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WATER QUALITY MONITORING OF JOHNSON SAUK TRAIL LAKE AFTER IMPLEMENTATION OF LAKE MANAGEMENT TECHNIQUES: AN INTERIM REPORT

by
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INTRODUCTION

Johnson Sauk Trail Lake, located in Henry County, Illinois, is a 57.4-acre (23.2-ha) lake with maximum and mean depths of 23.0 feet C7.0l m) and 8.2 feet (2.50 m) respectively. The lake and the surrounding Johnson Sauk Trail Lake State Park are managed by the Illinois Department of Conservation for outdoor recreational activities. These activities include bank fishing, boat fishing, ice fishing in season, boating, canoeing, camping, picnicking, hunting, horseback riding, and various other summer and winter outdoor recreational activities.

The lake's watershed with a total area of 876.1 acres '(354.6 ha) is in excellent condition with permanent vegetative cover in 86.6% of the watershed and with little or no land disturbance. The predominant land uses in the watershed are grassland (46.4%), woodland (40.2%), and recreational development (6.9%), and the rest is water.

A detailed limnological study of Johnson Sauk Trail Lake conducted during 1981 (Kothandaraman and Evans, I983) indicated that the lake remains highly eutrophic, even though the watershed has long been returned to an undisturbed condition. The lake water quality characteristics were found to be typical of midwestern lakes, with high alkalinity, conductivity, and dissolved solids. There was an abundance of phosphorus in the lake system all the time. The tributaries to the lake were not found to convey unusual amounts of suspended and nutrient loads. The lake received sediments from its watershed at the annual rate of 3.3 tons/acre. Internal regeneration of nitrogen and phosphorus under anoxic conditions during the summer thermal stratification accounted for 93.5% of the inorganic loading and 75% of the dissolved phosphorus loading to the lake. The tributaries contributed only 1.5 and 17.7% of inorganic nitrogen and dissolved phosphorus, respectively. The remainder emanated from atmospheric precipitation and dry fallout (ibid).

The detailed limnological data developed for the lake (Kothandaraman and Evans, 1983) identified the lake's major water quality problems as:

- Oxygen depletion at depths 8 feet below the water surface during the summer stratification period.

- Algal growths of bloom proportions in the lake, with blue-green algae as the dominant species.

- Extensive growth of macrophytes covering about 27% of the lake surface, which interferes with recreational activities.

Based on technical, environmenta, and economic considerations, the following in-lake management techniques were chosen for implementation in the lake:

* Aeration/destratification of the lake.

* Periodic applications of chelated copper sulfate followed by potassium permanganate applications.

* Harvesting and removal of macrophytes from selected areas inthelake.

* Lake shore stabilization at two on-shore locations totalling 300 feet in length.

Implementation of the in-lake water quality management techniques was approved by the Illinois Department of Conservation and the U.S. Environmental Protection Agency. It was jointly funded by these two agencies under the Clean Lakes Program, and the project administration was provided by the Illinois Environmental Protection Agency. The Water Quality Section of the Illinois State Water Survey, Division of Energy and Natural Resources, monitored the lake's water quality for a 12-month period during the implementation of the water quality management scheme. This interim report presents the data and results for the period from May 1984 to April 1985.

MATERIALS AND METHODS

An axial flow, low energy, mechanical pump similar to that developed by Quintero and Garton (1973) at Oklahoma State University, Stillwater, OK, was used to destratify Johnson Sauk Trail Lake. The destratifier consists of an 8-foot-diameter propeller with six variable pitch symmetrical blades mounted on a vertical shaft, driven by a 2 horsepower (220 V, single phase, 1740 RPM) motor through a system of gear reduction box (29.50) and pulley-belt arrangements. The system was mounted on a floating platform such that the propeller was located about 5 feet below the water surface. The pitch of the individual blade can be set at any desired angle within the range of 14 to 30 degrees. As the blades are symmetrical, the pumping efficiency will remain the same whether lake water is pumped from the surface toward the bottom or vice versa. A reversible switch in the system permits the direction of rotation of the motor and consequently the direction of rotation of the propeller to be reversed with ease.

The destratifier was installed on July 2, 1984 and began operating the next day. However, it remained inoperative most of the time until August 24, 1984 because of improper initial pulley size selection, inadequate fastening arrangement of the propeller to the vertical shaft, and a few other minor deficiencies in the design and fabrication of the system. The unit was hauled ashore and repaired and was then reinstalled on August 24, 1984, after which it operated well without any mechanical failure.

The destratifier was operated in the downflow mode during summer stratification and in the upflow mode during the winter months to bring the warmer near bottom waters to the surface to keep a portion of the lake from freezing up. The system was operated continuously from August 24, 1984 to early March 1985 when it was shut off because of the natural spring overturn. The unit was purchased and installed at a total cost of $11,000.

In order to assess the efficacy of the in-lake water quality management scheme from the standpoint of improving lake water quality, certain physical, chemical, and biological measurements were made. The locations of the destratifier and the sampling stations in the lake are shown in figure 1.

