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PILOT LAKE RESTORATION INVESTIGATIONS IN THE FOX CHAIN OF LAKES

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BACKGROUND

The Fox Chain of Lakes are experiencing luxuriant nuisance algal blooms, periodic fish kills, and offensive odors. These undesirable eutrophic symptoms have been a source of citizens' complaints for the past 35 years. A detailed 18-month investigation of the Chain was conducted by the Illinois State Water Survey and Illinois State Geological Survey (Kothandaraman et al., 1977). From this study it was determined that, through its tributaries, the lake system receives nutrients, particularly nitrogen and phosphorus, far in excess of limits which are likely to be assimilated without giving rise to nuisance algal blooms. The nutrients released from the lake bottom sediments under anaerobic conditions in deep lakes during periods of summer stagnation were also found to be sufficient to sustain algal growths of bloom proportions in the lakes.

The predominance of algal types, i.e., blue-green and diatoms, was found to be related to the physical characteristics of the lakes. The northern lakes in the system are relatively deep (20 to 40 feet) and their lesser expance of water surface makes them less exposed to wind action than the large shallow lakes in the system. The deep lakes support similar algal types, mainly blue-greens, whereas in the shallow lakes, diatoms were the dominant species. The highest algal counts in each of the lakes of the Fox Chain are in excess of 10,000 counts/ml.

Limiting the nutrient influx to the lakes is an essential step in reversing the eutrophic trend in the Fox Chain. Regional plans for pollution abatement in the Fox River watershed, including phosphorus emission control, are in various developmental stages in Illinois and Wisconsin. The time schedules for the implementation of these plans are not clear cut. It is unlikely that any significant reduction in nutrient influx can be effected within the next several years. In the interim, use of in-lake treatment techniques to enhance the water quality appears to be justified.

In order to assess the efficacy of in-lake treatment methods in the Fox Chain of Lakes, pilot studies were undertaken to investigate the responses of the lake system. In the earlier report (Kothandaraman et al., 1977), it was proposed to employ 1) artificial destratification and aeration in Lake Catherine, 2) nutrient inactivation by use of aluminum sulfate (alum) in Stanton Bay (Fox Lake), and 3) chemical control of algae blooms by the application of copper sulfate in Mineola Bay (Fox Lake). During the initial stages of the pilot investigation (May 1977), it was found that phosphorus concentrations in Stanton Bay were very low, and no useful purpose could be realized by the application of alum there. Bluff Lake, comparable in size to Stanton

Bay, was chosen for the nutrient inactivation demonstration. Figure 1 shows the sites and pilot demonstration schemes for the Fox Chain of Lakes.

For artificial destratification and aeration in Lake Catherine, compressed air and the Aquatic Environmental Control Company's (AECC) system were considered. The latter system consists essentially of a modified venturi system with an air induction and mixing chamber at the throat. Reliance is placed on a high velocity jet discharging from a nozzle for destratification. The AECC unit, which is extremely quiet in operation and is maintenance free, was chosen for use in Lake Catherine. Because the shoreline of Lake Catherine is fully developed for year-round residential purposes, the operating noise level was the primary criterion favoring the selection of the AECC system.

Even though all the equipment and accessories for lake destratification purposes were procured, the system could not be installed in the lake in 1977 because of some unforeseen legal difficulties with the owner of the site on which the unit was to be installed. All the legal problems have since been solved and the destratification unit was installed in May 1978, soon after the winter thawing of the lake. Results of pretreatment monitoring of Catherine and Channel Lakes are included in the appendix.

This report deals with the other two aspects of the demonstration project, namely, alum application in Bluff Lake and copper sulfate application to Mineola Bay in Fox Lake. Bluff Lake has a surface area of 92 acres with maximum and mean depths of 27.0 feet and 10.5 feet, respectively. Mineola Bay has a surface area of 200 acres with a mean depth of about 5 feet.

NUTRIENT INACTIVATION IN BLUFF LAKE

Materials and Method

As a preliminary step to alum application in Bluff Lake, laboratory 'jar tests' were performed with lake surface and deep water samples in order to determine the desirable alum dosage rate. Jar tests were run with water samples on a six-place Phipps and Bird variable speed paddle mixer. The alum dosage rates ranged from 50 to 150 mg/l , as $Al_2(SO_4)_3$, at 25 mg/l increments. A control without the addition of alum was included in each of the experiments. A 30-second rapid mix at 100 rps, followed by 10 minutes of gentle mixing at 30 rpm and then 1 hour of quiescent settling were the sequence of test conditions. At the end of the settling period, the clear supernate was syphoned and the following analyses were performed: alkalinity, pH, turbidity, and dissolved and total phosphorus. In addition qualitative observations on floc size and settleability were made and recorded.

