A Paleolimnological Study of the Water Quality Trends In Ashippun Lake, Waukesha County, Wisconsin

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Written By

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This project was undertaken in cooperation with the Ashippun Lake Management District and is one component of a comprehensive assessment of the water resources in the Upper Rock River Basin. Funding was provided by the Department of Natural Resources through the Wisconsin Lake Management Planning Grant Program and the Ashippun Lake Management District.

The other lakes included in this assessment were Druid Lake, Friess Lake, Fowler Lake, Moose Lake, Oconomowoc Lake, Okauchee Lake, Pike Lake, Pine Lake, and Silver Lake.

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Objective

This study's objective was to determine the water quality trends in Ashippun Lake, dating back to presettlement. A sediment core was collected and dated using Lead-210 to determine sediment age and accumulation rate. Total carbon, organic carbon, organic nitrogen, total phosphorus, total iron and manganese were also analyzed. Diatom frustules were identified in the core. Known changes in watershed landuse activities from early settlement to the present were correlated with changes in sedimentation rates, sediment chemistry and changes in water quality inferred from changes in the diatom community composition.

Introduction

Ashippun Lake is located in northwestern Waukesha County, in southeastern Wisconsin. It is a hardwater spring fed lake, which drains to the Ashippun River. The lake is moderately productive (mesotrophic). Ashippun Lake is 83 acres, 35 feet deep and the drainage area is 371 acres resulting in a direct drainage area to lake area ratio of 4.5 to 1. The 1990 land use in the direct drainage area is summarized in table 1 (SEWRPC, 1990).

Table 1. 1990 Land use in the direct drainage area of Ashippun Lake, Waukesha County, Wisconsin.

Land Use Type	Percent	Acres
Developed	14.9	55.2
Agriculture/Open	45.4	168.4
Woodlands	2.2	8.2
Wetlands	15.5	57.5
Water	22.0	81.6

Background

The water quality of Ashippun Lake was monitored between 1973 and 1978 and is summarized in a report entitled *A Water Quality Management Plan For Ashippun Lake* (SEWRPC, 1982). Prior to this period the water quality had been monitored only sporadically. Volunteers on the lake have been monitoring the water clarity of Ashippun Lake since 1990, however there is insufficient information to determine long term trends in water quality.

However, the historical water quality of Ashippun Lake can be determined by using techniques which use known relationships between algal communities, sediment/water interactions, and the rate of sedimentation. An analogy would be counting and measuring the width of tree rings for determining the age and rate of growth of a tree. The concentration of nutrients and other chemical parameters in the core provides a clue to the condition of the lake at a known period in time. The relative water quality was determined by examining the algal remains, specifically diatoms, in the core. Diatoms are algae which have cell walls composed of silica which resist degradation. The sedimentation rate is determined by the lead-210 activity in the sediment core. Lead-210 is a naturally occurring radionucleid with a half life of 22.3 years. The decay of lead-210 provides a means for determining the age of sediment and the rate of sedimentation.

Materials and Method

The following discussion describes the methods used to analyze the sediment parameters as well as what each parameter means in regards to interpreting watershed land use activities and water quality changes.

Field Sampling

A sediment core was collected from the deepest part of the lake (Figure 1), with a gravity corer. The core was taken back to the lab and sectioned into 2 centimeter (cm) sections. The sediment samples were placed in labeled preweighed bottles, weighed again then dried to a constant weight. The difference in wet and dry weight is used to calculate the porosity of the sediment (Formula A). The samples are then ground to a fine powder and stored until used.

Formula A

$$\text{Porosity} = \frac{(1-f)/D_w}{(1-f)/D_w + (f/D_s)}$$

Where:
D_w = Water Density (1.0 g/cm^3)
D_s = Sediment Density (2.45 g/cm^3)
f = Fraction Dry Weight (g/cm^3)

Sediment porosity is used to determine the size of sedimenting particles. A high porosity value indicates finer or smaller grained material compared to low porosity values which mean coarser material. Coarser material is characteristic of upland erosion. During periods of land disturbance or high erosion we would expect the sediment porosity to decrease.

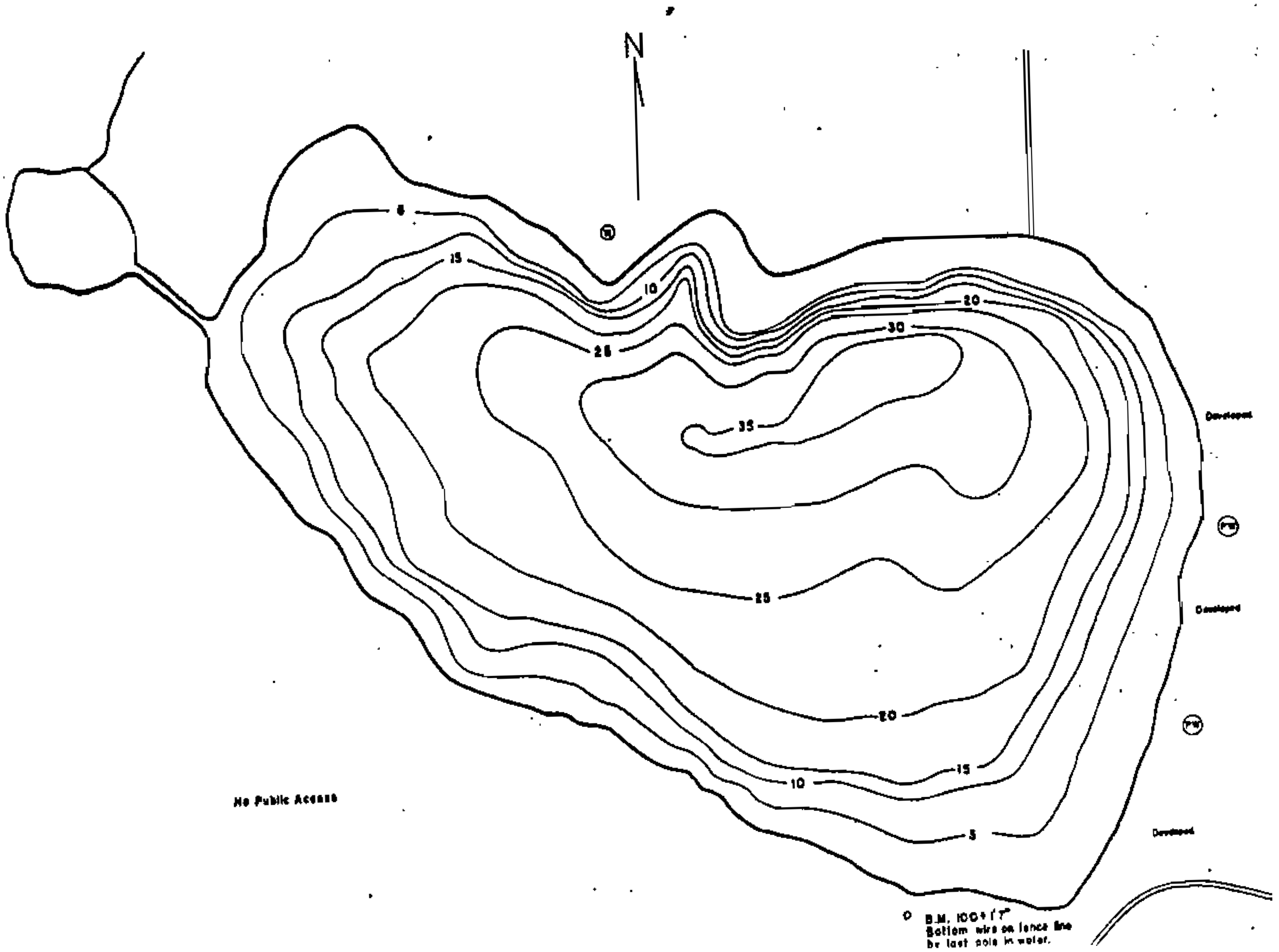


Figure 1. Ashippun Lake Map.

