.70	1.30	0.40	73.4	110.1	1.90
Hackert 11	8318	13477	1843	52315	25549	122.2	28.9	18.80	325	17.6	66.9	188.4	15.30	16.90	25.4	2.10	1.30	0.50	76.2	126.7	1.90
Hackert 12	7938	13085	1779	51268	24774	125.7	29.7	19.40	331	18.6	71.2	205.6	15.80	17.30	26.5	2.00	1.40	0.40	78.4	145.7	1.80
Hackert 13	8911	13864	1893	58921	27526	104.9	29.1	19.70	334	20.0	84.4	211.3	17.30	16.80	26.7	2.00	1.60	0.40	80.3	188.4	1.70
Hackert 14	9132	15486	1980	58019	26530	121.1	29.5	20.40	322	20.6	89.1	251.8	17.20	17.80	27.5	2.20	1.80	0.40	87.8	212.6	1.70
Hackert 15	7597	11777	1434	41831	22326	94.7	27.9	20.50	310	21.5	75.1	243.7	18.20	17.00	24.3	2.30	2.10	0.50	83.1	236.9	1.70
Hackert 16	9031	13702	1754	58785	25066	106.5	27.9	21.20	319	23.2	66.1	246.2	17.40	17.80	28.4	2.10	2.00	0.40	86.6	227.0	1.60
Hackert 17	9255	13550	1870	92881	23287	127.1	26.4	21.20	337	22.2	49.9	210.0	15.40	17.30	39.7	1.70	1.60	0.40	86.0	174.5	1.40
Hackert 18	8214	9103	1233	143242	17552	102.6	21.0	14.50	362	13.5	25.3	176.2	13.10	12.20	56.4	1.30	1.40	0.40	79.2	120.8	1.00
Hackert 19	8348	7731	1400	173577	14912	78.5	17.3	12.10	358	11.7	19.9	129.4	11.10	10.00	60.2	1.00	1.20	0.30	71.1	87.6	0.80
Hackert 20	7198	7590	973	150223	12823	96.2	18.2	12.70	358	12.1	19.5	171.6	11.00	11.40	62.2	1.00	1.30	0.40	77.6	86.8	0.80
Hackert 21	8076	7799	1015	178001	13400	83.0	16.9	11.80	362	11.5	17.5	125.1	10.50	10.50	64.7	1.00	1.30	0.30	75.9	84.0	0.70
Hackert 22	7720	6854	823	175823	12229	63.0	15.6	10.80	353	10.8	16.3	119.5	9.80	9.30	64.6	0.90	1.20	0.30	74.0	79.2	0.70
Hackert 23	7076	6862	827	160042	10901	91.3	16.7	11.60	353	11.0	15.9	120.2	10.50	10.80	67.6	1.00	1.30	0.40	78.4	73.8	0.70
Hackert 24	7687	7047	1037	183113	11578	74.9	15.5	10.70	350	10.4	15.3	115.6	9.90	10.00	67.3	1.00	1.20	0.20	85.5	63.8	0.70
Hackert 25	7740	6198	677	186104	10903	50.0	14.2	9.90	336	12.0	15.4	523.3	9.30	8.60	69.5	0.90	1.20	0.30	184.6	55.5	0.70
Hackert 26	7592	6613	707	188852	10704	53.9	14.4	10.00	339	9.9	13.6	103.0	9.30	9.20	67.5	0.90	1.10	0.20	80.6	49.3	0.70
Hackert 27	7705	6359	690	196432	10326	48.5	13.8	9.50	340	9.6	13.3	85.8	8.40	8.60	69.0	0.80	1.10	0.30	79.3	46.1	0.70
Hackert 28	7645	5879	632	201545	9759	41.8	13.3	9.10	338	9.2	12.8	84.7	8.20	8.30	71.4	0.80	1.10	0.20	82.0	43.8	0.70
Hackert 29	7514	5774	571	200339	8904	40.5	12.5	8.70	330	8.5	11.6	79.6	7.30	8.00	71.5	0.80	1.00	0.20	81.9	40.0	0.60

Metal Concentration in the Sediment: Hackert Lake

Concentration in mg/kg dry weight

Sample	Mg	Al	K	Ca	Fe	Ti	V	Cr	Mn	Ni	Cu	Zn	As	Rb	Sr	Mo	Cd	Sn	Ba	Pb	U
Hackert 30	7523	6043	628	204944	8962	45.5	12.4	8.80	330	8.7	11.5	73.9	7.00	8.50	72.0	0.70	0.90	0.20	82.6	36.5	0.60
Hackert 31	7280	5369	511	205332	8368	35.7	11.5	8.10	323	8.2	11.0	72.0	6.30	7.80	72.3	0.70	0.90	0.20	84.6	33.3	0.60
Hackert 32	7211	6524	696	198094	8613	62.7	12.7	9.20	313	9.3	11.2	91.1	6.60	9.60	70.8	0.70	0.90	0.20	90.4	31.7	0.60
Hackert 33	7240	6256	651	203080	8380	61.2	13.9	9.90	342	10.0	11.6	93.3	6.90	9.40	72.6	0.70	0.90	0.20	83.8	30.2	0.60
Hackert 34	8412	6185	768	235117	9232	32.4	11.6	8.40	318	9.6	9.6	100.5	7.20	7.90	75.0	0.70	0.90	0.20	87.6	31.5	0.60
Hackert 35	8526	6506	814	234873	9443	33.8	11.5	8.10	308	11.0	11.0	67.6	5.60	8.10	71.8	0.70	0.90	0.20	85.9	32.0	0.60
Hackert 36	7223	5685	559	204262	8021	33.0	11.6	8.30	303	11.2	11.2	68.3	5.50	8.10	71.0	0.70	0.90	0.10	85.9	32.0	0.60
Hackert 37	6908	6242	592	186793	8632	38.8	12.4	8.90	287	11.7	11.7	87.2	6.00	8.80	66.4	0.70	0.90	0.10	87.9	33.1	0.70
Hackert 38	6920	8147	923	176542	10208	71.8	14.0	10.10	270	11.1	11.1	79.1	6.80	11.40	61.4	0.80	1.00	0.10	89.6	33.8	0.80
Hackert 39	6860	7017	718	175573	9600	37.9	12.3	8.90	258	10.9	10.9	68.6	6.10	9.50	59.1	0.70	1.00	0.10	88.2	35.1	0.80
Hackert 40	6477	7892	888	163254	9478	69.7	14.1	10.20	262	11.5	11.5	74.5	6.90	11.50	59.4	0.70	1.00	0.10	89.9	34.5	0.70
Hackert 41	6688	7708	805	170673	9400	61.7	13.3	9.70	262	11.1	11.1	68.3	6.40	10.90	60.6	0.70	1.00	0.10	89.5	34.0	0.70
Hackert 42	6994	8349	992	177439	9961	95.8	13.5	9.80	259	11.0	11.0	68.0	6.40	11.10	60.5	0.70	1.00	0.20	91.8	34.5	0.70
Hackert 43	6704	7285	724	172410	9091	50.7	13.0	9.50	258	11.1	11.1	71.4	6.10	10.00	59.4	0.70	1.00	0.10	88.4	34.1	0.60
Hackert 44	6400	6193	574	169037	8285	32.7	11.6	8.40	250	10.7	10.7	67.9	5.50	8.50	58.0	0.60	1.00	0.10	85.1	33.7	0.60
Hackert 45	6731	7271	746	174717	8967	47.7	12.3	8.90	244	10.6	10.6	67.0	5.70	9.70	58.6	0.60	1.00	0.10	87.1	33.9	0.60
Hackert 46	4656	4720	421	121729	6207	36.3	11.7	8.40	241	10.5	10.5	70.0	5.60	8.80	57.1	0.60	1.00	0.10	86.0	34.8	0.60
Hackert 47	6641	7817	848	167188	9423	55.6	12.9	9.30	236	11.2	11.2	73.1	5.90	10.30	56.5	0.70	1.00	0.10	87.7	35.7	0.60
Hackert 48	6826	7667	802	172398	9249	51.1	12.9	9.40	242	11.2	11.2	70.4	5.70	10.00	57.9	0.60	1.00	0.10	87.8	35.1	0.60
Hackert 49	6318	6221	519	165118	8288	28.6	11.7	8.30	235	10.8	10.8	75.5	4.70	8.10	56.2	0.60	1.00	0.20	83.8	35.7	0.60
Hackert 50	6334	7536	747	158745	8991	48.7	12.9	9.30	232	11.1	11.1	74.9	5.70	10.10	55.4	0.70	1.00	0.20	86.6	37.2	0.60
Hackert 51	5481	7465	670	127943	9377	36.3	12.5	8.40	194	11.0	11.0	142.1	5.80	9.30	45.8	0.80	1.10	0.10	84.0	45.0	0.70
Hackert 52	5226	8222	743	111932	10278	37.0	12.8	8.50	179	11.4	11.4	78.3	6.50	9.60	38.3	0.90	1.10	0.10	82.3	49.4	0.80
Hackert 53	5279	9018	915	110923	10719	55.9	14.1	9.30	184	11.6	11.6	80.5	6.70	10.80	38.2	1.00	1.10	0.10	83.1	49.8	0.80
Hackert 54	4992	8032	884	103575	10227	31.5	13.0	8.50	176	12.0	12.0	81.6	6.20	8.70	35.3	1.00	1.10	0.10	77.4	50.0	0.80
Hackert 55	5334	8334	755	115704	9969	39.2	13.2	8.80	180	11.2	11.2	76.7	6.00	9.70	38.9	0.90	1.10	0.10	78.7	47.1	0.70
Hackert 56	4751	7924	696	97523	9362	25.1	12.3	7.90	162	11.5	11.5	75.3	4.70	8.30	31.9	1.10	1.10	0.10	78.2	43.2	0.80
Hackert 57	3572	10302	978	49821	10102	55.8	14.1	8.40	129	12.4	12.4	80.0	4.20	9.80	18.8	1.80	0.90	0.00	92.9	30.8	1.10
Hackert 58	3107	10548	1072	40013	9114	69.4	14.4	8.50	120	12.2	12.2	73.7	3.70	9.40	15.7	1.70	0.80	0.10	101.0	21.0	1.20
Hackert 59	2785	9904	876	29457	8682	51.2	14.2	8.10	116	12.4	12.4	78.7	3.00	8.40	12.8	1.60	0.70	0.10	104.1	17.8	1.30
Hackert 60	2733	9658	787	29696	8453	38.6	14.4	7.90	115	11.9	11.9	88.7	2.70	7.70	12.3	1.50	0.70	0.00	101.7	16.1	1.30