The results of the jar tests are shown in table 1 for Bluff Lake surface water sample and deep water sample (collected 1 foot above lake bottom), respectively. The surface sample was collected on June 6 and the deep sample on June 13, 1977. Summer stratification had set in by then, and the lake had begun to experience algal growth of bloom magnitude. Because of the utiliza-

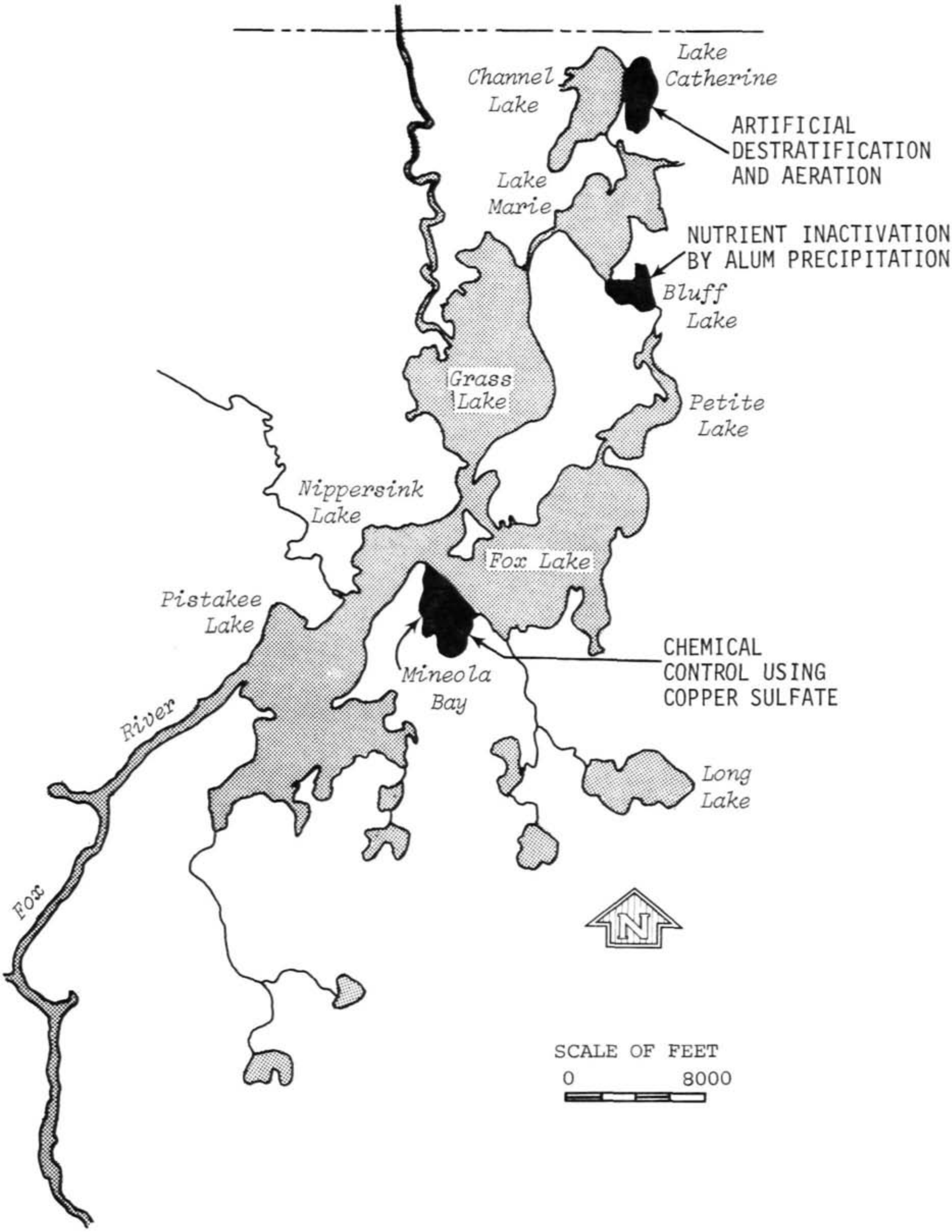

Figure 1. Pilot demonstration schemes in the Fox Chain of Lakes

Table 1. Bluff Lake Surface and Deep Water Sample Jar Tests

	Raw sample	Alum dosage (mg/l) 0	50	75	100	125	150
Surface water samples							
Total phosphorus (mg/l)	0.07	0.05	0.05	0.04	0.03	0.03	0.07
Total dissolved phosphorus (mg/l)	0.08	0.05	0.03	0.03	0.03	0.02	0.07
Turbidity (FTU)	11	5	4	4	3	2	2
pH	8.69	8.70	7.87	7.71	7.37	7.33	7.31
Alkalinity (mg/l)	162	162	152	136	126	111	101
Settleability			least rapid	→	→	→	most rapid
Deep water samples							
Total phosphorus (mg/l)		0.46	0.19	0.16	0.14	0.11	0.08
Total dissolved phosphorus (mg/l)		0.31	0.03	0.02	0.02	0.03	0.01
Turbidity (FTU)		4	3	3	3	3	2
pH		7.53	7.12	6.97	6.81	6.86	6.74
Alkalinity (mg/l)		197	172	162	152	146	131
Settleability			least rapid	→	→	→	most rapid

tion of nutrients by the standing algal crop, the phosphorus concentration in the surface water sample was only 0.07 mg/l, whereas in the deep water sample, the total phosphorus was 0.46 mg/l. Alkalinity and pH decreased progressively with increases in alum dosage rates. Turbidity and phosphorus levels declined rapidly with increased alum dosage and tended to level off at high dosage rates. Floc sizes were large and settleability was good in all cases. On the basis of the phosphorus reduction by precipitation and the turbidity data, a dosage rate of 100 mg/l as aluminum sulfate (15.8 mg/l as Al^{3+}) was chosen for application to Bluff Lake. Relying on the experience of the Wisconsin Department of Natural Resources in Horseshoe Lake (Peterson et al., 1973), it was decided to apply alum to the volume of lake water contained in the top 2 feet.