Lead-210 (Aging sediment samples)

Geochronology with the naturally occurring Lead-210 is based on the principle that the isotope has been continuously delivered to the earth's surface and undergoes continuous radioactive decay following incorporation into steadily accumulating sediments. The activity of Lead-210 in a sediment sample was used to determine the age of the sample. Lead-210, a weak beta emitter with low activity and is not readily detected therefore, Polonium-210, is actually measured. Polonium-210 is the alpha emitting granddaughter of Lead-210, and can be used to represent the actual Lead-210 activity in each sample because the two isotopes are assumed to be in seqular equilibrium. The daughter is used because in an acidic solution it will spontaneously plate on to a copper disk, which can then be counted on a high resolution alpha spectrometry system. A yield monitor, Polonium-208, is added to each sample so that the exact activity of Polonium-210 can be determined. The activity of Lead-210 at the time of sediment sampling is calculated from the count rates corrected for counting background, growth and decay, counting efficiency and recovery of the yield monitor.

The sediment accumulation rate is expressed as an accumulation of a mass of sediment (gm/cm2/yr) rather than as an accumulated depth. Since layers of sediment will become compacted by the addition of new sediment the depth can not be used to determine accumulation rates. Sediment mass is used to determine accumulation rates since no matter how compacted a layer becomes it's mass will remain.

The rate of sediment accumulation will vary depending on the sampling location in the lake. The greatest accumulation rate occurs at the maximum depth because of the lateral movement of sediment from shallow depths towards the deepest part of the lake (sediment focusing).

Total Iron and Total Manganese Analysis

Analysis of the Total Iron, and Total Manganese in the sediment was done using a acid digestion followed by analysis with a Atomic Absorption Analyzer. A known quantity of dried and ground sediment was digested using nitric acid and hydrogen peroxide. Following heated digestion the solution is filtered, and brought up to a known volume. This solution is then analyzed for iron and manganese.

The ratio of iron to manganese is used to assess the presence of oxygen in the hypolimnion of a lake. In addition the ratio of iron to phosphorus can be used to indicate periods of erosion in the watershed.

Carbon and Nitrogen Analysis

Total carbon, organic nitrogen and organic carbon are measured in a Carlo Erba Elemental Analyzer 1106. The technique used is flash combustion. The samples are held in a lightweight tin container and dropped at preset intervals of time into a vertical quartz tube, maintained at 1,030 degrees celsius (°C), through which a constant flow of helium is run. When the samples are introduced, the helium stream is temporarily enriched with pure oxygen. Flash combustion takes place, primed by the oxidation of the container. The individual components are then separated and eluted as N_2, CO_2, and H_2O. They are measured by a thermal conductivity detector, whose signal is fed into an integrator with digital printout of peak area. The instrument is calibrated by combustion of standards of known elemental composition. A sediment sample of known composition is also included in each sample run. The inorganic carbon is determined by subtracting the organic carbon from the total carbon in the sample.

The total carbon accumulation rate is a combination of organic and inorganic carbon (carbonates) sources. Organic carbon accumulation rates are used to infer overall lake productivity. Productive lakes have more algae, and aquatic plants and the sediment organic carbon is higher. Inorganic carbon accumulation rates are useful in determining the overall water quality and the source of sediment. The accumulation of inorganic carbon is typically found in hardwater or marl lakes which tend to be less productive.

Total Phosphorus

A known amount of dried, ground sediment is digested with nitric and sulfuric acids. Following digestion the solution is filtered, diluted and analyzed with a spectrophotometer.

The iron to phosphorus ratio is used as a surrogate to watershed erosion. As erosion in the watershed increases the ratio of iron to phosphorus also tends to increase. The phosphorus accumulation rate can be used alone as an indicator of water nutrient levels. The sediment/water interactions regulating phosphorus are complex and can make the interpretation of the profile difficult. Therefore, the phosphorus accumulation rate is generally used as supportive evidence with other sediment parameters.

Diatoms

A known amount of wet sediment is digested with a known amount of hydrogen peroxide and potassium dichromate. Following digestion the residue is washed with distilled water at least four times. A known amount of glass microspheres is added to the sample to more accurately determine diatom concentrations in the sample. A portion of the diatom suspension is dried on a coverslip and samples are mounted in Hyrax. A minimum of 100 frustules were identified and counted under oil immersion objectives (1400X).

All partial valves containing unique features such as identifiable central areas, or ends were tabulated. Counts were made continuously along randomly selected transects and all identifiable fragments were included in the count. When a fragment or frustule could not be identified, it was recorded as unknown and included in the total count. When valve ends were tabulated, the number recorded was divided by the number of ends a complete frustule would possess. Frustules and fragments were counted if they were completely in the field of view or in the case when only a portion of the frustule was visible, when the appropriate characteristic was visible in the right half of the field of view.

The diatom accumulation rate is used as a surrogate to lake productivity. As a lake becomes more nutrient rich and productive the diatom accumulation rate also increases. Changes in the diatom community within a core can also be used to indicate periods of changing water quality. The species also indicate the relative water quality. Since the relationship between certain species of diatoms and general water quality conditions is known, they provide an excellent tool to determine the historical water quality changes.

Results

The results are presented as accumulation rates rather than concentration for a particular period of time, with the exception of porosity and chemical ratios. The accumulation rate is calculated by multiplying the parameter concentration at a particular sediment depth with the corresponding calculated instantaneous sediment accumulation rate. The rate of accumulation gives the most accurate picture of changing lake conditions. An analogy is a small river flowing into Ashippun Lake. The concentration of phosphorus in the water may be very high but if there is little flow in the river the total quantity reaching the lake is small, however if the concentration of phosphorus is low but the river is in flood stage then the total amount of phosphorus entering the lake may be very high. While the concentration is important the load to the lake or sediment is critical to measure.

Appendix 1 graphically summarizes the sediment core results and Appendix 2 contains the sediment chemistry concentrations for future reference. Appendix 3 summarizes the sediment accumulation results. The sediment core results are truncated at the early 1800's since the lead-210 sediment dating technique is accurate for the last 150 years. Prior to the early 1800's the dates are only marginally accurate.