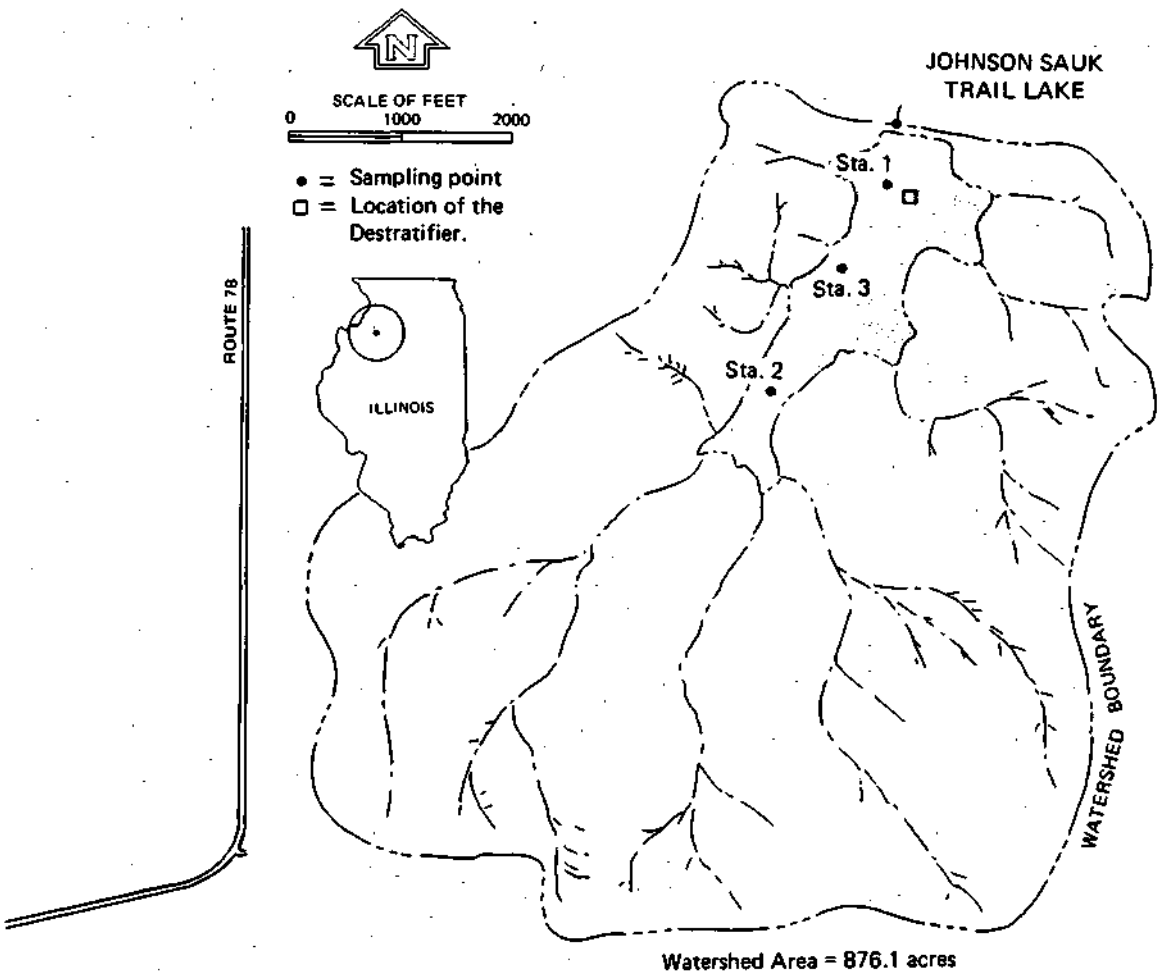

Figure 1. Locations of the sampling points and the destratifier in Johnson Sauk Trail Lake

The lake was monitored for dissolved oxygen, temperature, and secchi disc readings at stations 1 and 2, just as during the diagnostic-feasibility investigation. Observations for DO and temperature were made at 2-foot intervals commencing from the surface at station 1 and at 1-foot intervals at station 2.

Water samples for chemical analyses were taken at the deep station (station 1) from three different points: 1 foot below the surface, 1 foot above the bottom, and at mid-depth. Analyses were made for pH, alkalinity, conductivity, total suspended and dissolved solids, volatile suspended solids, turbidity, total phosphorus, dissolved phosphorus, nitrate-nitrogen, and Kjeldahl-nitrogen.

Integrated water samples (integrated to a depth of twice secchi depth) were collected at station 1 for chlorophyll-a concentrations and for identifying and enumerating algal density in the lake waters.

Lake bottom sediments were sampled with an Ekman dredge at stations 1 and 2 to identify and enumerate benthic organisms.

Physical and chemical water quality characteristics were evaluated at biweekly intervals from May to September and at monthly intervals during the remainder of the project period. Phytoplankton and chlorophyll were monitored at biweekly intervals from May to September, and benthos were examined once a month from June to September.