Metal Concentration in the Sediment: Hackert Lake

Concentration in mg/kg dry weight

Sample	Mg	Al	K	Ca	Fe	Ti	V	Cr	Mn	Ni	Cu	Zn	As	Rb	Sr	Mo	Cd	Sn	Ba	Pb	U
Hackert 61	2379	8716	683	25710	7634	40.3	16.3	8.50	119	12.4	12.4	85.6	2.80	7.90	12.9	1.40	0.70	0.10	108.6	15.4	1.30
Hackert 62	2559	10184	725	28221	8975	42.7	16.3	8.50	121	12.8	12.8	68.7	2.60	7.20	13.1	1.50	0.70	0.10	128.6	13.6	1.40
Hackert 63	2461	10782	879	21385	9137	54.9	19.5	9.40	116	13.1	13.1	67.7	2.90	8.40	10.7	1.60	0.80	0.10	109.7	11.7	1.50

Metal Concentration in the Porewater: Hackert Lake

Concentration in ng/mL, 0.0 Depth is the topwater sample

Sample	Depth	Mg	K	Ca	Mn	Fe	P	V	Cr	Ni	Cu	Zn	As	Rb	Sr	Mo	Cd	Ba	Pb	U	B	Al
Hackert 0	0.0	17257.6	1241.1	33966	431.8	38.9	93.7	0.23	0.12	0.79	0.17	342.9	1.86	1.13	39.7	0.10	0.03	17.2	0.1	0.12	18.08	2.4
Hackert 1	0.5	16714.6	1617.8	40593	546.4	89.9	236.9	1.26	0.13	0.82	0.92	281.6	6.24	1.15	42.3	1.00	0.03	30.4	0.3	0.22	21.63	6.1
Hackert 2	1.5	18218.2	2301.6	78607	765.8	664.2	1488.6	1.13	0.15	1.94	0.51	99.7	5.19	1.87	65.5	0.21	0.03	43.9	0.3	0.06	33.76	14.0
Hackert 3	2.5	17041.5	1977.3	60350	693.9	173.7	1107.8	1.63	0.17	0.63	0.80	200.0	7.67	1.60	54.7	0.48	0.03	40.8	0.6	0.16	36.69	16.7
Hackert 4	3.5	17689.8	2374.6	84231	753.9	1366.8	1743.0	1.21	0.14	0.59	0.46	142.5	3.05	2.09	71.1	0.19	0.03	49.3	0.3	0.05	38.35	13.7
Hackert 5	4.5	17884.3	2290.6	81674	764.4	907.3	1603.1	1.20	0.15	0.86	0.61	98.5	3.90	2.03	68.3	0.19	0.03	46.9	0.4	0.05	37.79	13.9
Hackert 6	5.5	17179.8	2415.9	87235	727.6	2133.4	1859.6	1.09	0.19	0.88	0.71	164.8	3.00	2.24	72.4	0.18	0.03	51.4	0.6	0.04	38.04	27.8
Hackert 7	6.5	16993.7	2018.1	66590	710.4	318.4	1243.9	1.29	0.18	0.47	0.52	183.6	6.93	1.63	56.7	0.35	0.03	35.1	0.5	0.09	32.55	13.7
Hackert 8	7.5	16541.1	1653.2	47394	589.1	71.6	646.4	1.23	0.12	1.28	1.04	175.7	6.35	1.39	46.4	0.63	0.03	30.6	0.4	0.18	29.36	11.6
Hackert 9	8.5	17106.8	1822.6	54386	679.1	89.4	1011.1	1.22	0.18	0.37	0.70	194.3	5.51	1.49	51.2	0.43	0.03	39.6	0.6	0.18	31.65	21.8
Hackert 10	9.5	16301.0	1833.3	57787	630.3	145.7	1041.1	1.45	0.14	0.48	0.82	167.0	7.14	1.54	52.0	0.46	0.03	33.1	0.7	0.14	32.10	28.7
Hackert 11	10.5	15933.7	2221.9	84272	675.1	2317.7	1509.2	1.13	0.17	0.69	0.68	305.0	3.11	2.12	69.9	0.23	0.03	39.0	0.7	0.06	33.48	29.7
Hackert 12	12.5	16229.8	1659.3	52858	457.4	86.5	816.4	1.06	0.14	0.98	0.98	106.1	8.34	1.45	49.2	0.53	0.03	29.8	0.5	0.17	31.55	15.6
Hackert 13	14.5	17063.9	2179.8	82912	707.3	1192.5	1370.8	1.04	0.14	0.47	0.51	131.7	3.73	2.03	66.1	0.20	0.03	42.4	0.5	0.05	34.96	24.3
Hackert 14	16.5	17090.4	1696.2	49963	708.1	52.2	1023.8	1.04	0.18	0.18	0.57	152.2	2.45	1.51	49.4	0.23	0.03	33.7	0.3	0.08	30.63	13.3
Hackert 15	18.5	18023.1	2037.5	74080	769.1	541.0	1591.1	1.05	0.16	7.67	0.71	82.7	4.93	1.92	65.1	0.21	0.03	40.8	0.5	0.06	35.21	14.1
Hackert 16	20.5	16501.3	2204.6	85692	692.8	1737.9	1516.3	1.34	0.18	1.38	0.63	283.7	3.30	2.31	72.5	0.23	0.03	42.5	0.5	0.06	35.86	23.2
Hackert 17	22.5	16943.3	1724.5	55511	683.7	92.9	1102.2	1.34	0.26	0.61	0.74	216.0	5.58	1.59	51.7	0.41	0.03	38.0	0.6	0.19	32.96	25.2
Hackert 18	24.5	16280.8	1505.8	44119	652.3	79.1	716.9	0.88	0.15	1.98	1.08	116.7	3.31	1.41	46.0	0.35	0.03	32.1	0.6	0.11	28.08	12.4
Hackert 19	26.5	16759.8	2170.5	86068	702.2	1921.8	1761.0	1.24	0.14	0.96	0.61	192.1	3.06	2.38	75.8	0.17	0.03	46.5	0.4	0.05	36.59	20.2
Hackert 20	28.5	17518.4	1942.9	75880	732.5	511.9	1445.4	1.19	0.13	0.96	0.59	162.2	4.55	1.99	65.5	0.21	0.03	38.6	0.3	0.06	35.95	13.5
Hackert 21	30.5	17687.4	2036.1	80962	751.5	782.8	1571.1	1.17	0.15	2.96	1.11	89.0	3.17	2.10	68.8	0.19	0.03	43.5	0.6	0.06	36.10	16.4
Hackert 22	32.5	17774.3	2074.9	84128	739.0	957.4	1515.2	1.48	0.12	0.96	0.39	316.3	3.35	2.21	71.5	0.22	0.03	41.7	0.2	0.08	37.22	12.3
Hackert 23	34.5	15473.3	1947.5	82821	658.6	2195.6	1488.3	1.11	0.18	1.49	1.02	279.6	2.40	2.15	71.0	0.22	0.03	38.0	0.7	0.05	33.81	32.0
Hackert 24	36.5	16463.3	1530.1	52558	612.3	66.9	848.5	1.32	0.13	1.42	1.36	254.5	8.32	1.56	49.6	0.56	0.03	29.0	0.5	0.19	31.49	15.7
Hackert 25	38.5	16881.8	2032.7	82704	702.9	985.2	1396.3	1.35	0.17	1.08	0.77	349.3	3.47	2.23	69.9	0.21	0.03	41.7	0.6	0.06	36.46	17.8
Hackert 26	40.5	16043.3	2077.8	84052	678.1	2089.1	1538.4	1.08	0.16	0.95	0.64	313.9	3.04	2.23	69.5	0.19	0.03	37.1	0.5	0.05	34.81	18.6
Hackert 27	42.5	17014.5	2115.3	85950	721.6	1600.3	1645.8	1.25	0.15	1.01	0.65	213.9	3.21	2.32	71.8	0.20	0.03	42.3	0.4	0.06	36.95	18.7
Hackert 28	44.5	14560.7	1860.6	77457	616.1	1990.8	1356.4	1.04	0.24	1.41	1.39	300.5	2.42	2.07	67.1	0.23	0.04	38.0	1.0	0.05	31.30	41.6

MICHIGAN STATE UNIVERSITY

Otter Lake Sediment Fact Sheet

Date Sampled: 14-Jul-04

County: Genesee, Lapeer, Tuscola

Lake Area (sq. km): 0.3

Sampling Site: 43º 12.982' N & 83º 27.500' W

Sampling site water depth (m): 36.9

Depth of Core (cm): 57.5

Watershed Area (sq. km): 3.4

Focusing Factor: 3.5

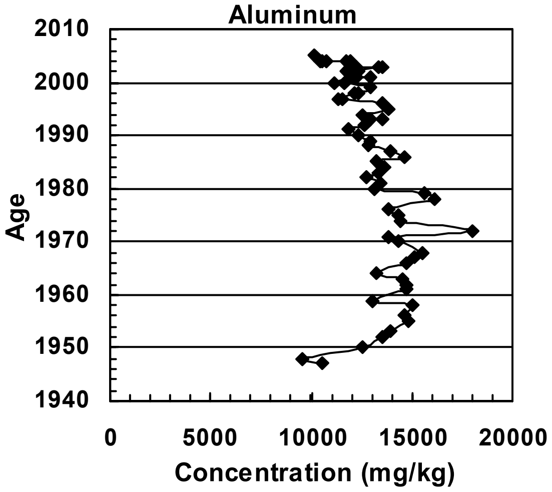
Sediment concentrations of PAHs, PCBs and Total pesticides were amongst the highest in Otter Lake when compared to all of the lakes studied in Michigan. Concentrations of PAHs, PCBs and Total Pesticides were greatest in the surface sediment.

