A Paleolimnological Study of the Water Quality Trends In Druid Lake, Washington County, Wisconsin

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Written By

Bob Wakeman

Wisconsin Department of Natural Resources

This project was undertaken in cooperation with the Druid Lake Protection and Rehabilitation 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 Druid Lake Protection and Rehabilitation District.

The other lakes included in this assessment were Ashippun 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 Druid Lake, dating back to presettlement times. 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

Druid Lake is located in the southwest portion of Washington County, in southeastern Wisconsin. It is a drainage lake, within the Ashippun River watershed. The lake is moderately to highly productive (meso-eutrophic). Druid Lake is 124 acres, 53 feet deep and the direct drainage area is 483 acres resulting in a direct drainage area to lake area ratio of 3.9 to 1. The 1990 land use in the direct drainage area is summarized in table 1.

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

Land Use Type	Percent	Acres
Developed	12.5	60.4
Agriculture/Open	57.9	279.6
Woodlands	6.9	33.3
Wetlands	20.6	99.5
Water	2.1	10.1

Background

The water quality of Druid Lake has been monitored on an annual basis since 1991 by the U.S. Geological Survey. This information provides an excellent assessment of the recent water quality trends. The data indicates that there has been only slight changes in the trophic status of Druid Lake. The lake has also been monitored by volunteers since 1990 providing valuable water quality information on Druid Lake.

The historical water quality of Druid 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 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 Methods

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.

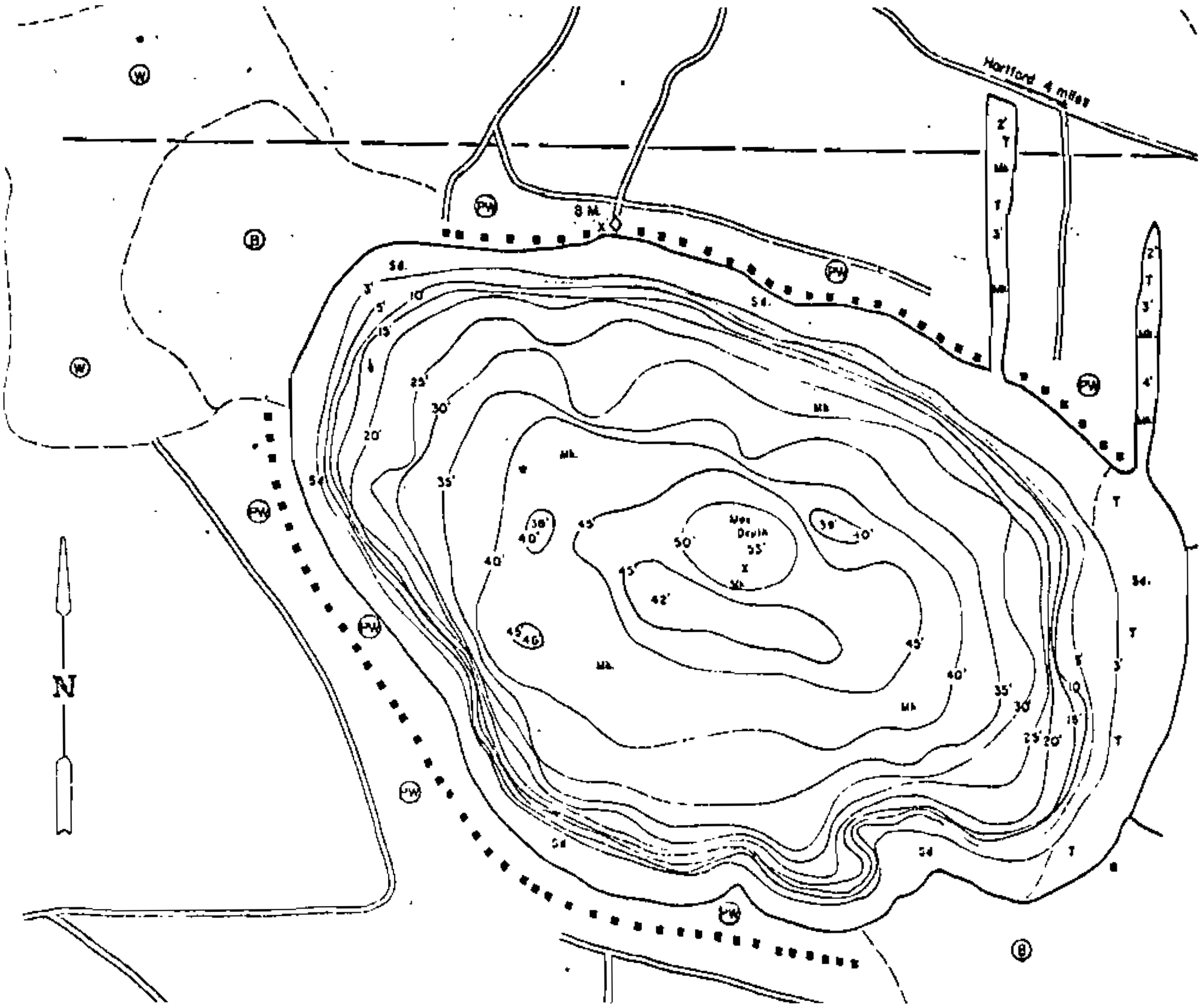


Figure 1. Druid Lake Map

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 was used to determine the rate of sediment accumulation. Lead-210, a weak beta emitter with low activity 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 concentration 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 high erosion in the watershed.

Carbon and Nitrogen Analysis

Total Carbon, Total 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°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 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 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 within the sediment. 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 recognizable fragments were included in the count. In the case when a fragment or frustule could not be identified, it was recorded as unknown and included in the total count. In the case 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 Druid 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 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 1850's the sediment accumulation rate increased steadily to a peak of 0.183 $gm/cm^2/yr$ in the 1950's (Figure 2). The rate decreased to 0.084 $gm/cm^2/yr$ in the 1980's then increased slightly to 0.1 $gm/cm^2/yr$ at the top of core (1995).