The details of the field and laboratory procedures used in this investigation can be found in the earlier report by Kothandaraman and Evans (1983):

Water samples obtained at the surface and 2 feet from the surface at stations 1, 2, and 3 were analyzed for copper immediately before and one day after the application of chelated copper sulfate to the lake for control of blue-green algae.

Macrophytes were harvested and removed from the lake during the period June 11, 1984 to June 17, 1984 using a 4-foot-cut mechanical harvester. The harvested macrophytes were manually removed from the harvester, loaded into pick-up trucks, transported, and disposed of on land within the park boundaries. The harvesting was accomplished at a contracted cost of $5,000 for 80 machine-hours excluding the cost of manpower involved in offsite disposal of the harvested weeds. Approximately 10 acres of the 15.4 acres of macrophyte beds were harvested. Though a regrowth of the macrophytes was anticipated during the late summer-early fall period, the harvested areas were weed-free for the remainder of the recreational season.

Copper sulfate chelated with citric acid was applied on August 8, 1984. A total of 300 pounds of $CuSO_4 \cdot 5H_2O$ was mixed with 150 pounds of citric acid. Burlap bags containing This mixture were tied to the destratifier raft, and the aerator was operated in an upflow mode. The flow induced by the destratifier past the bags dissolved the

chemicals. With the natural lake circulation aided by the induced mixing, copper was found to be uniformly distributed throughout the lake. Samples for copper analyses were collected on August 10, 1984 and 60 pounds of potassium permanganate was applied to the lake on August 10, 1984 in a manner similar to the application of copper sulfate.

RESULTS

A summary of the results of observations for some of the physical parameters and all the routinely monitored chemical parameters is shown in Table 1. The observed data for dissolved oxygen and temperature for stations 1 and 2 are given in appendix 1.

The DO and temperature data reveal that the lake remained stratified during the crucial summer months of June. July, and August. The system operated for one day on July 3. 1984, operated from July 20 to August 8. 1984 before all the system design deficiencies and installation problems were corrected, and began to function satisfactorily without breakdowns on August 24, 1984. The DO conditions in the deep station were found to be significantly improved on July 25, 1984, only a few days after the system was started on July 20. However, the DO conditions deteriorated rapidly, as indicated by the field observations on August 10, 1984 only two days after the breakdown of the destratifier. The lake became isothermal and DO concentrations in the deep water zones improved after the unit resumed operating on August 24, 1984. The efficacy of the destratification system in improving the DO conditions and the other water quality characteristics could not be fully assessed and documented because the system was not fully operational during the summer months. However,

Table 1. Summary of Water Quality Characteristics at Station 1, May 1984 to April 1985

Parameters	Near surface		Mid-depth		Near bottom	
	Mean	Range	Mean	Range	Mean	Range
Secchi readings (inches)	4.4	15-107				
Turbidity (NTU)	15.5	4.0-57.0	14.9	3.0-43.0	31.2	7.0-164.0
pH (dimensionless)	8.6	8.0-9.4	8.5	8.0-9.0	8.2	7.5-8.7
Alkalinity	176	150-211	178	160-208	190	168-218
Conductivity (umho/cm)	352	300-424	358	306-435	380	314-529
Total phosphate-P	0.11	0.02-0.28	0.16	0.02-0.95	0.24	0.01-0.80
Dissolved phosphate-P	0.05	0.00-0.16	0.06	0.00-0.19	0.11	0.00-0.75
Total ammonia-N	0.16	0.04-0.56	0.21	0.03-0.54	0.47	0.04-2.11
Nitrate-N	0.12	0.00-0.40	0.10	0.00-0.36	0.12	0.00-0.34
Total Kjeldahl-N	1.54	0.51-3.20	1.26	0.55-2.28	1.84	0.85-4.49
Dissolved solids	257	220-394	252	218-302	257	212-304
Total suspended solids	12.1	1.0-33.0	10.9	0.0-37.0	36.2	6.0-204.0
Volatile susp. solids	8.1	0.0-33.0	6.4	0.0-15.0	9.5	1.0-25.0

Note: Values in mg/1 unless otherwise indicated

with the continuation of the data collection efforts during the summer of 1985, a more detailed and thorough assessment of the impact of the in-lake management techniqueswill be included in the final report for this project.

The results presented in Table 1 for the near surface, mid-depth, and near bottom waters at station 1 indicate that there was a chemical stratification concomitant with the thermal stratification. The minimum and maximum pH values for the surface waters were higher than for the hypolimnetic waters because of algal photosynthesis. The mean alkalinity and conductivity values for the hypolimnetic waters were higher because of active mineralization of organic sediments under anaerobic conditions. For the same reason, the mean values for total phosphorus, dissolved phosphorus, ammonia, and Kjeldahl-nitrogen were higher for the near bottom waters than for the surface waters. The raw data for the chemical characteristics of Johnson Sauk Trail Lake are included in appendix 2.