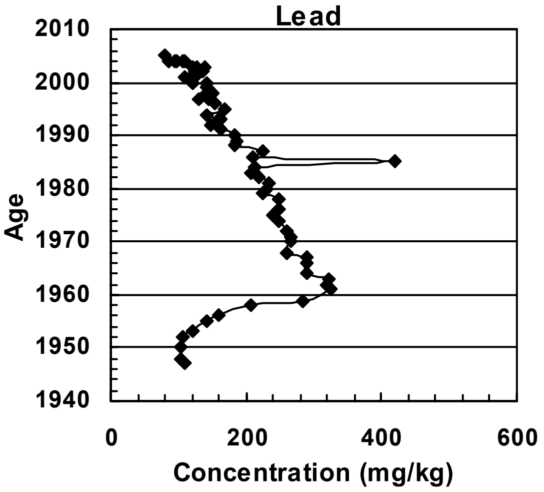
The arsenic surface concentration exceeded the PEC in Otter Lake. Cadmium, copper, lead and zinc surface sediment concentrations exceeded the TEC. Copper concentrations had increased over the last decade.

	Surface Concentration	Background Concentration	Trend
Cadmium (mg/kg)	1.28	NA	Decreasing
Copper (mg/kg)	54.2	NA	Increasing
Lead (mg/kg)	85.3	NA	Decreasing
Zinc (mg/kg)	207.0	NA	Decreasing
Total PAHs:	3323.0		Increasing
Total PCBs:	43.9		Increasing
Total Pesticides:	225.4		Increasing

NA indicates that the concentration could not be determined
Trends for organic contaminants are taken from only two data points and should be interpreted with care

Example Profiles





A Strategic Environmental Quality Monitoring Program for Michigan's Surface Waters: Sediments

Lake: Otter **Water Depth (m):** 36.9

Sampling Date: 7/14/2004 **Latitude (N):** 43.2164 **Longitude (W):** -83.4583

Core Description: lighter brown/tan with orange grains at sediment water interface. lighter color persists for top 3 cm, color is blackish gray for remaining length of core. Gas pockets visible ranging from 3-4 mm in diameter throuhgout the bottom 50 cm of the core.

Sample Number	Jar Number	Thickness (cm)	Total Thickness (cm)	Description
Otter 1	1	0.5	0.5	watery black (org), tan, orange grain
Otter 2	2	0.5	1.0	watery black (org), tan, orange grain
Otter 3	3	0.5	1.5	watery black organics dark brown and tan
Otter 4	4	0.5	2.0	watery, more black organics than brown/tan grains
Otter 5	5	0.5	2.5	watery, more black organics than brown/tan grains
Otter 6	6	0.5	3.0	becoming more solid, gray, black, tan grains
Otter 7	7	0.5	3.5	brownish and black color sediment
Otter 8	8	0.5	4.0	dark brown sediment with high organics
Otter 9	9	0.5	4.5	dark brown sediment with high organics
Otter 10	10	0.5	5.0	dark brown sediment with high organics
Otter 11	11	0.5	5.5	dark brown sediment with high organics
Otter 12	12	0.5	6.0	dark brown sediment with high organics
Otter 13	13	0.5	6.5	dark brown/black, consistent texture
Otter 14	14	0.5	7.0	dark brown/black, consistent texture
Otter 15	15	0.5	7.5	dark brown/black, consistent texture
Otter 16	16	0.5	8.0	dark brown/black, consistent texture
Otter 17	17	1.0	9.0	gdark black/olive, consistent texture
Otter 18	18	1.0	10.0	gdark black/olive, consistent texture
Otter 19	19	1.0	11.0	gdark black/olive, consistent texture
Otter 20	20	1.0	12.0	gdark black/olive, consistent texture
Otter 21	21	1.0	13.0	gdark black/olive, consistent texture
Otter 22	22	1.0	14.0	dark black/olive/brown, leaf
Otter 23	23	1.0	15.0	dark black/olive/brown
Otter 24	24	1.0	16.0	dark black/olive/brown, leaf
Otter 25	25	1.0	17.0	black/olive/brown, worms, filaments
Otter 26	26	1.0	18.0	black/olive/brown
Otter 27	27	1.0	19.0	black/olive/brown
Otter 28	28	1.0	20.0	black/olive/brown
Otter 29	29	1.0	21.0	black/olive/brown
Otter 30	30	1.0	22.0	black/olive/brown
Otter 31	31	1.0	23.0	dark olive/brown some black
Otter 32	32	1.0	24.0	dark olive/brown some black
Otter 33	33	1.0	25.0	dark olive/brown some black
Otter 34	34	1.0	26.0	dark olive/brown some black

Sample Number	Jar Number	Thickness (cm)	Total Thickness (cm)	Description
Otter 35	35	1.0	27.0	dark olive/brown some black, stem
Otter 36	36	1.0	28.0	dark olive/brown some black, stem
Otter 37	37	1.0	29.0	dark olive/brown some black, stem
Otter 38	38	1.0	30.0	dark brown, olive, smooth texture
Otter 39	39	1.0	31.0	dark brown, olive, smooth texture
Otter 40	40	1.0	32.0	dark brown, olive, smooth texture
Otter 41	41	1.0	33.0	dark brown, olive, smooth texture
Otter 42	42	1.0	34.0	dark brown, olive, smooth texture
Otter 43	43	1.0	35.0	dark brown, olive, smooth texture
Otter 44	44	1.0	36.0	dark brown, olive, smooth texture
Otter 45	45	1.0	37.0	dark brown, olive, smooth texture
Otter 46	46	1.0	38.0	dark brown, olive, smooth texture
Otter 47	47	1.0	39.0	dark brown/grayish smooth texture
Otter 48	48	1.0	40.0	dark brown/grayish smooth texture
Otter 49	49	1.0	41.0	grayish black
Otter 50	50	1.0	42.0	grayish black
Otter 51	51	1.0	43.0	grayish black
Otter 52	52	1.0	44.0	grayish black
Otter 53	53	1.0	45.0	grayish black, single filament 10-11 cm
Otter 54	54	1.0	46.0	grayish black
Otter 55	55	1.0	47.0	grayish black
Otter 56	56	1.0	48.0	grayish black, stem

210-Pb Analysis: Otter Lake

Data provided by Paul Wilkinson, Freshwater Institute, Manitoba, Canada

Sample	Dry Weight (g)	Accumulated Dry Weight (g/sq. cm)	Porosity	Percent Water	Excess Pb-210 (Bq/g)	Activity Bq/g +/- 2SD Pb-210 +/- Error	Activity Bq/g +/- 2SD Cs-137 +/- Error
Otter 1	0.57	0.0080	0.99	98.1	9.34E-01	9.84E-01 +/- 2.14E-02	8.10E-02 +/- 2.11E-02
Otter 2	1.07	0.0231	0.99	96.6	1.01E+00	1.06E+00 +/- 1.76E-02	
Otter 3	1.36	0.0423	0.99	95.9	7.72E-01	8.22E-01 +/- 1.71E-02	4.38E-02 +/- 6.83E-03
Otter 4	1.54	0.0641	0.98	95.4	9.57E-01	1.01E+00 +/- 2.15E-02	
Otter 5	1.81	0.0896	0.98	93.8	4.68E-01	5.18E-01 +/- 1.40E-02	5.86E-02 +/- 7.44E-03
Otter 6	1.46	0.1102	0.98	95.0	6.11E-01	6.61E-01 +/- 1.41E-02	
Otter 7	1.46	0.1308	0.98	94.5	5.91E-01	6.41E-01 +/- 1.45E-02	6.60E-02 +/- 8.51E-03
Otter 8	2.53	0.1665	0.98	93.5	3.33E-01	3.83E-01 +/- 1.43E-02	
Otter 9	1.93	0.1937	0.98	93.4	4.99E-01	5.49E-01 +/- 1.24E-02	6.52E-02 +/- 8.20E-03
Otter 10	2.27	0.2257	0.98	93.2	8.23E-01	8.73E-01 +/- 1.97E-02	
Otter 11	2.02	0.2542	0.98	93.9	1.02E+00	1.07E+00 +/- 2.48E-02	7.40E-02 +/- 4.95E-03
Otter 12	1.97	0.2820	0.98	93.7	8.00E-01	8.50E-01 +/- 2.33E-02	
Otter 13	1.83	0.3078	0.98	93.7	9.21E-01	9.71E-01 +/- 2.17E-02	6.87E-02 +/- 8.05E-03
Otter 14	2.33	0.3407	0.97	93.0	5.45E-01	5.95E-01 +/- 2.05E-02	
Otter 15	2.28	0.3729	0.97	91.8	6.05E-01	6.55E-01 +/- 1.41E-02	5.68E-02 +/- 6.08E-03
Otter 16	2.25	0.4046	0.97	92.4	8.08E-01	8.58E-01 +/- 2.18E-02	
Otter 17	4.66	0.4704	0.97	92.5	7.11E-01	7.61E-01 +/- 1.54E-02	7.29E-02 +/- 4.47E-03
Otter 18	4.97	0.5405	0.97	92.8	7.94E-01	8.44E-01 +/- 1.55E-02	
Otter 19	4.59	0.6052	0.97	92.7	7.13E-01	7.63E-01 +/- 1.65E-02	8.00E-02 +/- 4.55E-03
Otter 20	3.86	0.6597	0.97	92.9	7.71E-01	8.21E-01 +/- 1.53E-02	
Otter 21	4.27	0.7199	0.98	93.2	6.94E-01	7.44E-01 +/- 1.51E-02	7.72E-02 +/- 2.83E-03
Otter 22	4.33	0.7810	0.98	93.4	5.90E-01	6.40E-01 +/- 1.21E-02	
Otter 23	4.47	0.8441	0.97	92.5	5.38E-01	5.88E-01 +/- 1.38E-02	7.63E-02 +/- 4.84E-03
Otter 24	5.03	0.9151	0.97	91.7	5.30E-01	5.80E-01 +/- 1.64E-02	
Otter 25	5.52	0.9929	0.97	91.2	3.80E-01	4.30E-01 +/- 9.68E-03	8.56E-02 +/- 4.43E-03
Otter 26	6.30	1.0818	0.97	91.6	3.57E-01	4.07E-01 +/- 8.75E-03	
Otter 27	5.58	1.1606	0.97	91.4	3.60E-01	4.10E-01 +/- 9.59E-03	8.80E-02 +/- 4.81E-03
Otter 28	5.30	1.2353	0.97	91.8	3.97E-01	4.47E-01 +/- 1.07E-02	
Otter 29	4.47	1.2984	0.97	92.1	4.99E-01	5.49E-01 +/- 1.62E-02	8.70E-02 +/- 2.71E-03
Otter 30	5.92	1.3819	0.97	91.4	3.84E-01	4.34E-01 +/- 1.20E-02	
Otter 31	6.03	1.4670	0.96	89.9	3.37E-01	3.87E-01 +/- 9.33E-03	1.05E-01 +/- 1.99E-03
Otter 32	5.99	1.5515	0.97	90.6	3.24E-01	3.74E-01 +/- 1.13E-02	
Otter 33	6.47	1.6428	0.96	90.0	3.86E-01	4.36E-01 +/- 7.34E-03	1.01E-01 +/- 4.60E-03
Otter 34	7.02	1.7418	0.96	90.0	4.11E-01	4.61E-01 +/- 1.09E-02	