Though it is ideal to apply alum to the lake soon after winter thaw and prior to the onset of any algal blooms, a decision was made to apply alum as early as practicable. It was anticipated that after the alum application the phosphorus concentration in the photic zone would be reduced minimizing subsequent algal blooms, and that the settling floc would remove particulate phosphorus and dissolved phosphorus by sorption and entrapment, in the process of settling to the bottom. It was also anticipated that the alum floc blanket formed over the lake sediments would tend to reduce the anaerobic release of phosphorus from the lake sediments. Above all, the clarity of the lake could be improved immediately, enhancing the aesthetic attractiveness of the lake.

An attempt was made to apply alum to the lake on July 19, 1977. This effort had to be abandoned because of a malfunctioning outboard motor. The pontoon barge employed in the operation proved to be inadequate and unsafe. However, the task was successfully completed on August 10, 1977, with the aid of better designed equipment and facilities.

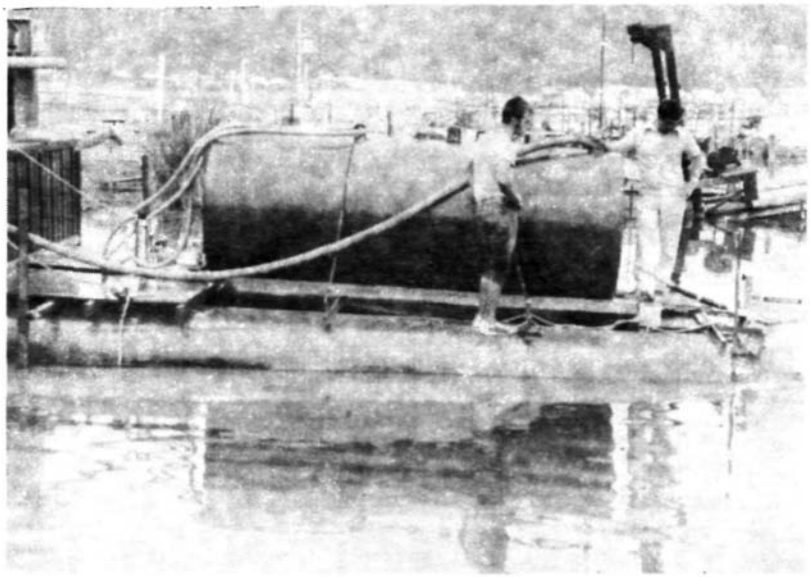

Figure 2. Pontoon tank used in alum application

Alum was applied by means of a center feed underwater sprayer of galvanized iron pipe 20 feet long and 1.5 inches in diameter with 5/16-inch diameter holes at 12-inch intervals. Alum was applied from a tank barge, shown in figure 2, with a 3 hp gasoline-powered centrifugal pump. The flow of fluid through the system was monitored by a flow meter. The pump and flow meter used in applying alum are shown in figure 3. A Fischer and Porter variable area flow meter, capable of registering a flow of 20 gpm of water, was used. Nomographic charts are available for estimating flows of fluids of different densities from the permanent graduations on the flow meter.

The spray header was held by means of 'U' bolts to vertical struts which were structurally fastened to the barge pontoons. Holes were drilled in the vertical struts so that the header could be fixed at three different positions approximately 15, 21, and 27 inches below water surface. The worktng platform and spray header support system were designed and fabricated by Donald Roseboom of the Water Survey. Details of the working platform, sprayer supporting structures, and the center feed unit of the sprayer are shown In figures 3 and 4.

Bulk alum was stored in a semi-trailer tank (figure 5) for the duration of the lake work. The charge for this storage facility was less than the cost of a 15~foot diameter, 3"foot 6-inch high portable swimming pool initially considered. Alum was transferred by gravity flow from the storage tank to the barge tank.

The tank barge was loaned to the Survey by Mr. Clem Haley, owner-operator of the Grass Lake Marina. The barge is used to transport sanitary waste from the Blarney Island tavern and resturant in Grass Lake to the main shore for final disposal. Prior to the use of the barge for alum application, the tank was flushed four times with lake water transferring the rinse waters to a tank truck hauling sanitary waste. The barge tank was then treated with 5 pounds of high test hypochlorite, allowing a 30-minute contact time.