The results of algal identification and enumeration along with chlorophyll-a values for the period May to September are shown in Table 2. Blue-green algae were the dominant species and reached the highest value of 40,000 on July 5, 1984. However, the species dominance shifted to greens after the single application of chelated copper sulfate on August 8, 1984. Chlorophyll-a values ranged from 9.1 to 165.0 µg/l with the maximum value observed on August 1, 1984. The results of benthic macroinvertebrate examinations are shown in Table 3.

The distribution of copper, expressed as Cu^{2+}, in the lake after the copper sulfate application is shown in Table 4. The background copper concentrations were below the detection limit. The copper was found to be uniformly distributed throughout the lake. A

Table 2. Algal Types and Densities and Chlorophyll-a in Johnson Sauk Trail Lake
(Algal densities in counts per milliliters)

Date	BG	G	D	F	O	Total	Chlorophyll-a (µg/1)
5/9/84	10		1020			1,030	13.9
5/23/84	120		20	10.0		240	9.1
6/6/84	600		100	40		740	23.5
6/20/84	1,000	50	10			1,060	16.8
7/5/84	40,000			210		40,210	132.0
7/18/84	230	10		20		260	56.6
8/1/84	450		30			480	165.0
8/22/84	40	80		10		130	49.5
9/5/84	70	160		10		240	20.4
9/19/84		260				26	63.3

Table 3. Benthic Macroinvertebrates Collected from Johnson. Sauk Trail Lake (Individuals per square meter)

	Station 1			
	6/6/84	7/5/84	8/22/84	9/5/84
Chironomidae (midge)	488	129	187	43
Chaoborus (phantom midge fly)	6355	3257	416	1277
Total	6843	3386	603	1320
	Station 2			
Chironomidae (midge)	187	674	559	588
Chaoborus (phantom midge fly)	373	258	129	158
Total	560	932	688	746

Table 4. Distribution of Copper in Johnson Sauk Trail Lake on 8/10/84 (mg/1 as Cu^{2+})

Station	Surface	2 feet below surface
1	0.06	0.05
2	.0.06	0.06
3	0.06	0.06

concentration of 0.1 mg/l as Cu^{2+} has been found adequate to control blue-green algae. Because of the chelating agent (citric acid) used along with copper sulfate in Johnson Sauk Trail Lake, which has high alkalinity (>40 mg/l as $CaCO_3$), adequate levels of Cu concentrations were maintained even after 48 hours.

A total of 172 tons (wet weight) of macrophytes was harvested and removed from the lake. This is estimated to have resulted in an export of 125 pounds of total phosphorus from the lake. This represents approximately 3 1 percent of the gross phosphorus loading to the lake .

SUMMARY

Johnson Sauk Trail Lake was monitored for physical, chemical, and biological characteristics during the period May 1984 to April 1985 to assess the impact of the in-lake water quality management techniques implemented for the lake. Oestratification, control of blue-green algae by application of chelated copper sulfate followed by potassium permanganate, macrophyte harvesting/removal, and shoreline stabilization were tried to enhance the water quality conditions.

A low energy axial flow mechanical destratifier was installed at the deepest part of the lake on July 3, 1984. The system operated only intermittently until August 24, 1984 because of design, fabrication, and installation deficiencies. The unit then performed continuously without interruption until early March 1985 when it was turned off because of the spring turnover. From the limited amount of data pertaining to the summer period when the system was operating, it was found that the destratifier was capable of improving the oxygen conditions throughout the lake. The chelated copper sulfate application was found to be effective in high alkalinity waters. Copper was found to be well and uniformly distributed in the top two feet of the lake with a concentration of approximately 0.06 mg/1 (as Cu^{2+}). The efficacy of the destratifier in enhancing the lake's water quality characteristics could not be fully assessed because the system was not in operation during the critical summer months of June, July, and most of August. With the continuation of the data collection during the summer of 1985, a complete and thorough analysis of the response of the lake to implementation of the techniques recommended in the diagnostic/feasibility study of the lake (Kothandaraman and Evans, 1983) will be included in the final report.

The macrophyte harvesting and removal was found to improve the general aesthetic conditions and the bank and boat fishing opportunities in the lake. Only one harvest was found necessary, even though harvesting the lake twice was initially anticipated.

REFERENCES

Kothandaraman, V., and R. L. Evans. 1983. Diagnostic-feasibility study of Johnson Sauk Trail Lake. Illinois State Water Survey Contract Report 312, 126 p.

Quintero, J.E., and J.E. Garton. 1973. A low energy lake destratifier. Transactions of the American Society of Agricultural Engineers, v. 16[5] : 973-978.