Lead-210 (Sedimentation Rate)

Since the 1840's the sediment accumulation rate increased steadily to a maximum rate of 0.063 gm/cm2/yr in the 1930's (Figure 2). The rate decreased until the 1970's then increased to the present (1995) rate of 0.055 gm/cm2/yr.

Porosity

Between 1800 and the 1840's the porosity remained nearly constant (Figure 3). Between the 1840's and 1940 the porosity decreased to a minimum of 0.8944. After the 1940's the porosity increased again to the current (1995) value of 0.9511.

Carbon Accumulation Rates

Between 1800 and 1840 there was little change in the total carbon deposition rate (Figure 4). After the 1840's the total carbon accumulation rate increased substantially until the 1860's. This increase was due to an increase in the inorganic carbon accumulation rate. Between the 1860's and the 1980's the total carbon accumulation rate remained fairly constant. Since the 1980's the total carbon accumulation rate substantially increased as a result of an increase in both organic and inorganic carbon accumulation.

Total Phosphorus

Since the 1840's the phosphorus accumulation rate substantially increased (Figure 5). The rate reached a maximum in the 1930's, then decreased substantially until the 1960's. The phosphorus accumulation rate increased between the 1960's and the 1980's and decreased slightly during the most recent time.

Iron/Phosphorus Ratio

Since the mid 1800's the iron to phosphorus ratio increased to a maximum in the 1950's (Figure 6). The ratio decreased after the 1950's until the 1990's when it substantially increased.

Diatoms

The diatom accumulation rate (Figure 7) peaked in the early 1900's and again in the 1920's. Since the 1920's the accumulation rate decreased until the 1970's when it increased to present levels (1995).

In the early 1800's (Figure 8), *Navicula pseidoventralis*, *Staurosira construens*, and *S. construens var. venter* dominated. These taxa suddenly decreased around 1835 and were replaced by *Cyclotella michiganiana* and *Cyclotella pseudostelligera* and to a lesser extent *Asterinella formosa*. In the early 1900's *Stephanodiscus medius* appeard and was relatively abundant until the 1970's. *Cylotella michiganiana* reappears in the core beginning in the 1960's.

Discussion

The following discussion will first focus on the watershed activites which were taking place at known periods of time. This will then be related to the sediment core results to show the impact land use activites had on the water quality of Ashippun Lake.

Initial settlement of southeastern Wisconsin started in the 1830's and continued through the 1850's. German farmers settled the area and cultivated predominately wheat and lesser amounts of corn, oats and hay. Around the 1880's wheat farming declined and farmers turned to corn, oats, hay and began to develop dairy herds. By the 1930's agriculture was beginning to grow rapidly, and was becoming mechanized. Through the 1980's dairy farms were numerous in southeastern Wisconsin. In the early 1990's dairy farming has declined and cash cropping which require less labor but can also result in greater soil loss has increased.

From the 1940's to the 1960's there was a tremendous increase in the population, especially around the lakes in the Washington, Waukesha County areas. Lake shorelines that were once farmed were being sold for seasonal homes. By 1950 the majority of the shoreline had been developed with seasonal homes.

Continued urbanization of the watershed contributes increased stormwater inputs to the lakes and rivers. Stormwater is the source of nutrients and other pollutants which are conveyed in stormsewers directly to the surface waters rather than being filtered in vegetated drainage ways.

The results of the sediment analysis will be broken into time periods which reflect either a period of status quo or periods of significant change. These periods can then be compared to watershed activities to see how the activity on the land influenced the lake. Table 2 summarizes the watershed activities and corresponding sediment core results.

1800 - 1830

Presettlement water quality conditions for Ashippun Lake were excellent. The lake experienced a very low sedimentation rate of 0.010 gm/cm^2/yr and had diatom taxa indicative of excellent water clarity and low nutrient levels.

1830 - 1930

The steady increase in the sedimentation rate from the 1840's until the peak in the 1930's (Figure 2) corresponds with an increase in the development and agricultural activity within the watershed. The initial settlement and agricultural activity in the watershed, decreased the water quality of Ashippun Lake. This is supported by a decrease in particle size as indicated by porosity, an increase in total carbon, diatom accumulation rates and diatom species indicative of increasing nutrient levels.

1930 - 1970

Since the 1930's the sedimentation rate declined until the 1970's. This decline does not correspond to an improvement in water quality. The diatom taxa during this period indicate increasing nutrient levels in Ashippun Lake.

An increase in nutrient loading and decreasing sedimentation rate is possible if nutrients are reaching the lake that are not associated with sediment. Urban development in the watershed, specifically around the perimeter of the lake increased substantially between 1950 and 1975. This may have increased nutrient loading from septic systems and lawn care without the associated sediment load. The first urban development occurred in the 1950's on soils which were poorly suited for individual septic systems and probably resulted in increased nutrient loading to the lake. While soil erosion may have been decreased due to improved agricultural and erosion control practices, fertilizers may be enriching the soil, so that even though there is less sediment entering the lake it contains a greater amount of phosphorus. It is not possible to differentiate between these two explanations with the existing information.

1970 - Present

Since the 1970's the increase in sedimentation rate is due to an increase in the deposition of inorganic and organic carbon rather than from external sources. External sediment sources would have resulted in an increase in the iron to phosphorus ratio and a decrease in the sediment porosity. The iron to phosphorus ratio does increase but not until the mid 1990's. The sediment porosity indicates continued sedimentation of finer grained material which also supports the theory that the sediment is not from external sources. In addition, the diatom community over the last 20 years suggest that nutrient levels are declining and water clarity is actually improving.

Table 2. Summary of watershed activity and sediment core results.

Time Period	Watershed Activity	Sediment Core Results
1800 - 1830	Presettlement conditions	Low sedimentation rate ($0.010\ g/cm^2/yr$) Diatom taxa indicative of excellent water quality.
1830 - 1930	Substantial increase in agricultural activity	Steady increase in sedimentation rate from $0.010\ g/cm^2/yr$ to $0.063\ g/cm^2yr$ Decrease in sediment porosity Increase in sediment total carbon Increase in diatom accumulation rate Diatom taxa indicative of increasing nutrient levels
1930 - 1970	1950 eastern shore of lake developed (residential) 1970 - 1975 additional urban development in watershed Agriculture status quo	Sedimentation rate declines Diatom taxa indicative of elevated nutrient levels Diatom accumulation rate decreasing
1970 - 1995	Shoreline agriculture activity decreased Low density residential development increased Transition from seasonal to year round homes	Increase in sedimentation rate Diatom taxa indicative of elevated nutrient levels Diatom accumulation rate increasing

Conclusions

Initial land clearing and agricultural activity in the watershed had a significant adverse impact upon the water quality of Ashippun Lake. Sedimentation rates, sediment chemistry and diatom species indicate that presettlement water quality conditions of Ashippun Lake was close to the least productive of the lakes examined. Increased agricultural activity resulted in a steady increase in sedimentation rates and nutrient levels until the 1930's when the sedimentation rate decreased.

Following the 1930's the nutrient loading remained elevated. Since the 1970's the total carbon accumulation rate has increased however the diatom community indicate improved water clarity.