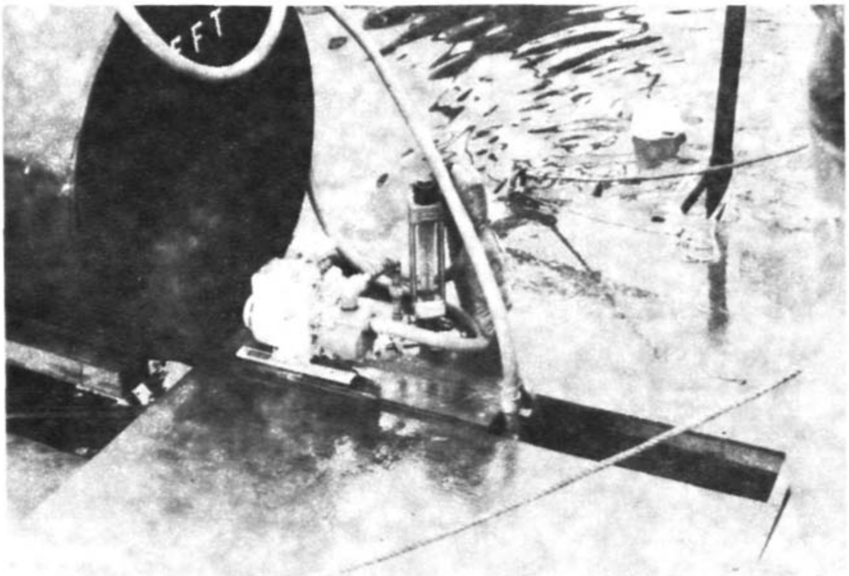

Figure 3. View of the pump, flow meter, and work platform

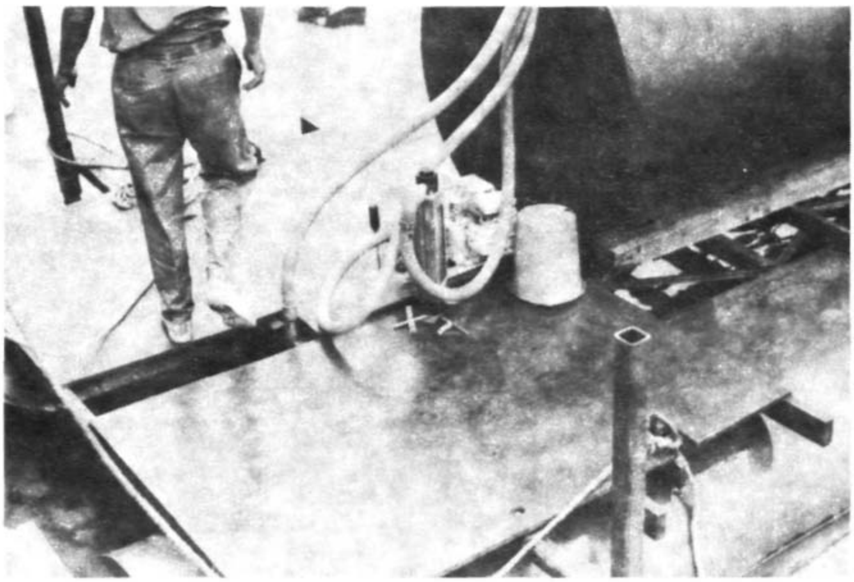

Figure 4. View of the spray header supports

The barge was powered by a 25 hp outboard motor. The steering mechanism of the outboard was modified to enable the operator of the barge to look ahead over the tank (figure 6). The barge is shown loaded to the maximum extent. Though the tank has a capacity of 940 gallons (4-foot diameter, 10 feet long), the barge can safely carry only about 5000 pounds of liquid.

The speed of the barge was determined by noting the time to traverse between two fixed points at a known distance in Grass Lake. The tank was filled with water to its safe limit initially, and the outboard was operated with the