Porosity

Sediment porosity in the Druid Lake sediment core is shown in Figure 3. In the early to mid 1800's the porosity is constant. After the 1860's the porosity decreased to a minimum of 0.8575 during the 1920's. Since the 1920's the porosity steadily increased to a maximum of 0.9433 in the 1990's.

Carbon Accumulation Rates

Since the 1920's the has been a substantial increase in the rate of carbon deposition (Figure 4). The rate peaked during the 1950's then decreased steadily until the 1980's. Between 1980 and 1995 there has been an increase in the carbon accumulation rate. There is little change in the proportion of organic to inorganic carbon deposited in the lake as seen in figure 4.

Total Phosphorus

In the early 1900's there was a substantial increase in the total phosphorus accumulation rate (Figure 5). The rate increased and peaked in the 1950's after which it decreased until the 1980's. Since the 1980's the rate of phosphorus accumulation increased substantially.

Iron/Phosphorus Ratio

Between the mid 1800's and 1900 the ratio of iron to phosphorus increased slightly (Figure 6). Following the early 1900's the ratio increased substantially to a maximum of 27.1 in the 1920's. Since the 1920's the ratio decreased to 12.6 during the 1970's then increased over the next decade. The ratio decreased after the 1980's to a minimum of 10.4 in the early 1990's.

Diatoms

The dominant diatom throughout the entire length of the core is *Stephanodiscus medius* (Figure 7). The next two dominant diatoms throughout the entire core are *Asterionell formosa* and *Fragilaria crotonensis*, although *F. crotonensis* first appears around 1875.

Figure 8, summarizes the diatom accumulation rates for Druid Lake.

The diatom accumulation rate increased between the mid 1800's to the 1920's (Figure 8). After the 1920's the accumulation rate increased substantially. Since the 1930's the accumulation rate has been variable but consistently higher than pre-1920'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 Druid 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 1963 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 - 1860

During presettlement and early settlement Druid Lake had a low sedimentation rate of 0.013 gm/cm^2/yr. The diatom taxa which dominated the sediment core are indicative of relatively high nutrient levels and only moderate water clarity.

Table 2. Summary of watershed landuse activities and sediment core results.

Time Period	Watershed Landuse Activity	Sediment Core Result
1800 - 1860	Presettlement and early settlement Wheat farming dominant	Low sedimentation rate (0.013 $g/cm^2/yr$) Diatom taxa suggest elevated nutrient levels with moderate water clarity
1860 - 1950	Wheat farming and dairy farming take turns during this period Majority of shoreline urbanized by 1950	Increasing sedimentation rate to a peak of 0.135 $g/cm^2/yr$ Increased in diatom accumulation rate Presence of diatom taxa indicative of elevated nutrient levels
1950 - 1995	Urbanization of watershed and shoreline Dairy farming dominates agricultural activities	Decline in sedimenation rate between 1950 and 1980's, however no improvement in water quality as indicated by diatom taxa Diatom accumulation rate declined despite taxa indicators

1860 - 1950

The increase in the sedimentation rate from the 1860's until the peak in the 1950's (Figure 2) corresponds well with the increased development and agricultural activity within the watershed. A decrease in porosity indicates deposition of coarser material most likely coming from the disturbance of the land. The increase in diatom accumulation rates indicates an increase in the primary productivity. Diatom species indicative of elevated nutrient levels found throughout the sediment core suggest that Druid Lake was a highly productive lake even prior to settlement of the watershed.

1950 - Present

Since the 1950's the sedimentation rate has declined until the 1980's when it increased slightly. This decline in sedimentation rate does not correspond to an improvement in water quality. The diatom taxa indicate that the lake is still nutrient rich. The diatom accumulation rate however suggests that since the 1950's the level of primary productivity has decreased.

Conclusions

Early settlement and agricultural activity in the watershed significantly increased the sedimentation rate in Druid Lake prior to the 1960's. During presettlement the sedimentation rate was 0.013 gm/cm^2/yr compared to 0.1 gm/cm^2/yr presently. The level of primary productivity also increased during this period. The diatom taxa present throughout the sediment core indicate that Druid Lake has been nutrient rich since prior to settlement and the increased watershed activity had little influence on the nutrient levels.

While the results indicate that Druid Lake has always been moderately to highly productive there is still a need to control sediment and nutrients to the lake.

Acknowledgments

The author would like to acknowledge the assistance of Mr. Paul Garrison and Ms. Molli MacDonald from the Department of Natural Resources for completion of the diatom profiles and interpretation of the sediment profiles. Completion of this project would not have been possible without the assistance of Mr. Pat Anderson from the Center for Great Lakes Studies. Mr. Anderson's assistance with the sediment chemistry analysis and interpretation provided excellent quality control and insight into the sediment results. I would also like to thank Dr. David Edgington from the Center for Great Lakes Studies for his time in assessing the lead-210 profiles and sediment chemistry results.

A special thank you to Ms. Chris Hinz from the Southeastern Wisconsin Regional Planning Commission for her assistance in collection of the sediment core and patience during periods of technical difficulty. Dr. Jeff Thornton from the Southeastern Wisconsin Regional Planning Commission provided technical assistance and information on the land use, soils and urban growth of the area to which the interpretation of the results could not have been completed. Dan Helsel from the Department of Natural Resources was most helpful in reviewing drafts of this report and making constructive suggestions to organization and content.

The author also wishes to acknowledge the participation of the Druid Lake Protection and Rehabilitation District for participating in this study.

The results provide a valuable amount of information regarding the importance of proper land management and should provide the District with added information to influence property owners to be conscious of their activities.