Sample	Dry Weight (g)	Accumulated Dry Weight (g/sq. cm)	Porosity	Percent Water	Excess Pb-210 (Bq/g)	Activity Bq/g +/- 2SD Pb-210 +/- Error	Activity Bq/g +/- 2SD Cs-137 +/- Error
Otter 35	6.67	1.8359	0.96	90.1	3.54E-01	4.04E-01 +/- 9.24E-03	9.60E-02 +/- 4.57E-03
Otter 36	7.06	1.9355	0.96	89.8	3.68E-01	4.18E-01 +/- 9.92E-03	
Otter 37	6.50	2.0272	0.96	89.5	3.59E-01	4.09E-01 +/- 1.01E-02	1.14E-01 +/- 4.78E-03
Otter 38	7.19	2.1287	0.96	89.5	3.31E-01	3.81E-01 +/- 1.12E-02	
Otter 39	7.48	2.2342	0.96	89.0	2.71E-01	3.21E-01 +/- 9.78E-03	1.07E-01 +/- 2.23E-03
Otter 40	8.12	2.3488	0.96	88.3	3.06E-01	3.56E-01 +/- 1.05E-02	
Otter 41	8.37	2.4668	0.96	88.1	2.90E-01	3.40E-01 +/- 9.49E-03	1.28E-01 +/- 4.84E-03
Otter 42	8.05	2.5804	0.96	88.0	2.92E-01	3.42E-01 +/- 1.15E-02	
Otter 43	8.27	2.6971	0.95	87.3	2.83E-01	3.33E-01 +/- 1.12E-02	1.33E-01 +/- 4.45E-03
Otter 44	8.83	2.8217	0.95	87.3	2.80E-01	3.30E-01 +/- 1.18E-02	
Otter 45	8.84	2.9464	0.95	87.1	2.51E-01	3.01E-01 +/- 7.70E-03	1.48E-01 +/- 3.51E-03
Otter 46	9.11	3.0749	0.95	87.0	2.45E-01	2.95E-01 +/- 6.97E-03	
Otter 47	9.25	3.2054	0.95	86.5	3.12E-01	3.62E-01 +/- 9.02E-03	1.73E-01 +/- 4.09E-03
Otter 48	8.49	3.3252	0.95	87.1	2.71E-01	3.21E-01 +/- 8.78E-03	
Otter 49	9.01	3.4523	0.95	87.0	2.55E-01	3.05E-01 +/- 8.21E-03	1.85E-01 +/- 5.59E-03
Otter 50	8.35	3.5701	0.95	87.2	2.44E-01	2.94E-01 +/- 6.91E-03	
Otter 51	8.80	3.6943	0.95	87.2	2.74E-01	3.24E-01 +/- 7.44E-03	1.92E-01 +/- 5.69E-03
Otter 52	9.13	3.8231	0.95	86.7	2.80E-01	3.30E-01 +/- 8.69E-03	2.99E-01 +/- 6.49E-03
Otter 53	8.26	3.9396	0.95	87.4	2.96E-01	3.46E-01 +/- 8.34E-03	3.84E-01 +/- 7.27E-03
Otter 54	8.02	4.0528	0.95	87.3	3.21E-01	3.71E-01 +/- 9.34E-03	3.39E-01 +/- 6.47E-03
Otter 55	8.94	4.1789	0.95	86.6	2.99E-01	3.49E-01 +/- 8.72E-03	2.38E-01 +/- 5.62E-03
Otter 56	8.88	4.3042	0.95	86.7	2.93E-01	3.43E-01 +/- 8.43E-03	

Metal Concentration in the Sediment: Otter Lake

Concentration in mg/kg dry weight

Sample	Mg	Al	K	Ca	Fe	Ti	V	Cr	Mn	Ni	Cu	Zn	As	Rb	Sr	Mo	Cd	Sn	Ba	Pb	U
Otter 1	6565	10108	1607	19424	69194	231.9	38.3	18.78	5932	30.8	52.1	196.9	58.20	16.24	33.8	2.60	1.35	1.09	758.2	78.4	0.00
Otter 2	6521	10739	1455	17443	56371	169.5	39.1	18.95	3709	28.9	55.5	214.2	39.10	16.02	27.3	2.26	1.33	0.97	490.4	84.3	0.16
Otter 3	6654	10562	1350	16087	48374	171.7	39.3	19.08	3659	27.6	54.9	210.0	29.26	15.39	24.1	1.91	1.17	0.98	352.2	93.2	0.16
Otter 4	6058	10427	1281	14544	40771	155.7	35.6	17.81	3460	26.0	47.3	202.7	26.11	15.15	21.2	1.79	1.11	1.01	272.7	96.8	0.15
Otter 5	6447	11708	1438	14567	38010	134.3	37.9	19.91	3834	28.6	49.5	250.8	28.72	17.26	21.7	1.74	1.15	0.70	275.2	107.9	0.09
Otter 6	6362	11980	1538	14120	34484	140.9	35.7	20.27	3470	27.1	50.8	225.8	26.03	17.64	21.3	1.92	1.32	0.79	255.0	106.6	0.02
Otter 7	6258	12190	1427	13617	31033	101.2	35.9	21.81	3021	30.0	48.2	240.0	24.39	18.33	21.8	1.84	1.44	0.72	270.7	120.2	0.06
Otter 8	6343	13335	1654	13475	28675	109.9	38.2	22.69	2284	29.4	49.5	240.7	23.55	20.25	22.3	1.38	1.19	0.47	258.1	128.4	0.04
Otter 9	7062	13551	1944	21009	32439	104.9	40.7	23.58	2232	30.0	64.5	277.3	27.81	20.50	23.1	1.58	1.54	0.63	264.8	137.9	0.13
Otter 10	6268	11823	1503	14859	37973	92.8	38.5	20.47	1918	26.3	76.4	237.0	36.69	17.56	20.2	1.81	1.14	0.45	234.0	123.9	0.26
Otter 11	7019	12319	1471	15737	44761	102.8	42.3	21.39	2599	28.2	81.5	268.4	40.31	17.88	23.0	1.84	1.27	0.67	256.8	135.2	0.35
Otter 12	6833	11765	1352	15362	42502	100.3	40.4	20.46	2621	30.9	83.9	248.4	36.54	16.85	21.2	2.00	1.52	0.84	247.3	134.6	0.22
Otter 13	6903	12071	1435	17859	35715	99.1	37.6	20.36	2473	27.9	65.2	242.1	26.03	16.92	19.9	1.38	1.21	0.57	241.6	122.7	0.06
Otter 14	6396	12900	1797	15653	34450	131.6	40.1	21.46	4091	29.2	63.5	217.5	27.67	19.42	20.2	1.46	1.09	0.53	236.3	108.8	0.02
Otter 15	6736	12227	1497	15401	40058	115.8	40.9	21.16	3908	29.7	82.0	221.3	34.41	18.05	20.9	1.97	1.37	0.77	247.6	116.9	0.21
Otter 16	6451	11192	1361	15285	43173	150.4	39.7	20.10	3775	29.8	82.3	229.5	35.86	16.94	20.9	2.09	1.64	1.10	251.7	120.5	0.22
Otter 17	7126	11673	1312	16048	42779	153.5	39.3	20.70	4036	30.4	64.6	262.6	32.07	16.92	20.7	1.53	1.44	1.38	257.7	141.7	0.04
Otter 18	7568	12946	1547	17148	43922	128.1	41.3	21.91	2999	29.7	45.0	276.4	32.04	17.74	21.3	2.02	1.38	0.75	268.0	141.0	0.15
Otter 19	7073	12300	1386	14942	37385	81.2	39.5	21.57	2011	28.8	39.7	249.8	33.02	17.80	20.7	2.08	1.53	0.58	250.9	141.8	0.30
Otter 20	7098	12177	1402	15692	43768	91.5	42.8	22.35	2229	29.7	43.9	272.5	45.97	18.06	22.3	2.31	1.31	0.58	263.1	150.3	0.43
Otter 21	6939	11507	1255	16402	48192	94.4	37.8	19.06	2531	27.4	39.8	233.5	40.35	15.31	20.1	2.10	1.46	0.76	233.9	130.1	0.24
Otter 22	6305	11356	1199	14271	42312	104.1	38.0	20.25	2479	27.6	38.3	250.4	31.31	15.91	20.4	1.50	1.38	0.82	257.8	145.7	0.21
Otter 23	6423	13525	1528	14122	40542	130.8	41.1	22.57	3054	29.9	37.8	267.7	30.14	19.13	21.4	1.56	1.44	0.81	271.9	152.3	0.14
Otter 24	6863	13790	1509	13913	35882	114.5	39.0	23.15	2840	30.3	37.3	271.7	24.38	19.66	21.0	1.68	1.86	0.81	259.6	169.0	0.10
Otter 25	6231	12530	1294	13478	30632	82.2	34.3	20.37	2070	27.5	33.0	228.7	21.65	16.99	19.3	1.45	1.54	0.66	246.3	142.5	0.00
Otter 26	6595	13518	1535	13829	36505	102.8	38.5	22.23	2042	29.5	36.5	257.1	29.78	19.78	20.8	1.60	1.40	0.57	251.4	161.5	0.09
Otter 27	7031	12985	1409	14846	34848	80.8	35.3	21.22	1994	28.7	36.7	249.7	22.77	17.78	19.7	1.20	1.33	0.54	254.2	158.1	0.02
Otter 28	6526	12598	1510	14993	39878	88.9	38.2	21.37	1851	29.3	38.4	246.2	32.55	18.38	20.4	1.65	1.31	0.49	246.1	147.2	0.19
Otter 29	6446	11836	1348	13980	46397	111.0	38.1	20.51	2253	31.8	41.7	273.5	31.69	16.72	20.5	1.59	1.44	0.74	265.4	163.6	0.19