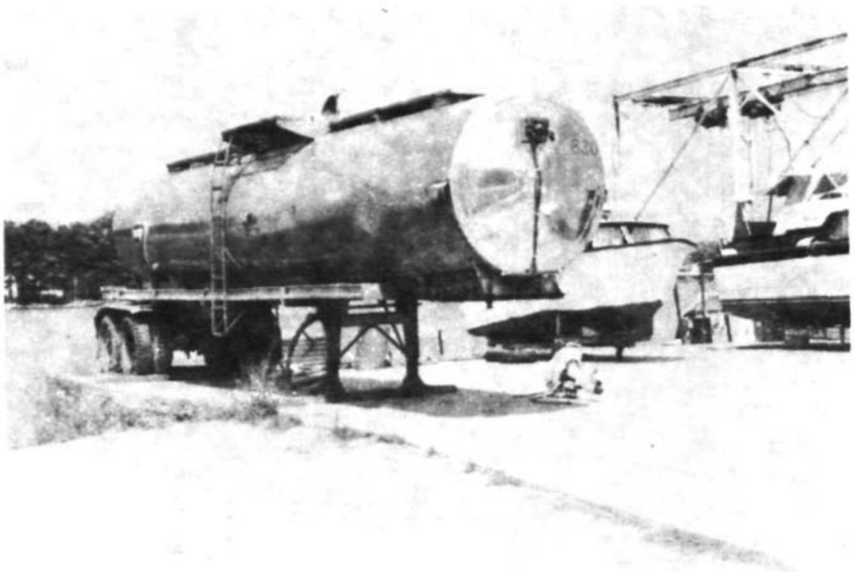

Figure 5. Bulk alum storage facility

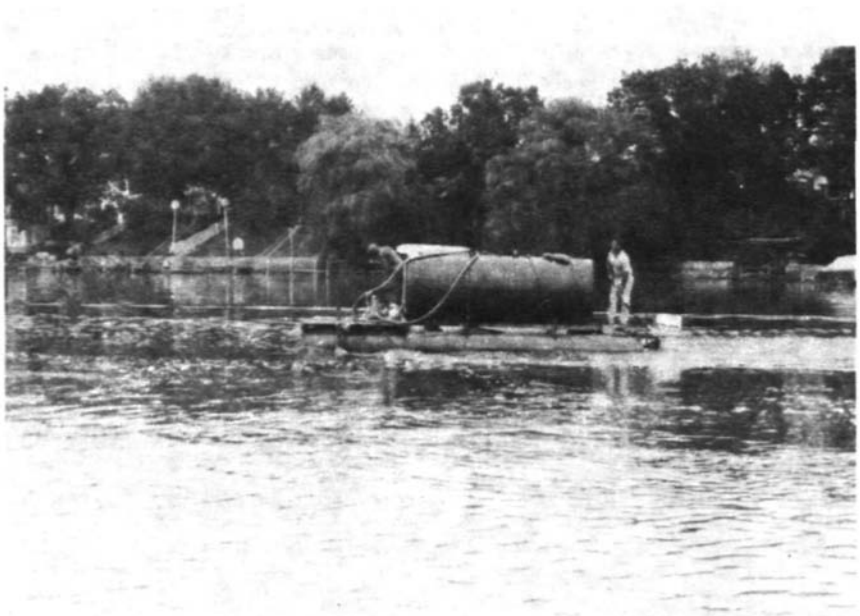

Figure 6. View of the pontoon tank fully loaded

throttle fully open. The contents of the tank were discharged through the header at the same time. This very nearly simulated the operating conditions in Bluff Lake during alum application. The barge covered a distance of 6600 feet in 19 minutes giving an average speed of 3.95 miles per hour.

Because the alum applicator length was 20 feet, the alum dosage rate was 100 mg/l, the commercial liquid alum contained approximately 50 percent aluminum sulfate, and the speed of the barge was 347.4 feet per minute, it was computed that the system should deliver alum at the rate of 15.73 gallons per minute. The flow meter reading of 18 was determined from a nomograph supplied by the manufacturer, on the basis of the density of alum (11 pounds per gallon). The flow rate could be adjusted by a gate valve on the delivery line, or by adjusting the speed of the gasoline engine, or by a combination of these two techniques. A calibrated float gage shown in figure 7 was used to indicate the liquid level in the tank. The gage was inserted into the tank through one of the plug holes located on top of the tank.

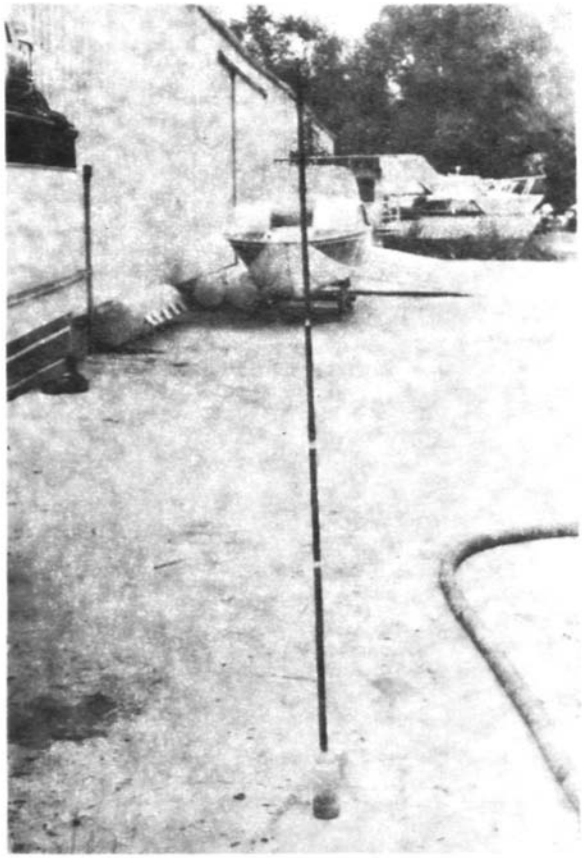

Figure 7. Calibrated float gage

As shown in figure 8, Bluff Lake was divided into two sections by use of regulatory buoys in an east-west orientation. When one segment of the lake was being treated, general boat traffic was diverted through the other segment. Application was started in 20-foot wide strips (figure 8) adjacent to the central dividing line. To demarcate the edges of the treated lanes, floats consisting of 1 gallon jars tied to a brick with a 35-foot nylon cord wound around the brick (figure 9) were dropped at frequent intervals from a boat following behind the barge. By this arrangement, irrespective of the depth of water column, the cord would unwind until the brick reached the bottom, thus anchoring the float in place. The cord must be longer than the water column to keep the float from drifting away. The ends of the spray header were marked by plastic bottle floats, one of which is visible in figure 3. Consecutive 20-foot wide strips of the lake surface were treated, working from the center toward the north and then the south end of the lake.