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Appendix 1. Dissolved oxygen, temperature observations in Johnson Sauk Trail Lake, Station 1

Depth	5/09/84		5/23/84		6/06/84		6/20/84		7/05/84		7/18/84	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	9.3	13.5	9.7	19.5	10.5	21.6	12.2	26.0	16.6	25.0	6.7	25.5
2	9.3	13.5	9.0	19.3	10.4	21.6	12.2	26.0	15.4	24.4	5.2	25.0
4	9.3	13.5	8.9	19.0	10.3	21.6	10.1	26.0	12.0	24.0	4.1	25.0
6	9.1	13.1	8.6	19.0	9.4	21.6	8.2	25.0	5.1	23.5	3.3	25.0
8	9.0	13.0	8.4	19.0	9.4	21.6	5.8	24.5	4.1	23.2	0.9	25.0
10	8.9	13.0	8.1	18.8	9.4	21.6	3.1	23.5	3.6	23.1	0.8	24.5
12	8.9	13.0	5.8	17.8	9.4	21.6	1.5	22.2	2.4	23.0	0.7	23.0
14	8.4	13.0	2.9	18.5	1.7	15.6	1.1	20.5	0.5	22.2	0.7	22.0
16	6.0	12.5	1.3	14.5	1.4	14.2	1.1	17.0	0.5	21.5	0.7	21.0
18	3.9	12.0	0.7	13.2	1.2	13.9	1.1	15.5	0.5	21.0	0.6	20.0
20	1.7	11.9	--	--	1.5	14.0	1.1	14.0	0.5	21.0	0.5	18.5
22	--	--	--	--	1.1	13.5	--	--	--	--	--	--

Depth	7/25/84		8/01/84		8/10/84		8/22/84		9/05/84		9/19/84	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	4.6	26.2	14.4	26.0	4.2	28.0	5.3	25.8	3.6	22.0	8.9	19.6
2	4.5	26.2	14.3	26.0	4.1	28.0	3.8	25.2	3.5	22.0	8.5	19.2
4	4.5	26.2	11.4	25.5	3.5	27.5	3.6	25.0	3.5	22.0	8.1	18.9
6	4.2	26.2	10.4	25.2	2.4	27.5	2.8	25.0	3.5	22.0	7.8	18.9
8	3.7	26.1	10.0	25.2	2.4	27.5	2.8	24.9	3.5	22.0	7.6	18.9
10	3.6	26.1	9.2	25.0	1.7	27.5	2.8	24.9	3.5	22.0	7.6	18.9
12	3.6	28.1	8.2	25.0	1.1	27.0	2.6	24.9	3.5	22.0	7.6	18.9
14	3.3	26.1	5.2	24.4	0.7	27.0	2.2	24.9	3.5	22.0	7.6	18.9
16	2.9	26.1	5.2	24.9	0.7	26.0	2.2	24.8	3.5	22.0	7.5	18.9
18	2.7	26.1	3.9	24.2	0.7	26.0	0.7	24.6	3.5	22.0	7.3	18.8
20	2.1	26.1	2.7	24.2	0.7	26.0	0.6	23.6	2.7	22.0	4.4	18.7
22	0.7	25.5	2.0	24.1	0.7	25.0	--	--	--	--	--	--

Appendix 1. Dissolved oxygen, temperature observations in Johnson Sauk Trail Lake, Station 1

Depth	10/17/84		11/15/84		12/12/84		1/22/85		2/15/85		3/13/85	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	6.3	16.0	11.2	6.5	12.0	3.5	11.5	1.0	11.5	1.0	11.5	2.8
2	6.2	16.0	11.2	6.5	12.0	3.5	11.5	1.5	11.5	1.0	11.4	2.8
4	6.2	16.0	11.2	6.5	12.0	3.5	11.5	1.5	11.5	1.0	11.4	2.8
6	6.2	16.2	11.2	6.5	12.0	3.5	10.6	1.5	11.5	1.0	11.4	2.8
8	6.2	16.0	11.2	6.5	12.0	3.5	5.2	1.5	11.5	1.0	11.4	2.8
10	6.2	16.0	11.2	6.5	12.0	3.5	--	--	11.5	1.0	11.4	2.8
12	6.2	16.0	11.2	6.5	12.0	3.5	--	--	9.2	1.0	11.3	2.8
14	5.9	16.0	11.2	6.5	12.0	3.5	--	--	--	--	11.2	2.7
16	5.9	16.0	11.2	6.5	12.0	3.5	--	--	--	--	11.2	2.7
18	5.9	16.0	--	--	12.0	3.5	--	--	--	--	11.2	2.7
20	5.6	16.0	--	--	1.3	3.5	--	--	--	--	10.8	2.7

Depth	4/16/85	
feet	D.O.	Temp.
0	13.6	13.8
2	13.1	13.7
4	13.3	13.3
6	13.3	13.0
8	13.3	13.0
10	13.2	12.6
12	13.0	12.4
14	12.9	12.1
16	12.0	11.2
18	10.3	10.2
20	9.1	9.9

Appendix 1. Dissolved oxygen, temperature observations in Johnson Sauk Trail Lake, Station 2