The management implications of this work clearly point to the need to manage nutrient loading to Ashippun Lake. The results show how the lake responded to periods of high sediment and nutrient loading and provides the evidence to reduce the phosphorus load. The existing sediment load appears to be less of a problem than the phosphorus load at the present time.

Acknowledgements

The author would like to acknowledge the assistance of Mr. Paul Garrison and Molli MacDonald from the Department of Natural Resources for completion of the diatom profiles and interpretation of the sediment profiles. Mr. Pat Anderson from the Center for Great Lakes Studies for his assistance in sediment chemistry analysis and interpretation. Mike Bruch from the Department of Natural Resources for his assistance in collection of the sediment core. The Southeastern Wisconsin Regional Planning Commission was very helpful in providing information on the soils, land use and extent of urban development within the watershed. Dan Helsel was extremely helpful in reviewing drafts of this report and providing constructive comments on organization and content. The author also wishes to thank the Ashippun Lake Protection and Rehabilitation District for participating in this study. The results provide a great deal of information on the historical water quality trends in Ashippun Lake and the importance of managing nutrient loads to the lake.

Sediment Accumulation Rate

Ashippun Lake, Waukesha County

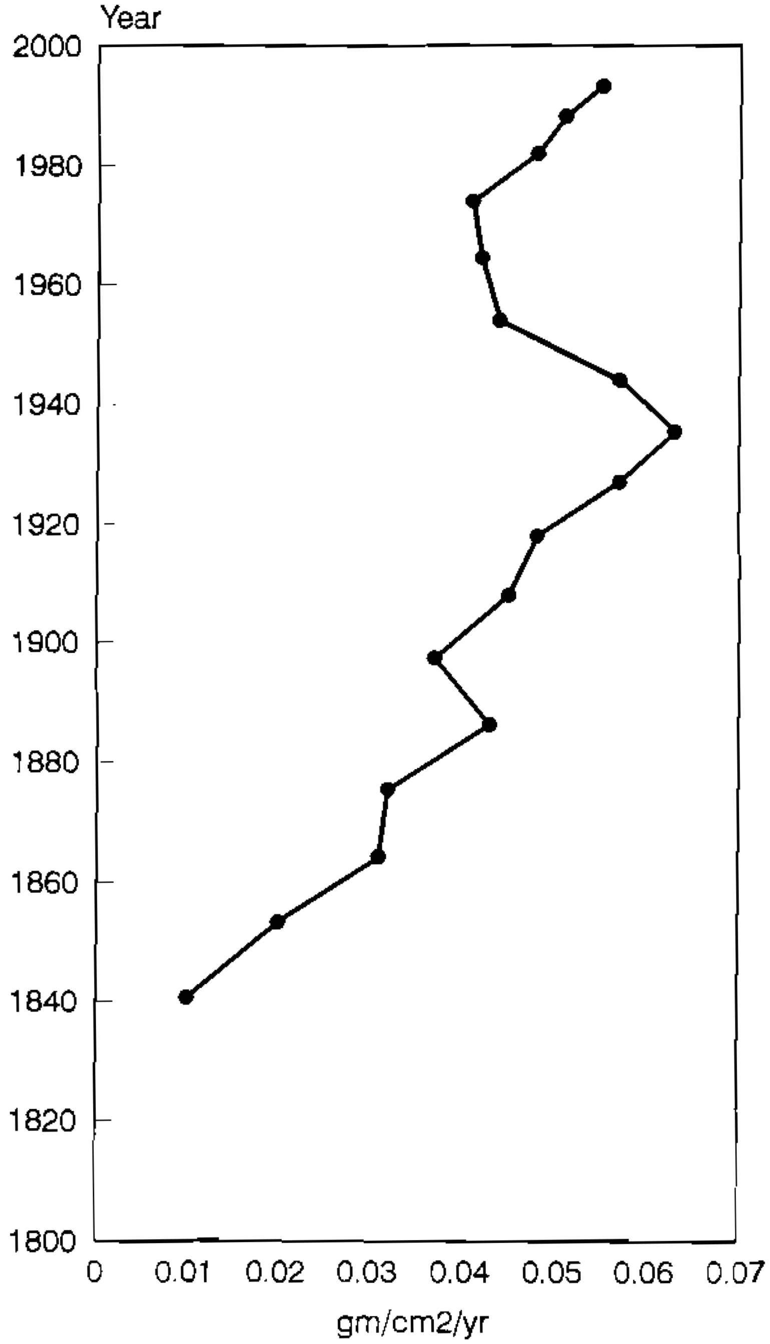


Figure 2. 1995 Upper Rock River Basin Assessment

Porosity

Ashippun Lake, Waukesha County

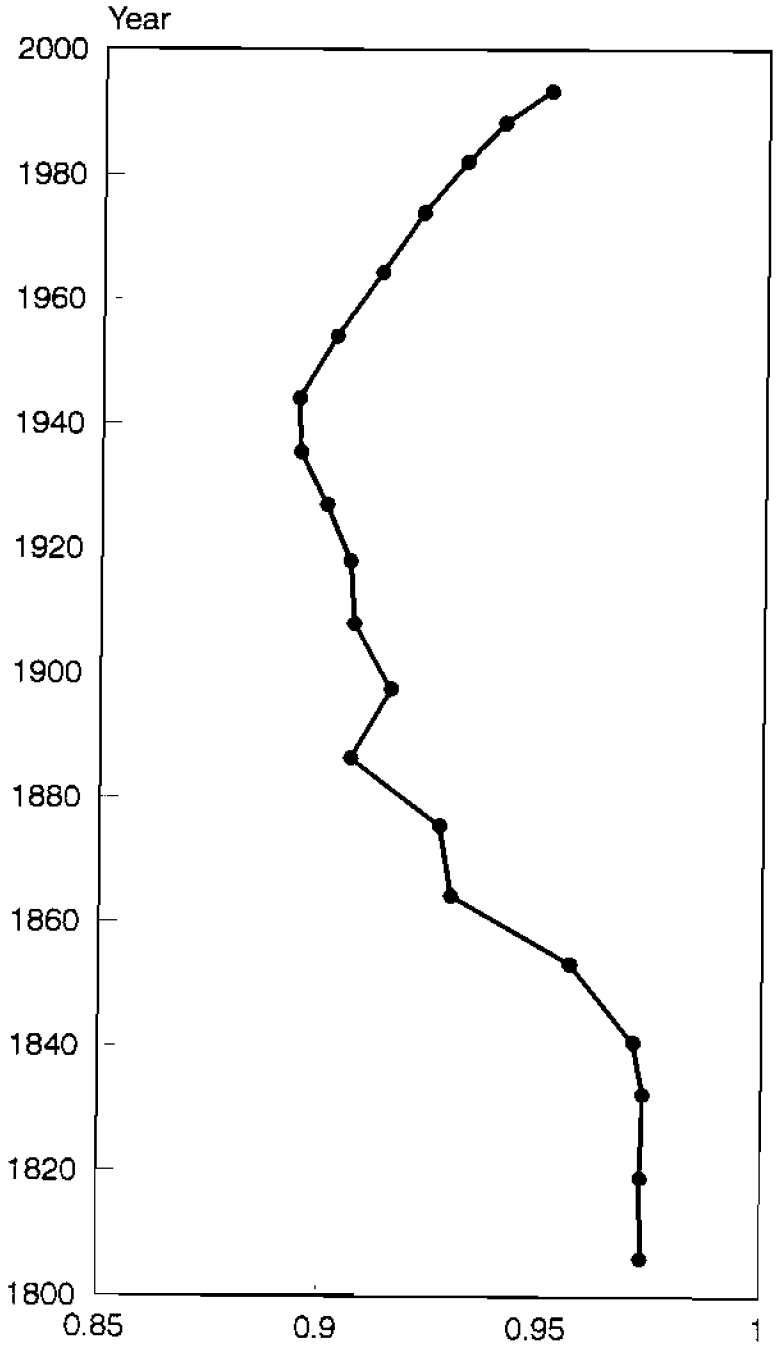


Figure 3. 1995 Upper Rock River Basin Assessment

Carbon Accumulation Rate

Ashippun Lake, Waukesha County

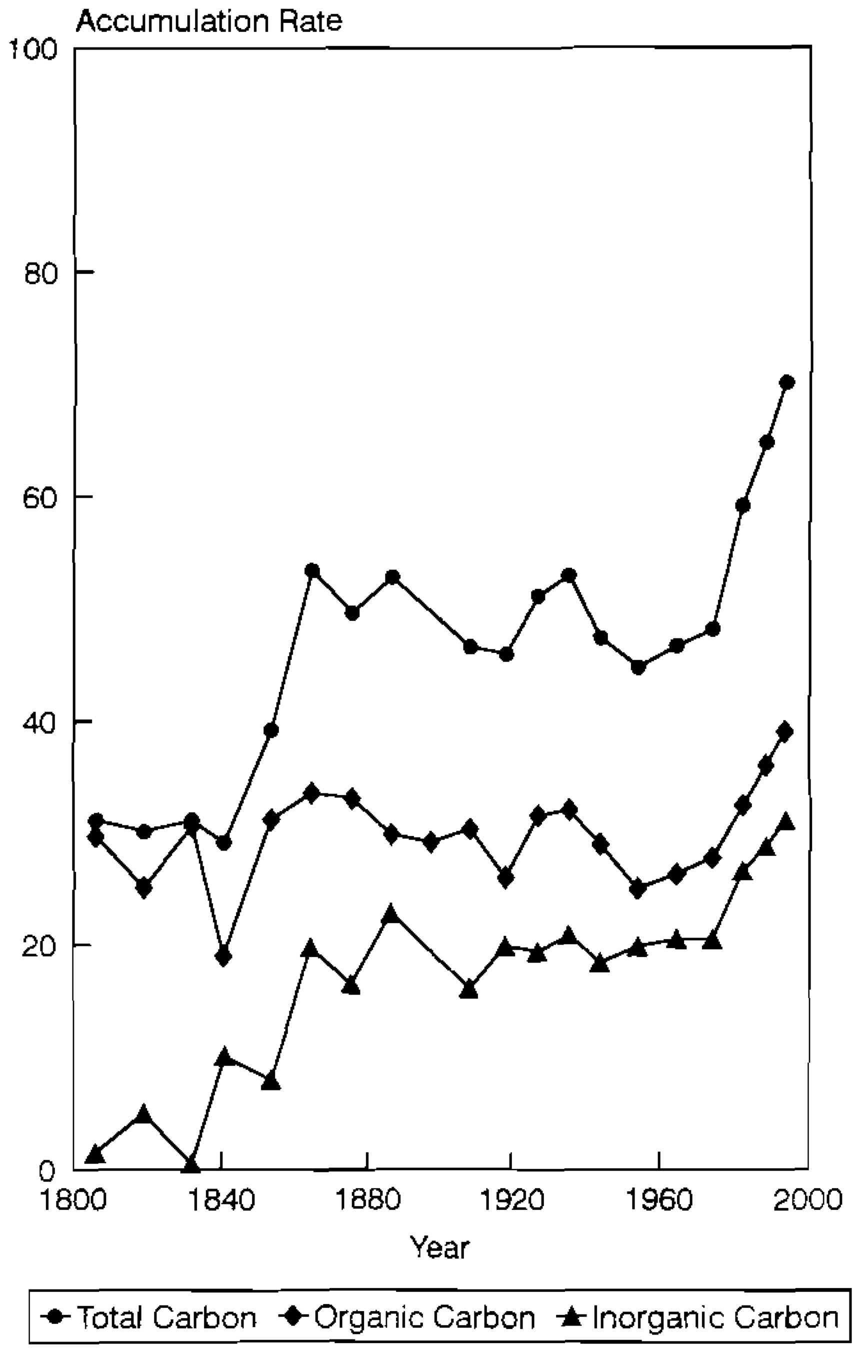