After two consecutive strips were treated, floats from the edge of the outer strip were retrieved and reused. Figure 10 shows a row of floats in the lake and the retrieving boat.

A total of 43.2 tons of liquid alum was applied to about 90 percent of the lake surface. Part of the lake surface was inaccessible because of boat docks.

Mounting of the underwater alum sprayer at the front end of the pontoons afforded quick mixing of the alum by the turbulence created by the pontoons and the outboard. A trail of aluminum hydroxide floc was visible immediately behind the pontoon barge.

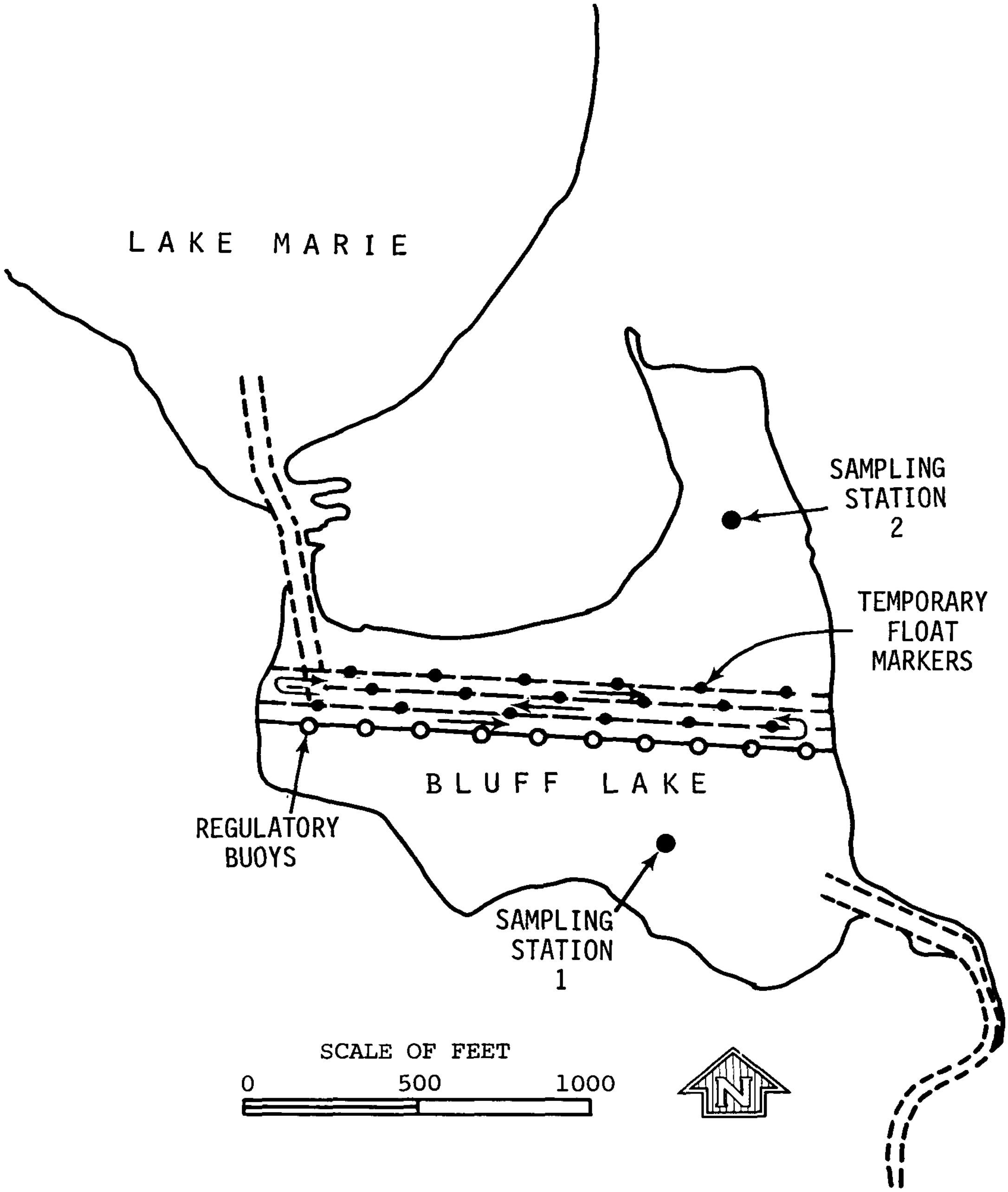

Figure 8. Bluff Lake

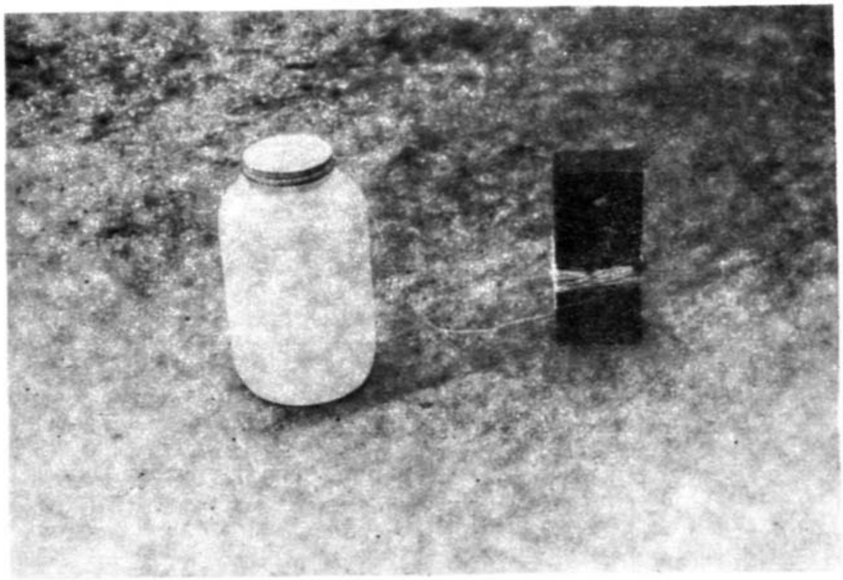

Figure 9. Float used to demarcate the treated strip of take surface

Figure 10. A row of floats in the lake

Results of Alum Application

Pretreatment monitoring of Bluff Lake for its water quality characteristics started on May 31, 1977, on a weekly schedule. Sampling Station 1, shown in figure 8, was established at the deepest part of the lake. Station 2 was established for the shallow bay area in the northeast portion of the lake. *In-situ* observations of secchi disc transparency, temperature, and dissolved oxygen were made. At the deep station, temperature and dissolved oxygen measurements were made at 2-foot depth intervals. At Station 2, these observations were made at 1-foot intervals. Water samples were collected at surface, mid-depth, and deep portions of Station 1, and only surface samples were collected at Station 2. Mud-water interface samples were initially collected at both stations on August 11, 1977, with an interface sampler developed by the Survey as described by Sullivan (1967). Sampling and analytical procedures were as detailed in the earlier report of the Fox Chain of Lakes (Kothandaraman et al., 1977). The following determinations were made on water samples: turbidity, pH, alkalinity, hardness, nitrate, ammonia, sulfate, total and dissolved solids, total and dissolved phosphorus, aluminum, and algal identification and enumeration.

Water quality characteristics of Bluff Lake for Stations 1 and 2 are given in tables 2 through 6. Figure 11 shows the temporal variations in surface dissolved oxygen concentrations, secchi disc transparency, algal counts, and total and dissolved phosphorus. The figure also includes the phosphorus concentrations in mid-depth and deep water samples.