Sediment Accumulation Rate

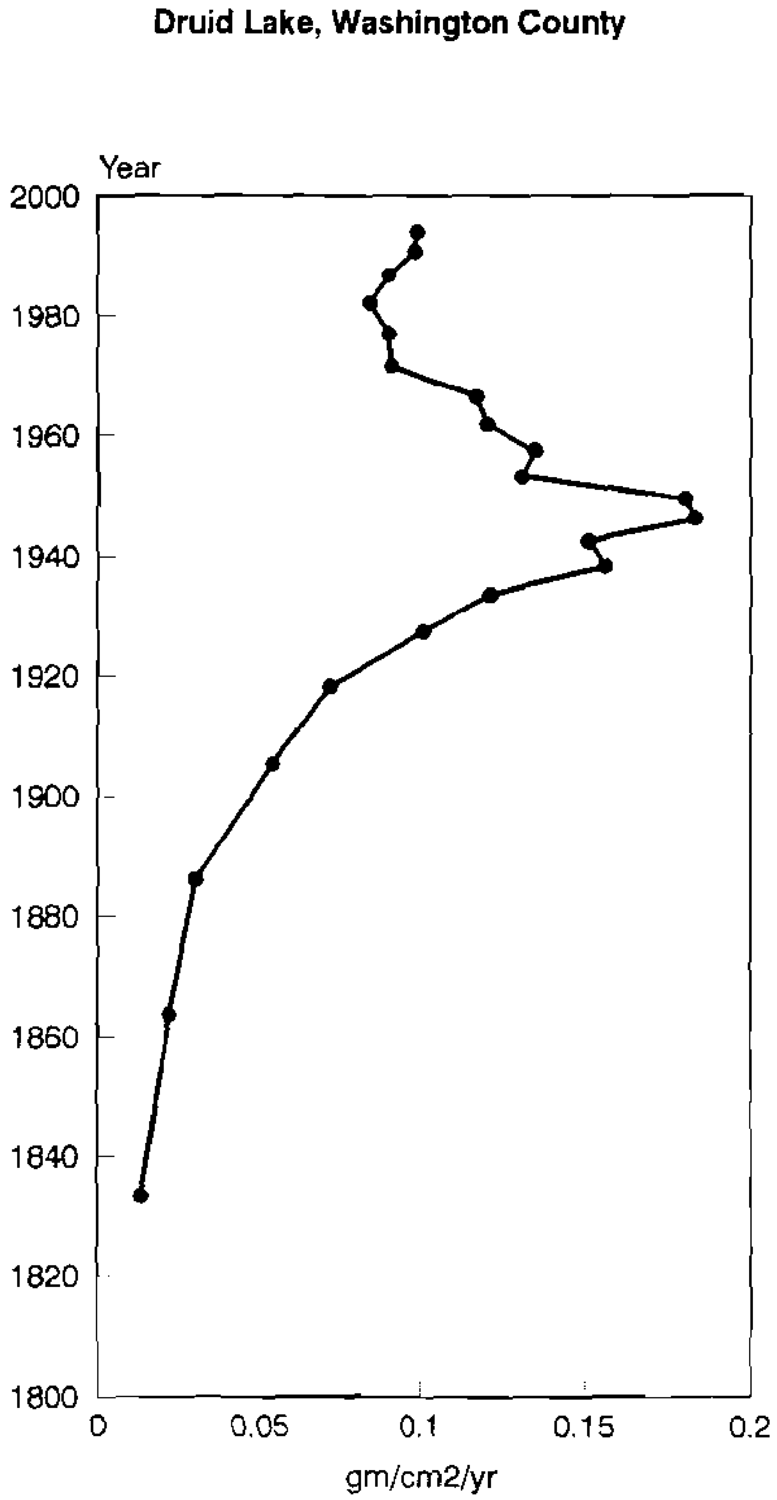


Figure 2. 1995 Upper Rock River Basin Assessment

Porosity

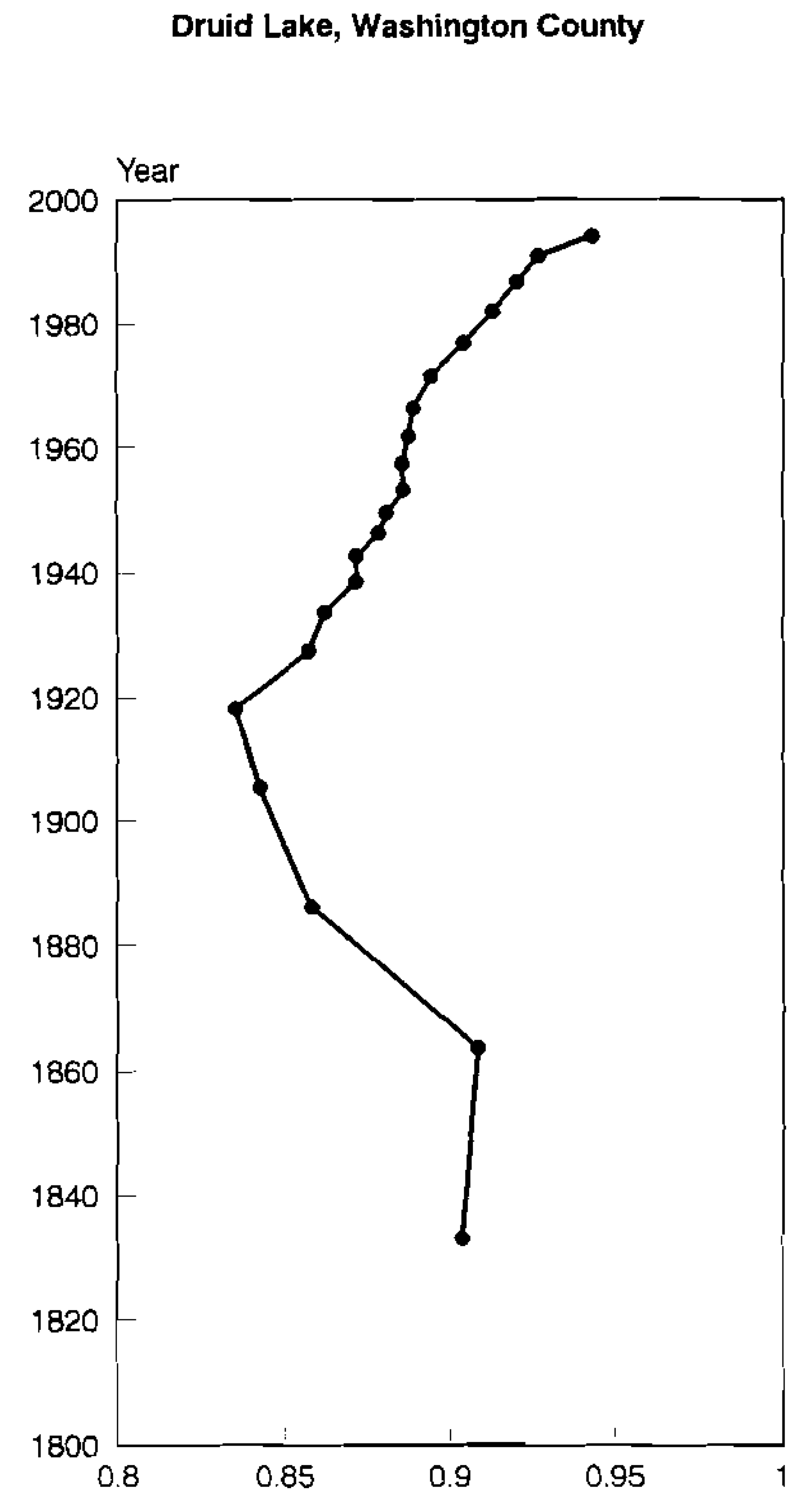