Figure 4. 1995 Upper Rock River Basin Assessment

Phosphorus Accumulation Rate

Ashippun Lake, Waukesha County

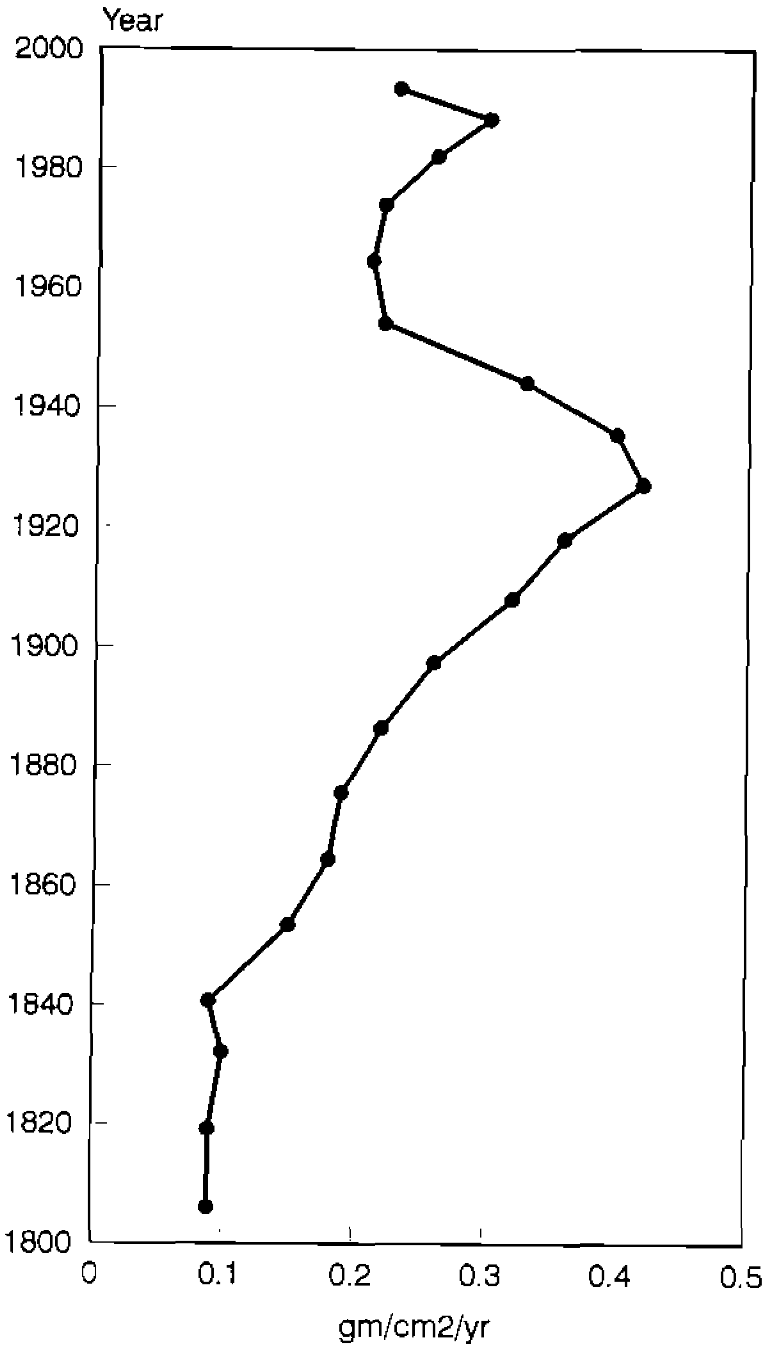


Figure 5. 1995 Upper Rock River Basin Assessment

Iron:Phosphorus Ratio

Ashippun Lake, Waukesha County

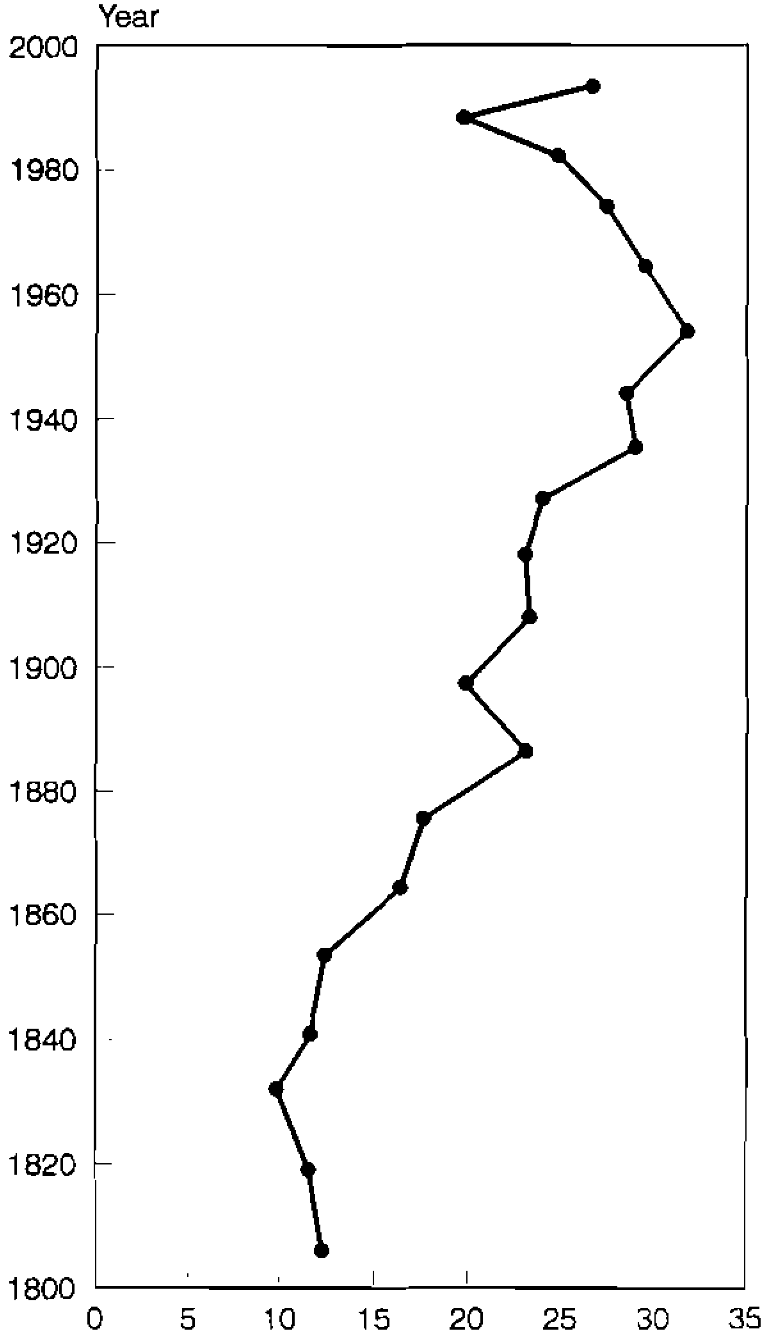


Figure 6. 1995 Upper Rock River Basin Assessment

Diatom Accumulation Rate

Ashippun Lake, Waukesha County

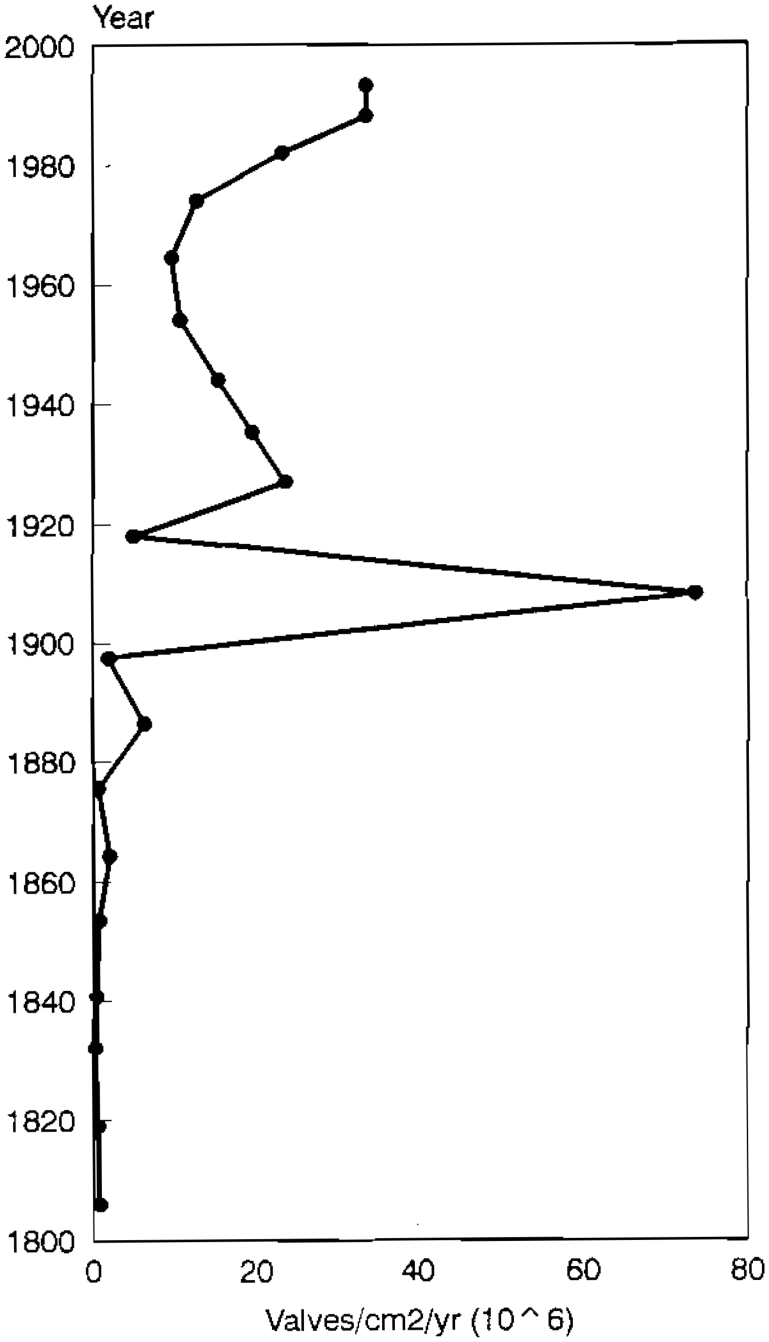
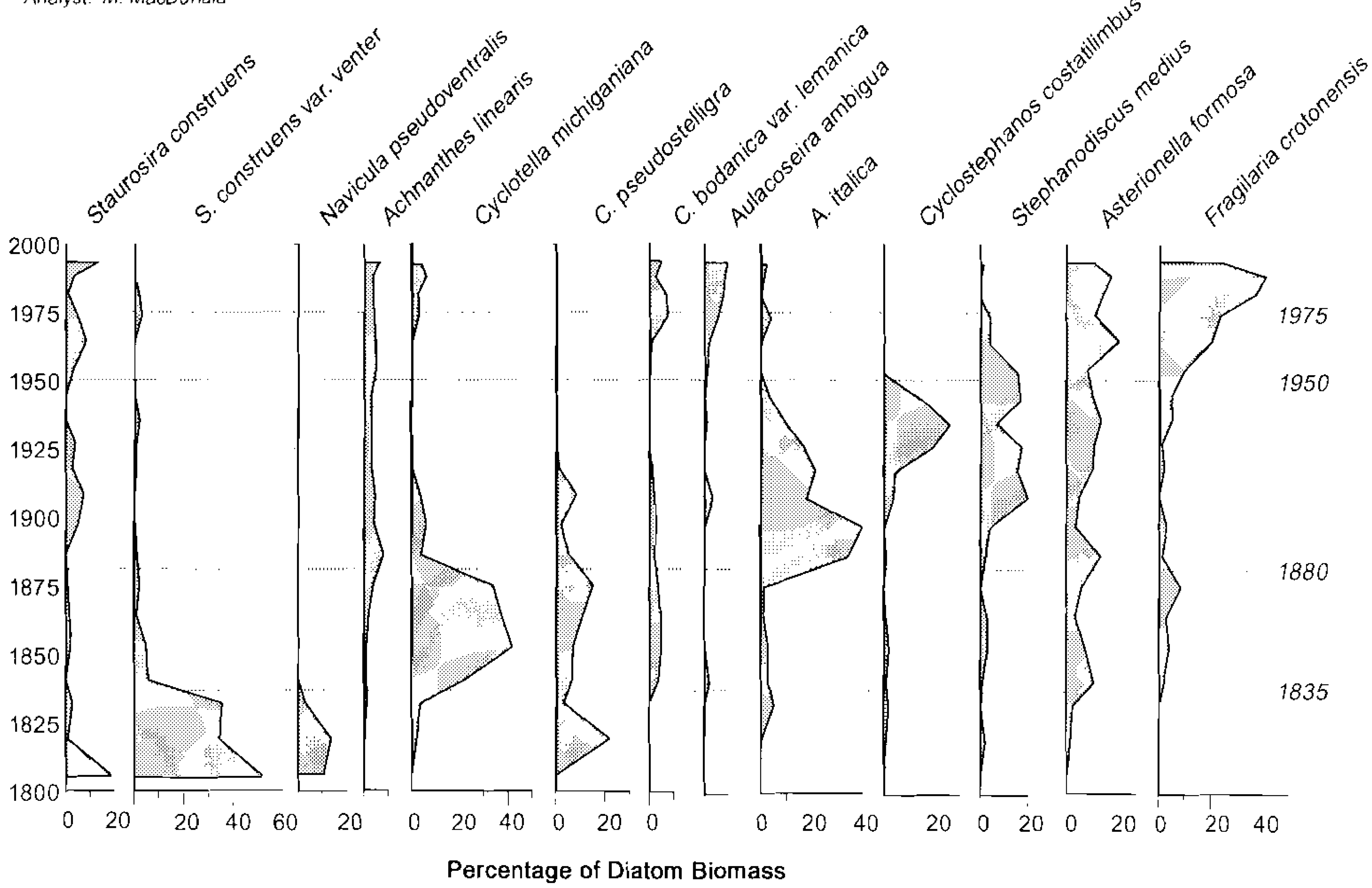


Figure 7. 1995 Upper Rock River Basin Assessment

Ashippun Lake

Waukesha Co.

Analyst: M. MacDonald



Ashippun Lake, Waukesha County sediment chemistry results.

SEDIMENT DEPTH	POROSITY	TOTAL PHOSPHORUS	TOTAL CARBON	TOTAL NITROGEN	TOTAL ORGANIC CARBON	IRON Fe	MANGANESE Mn	YEAR (Mid)
cm.		ug/gm	WT. %	WT. %	WT. %	ug/gm	ug/gm	
0-2	0.9511	424	12.85	0.798	7.15	11299	964	1993.4
2-4	0.9407	590	12.71	0.778	7.065	11637	966	1989.3