The day after the completion of alum application in the lake, aluminum concentrations (Al^{3+}) in the surface, mid-depth, deep, and interface samples were 0.37, 0.26, 0.04, and 8.97 mg/l, respectively. This indicated that the alum floc had settled to the bottom of the lake. Aluminum concentration of the bay area surface water sample (8/11/77) was 0.34 mg/l and the bay's interface sample showed a concentration of 2.26 mg/l. Aluminum concentrations in the water columns, in both the main lake and the bay area, decreased to about 0.04 mg/1 in a week and remained at that level until this investigation ended. The interface aluminum concentrations also showed a significant decrease.

As expected, the immediate effect of the alum treatment was a dramatic improvement in lake transparency and a decrease in algal counts due to precipitation and settling of algal cells. The transparency increased from an average value of about 23 inches prior to alum treatment to 45 inches. The algal counts decreased from an average value of 5240 to 920 counts/ml. Likewise, in the bay area transparency improved from a background level of 18 to 33 inches. Algal counts of 620/ml were observed.

As seen from figure 11 and table 2, these improvements did not last more than a few days. The conditions of lake clarity and algal density reverted to normal levels. This is mainly because of the interchanges in flows between Bluff Lake and adjacent lakes. The problem is compounded by the heavy usage of high speed boats and yachts in the lake system. Even though the algal

Table 2. Water Quality Characteristics, Bluff Lake, Surface

Date	Trans-parency (inches)	Tur-bidity (FTU)	pH	Alka-linity (mg/l)	Hard-ness (mg/l)	Ni-trate (mg/l)	Ammo-nia (mg/l)
5/31/77	24	10	8.62	164	265	0.16	0.18
6/6/77	26	5	8.57	172	219	0.12	0.23
6/13/77	24	7	8.53	177	252	0.15	0.44
6/20/77	22	7	8.27	187	232	0.15	0.03
6/27/77	24	6	7.72	152	166	0.10	0.17
7/5/77	21	12	8.27	167	192	0.18	0.21
7/11/77	18	12	8.45	167	159	0.12	0.15
7/18/77	18	9	7.95	164	293	0.11	0.28
7/26/77	21	6	8.40	172	113	0.20	0.20
8/1/77	24	8	8.35	172	313	0.13	0.24
8/8/77	30	7	8.15	177	307	0.10	0.34
8/11/77	45						
8/17/77	27	15	8.25	177	287	0.10	0.31
8/22/77	30	11	8.30	187	287	0.12	0.14
8/30/77	24	11	8.60	177	293	0.15	0.12
9/6/77	21	14	8.65	192	307	0.05	0.18
9/27/77	18	30	8.30	187	300	0.18	0.94