Metal Concentration in the Sediment: Otter Lake

Concentration in mg/kg dry weight

Sample	Mg	Al	K	Ca	Fe	Ti	V	Cr	Mn	Ni	Cu	Zn	As	Rb	Sr	Mo	Cd	Sn	Ba	Pb	U
Otter 30	6751	12382	1294	14375	35555	110.9	36.6	21.31	2778	29.7	37.4	285.4	21.54	17.84	19.8	1.52	1.88	0.91	266.7	184.5	0.02
Otter 31	6764	12930	1366	13920	31500	115.9	37.0	22.52	2686	29.4	37.3	279.5	21.54	19.17	20.4	1.02	1.59	0.85	275.5	185.9	0.00
Otter 32	6796	12845	1363	14009	33463	102.6	36.7	21.68	2576	29.0	36.6	265.8	21.28	18.38	20.1	1.03	1.58	0.82	274.1	183.2	0.06
Otter 33	7620	13896	1578	17094	44576	93.8	40.6	23.14	2872	30.2	40.7	320.5	30.84	19.67	23.8	1.39	1.78	0.84	292.1	224.2	1.15
Otter 34	7023	14633	1641	13273	44301	133.2	42.8	23.41	3455	30.3	39.3	286.4	31.15	21.38	23.9	1.40	1.78	1.07	292.6	211.2	1.09
Otter 35	6582	13277	1407	12647	38720	99.1	39.9	22.44	3070	29.9	39.0	293.1	27.88	19.62	23.3	1.27	1.76	0.95	298.5	420.7	1.06
Otter 36	6693	13612	1461	12948	39815	108.4	39.1	22.78	2494	30.5	38.7	277.0	28.01	19.85	22.3	2.03	2.18	0.82	288.4	212.5	1.15
Otter 37	6624	13318	1382	13051	39567	122.5	39.7	21.96	3031	29.2	39.0	277.2	25.34	18.83	22.3	1.51	1.98	0.79	296.7	207.9	1.04
Otter 38	6442	12707	1344	12611	39500	110.5	39.3	22.10	3205	30.0	39.4	284.2	25.36	18.57	22.5	1.66	2.05	0.73	300.1	220.0	1.06
Otter 39	6967	13463	1367	13103	38718	106.3	39.7	22.82	2848	30.0	40.4	303.2	24.39	18.93	23.0	1.51	2.18	0.77	303.9	233.0	1.05
Otter 40	6807	13126	1271	12275	40120	101.0	39.5	22.41	2940	29.8	39.5	303.7	22.58	18.16	21.7	1.61	2.23	0.82	303.9	229.1	1.06
Otter 41	7188	15641	1750	12621	41294	120.3	42.7	25.01	2716	31.7	40.1	317.3	28.29	22.61	23.3	1.81	2.21	0.69	316.6	224.3	1.14
Otter 42	7365	16108	1766	13050	44364	126.9	44.7	26.37	2616	33.9	41.9	338.3	30.28	23.41	24.4	1.74	2.27	0.69	343.2	249.0	1.18
Otter 43	7025	13872	1417	14124	42064	102.8	40.7	23.92	2680	31.7	41.0	335.4	24.92	19.87	22.1	1.94	2.57	0.85	323.4	249.7	1.13
Otter 44	7071	14333	1453	11996	40749	89.2	40.6	24.43	2272	31.8	40.4	346.1	24.43	20.61	22.1	1.68	2.34	0.66	324.2	240.7	1.11
Otter 45	6999	14432	1532	12445	41835	98.5	41.6	24.66	2323	32.7	40.4	339.4	28.27	20.96	22.8	2.03	2.65	0.83	327.9	247.8	1.19
Otter 46	7488	18044	1742	12814	42496	119.4	44.0	26.69	2661	34.4	41.6	361.5	32.00	23.25	23.7	2.04	2.84	0.97	347.2	259.5	1.18
Otter 47	7291	13870	1395	12915	45062	84.1	40.8	23.74	2129	31.6	40.4	343.6	29.17	19.45	22.0	1.86	2.36	0.98	321.2	266.2	1.14
Otter 48	7215	14372	1516	12507	45162	99.6	42.9	24.58	2314	33.3	41.7	352.5	32.38	21.01	22.5	2.25	2.69	0.90	332.4	266.0	1.23
Otter 49	7409	15542	1733	12960	45430	105.8	44.7	25.65	2196	33.4	41.7	376.4	34.52	22.08	23.1	2.34	2.76	0.83	338.5	261.3	1.30
Otter 50	7642	15093	1705	14451	56145	110.7	47.1	24.95	2612	33.9	43.2	363.0	39.87	21.09	23.6	2.61	2.72	0.99	340.4	288.5	1.28
Otter 51	8224	14759	1548	14786	54901	91.3	46.4	25.67	2340	36.1	45.5	367.4	34.98	20.53	23.4	2.65	2.73	1.08	362.1	290.2	1.27
Otter 52	7529	13262	1354	14139	55772	74.4	45.2	23.26	2215	33.1	43.9	373.2	37.87	18.49	22.8	2.88	2.56	0.66	340.1	289.0	1.28
Otter 53	7593	14528	1602	15651	65843	87.8	48.4	25.34	2267	35.0	47.4	411.2	40.63	19.98	24.6	3.76	2.92	0.92	373.1	321.2	1.39
Otter 54	7342	14702	1563	14330	65782	119.5	48.9	25.93	3448	34.7	48.2	426.5	40.46	20.53	26.0	2.84	2.78	1.15	373.5	319.5	1.28
Otter 55	7153	14734	1539	15127	64001	159.2	49.6	25.49	3973	35.4	49.8	489.2	46.03	19.91	28.5	2.59	3.33	1.75	399.4	324.0	1.28
Otter 56	6602	12999	1236	13548	66867	124.6	46.6	23.65	3546	32.3	46.4	480.4	38.56	17.53	26.8	2.95	3.42	1.65	385.3	282.7	1.22
Otter 57	7083	15048	1731	15378	65180	187.3	43.4	23.59	3747	30.6	57.3	351.4	41.37	20.27	25.0	2.41	2.53	1.58	350.7	207.7	1.08
Otter 58	6567	14642	1542	12354	60686	220.1	40.3	22.14	3510	29.8	38.0	301.5	30.86	19.94	21.6	1.80	2.35	1.85	338.1	159.4	0.90
Otter 59	6215	14794	1568	11610	62038	249.3	40.1	22.00	3809	29.6	35.4	303.0	31.65	20.92	20.2	1.65	2.48	2.04	337.4	143.3	0.85
Otter 60	5459	13942	1329	9591	65250	250.4	37.3	21.32	3578	28.0	32.3	262.6	27.98	19.80	17.5	1.73	2.18	1.85	318.6	122.4	0.79

Metal Concentration in the Sediment: Otter Lake

Concentration in mg/kg dry weight

Sample	Mg	Al	K	Ca	Fe	Ti	V	Cr	Mn	Ni	Cu	Zn	As	Rb	Sr	Mo	Cd	Sn	Ba	Pb	U
Otter 61	5038	13571	1215	8965	62782	247.5	34.8	19.11	3861	26.0	30.0	224.8	24.25	19.24	15.9	1.59	1.88	1.52	314.9	105.0	0.72
Otter 62	4893	12536	1118	9470	63495	251.3	33.2	18.06	3587	25.2	29.4	221.7	24.10	17.96	15.6	1.61	1.96	1.73	311.6	102.4	0.72
Otter 63	4277	9543	688	8970	58498	259.1	30.8	15.43	3673	22.3	28.9	192.0	18.78	12.36	14.6	1.66	1.78	2.10	295.6	102.2	0.66
Otter 64	4444	10592	975	9622	59643	312.8	33.6	16.45	3757	23.0	30.7	185.1	25.29	14.92	16.1	1.91	1.64	2.17	307.0	108.3	0.70

Round D Lake Sediment Fact Sheet

Date Sampled:	29-Jun-04	**Sampling site water depth (m):**	16.0
County:	Alger, Delta	**Depth of Core (cm):**	54
Lake Area (sq. km):	1.8	**Watershed Area (sq. km):**	2.0
Sampling Site:	46º 08.771' N & 86º 44.939' W	**Focusing Factor:**	2.4

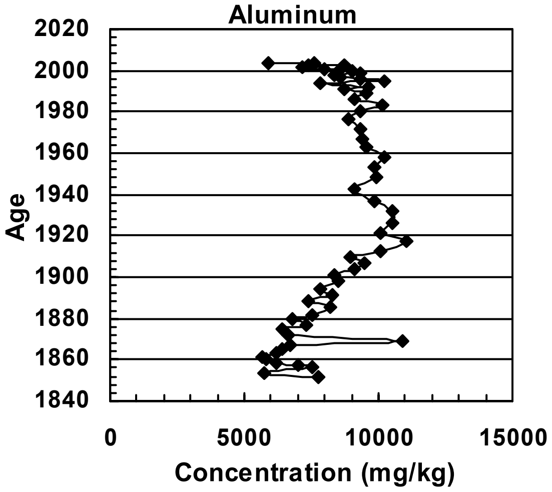
Sediment concentrations of PAHs, PCBs and Total Pesticides were greatest in the surface sediment. Sediment concentrations of PAHs and PCBs were high when compared to most other Upper Peninsula lakes.