Depth	5/09/84		5/23/84		6/06/84		6/20/84		7/05/84		7/18/84	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	9.1	14.0	8.6	19.8	9.0	21.2	14.1	26.2	16.0	26.0	7.8	26.0
1	9.1	14.0	8.6	19.8	8.9	21.0	14.1	26.0	15.9	24.8	7.8	26.0
2	9.1	14.0	8.6	19.8	8.8	21.0	14.0	26.0	12.0	24.2	7.8	26.0
3	9.1	13.9	8.6	19.8	8.7	21.0	14.0	26.0	12.4	24.2	7.8	26.0
4	9.2	13.9	8.6	19.8	8.9	20.8	14.0	26.0	8.2	24.0	7.8	26.0
5	9.2	13.8	8.6	19.5	8.7	20.2	14.0	25.9	9.9	24.0	7.7	26.0
6	9.2	13.8	8.6	19.5	8.6	20.2	12.6	25.5	8.1	23.9	7.8	26.0
7	9.5	12.5	8.5	18.8	8.4	19.9	11.1	25.0	4.2	23.6	8.1	25.5
8	9.4	12.0	8.5	18.5	7.8	19.6	4.1	24.5	--	--	3.5	25.0
9	9.1	11.5	5.5	18.2	6.3	19.1	4.0	24.5	--	--	--	--
10	--	--	5.2	18.0	5.7	19.0	--	--	--	--	--	--

Depth	7/25/84		8/01/84		8/10/84		8/22/84		9/05/84		9/19/84	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	9.8	26.9	11.8	25.6	4.5	28.0	8.3	26.0	5.1	22.0	8.5	19.0
1	9.0	26.8	10.2	25.5	4.3	28.0	8.0	26.0	5.0	22.0	8.4	18.9
2	7.8	26.8	9.4	25.0	4.3	28.0	8.0	25.9	5.0	22.0	8.4	18.8
3	6.4	26.6	9.5	24.7	4.4	28.0	4.3	25.2	4.8	22.0	8.3	18.4
4	6.0	26.6	9.4	24.8	4.4	28.0	4.1	25.0	4.8	22.0	8.0	18.2
5	5.8	26.6	9.2	24.7	4.4	28.0	4.0	25.0	4.8	22.0	7.9	18.1
6	5.8	26.5	9.1	24.6	4.4	28.0	3.6	24.9	4.6	22.0	7.4	18.0
7	4.6	26.4	8.9	24.6	3.8	28.0	3.5	24.9	4.3	21.5	7.4	17.8
8	3.5	26.2	8.9	24.4	4.3	28.0	2.9	24.4	4.1	21.5	5.5	17.5
9	--	--	--	--	--	--	--	--	2.8	21.0	5.8	17.2

Appendix 1. Dissolved oxygen, temperature observations in Johnson Sauk Trail Lake, Station 2

Depth	10/17/84		11/15/84		12/12/84		1/22/85		2/15/85		3/13/85	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	6.9	16.0	11.2	6.5	--	--	10.8	1.0	12.1	0.0	11.8	2.8
1	6.8	16.0	11.0	6.5	--	--	10.4	1.5	11.9	1.0	11.5	2.8
2	6.8	16.0	11.0	6.5	--	--	10.4	1.5	11.2	1.0	11.5	2.8
3	6.8	16.0	11.0	6.5	--	--	10.2	1.8	11.1	1.0	11.4	2.8
4	6.8	16.0	11.0	6.5	--	--	10.0	1.9	11.1	1.5	11.4	2.8
5	6.8	15.5	11.0	6.5	--	--	10.0	2.0	11.1	1.5	11.3	2.8
6	6.8	15.0	11.0	6.5	--	--	10.0	2.0	11.1	1.5	11.3	2.8
7	6.8	15.0	11.0	6.5	--	--	10.0	2.0	11.0	1.5	11.2	2.8
8	3.4	15.0	11.0	6.5	--	--	10.0	2.0	11.0	1.5	11.2	2.8
9	---	---	1.5	6.5	--	--	10.0	2.0	11.0	1.5	11.2	2.8
10	---	---	---	---	--	--	---	---	---	---	9.4	2.8

Depth	4/16/85	
feet	D.O.	Temp.
0	13.8	14.3
1	13.8	14.3
2	13.8	14.3
3	13.8	14.2
4	13.8	14.2
5	13.8	14.1
6	13.8	14.0
7	13.8	13.8
8	14.2	13.8
9	14.1	13.8

Appendix 2. Physical and chemical quality characteristics of surface waters at station 1 in Johnson Sauk Trail Lake

Parameters	5/09/84	5/23/84	6/06/84	6/20/84	7/05/84	7/18/84
Secchi disc readings (inches)	43.00	60.00	45.00	47.00	27.00	32.00
Turbidity (NTU)	11.00	6.00	20.00	17.00	16.00	13.00
pH (dimensionless)	8.30	8.60	8.70	8.90	9.40	9.00
Alkalinity	172.00	188.00	180.00	178.00	156.00	150.00
Conductivity (umho/cm)	424.00	397.00	392.00	362.00	336.00	333.00
Total phosphate - P	.03	.05	.05	.03	.12	.13
Dissolved phosphate - P	0.00	.02	.02	.01	.04	.04
Total ammonia - N	.04	.04	.07	.10	.06	.19
Nitrate - N	0.00	.19	.17	.07	.06	.06
Kjeldahl - N	.51	.86	3.16	1.53	2.86	---
Dissolved solids	251.00	293.00	246.00	248.00	232.00	224.00
Total suspended solids	4.00	5.00	11.00	5.00	22.00	10.00
Volatile suspended solids	2.00	5.00	6.00	5.00	18.00	6.00