Figure 3. 1995 Upper Rock River Basin Assessment

Carbon Accumulation Rate

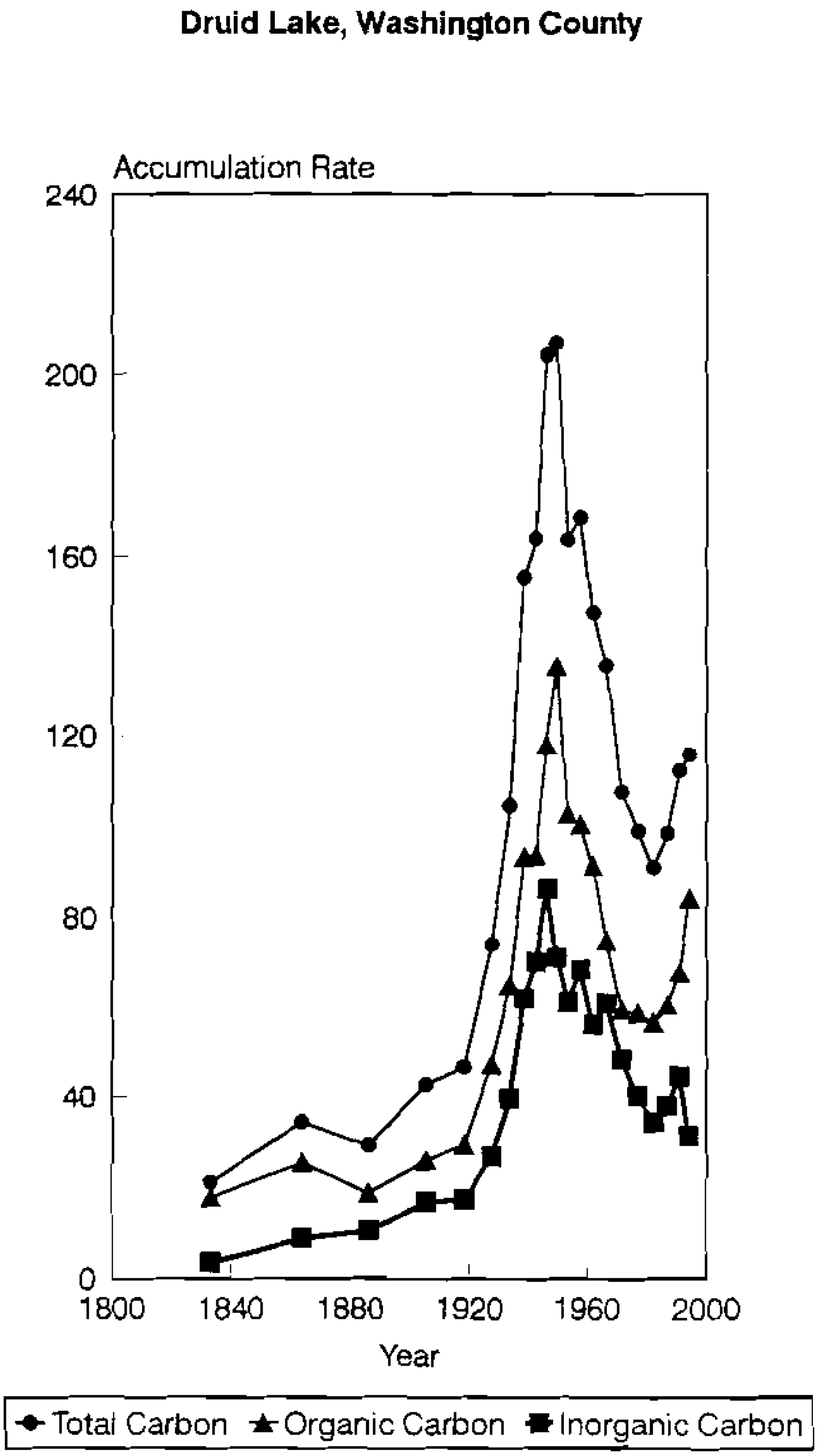


Figure 4. 