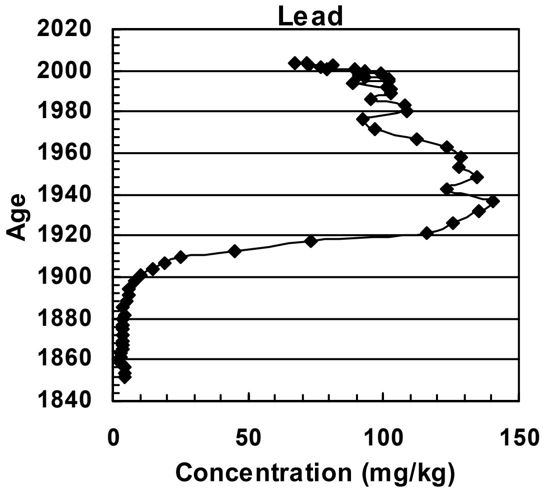
Cadmium, copper, lead and zinc sediment concentrations had decreased over the last the decade. However, cadmium, copper and zinc FCAAR had increased in recent years.

	Surface Concentration	Background Concentration	Trend
Cadmium (mg/kg)	1.90	0.85	Decreasing
Copper (mg/kg)	64.8	21.6	Decreasing
Lead (mg/kg)	70.5	3.6	Decreasing
Zinc (mg/kg)	174.9	87.0	Decreasing
Total PAHs:	1887.7		Increasing
Total PCBs:	29.2		Increasing
Total Pesticides:	115.7		Increasing

NA indicates that the concentration could not be determined
Trends for organic contaminants are taken from only two data points and should be interpreted with care

Example Profiles





A Strategic Environmental Quality Monitoring Program for Michigan's Surface Waters: Sediments

Lake: Round D **Water Depth (m):** 16.0

Sampling Date: 6/29/2004 **Latitude (N):** 46.1462 **Longitude (W):** -86.749

Core Description: top 10 cm has round sand striations. top sediment has living worms (4), appear to be different species. worms burrow in top 5 cm of core. fluffy top 6-7 cm, grayish brown and black in color, remainder of core is black in color.

Sample Number	Jar Number	Thickness (cm)	Total Thickness (cm)	Description
Round D 1	1	0.5	0.5	viscous, watery black, brown sandy particles
Round D 2	2	0.5	1.0	viscous, watery black, brown sandy particles
Round D 3	3	0.5	1.5	more solid than 1 or 2, black brown, reddish grains
Round D 4	4	0.5	2.0	more solid than 1 or 2, black brown, reddish grains
Round D 5	5	0.5	2.5	getting thicker, black (org), brown, red grains
Round D 6	6	0.5	3.0	getting thicker, black (org), brown, red grains with worms
Round D 7	7	0.5	3.5	getting thicker, black (org), brown, red grains
Round D 8	8	0.5	4.0	getting thicker still, more org with brown, tan grains
Round D 9	9	0.5	4.5	getting thicker still, more org with brown, tan grains
Round D 10	10	0.5	5.0	getting thicker still, more org with brown, tan grains
Round D 11	11	0.5	5.5	getting thicker still, more org with brown, tan grains (top off)
Round D 12	12	0.5	6.0	getting thicker still, more org with brown, tan grains
Round D 13	13	0.5	6.5	thicker still, organic, more sand than above
Round D 14	14	0.5	7.0	thicker still, organic, more sand than above
Round D 15	15	0.5	7.5	decreasing organic matter, more brown grains
Round D 16	16	0.5	8.0	decreasing organic matter, more brown grains
Round D 17	17	1.0	9.0	defined black specs of organic, brown tan grains
Round D 18	18	1.0	10.0	grayish brown, brown grains, specs of org
Round D 19	19	1.0	11.0	grayish brown, brown grains, specs of org
Round D 20	20	1.0	12.0	grayish brown, brown grains, specs of org
Round D 21	21	1.0	13.0	grayish brown, brown grains, specs of org with worms
Round D 22	22	1.0	14.0	grayish brown, brown grains, specs of org
Round D 23	23	1.0	15.0	grayish brown, grains of brown, tan, black, stick
Round D 24	24	1.0	16.0	grayish brown, grains of brown, tan, black, stick
Round D 25	25	1.0	17.0	grayish brown, grains of brown, tan, black, stick
Round D 26	26	1.0	18.0	grayish brown, grains of brown, tan, black, stick
Round D 27	27	1.0	19.0	becoming more blackish gray, with brown, tan grains
Round D 28	28	1.0	20.0	blackish gray with brown and tan grains
Round D 29	29	1.0	21.0	blackish gray with brown and tan grains with worms
Round D 30	30	1.0	22.0	blackish gray with brown and tan grains
Round D 31	31	1.0	23.0	homogenous grayish black color
Round D 32	32	1.0	24.0	homogenous grayish black color
Round D 33	33	1.0	25.0	homogenous grayish black color with worms
Round D 34	34	1.0	26.0	homogenous grayish black color with worms

Sample Number	Jar Number	Thickness (cm)	Total Thickness (cm)	Description
Round D 35	35	1.0	27.0	homogenous grayish black color with worms
Round D 36	36	1.0	28.0	homogenous grayish black color more worms and a stick
Round D 37	37	1.0	29.0	homogenous grayish black color
Round D 38	38	1.0	30.0	homogenous blackish gray
Round D 39	39	1.0	31.0	homogenous blackish gray
Round D 40	40	1.0	32.0	homogenous blackish gray
Round D 41	41	1.0	33.0	homogenous blackish gray
Round D 42	42	1.0	34.0	homogenous blackish gray
Round D 43	43	1.0	35.0	homogenous blackish gray
Round D 44	44	1.0	36.0	homogenous blackish gray
Round D 45	45	1.0	37.0	homogenous blackish gray
Round D 46	46	1.0	38.0	homogenous blackish gray
Round D 47	47	1.0	39.0	homogenous blackish gray
Round D 48	48	1.0	40.0	homogenous blackish gray
Round D 49	49	1.0	41.0	homogenous blackish gray
Round D 50	50	1.0	42.0	homogenous blackish gray
Round D 51	51	1.0	43.0	homogenous blackish gray
Round D 52	52	1.0	44.0	homogenous blackish gray with a stick
Round D 53	53	1.0	45.0	homogenous blackish gray
Round D 54	54	1.0	46.0	homogenous blackish gray
Round D 55	55	1.0	47.0	homogenous blackish gray
Round D 56	56	1.0	48.0	homogenous blackish gray
Round D 57	57	1.0	49.0	homogenous blackish gray
Round D 58	58	1.0	50.0	homogenous blackish gray
Round D 59	59	1.0	51.0	homogenous blackish gray
Round D 60	60	1.0	52.0	homogenous blackish gray
Round D 61	61	1.0	53.0	homogenous blackish gray