Parameters	8/01/84	8/22/84	9/05/84	9/19/84	10/17/84	11/15/84
Secchi disc readings (inches)	15.00	31.00	24.00	21.00	30.00	39.00
Turbidity (NTU)	57.00	14.00	24.00	27.00	16.00	11.00
pH (dimensionless)	9.30	8.70	8.50	8.60	8.50	8.20
Alkalinity	160.00	176.00	182.00	180.00	168.00	182.00
Conductivity (umho/cm)	300.00	418.00	312.00	313.00	322.00	324.00
Total phosphate - P	.28	.23	.27	.21	.17	.07
Dissolved phosphate - P	.10	.12	.16	.10	.10	.03
Total ammonia - N	.14	.12	.56	.44	.35	.16
Nitrate - N	.12	.05	.08	.17	.05	.17
Kjeldahl - N	3.20	2.37	1.79	2.02	.99	1.32
Dissolved solids	220.00	245.00	248.00	246.00	246.00	248.00
Total suspended solids	33.00	8.00	17.00	33.00	10.00	4.00
Volatile suspended solids	33.00	8.00	16.00	12.00	7.00	4.00

Note: Values in mg/1 unless otherwise indicated.

Appendix 2. Physical and chemical quality characteristics of surface waters at station 1 in Johnson Sauk Trail Lake

Parameters	12/12/84	1/16/85	1/22/85	2/15/85	3/13/85	4/16/85
Secchi disc readings (inches)	61.00	---	72.00	72.00	26.00	107.00
Turbidity (NTO)	5.00	8.00	4.00	7.00	19.00	4.00
" pH (dimensionless)	8.30	8.20	8.10	8.00	8.30	8.50
Alkalinity	175.00	174.00	194.00	211.00	172.00	177.00
Conductivity (µmho/cm)	348.00	367.00	357.00	400.00	319.00	325.00
• Total phosphate - P	.07	.07	.05	.03	.02	.02
Dissolved phosphate - P	.02	.02	.02	.01	.02	.01
Total ammonia - N	.09	.05	.06	.16	.09	.17
Nitrate - N	.01	.40	.02	.13	.34	.03
Kjeldahl - N	1.19	.75	.86	1.08	1.13	.62
Dissolved solids	250.00	394.00	263.00	296.00	230.00	252.00
Total suspended solids	2.00	24.00	4.00	11.00	13.00	1.00
Volatile suspended solids	2.00	3.00	3.00	8.00	7.00	0.00

Note: Values in mg/1 unless otherwise indicated.

Appendix 2. Physical and chemical quality characteristics of mid-depth waters at station 1 in Johnson Sauk Trail Lake

Parameters	5/09/84	5/23/84	6/06/84	6/20/84	7/05/84	7/18/84
Secchi disc readings (inches)	---	---	---	---	---	---
Turbidity (NTU)	12.00	11.00	16.00	10.00	6.00	12.00
pH (dimensionless)	8.30	8.50	8.70	8.50	8.70	8.50
Alkalinity	181.00	196.00	180.00	170.00	168.00	160.00
Conductivity (µmho/cm)	424.00	393.00	394.00	378.00	362.00	352.00
Total phosphate - P	.03	.05	.05	.04	.15	.24
Dissolved phosphate - P	0.00	.02	.02	.01	.08	.11
Total ammonia - N	.04	.06	.07	.15	.27	.43
Nitrate - N	0.00	.18	.23	.36	.05	.05
Kjeldahl - N	.55	.90	2.28	1.42	1.64	---
Dissolved solids	249.00	299.00	244.00	256.00	240.00	240.00
Total suspended solids	7.00	6.00	8.00	0.00	10.00	10.00
Volatile suspended solids	3.00	6.00	4.00	0.00	4.00	5.00

Parameters	8/01/84	8/22/84	9/05/84	9/19/84	10/17/84	11/15/84
Secchi disc readings (inches)	---	---	---	---	---	---
Turbidity (NTU)	43.00	16.00	24.00	27.00	25.00	12.00
pH (dimensionless)	9.00	8.70	8.50	8.50	8.30	8.20
Alkalinity	164.00	168.00	182.00	184.00	168.00	182.00
Conductivity (µmho/cm)	321.00	435.00	306.00	319.00	322.00	322.00
Total phosphate - P	.95	.22	.28	.22	.19	.09
Dissolved phosphate - P	.11	.14	.19	.10	.11	.04
Total ammonia - N	.06	.42	.54	.45	.27	.16
Nitrate - N	.11	.01	.05	.02	.03	.17
Kjeldahl - N	2.02	1.60	1.85	2.11	.74	.97
Dissolved solids	218.00	246.00	248.00	244.00	246.00	246.00
Total suspended solids	20.00	8.00	17.00	37.00	15.00	6.00
Volatile suspended solids	15.00	8.00	14.00	14.00	7.00	3.00

Note: Values in mg/1 unless otherwise indicated.