1995 Upper Rock River Basin Assessment

Phosphorus Accumulation Rate

Druid Lake, Washington County

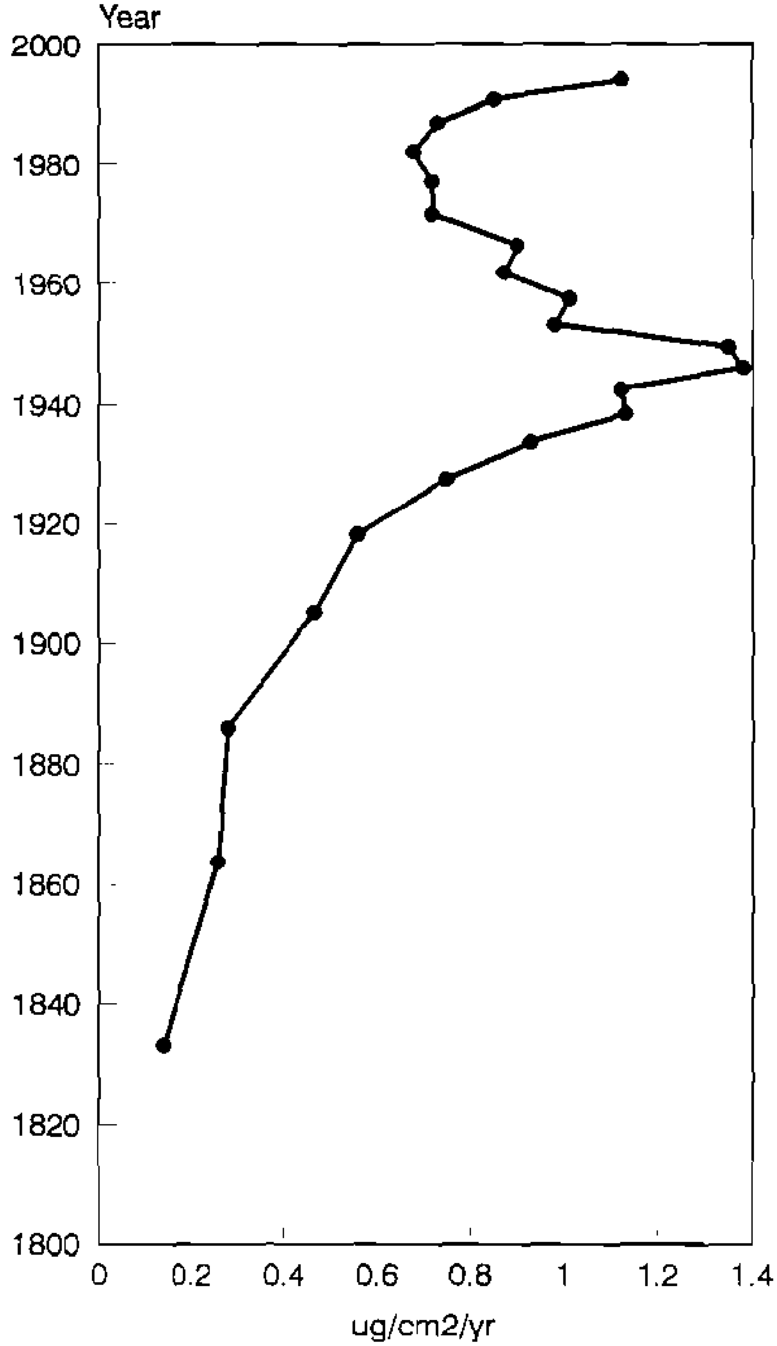


Figure 5. 1995 Upper Rock River Basin Assessment