210-Pb Analysis: Round D Lake

Data provided by Paul Wilkinson, Freshwater Institute, Manitoba, Canada

Sample	Dry Weight (g)	Accumulated Dry Weight (g/sq. cm)	Porosity	Percent Water	Excess Pb-210 (Bq/g)	Activity Bq/g +/- 2SD Pb-210 +/- Error	Activity Bq/g +/- 2SD Cs-137 +/- Error
Round D 1	0.65	0.0092	0.99	95.8	1.17E+00	1.20E+00 +/- 2.37E-02	1.23E-01 +/- 1.48E-02
Round D 2	1.11	0.0248	0.97	92.7	1.12E+00	1.15E+00 +/- 1.94E-02	
Round D 3	1.76	0.0497	0.98	94.6	1.11E+00	1.14E+00 +/- 1.85E-02	1.24E-01 +/- 3.99E-03
Round D 4	1.63	0.0727	0.98	93.8	1.10E+00	1.13E+00 +/- 2.31E-02	
Round D 5	1.64	0.0958	0.98	94.5	1.08E+00	1.11E+00 +/- 1.91E-02	1.38E-01 +/- 8.75E-03
Round D 6	1.68	0.1195	0.97	92.5	1.11E+00	1.14E+00 +/- 1.94E-02	
Round D 7	1.78	0.1446	0.98	94.3	1.13E+00	1.16E+00 +/- 1.98E-02	1.44E-01 +/- 7.69E-03
Round D 8	1.65	0.1679	0.98	94.2	1.09E+00	1.12E+00 +/- 2.58E-02	
Round D 9	1.79	0.1931	0.97	92.4	1.17E+00	1.20E+00 +/- 2.27E-02	1.34E-01 +/- 8.38E-03
Round D 10	2.03	0.2218	0.98	93.9	1.16E+00	1.19E+00 +/- 2.21E-02	
Round D 11	2.10	0.2514	0.98	93.3	1.18E+00	1.21E+00 +/- 2.33E-02	1.50E-01 +/- 4.21E-03
Round D 12	2.12	0.2813	0.98	93.4	1.18E+00	1.21E+00 +/- 1.98E-02	
Round D 13	2.20	0.3124	0.98	93.6	1.18E+00	1.21E+00 +/- 1.70E-02	1.47E-01 +/- 6.81E-03
Round D 14	2.21	0.3435	0.97	90.9	1.16E+00	1.19E+00 +/- 1.85E-02	
Round D 15	2.08	0.3729	0.98	94.0	1.20E+00	1.23E+00 +/- 2.04E-02	1.46E-01 +/- 7.27E-03
Round D 16	2.28	0.4051	0.98	93.7	1.17E+00	1.20E+00 +/- 2.23E-02	
Round D 17	4.59	0.4698	0.98	93.2	1.14E+00	1.17E+00 +/- 2.25E-02	1.51E-01 +/- 4.91E-03
Round D 18	4.27	0.5301	0.97	93.0	1.10E+00	1.13E+00 +/- 2.27E-02	
Round D 19	4.39	0.5920	0.97	92.6	1.13E+00	1.16E+00 +/- 2.27E-02	1.43E-01 +/- 5.08E-03
Round D 20	4.28	0.6524	0.97	93.1	1.04E+00	1.07E+00 +/- 2.56E-02	
Round D 21	4.72	0.7190	0.98	93.2	1.06E+00	1.09E+00 +/- 2.31E-02	1.53E-01 +/- 1.76E-03
Round D 22	4.60	0.7839	0.98	93.4	9.77E-01	1.01E+00 +/- 2.32E-02	1.56E-01 +/- 5.43E-03
Round D 23	4.91	0.8531	0.98	93.4	8.89E-01	9.19E-01 +/- 1.97E-02	1.66E-01 +/- 5.76E-03
Round D 24	5.04	0.9242	0.98	93.2	6.92E-01	7.22E-01 +/- 1.91E-02	1.35E-01 +/- 4.78E-03
Round D 25	5.32	0.9993	0.97	91.2	6.20E-01	6.50E-01 +/- 1.46E-02	1.42E-01 +/- 4.89E-03
Round D 26	5.80	1.0811	0.97	92.4	5.66E-01	5.96E-01 +/- 2.10E-02	
Round D 27	5.61	1.1603	0.97	92.2	4.72E-01	5.02E-01 +/- 1.46E-02	1.12E-01 +/- 3.34E-03
Round D 28	5.37	1.2360	0.97	92.3	4.17E-01	4.47E-01 +/- 1.29E-02	
Round D 29	5.27	1.3104	0.97	92.4	3.73E-01	4.03E-01 +/- 8.07E-03	7.69E-02 +/- 3.13E-03
Round D 30	5.44	1.3871	0.97	92.5	3.14E-01	3.44E-01 +/- 8.38E-03	
Round D 31	5.86	1.4698	0.97	92.5	2.48E-01	2.78E-01 +/- 7.56E-03	5.82E-02 +/- 4.14E-03
Round D 32	5.30	1.5446	0.97	92.5	1.84E-01	2.14E-01 +/- 8.60E-03	
Round D 33	5.83	1.6268	0.97	92.4	1.37E-01	1.67E-01 +/- 5.69E-03	3.80E-02 +/- 4.56E-03
Round D 34	5.78	1.7084	0.97	92.3	1.01E-01	1.31E-01 +/- 5.13E-03	

Sample	Dry Weight (g)	Accumulated Dry Weight (g/sq. cm)	Porosity	Percent Water	Excess Pb-210 (Bq/g)	Activity Bq/g +/- 2SD Pb-210 +/- Error	Activity Bq/g +/- 2SD Cs-137 +/- Error
Round D 35	5.26	1.7826	0.97	92.6	8.55E-02	1.16E-01 +/- 4.89E-03	2.25E-02 +/- 2.82E-03
Round D 36	5.16	1.8554	0.97	92.9	8.38E-02	1.14E-01 +/- 4.94E-03	
Round D 37	5.13	1.9278	0.97	93.1	7.15E-02	1.01E-01 +/- 5.00E-03	2.16E-02 +/- 3.88E-03
Round D 38	5.07	1.9993	0.98	93.1	7.28E-02	1.03E-01 +/- 4.93E-03	
Round D 39	5.36	2.0749	0.97	93.0	6.74E-02	9.74E-02 +/- 5.50E-03	1.77E-02 +/- 2.15E-03
Round D 40	5.27	2.1493	0.97	92.6	5.33E-02	8.33E-02 +/- 4.10E-03	
Round D 41	5.17	2.2222	0.97	92.7	5.50E-02	8.50E-02 +/- 4.45E-03	1.23E-02 +/- 2.55E-03
Round D 42	5.62	2.3015	0.97	92.7	4.60E-02	7.60E-02 +/- 4.18E-03	
Round D 43	5.21	2.3750	0.97	92.6	3.80E-02	6.80E-02 +/- 3.29E-03	1.03E-02 +/- 2.94E-03
Round D 44	5.66	2.4549	0.97	92.3	2.98E-02	5.98E-02 +/- 3.79E-03	
Round D 45	5.67	2.5348	0.97	92.4	2.40E-02	5.40E-02 +/- 3.32E-03	7.88E-03 +/- 1.54E-03
Round D 46	5.66	2.6147	0.97	92.5	2.61E-02	5.61E-02 +/- 2.76E-03	
Round D 47	5.34	2.6900	0.97	92.8	2.57E-02	5.57E-02 +/- 2.93E-03	1.07E-02 +/- 2.66E-03
Round D 48	5.61	2.7692	0.97	92.7	2.37E-02	5.37E-02 +/- 3.53E-03	
Round D 49	5.67	2.8492	0.97	92.5	1.82E-02	4.82E-02 +/- 3.00E-03	0.00E+00 +/- 0.00E+00
Round D 50	5.93	2.9328	0.97	92.3	1.86E-02	4.86E-02 +/- 2.34E-03	
Round D 51	5.50	3.0104	0.97	92.0	1.18E-02	4.18E-02 +/- 2.26E-03	
Round D 52	6.39	3.1006	0.97	91.9	9.18E-03	3.92E-02 +/- 2.73E-03	
Round D 53	5.65	3.1803	0.97	91.7	9.05E-03	3.90E-02 +/- 2.54E-03	
Round D 54	6.36	3.2700	0.97	91.6	8.14E-03	3.81E-02 +/- 2.88E-03	
Round D 55	6.67	3.3641	0.97	90.9	9.80E-03	3.98E-02 +/- 2.62E-03	
Round D 56	7.82	3.4745	0.96	90.0	3.35E-03	3.33E-02 +/- 2.60E-03	
Round D 57	7.64	3.5823	0.96	89.4	2.80E-03	3.28E-02 +/- 2.46E-03	
Round D 58	7.69	3.6907	0.96	89.3		3.00E-02 +/- 1.71E-03	
Round D 59	7.92	3.8025	0.96	90.0		3.37E-02 +/- 2.16E-03	
Round D 60	8.53	3.9228	0.96	89.6		3.20E-02 +/- 1.68E-03	