4-6	0.9323	533	12.31	0.745	6.77	13224	994	1982.1
6-8	0.9225	532	11.67	0.713	6.715	14590	986	1974.0
8-10	0.9132	507	11.04	0.675	6.205	14963	923	1964.4
10-12	0.9030	495	10.10	0.628	5.645	15717	830	1954.0
12-14	0.8944	587	8.32	0.565	5.085	16729	846	1944.0
14-16	0.8949	632	8.44	0.575	5.105	18331	790	1935.4
16-18	0.9009	738	9.97	0.603	5.555	17727	896	1927.0
18-20	0.9065	757	9.61	0.638	5.44	17442	916	1918.0
20-22	0.9075	702	10.36	0.745	6.755	16335	827	1908.1
22-24	0.9160	718		0.850	7.995	14283	843	1897.4
24-26	0.9069	501	12.26	0.805	6.94	11569	758	1886.4
26-28	0.9272	577	15.47	1.135	10.315	10178	795	1875.5
28-30	0.9299	591	17.35	1.225	10.915	9688	801	1864.3
30-32	0.9568	749	19.80	1.723	15.74	9160	633	1853.4
32-34	0.9712	879	29.84	2.715	19.475	10192	394	1840.7
34-36	0.9734	1001	31.13	3.503	30.625	9797	320	1832.3

Ashippun Lake, Waukesha County sediment chemistry results (Con't).