Iron/Phosphorus Ratio

Druid Lake, Washington County

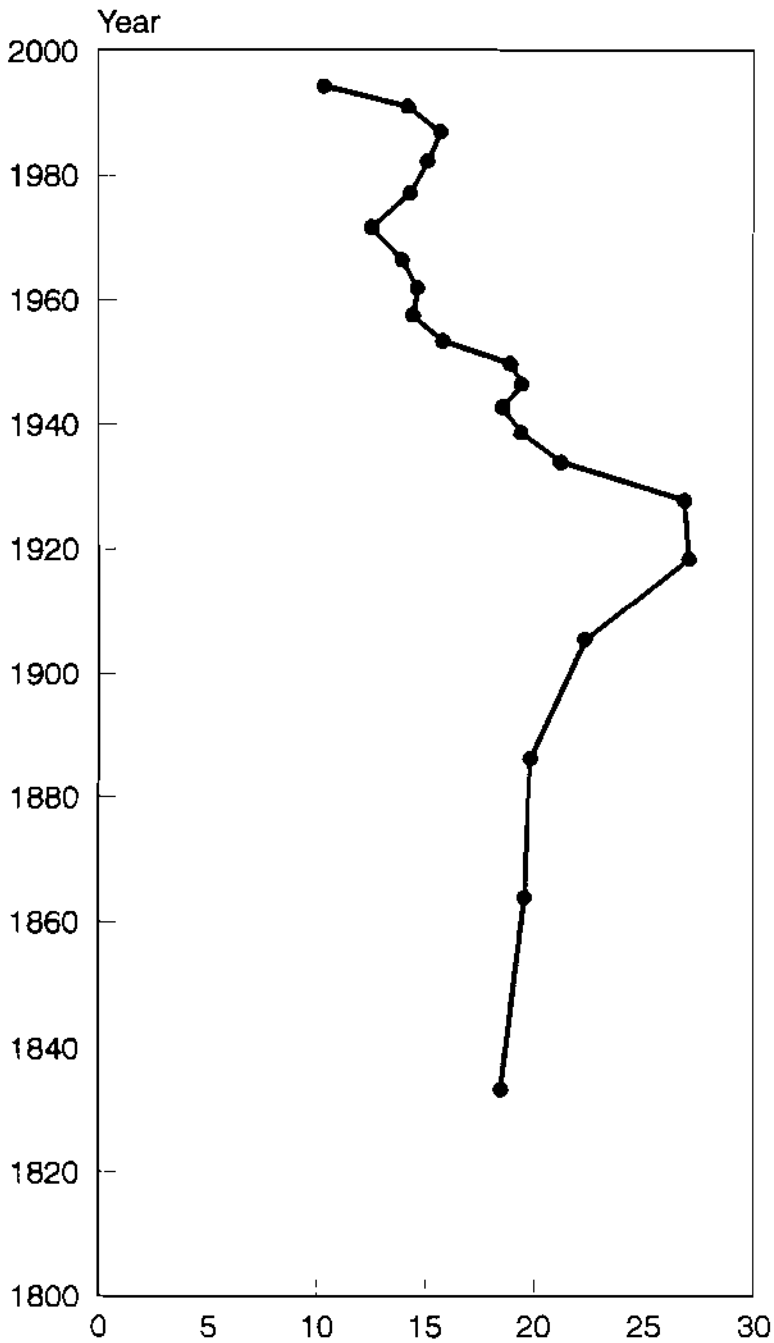
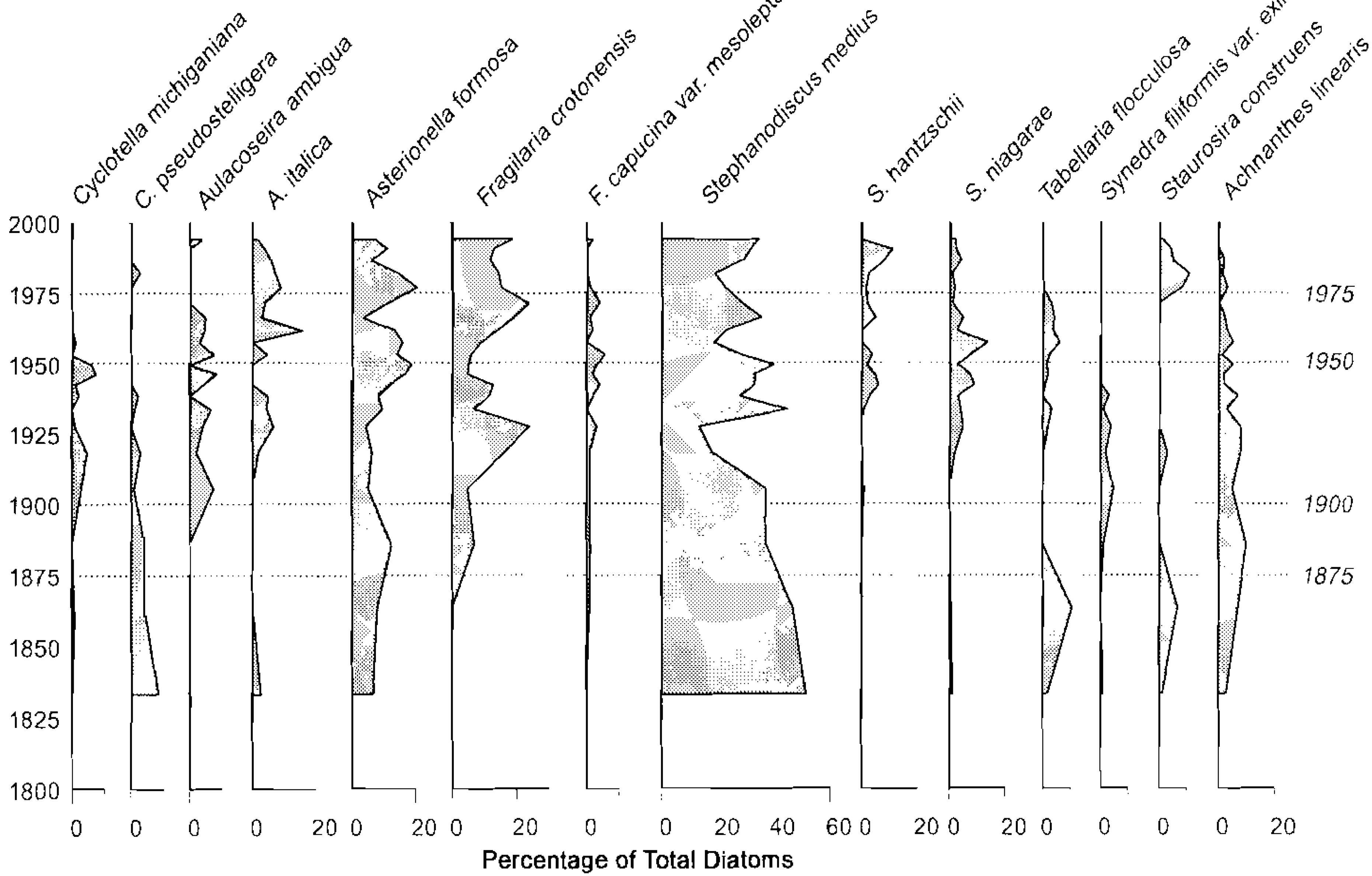