Metal Concentration in the Sediment: Round D Lake

Concentration in mg/kg dry weight

Sample	Mg	Al	K	Ca	Fe	Ti	V	Cr	Mn	Ni	Cu	Zn	As	Rb	Sr	Mo	Cd	Sn	Ba	Pb	U
Round D 1	1694	5893	577	11689	157884	148.4	87.3	23.06	2285	15.6	62.0	167.0	40.41	4.68	35.5	0.75	1.72	0.75	425.4	67.2	1.16
Round D 2	1876	7611	761	12565	173898	210.1	95.1	26.74	2402	17.5	66.8	179.5	49.98	6.30	38.1	0.83	2.02	1.02	453.3	72.0	1.25
Round D 3	1783	7369	650	9609	152975	196.6	93.6	26.74	1820	15.9	65.7	178.2	44.33	6.07	34.2	0.74	1.95	0.97	400.3	72.3	1.20
Round D 4	2039	8709	754	10827	163907	207.4	100.6	29.13	1726	17.1	70.6	198.5	42.45	6.90	34.3	0.76	2.07	1.05	394.4	81.3	1.25
Round D 5	1781	7197	543	9635	142831	152.7	90.7	25.57	1516	16.2	64.8	173.1	35.47	5.33	29.8	0.69	1.90	0.86	348.5	76.5	1.16
Round D 6	1873	7998	623	9285	135112	166.7	95.3	26.67	1455	15.9	67.3	184.2	32.24	5.87	28.8	0.71	1.97	0.86	322.7	79.0	1.34
Round D 7	2029	8559	643	10107	143315	165.8	106.0	29.30	1583	16.9	74.9	200.7	33.74	6.34	31.0	0.82	2.20	0.90	348.5	89.3	1.46
Round D 8	2112	9042	694	10078	145059	178.0	109.1	30.23	1553	17.6	75.3	209.6	33.54	6.91	31.2	0.88	2.29	0.99	337.4	93.3	1.52
Round D 9	2133	9300	681	10095	144903	179.7	112.6	31.06	1556	18.2	76.1	214.4	32.70	7.10	31.7	0.94	2.38	1.00	332.9	98.7	1.58
Round D 10	1916	8371	848	8867	117644	184.4	101.2	28.24	1328	16.9	69.0	196.6	28.02	7.01	27.0	0.84	2.08	0.78	274.0	90.6	1.44
Round D 11	1975	8600	625	9252	135488	153.4	100.6	27.67	1402	17.0	69.7	194.9	29.51	6.22	27.0	0.83	2.14	0.92	283.4	93.4	1.48
Round D 12	2095	9350	671	9540	141491	196.9	113.0	31.12	1525	18.2	76.8	221.5	30.10	7.17	29.3	0.96	2.36	1.02	290.4	101.6	1.56
Round D 13	2229	10232	766	9795	146038	204.2	113.9	32.75	1473	18.5	78.0	216.7	30.33	7.88	29.7	0.94	2.36	1.06	291.7	102.1	1.57
Round D 14	1749	7851	507	7783	116781	158.6	97.8	26.98	1254	16.0	65.9	188.0	25.29	6.23	24.8	0.82	2.03	0.75	246.6	88.6	1.36
Round D 15	2133	9636	687	9513	146408	186.4	112.9	31.55	1467	18.8	77.6	214.7	30.54	7.25	28.5	0.99	2.36	0.94	289.7	101.4	1.59
Round D 16	1993	8719	505	9433	146030	139.3	112.3	30.55	1487	18.2	76.9	226.2	25.97	5.97	27.5	0.88	2.36	0.81	278.0	103.1	1.54
Round D 17	2068	9555	650	9046	140865	183.0	110.6	31.02	1411	17.9	70.0	219.0	27.65	7.08	26.9	0.93	2.33	0.89	261.6	102.5	1.53
Round D 18	1965	9077	649	8362	130374	179.7	101.8	28.57	1296	16.4	65.5	200.1	26.15	6.92	25.1	0.91	2.11	0.85	239.5	95.4	1.41
Round D 19	2189	10161	711	9250	143893	194.1	114.8	31.96	1452	19.6	72.6	246.1	29.33	7.73	27.8	1.08	2.52	0.98	256.2	107.9	1.62
Round D 20	2070	9297	564	9002	141417	166.7	113.0	31.23	1451	18.3	69.0	232.6	28.46	6.85	27.2	1.01	2.38	0.75	248.8	108.3	1.54
Round D 21	1901	8845	589	8079	126358	160.6	95.5	26.76	1229	15.8	60.3	195.9	25.31	6.40	23.6	0.87	2.04	0.75	211.1	92.1	1.31
Round D 22	2022	9360	602	10134	135929	161.8	99.1	27.74	1277	16.1	58.8	209.6	26.39	6.54	24.7	0.93	2.13	0.84	216.4	96.9	1.37
Round D 23	2009	9417	577	8340	134952	175.2	109.9	30.38	1385	18.4	59.9	230.4	29.49	7.35	28.1	1.09	2.46	0.92	234.1	112.7	1.54
Round D 24	2117	9519	608	9029	142269	160.4	114.0	30.92	1447	18.7	59.2	246.3	30.12	6.99	29.2	1.15	2.56	0.82	243.1	123.0	1.56
Round D 25	2212	10256	668	9109	146105	189.1	117.0	31.97	1561	19.2	58.2	242.9	32.06	7.94	30.1	1.18	2.56	0.90	241.7	128.2	1.60
Round D 26	2164	9817	562	9133	148422	141.2	113.7	30.94	1546	18.7	52.7	248.2	31.05	6.90	30.6	1.16	2.70	0.78	241.7	127.8	1.52
Round D 27	2172	9911	559	9162	153461	165.2	115.3	31.06	1813	19.3	51.3	256.6	33.70	7.19	31.3	1.23	2.77	0.91	237.7	134.7	1.55
Round D 28	2002	9133	539	8316	141239	153.4	104.0	28.44	1767	17.6	44.9	245.5	30.82	6.67	28.8	1.10	2.55	0.87	211.6	123.1	1.39
Round D 29	2175	9880	578	9035	155154	175.2	114.2	31.09	2012	20.0	47.4	259.7	35.16	7.48	32.6	1.33	2.91	1.00	231.9	140.6	1.52

Metal Concentration in the Sediment: Round D Lake

Concentration in mg/kg dry weight

Sample	Mg	Al	K	Ca	Fe	Ti	V	Cr	Mn	Ni	Cu	Zn	As	Rb	Sr	Mo	Cd	Sn	Ba	Pb	U
Round D 30	2287	10559	637	9305	156174	173.9	116.6	31.88	1828	32.2	45.9	261.9	33.86	7.81	33.9	1.26	2.93	0.97	234.3	135.0	1.55
Round D 31	2235	10509	616	9233	152191	160.5	115.8	31.52	1731	18.6	42.9	246.2	32.58	7.44	34.5	1.19	2.83	0.79	230.2	125.8	1.54
Round D 32	2190	10097	585	9527	148855	153.9	114.3	30.99	1718	18.0	40.9	231.7	30.94	6.97	34.9	1.16	2.68	0.75	224.1	115.8	1.49
Round D 33	2206	11063	479	9990	156812	163.9	120.9	31.73	1471	16.2	34.4	174.9	26.76	6.44	37.4	1.09	2.04	0.58	224.4	72.8	1.47
Round D 34	2015	10108	502	9802	151962	155.8	123.3	31.41	1360	15.2	30.0	133.8	25.10	5.50	39.9	1.12	1.47	0.31	224.0	44.7	1.56
Round D 35	1811	8969	400	9082	148551	140.4	110.5	27.89	1229	13.7	25.5	106.9	21.42	4.41	35.6	0.96	1.00	0.20	195.3	24.9	1.36
Round D 36	1959	9492	463	9704	171146	165.7	117.8	29.38	1456	14.5	26.5	112.5	24.76	4.76	39.5	1.16	1.08	0.22	199.0	19.1	1.51
Round D 37	1933	9113	384	9767	178380	163.1	113.1	28.50	1538	14.7	26.4	111.7	26.65	4.42	41.4	1.31	1.13	0.23	188.3	14.8	1.58
Round D 38	1794	8346	332	9385	176473	152.3	103.9	26.18	1567	14.4	25.1	117.6	26.22	3.80	40.6	1.41	1.08	0.19	168.6	10.5	1.51
Round D 39	1869	8532	362	9423	184967	148.7	97.4	24.86	1590	13.6	23.2	98.9	26.37	4.09	41.1	1.33	0.99	0.15	157.7	7.8	1.42
Round D 40	1738	7805	317	8777	178945	131.3	87.6	22.21	1575	13.1	20.9	124.1	26.23	3.90	39.4	1.32	0.89	0.15	143.9	6.1	1.32
Round D 41	1867	8252	352	9159	186967	139.4	90.0	23.33	1767	14.0	23.0	107.4	28.17	4.48	42.5	1.52	0.95	0.22	151.6	6.1	1.39
Round D 42	1726	7385	320	8509	176850	137.3	82.2	21.36	1789	13.0	21.3	81.7	25.47	3.74	39.6	1.38	0.86	0.15	134.9	5.1	1.27
Round D 43	1973	8215	354	12857	210800	196.6	94.5	22.26	2967	14.4	23.3	86.7	33.25	1.63	46.7	0.89	0.96	0.27	132.5	3.8	1.31
Round D 44	1843	7533	285	9520	212172	176.9	92.6	23.31	2145	14.9	23.8	96.7	30.10	3.31	45.8	1.61	1.02	0.16	138.9	4.2	1.43
Round D 45	1776	6780	238	9072	219827	191.4	86.8	21.48	2348	13.2	22.4	79.7	28.70	2.84	44.4	1.39	0.90	0.31	129.8	3.9	1.28
Round D 46	1924	7280	281	9749	255037	223.6	93.2	23.45	3014	15.2	23.6	88.2	34.51	3.21	49.5	1.50	0.98	0.30	138.6	3.9	1.34
Round D 47	1683	6385	224	8314	219284	176.7	81.3	20.41	2550	13.1	20.9	80.6	29.84	2.83	43.1	1.33	0.86	0.35	117.8	3.5	1.23
Round D 48	1774	6649	239	8791	215904	160.8	85.6	21.93	2691	13.6	22.7	99.4	29.57	2.83	45.6	1.49	0.93	0.15	126.7	3.9	1.32
Round D 49	1792	10873	266	8567	202792	166.9	84.3	22.39	2274	13.5	22.9	89.1	28.39	3.06	45.2	1.37	0.85	0.15	126.0	4.1	1.32
Round D 50	1802	6748	269	8569	202722	180.3	83.3	21.90	2293	13.3	23.0	85.1	27.33	3.05	45.9	1.43	0.87	0.17	124.0	3.5	1.34
Round D 51	1759	6420	184	8428	204614	181.1	81.4	21.49	2366	13.0	22.9	84.3	27.61	2.79	45.9	1.46	0.86	0.22	122.0	3.7	1.29
Round D 52	1748	6174	203	8270	212870	171.4	75.7	20.13	2315	12.7	21.7	78.9	27.88	2.67	44.2	1.45	0.85	0.16	114.0	3.2	1.23
Round D 53	1651	5664	216	7574	206350	169.4	69.9	18.76	2231	12.4	20.1	75.0	27.16	2.78	41.6	1.34	0.76	0.13	104.5	2.8	1.17
Round D 54	1701	5789	212	7388	204756	183.4	70.3	19.16	2290	12.5	20.3	79.7	26.95	3.09	41.7	1.39	0.82	0.15	104.4	2.6	1.22
Round D 55	1851	6209	309	7209	176078	168.4	66.8	18.91	1932	11.6	19.7	86.6	23.59	3.97	39.4	1.32	0.79	0.21	104.1	3.0	1.20
Round D 56	2126	6984	496	7391	156333	142.0	65.1	19.94	1582	11.9	20.0	83.5	22.07	5.66	47.4	1.57	0.79	0.17	113.5	3.6	1.21
Round D 57	2293	7571	596	7207	141271	162.4	67.3	21.49	1370	13.1	21.1	91.7	23.25	7.19	42.5	2.08	0.83	0.13	121.5	4.1	1.32
Round D 58	1721	5779	414	5452	95756	163.8	69.8	23.12	1181	13.3	22.8	95.8	22.14	7.23	45.0	3.12	0.90	0.13	128.7	4.3	1.43
Round D 59	2321	7787	586	7536	115776	142.8	69.7	23.53	864	12.8	23.3	101.4	20.40	7.00	44.7	4.34	0.89	0.11	127.3	4.6	1.49