SEDIMENT DEPTH	POROSITY	TOTAL PHOSPHORUS	TOTAL CARBON	TOTAL NITROGEN	TOTAL ORGANIC CARBON	IRON Fe	MANGANESE Mn	YEAR (Mid)
cm		ug/gm	WT. %	WT. %	WT. %	ug/gm	ug/gm	
36-38	0.9729	930	30.15	3.048	25.13	10797	314	1819
38-40	0.9732	936	31.13	3.403	29.66	11459	284	1806
40-42	0.9723	942	32.00	3.453	30.3	12428	268	1793
42-44	0.9712	961	31.01	3.340	30.645	11275	262	1779
44-46	0.9686	982	28.45	3.020	26.605	11433	256	1763
46-48	0.9668	960	27.93	2.890	25.03	11757	262	1747
48-50	0.9659	965	26.13	2.730	25.185	11681	405	1731
50-52	0.9600	974	25.36	2.558	23.595	12301	305	1711
52-54	0.9621	943	26.72	2.560	23.77	12020	320	1693
54-56	0.9614	983	26.93	2.735	25.525	12592	367	1674

Ashippun Lake, Waukesha County sediment chemistry results (Cont).

SEDIMENT DEPTH	Fe:Mn	Fe:P	YEAR (Mid)	SEDIMENT ACCUM. RATE	TOTAL DIATOMS
cm				gm/cm2/yr	valve/g dry wt.
0-2	11.7	26.6	1993.4	0.055	6.18e+08
2-4	12.0	19.7	1988.3	0.051	6.61e+08
4-6	13.3	24.8	1982.1	0.048	4.87e+08
6-8	14.8	27.4	1974.0	0.041	3.06e+08
8-10	16.2	29.5	1964.4	0.042	2.26e+08
10-12	18.9	31.8	1954.0	0.044	2.40e+08
12-14	19.8	28.5	1944.0	0.057	2.68e+08
14-16	23.2	29.0	1935.4	0.063	3.11e+09
16-18	19.8	24.0	1927.0	0.057	4.16e+08
18-20	19.0	23.0	1918.0	0.048	1.02e+08
20-22	19.8	23.3	1908.1	0.045	1.64e+09
22-24	16.9	19.9	1897.4	0.037	5.05e+07
24-26	15.3	23.1	1886.4	0.043	1.45e+08
26-28	12.8	17.6	1875.5	0.032	1.77e+07
28-30	12.1	16.4	1864.3	0.031	6.34e+07
30-32	14.5	13.4	1853.4	0.020	3.46e+07
32-34	25.9	11.6	1840.7	0.010	4.33e+07
34-36	30.6	9.8	1832.3	0.010	2.42e+07

Ashippun Lake, Waukesha County sediment chemistry results (Con't).

SEDIMENT DEPTH	Fe:Mn	Fe:P	YEAR (Mid)	SEDIMENT ACCUM. RATE	TOTAL DIATOMS
cm				gm/cm2/yr	valve/g dry wt.
36-38	34.1	11.5	1819	0.010	5.99e+07
38-40	40.3	12.2	1806	0.010	8.42e+07
40-42	46.3	13.2	1793	0.010	1.39e+08
42-44	43.0	11.7	1779	0.010	1.07e+08
44-46	44.6	11.6	1763	0.010	3.54e+08
46-48	44.8	12.2	1747	0.010	1.70e+08
48-50	39.0	12.1	1731	0.010	5.74e+07
50-52	40.3	12.6	1711	0.010	2.68e+07
52-54	37.6	12.7	1693	0.010	7.63e+07
54-56	34.3	12.8	1674	0.010	4.56e+07

Ashippun Lake, Waukesha County sediment chemistry accumulation results.

YEAR	TOTAL PHOSPHORUS	TOTAL NITROGEN	TOTAL CARBON	TOTAL ORGANIC CARBON	INORGANIC CARBON (CaCO3)	IRON Fe	MANGANESE Mn	TOTAL DIATOMS
	ug/cm2/yr					ug/cm2/yr	ug/cm2/yr	valve/cm2/yr *10^6
1993.4	0.23	4.4	70.2	39.1	31.1	6.18	0.53	33.77
1988.3	0.30	4.0	64.9	36.1	28.8	5.95	0.49	33.77
1982.1	0.26	3.6	59.2	32.5	26.6	6.36	0.48	21.40
1974.0	0.22	2.9	48.2	27.8	20.5	6.03	0.41	12.63
1964.4	0.21	2.9	46.7	26.3	20.5	6.34	0.39	9.59
1954.0	0.22	2.8	44.8	25.0	19.8	6.97	0.37	10.63
1944.0	0.33	3.2	47.4	29.0	18.4	9.54	0.48	15.27
1935.4	0.40	3.6	53.0	32.1	20.9	11.51	0.50	19.54
1927.0	0.42	3.4	41.1	21.6	19.4	10.10	0.51	22.79
1918.0	0.36	3.1	46.0	26.1	20.0	8.26	0.44	4.92
1908.1	0.32	3.4	46.6	30.4	16.2	7.35	0.37	73.63
1897.4	0.26	3.2	0.0	29.2		5.22	0.31	1.89
1886.4	0.23	3.5	52.8	29.9	22.9	4.98	0.32	6.24
1875.5	0.19	3.6	49.6	33.1	16.5	3.27	0.26	0.57
1864.3	0.18	3.8	53.4	33.6	19.8	2.98	0.25	1.95
1853.4	0.15	3.4	39.2	31.2	8.0	1.82	0.13	0.69
1840.7	0.09	2.6	29.1	19.0	10.1	0.99	0.04	0.42
1832	0.10	3.5	31.1	30.6	0.5	0.98	0.03	0.24
1819	0.09	3.0	30.1	25.1	5.0	1.07	0.02	0.60
1806	0.09	3.4	31.2	29.7	1.5	1.15	0.03	0.94
1793	0.09	3.5	32.0	30.3	1.7	1.24	0.04	1.39

YEAR	TOTAL PHOSPHORUS	TOTAL NITROGEN	TOTAL CARBON	TOTAL ORGANIC CARBON	INORGANIC CARBON (CaCO3)	IRON Fe	MANGANESE Mn	TOTAL DIATOMS
	ug/cm2/yr					ug/cm2/yr	ug/cm2/yr	valves/cm2/yr *10^6
1779	0.10	3.3	31.0	30.6	0.4	1.17	0.03	1.07
1763	0.10	3.0	28.4	26.6	1.8	1.14	0.03	3.54
1747	0.10	2.9	27.9	25.0	2.9	1.18	0.03	1.70
1731	0.10	2.7	26.2	25.2	1.0	1.17	0.03	0.57
1711	0.10	2.6	25.4	23.6	1.8	1.23	0.03	0.27
1693	0.09	2.6	26.7	23.8	2.9	1.20	0.03	0.76
1674	0.10	2.7	26.9	25.5	1.4	1.26	0.04	0.46