Figure 6. 1995 Upper Rock River Basin Assessment

Druid Lake

Washington County

Analyst: M. MacDonald



Diatom Accumulation Rate

Druid Lake, Washington County

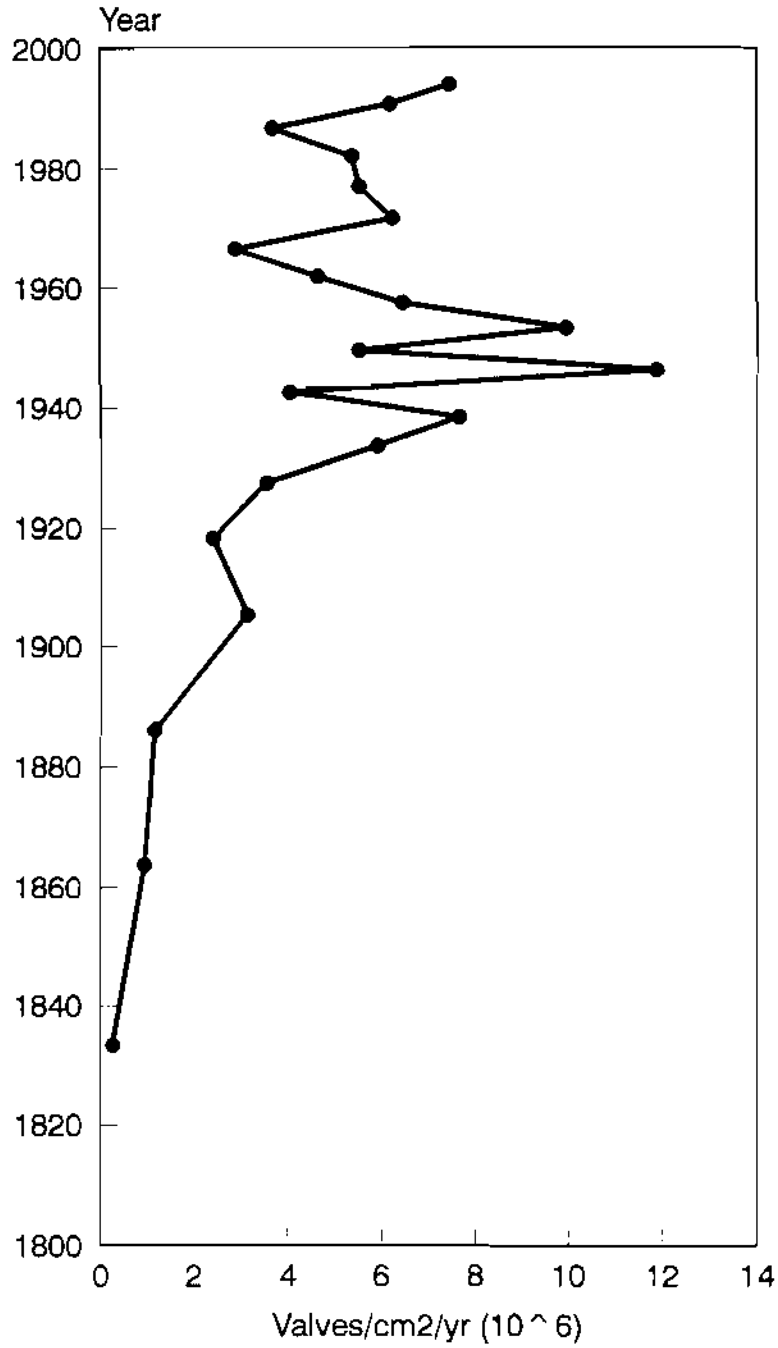


Figure 8. 1995 Upper Rock River Basin Assessment

Druid Lake Washington County, Sediment chemistry results.

SEDIMENT DEPTH	POROSITY	TOTAL PHOSPHORUS	TOTAL CARBON	ORGANIC NITROGEN	TOTAL ORGANIC CARBON	TOTAL IRON	TOTAL MANGANESE	YEAR (Mid)
cm		ug/gm	WT %	WT %	WT %	ug/gm	ug/gm	
0-2	0.9433	1133	11.74	0.82	8.54	11785	749	1994.2
2-4	0.9270	874	11.51	0.72	6.93	12531	743	1990.9
4-6	0.9207	810	10.91	0.69	6.70	12788	703	1986.9
6-8	0.9131	804	10.84	0.69	6.73	12231	672	1982.2
8-10	0.9043	802	11.04	0.66	6.54	11565	683	1977.1
10-12	0.8945	794	11.80	0.62	6.51	10002	723	1971.7
12-14	0.8890	770	11.59	0.63	6.40	10801	704	1966.5
14-16	0.8876	725	12.29	0.70	7.60	10679	712	1961.9
16-18	0.8858	748	12.51	0.70	7.45	10875	732	1957.5
18-20	0.8860	753	12.53	0.73	7.86	11952	723	1953.3
20-22	0.8808	750	11.49	0.71	7.53	14273	671	1949.6
22-24	0.8785	751	11.15	0.64	6.44	14659	686	1946.3
24-26	0.8717	744	10.86	0.62	6.21	13841	630	1942.6
26-28	0.8715	720	9.93	0.59	5.97	14026	630	1938.5
28-30	0.8623	765	8.63	0.55	5.36	16291	595	1933.7
30-32	0.8575	750	7.36	0.50	4.69	20188	583	1927.5

Druid Lake Washington County, Sediment chemistry resutlts.

SEDIMENT DEPTH	POROSITY	TOTAL PHOSPHORUS	TOTAL CARBON	ORGANIC NITROGEN	TOTAL ORGANIC CARBON	TOTAL IRON	TOTAL MANGANESE	YEAR (Mid)
cm		ug/gm	WT %	WT %	WT %	ug/gm	ug/gm	
32-34	0.8355	784	6.53	0.45	4.11	21208	544	1918.3
34-36	0.8426	872	7.91	0.51	4.83	19514	568	1905.4
36-38	0.8583	914	9.72	0.63	6.22	18162	540	1886.1
38-40	0.9085	1169	15.37	1.05	11.43	22909	597	1863.8
40-42	0.9039	1112	16.28	1.08	13.61	20605	671	1833.2
42-44	0.9057	1151	15.38	0.98	10.49	20211	881	1797
44-46	0.8971	1187	14.64	0.88	9.71	20630	980	1762
46-48	0.8969		15.08	0.90	9.89	20444	942	1723
48-50	0.8806		15.61	0.85	9.52	22816	1005	1685
50-52	0.8560		14.72	0.69	9.05	22128	1030	1640

Druid Lake Washington County, Sediment chemistry results.