Appendix 2. Physical and chemical quality characteristics of mid-depth waters at station 1 in Johnson Sauk Trail Lake

Parameters	12/12/84	1/16/85	1/22/85	2/15/85	3/13/85	4/16/85
Secchi disc readings (inct	---	---	---	---	---	---
Turbidity (NTU)	5.00	---	6.00	3.00	20.00	5.00
pH (dimensionless)	8.30	---	8.10	8.00	8.30	8.50
Alkalinity	176.00	---	194.00	208.00	173.00	178.00
Conductivity (µmho/cm)	349.00	---	352.00	404.00	320.00	325.00
Total phosphate - P	.05	---	.06	.04	.06	.02
Dissolved phosphate - P	.01	---	.02	.02	.02	.01
Total ammonia - N	.10	---	.05	.22	.03	.33
Nitrate - N	.01	---	.02	.11	.34	.03
Kjeldahl - N	1.05	---	.74	.90	.74	.64
Dissolved solids	250.00	---	265.00	302.00	230.00	256.00
Total suspended solids	3.00	---	13.00	8.00	11.00	6.00
Volatile suspended solids	3.00	---	10.00	4.00	7.00	1.00

Note: Values in mg/1 unless otherwise indicated.

Appendix 2. Physical and chemical quality characteristics of bottom waters at station 1 in Johnson Sauk Trail Lake

Parameters	5/09/84	5/23/84	6/06/84	6/20/84	7/05/84	7/18/84
Secchi disc readings (inches)	---	---	---	---	---	---
Turbidity (NTU)	16.00	10.00	22.00	15.00	19.00	7.00
pH (dimensionless)	8.10	8.40	7.50	8.20	8.10	8.20
Alkalinity	208.00	200.00	218.00	192.00	184.00	204.00
Conductivity (umho/cm)	429.00	414.00	454.00	413.00	398.00	412.00
Total phosphate - P	.04	.06	.22	.01	.43	.80
Dissolved phosphate - P	0.00	.03	.13	0.00	.30	.75
Total ammonia - N	.04	.08	.18	.45	.77	2.11
Nitrate - N	0.00	.18	.27	.33	.05	.03
Kjeldahl - N	.85	1.03	2.86	1.50	2.15	---
Dissolved solids	257.00	302.00	272.00	270.00	246.00	272.00
Total suspended solids	12.00	6.00	22.00	10.00	21.00	6.00
Volatile suspended solids	4.00	6.00	7.00	8.00	6.00	2.00

Parameters	8/01/84	8/22/84	9/05/84	9/19/84	10/17/84	11/15/84
Secchi disc readings (inches)	---	---	---	---	---	---
Turbidity (NTD)	68.00	17.00	30.00	43.00	25.00	164.00
pH (dimensionless)	8.70	8.20	8.50	8.50	8.60	8.10
Alkalinity	168.00	198.00	182.00	186.00	170.00	186.00
Conductivity (umho/cm)	334.00	529.00	317.00	314.00	320.00	321.00
Total phosphate - P	.62	.53	.29	.25	.19	.24
Dissolved phosphate - P	.14	.14	.18	.01	.11	.03
Total ammonia - N	.19	1.91	.59	.53	.28	.20
Nitrate - N	.12	.02	.06	.18	.03	.20
Kjeldahl - N	2.10	4.49	2.03	2.11	.90	2.12
Dissolved solids	212.00	258.00	248.00	246.00	242.00	248.00
Total suspended solids	70.00	16.00	18.00	56.00	11.00	204.00
Volatile suspended solids	15.00	10.00	15.00	16.00	7.00	25.00

Note: Values in mg/1 unless otherwise indicated.

Appendix 2. Physical and chemical quality characteristics of bottom waters at station 1 in Johnson Sauk Trail Lake

Parameters	12/12/84	1/16/85	1/22/85	2/15/85	3/13/85	4/16/85
Secchi disc readings (inches)	---	---	---	---	---	---
Turbidity (NTU)	7.00	---	10.00	38.00	30.00	10.00
pH (dimensionless)	8.30	---	8.10	8.00	8.30	8.30
Alkalinity	183.00	---	193.00	210.00	173.00	181.00
Conductivity (µmho/cm)	396.00	---	358.00	393.00	323.00	333.00
Total phosphate - P	.05	---	.07	.13	.09	.05
Dissolved phosphate - P	.01	---	.02	.02	.02	.01
Total ammonia - N	.15	---	.08	.19	.05	.23
Nitrate - N	.01	---	.02	.10	.34	.03
Kjeldahl - N	1.27	---	.98	1.89	1.41	1.73
Dissolved solids	248.00	---	267.00	304.00	228.00	256.00
Total suspended solids	14.00	---	23.00	91.00	26.00	10.00
Volatile suspended solids	13.00	---	8.00	11.00	8.00	1.00

Note: Values in mg/1 unless otherwise indicated.