SEDIMENT DEPTH	FE:MN	FE:P	YEAR (Mid)	SEDIMENT ACCUM. RATE	TOTAL DIATOMS
cm				gm/cm2/yr	valve/gm. dry. wt.
0-2	15.7	10.4	1994.2	0.099	7.55e+08
2-4	16.9	14.3	1990.9	0.098	6.34e+08
4-6	18.2	15.8	1986.9	0.090	4.10e+08
6-8	18.2	15.2	1982.2	0.084	6.41e+08
8-10	16.9	14.4	1977.1	0.090	6.18e+08
10-12	13.8	12.6	1971.7	0.091	6.85e+08
12-14	15.3	14.0	1966.5	0.117	2.48e+08
14-16	15.0	14.7	1961.9	0.120	3.88e+08
16-18	14.9	14.5	1957.5	0.135	4.79e+08
18-20	16.5	15.9	1953.3	0.131	7.62e+08
20-22	21.3	19.0	1949.6	0.180	3.08e+08
22-24	21.4	19.5	1946.3	0.183	6.49e+08
24-26	22.0	18.6	1942.6	0.151	2.70e+08
26-28	22.3	19.5	1938.5	0.156	4.90e+08
28-30	27.4	21.3	1933.7	0.121	4.90e+08
30-32	34.7	26.9	1927.5	0.101	3.56e+08

Druid Lake, Washington County, Sediment chemistry results.

SEDIMENT DEPTH	FE:MN	FE:P	YEAR (Mid)	SEDIMENT ACCUM. RATE	TOTAL DIATOMS
cm				gm/cm2/yr	valve/gm. dry. wt.
32-34	39.0	27.1	1918.3	0.072	3.40e+08
34-36	34.3	22.4	1905.4	0.054	5.88e+08
36-38	33.6	19.9	1886.1	0.030	3.94e+08
38-40	38.4	19.6	1863.8	0.022	4.30e+08
40-42	30.7	18.5	1833.2	0.013	2.06e+08
42-44	22.9	17.6	1797	0.013	4.80e+08
44-46	21.1	17.4	1762	0.013	1.89e+08
46-48	21.7		1723	0.013	1.97e+08
48-50	22.7		1685	0.013	3.51e+07
50-52	21.5		1640	0.013	7.86e+06

Druid Lake Washington County, sediment chemistry accumulation results.

YEAR (mid)	TOTAL PHOSPHORUS	TOTAL NITROGEN	TOTAL CARBON	TOTAL ORGANIC CARBON	INORGANIC CARBON	IRON Fe	MANGANESE Mn	TOTAL DIATOMS
	gm/m2/yr					ug/cm2/yr	ug/cm2/yr	valves/cm^2/yr (*10^7)
1994.2	1.12	8.1	115.9	84.3	31.5	11.63	0.74	7.46
1990.9	0.85	7.0	112.4	67.7	44.7	12.23	0.73	6.19
1986.9	0.73	6.2	98.4	60.4	38.0	11.53	0.63	3.69
1982.2	0.68	5.8	91.0	56.5	34.5	10.27	0.56	5.38
1977.1	0.72	5.9	99.0	58.6	40.3	10.37	0.61	5.54
1971.7	0.72	5.7	107.5	59.3	48.2	9.11	0.66	6.24
1966.5	0.90	7.4	135.6	74.8	60.7	12.64	0.82	2.90
1961.9	0.87	8.4	147.3	91.2	56.2	12.81	0.85	4.66
1957.5	1.01	9.5	168.6	100.4	68.2	14.66	0.99	6.46
1953.3	0.98	9.5	163.7	102.7	61.0	15.61	0.94	9.96
1949.6	1.35	12.7	206.7	135.4	71.2	25.67	1.21	5.53
1946.3	1.38	11.7	204.3	118.0	86.3	26.86	1.26	11.89
1942.6	1.12	9.4	163.8	93.7	70.1	20.88	0.95	4.07
1938.5	1.13	9.2	155.3	93.4	61.9	21.95	0.99	7.66
1933.7	0.93	6.6	104.4	64.8	39.6	19.70	0.72	5.93
1927.5	0.75	5.0	74.1	47.2	26.9	20.32	0.59	3.58

Druid Lake, Washington County Sediment chemistry accumulation results.

YEAR (mid)	TOTAL PHOSPHORUS	TOTAL NITROGEN	TOTAL CARBON	TOTAL ORGANIC CARBON	INORGANIC CARBON	IRON Fe	MANGANESE Mn	TOTAL DIATOMS
	gm/m2/yr					ug/cm2/yr	ug/cm2/yr	valves/ cm^2/yr (*10^7)
1918.3	0.56	3.2	46.7	29.4	17.3	15.18	0.39	2.43
1905.4	0.47	2.7	42.6	26.0	16.6	10.51	0.31	3.17
1886.1	0.28	1.9	29.3	18.8	10.6	5.48	0.16	1.19
1863.8	0.26	2.3	34.4	25.5	8.8	5.12	0.13	0.96
1833.2	0.14	1.4	21.2	17.7	3.5	2.68	0.09	0.27
1797.3	0.15	1.3	20.0	13.6	6.4	2.63	0.11	0.62
1762.0	0.15	1.1	19.0	12.6	6.4	2.68	0.13	0.25
1723.4		1.2	19.6	12.9	6.8	2.66	0.12	0.26
1684.8		1.1	20.3	12.4	7.9	2.97	0.13	0.05
1640.0		0.9	19.1	11.8	7.4	2.88	0.13	0.01