Date	Sul-fate (mg/l)	Solids (mg/l) Total	Diss.	Phosphorus (mg/l) Total	Diss.	Alu-minum (mg/l)	Algae (counts/ml)
5/31/77	76.9	332	298	0.10	0.02		4350
6/6/77	74.2	518	484	0.13	0.03		2470
6/13/77	77.8	488	426	0.15	0.03		3430
6/20/77	80.9	358	348	0.34	0.11		4390
6/27/77	94.3	332	237	0.08	0.03		3610
7/5/77	71.8	408	356	0.14	0.02		2750
7/11/77	78.5	378	360	0.13	0.02		8170
7/18/77	77.2	384	352	0.11	0.03		9060
7/26/77	69.8	432	344	0.12	0.02		6920
8/1/77	68.8	426	278	0.15	0.02		6630
8/8/77	65.5	554	192	0.14	0.03		5840
8/11/77						0.37	920
8/17/77	66.5	414	390	0.18	0.10	0.05	3420
8/22/77	63.7	370	200	0.17	0.03	0.04	3811
8/30/77	59.2	408	386	0.17	0.03	0.01	2280
9/6/77	63.1	480	416	0.17	0.03	0.05	2740
9/27/77	59.A	504	360	0.21	0.07	0.03	750

Table 3. Water Quality Characteristics, Bluff Lake, Mid-depth

Date	*Turbidity (FTU)*	*pH*	*Alkalinity (mg/l)*	*Hardness (mg/l)*	*Nitrate (mg/l)*	*Ammonia (mg/l)*
5/31/77	6	8.54	167	278	0.16	0.24
6/6/77	3	8.54	175	185	0.09	0.21
6/13/77	7	8.37	174	232	0.15	0.36
6/20/77	5	8.04	159	265	0.15	0.39
6/27/77	5	7.92	184	166	0.15	0.61
7/5/77	5	7.75	169	139	0.22	0.50
7/11/77	5	7.85	174	166	0.14	0.35
7/18/77	5	7.75	162	440	0.11	0.45
7/26/77	6	7.95	172	160	0.12	0.20
8/1/77	5	8.15	177	300	0.13	0.17
8/8/77	4	7.90	182	267	0.10	0.51
8/17/77	10	8.30	182	313	0.09	0.29
8/22/77	7	8.15	182	307	0.12	0.14
8/30/77	6	8.20	184	280	0.14	0.01
9/6/77	10	8.35	182	347	0.07	0.13
9/27/77	28	8.20	192	307	0.17	0.64

Date	*Sulfate (mg/l)*	*Solids (mg/l)*		*Phosphorus (mg/l)*		***Alu**minum (mg/l)*	*Algae (counts/ml)*
		Total	*Diss.*	*Total*	*Diss.*		
5/31/77	78.6	322	316	0.13	0.02		2700
6/6/77	76.9	528	490	0.14	0.02		3350
6/13/77	76.9	490	426	0.18	0.04		2240
6/20/77	80.9	368	360	0.22	0.22		3210
6/27/77	80.7	326	233	0.14	0.08		3170
7/5/77	74.2	412	344	0.10	0.03		1850
7/11/77	78.5	338	296	0.13	0.06		5320
7/18/77	73.8	388	348	0.12	0.04		4110
7/26/77	71.4	426	334	0.12	0.03		4500
8/1/77	71.8	424	308	0.19	0.04		3510
8/8/77	69.0	472	200	0.13	0.08		2600
8/11/77						0.26	2970
8/17/77	70.3	390	374	0.19	0.05	0.04	950
8/22/77	65.8	348	242	0.12	0.05	0.03	810
8/30/77	59.0	424	404	0.12	0.04	0.01	180
9/6/77	62.7	476	434	0.14	0.05	0.05	740
9/27/77	61.6	498	350	0.22	0.10	0.03	600

Table 4. Water Quality Characteristics, Bluff Lake, Deep

Date	Turbidity (FTU)	pH	Alkalinity (mg/l)	Hardness (mg/l)	Nitrate (mg/l)	Ammonia (mg/l)
5/31/77	6	7.47	212	351	0.11	4.13
6/6/77	2	7.53	146	232	0.18	3.15
6/13/77	50	7.38	222	278	0.15	4.09
6/20/77	5	7.99	205	252	0.17	2.26
6/27/77	4	7.52	235	225	0.15	4.63
7/5/77	8	7.40	220	205	0.17	8.40
7/11/77	8	7.60	270	245	0.19	5.08
7/18/77	34	7.40	263	440	0.14	7.76
7/26/77	4	7.25	265	200	0.15	4.67
8/1/77	23	7.60	278	360	0.13	8.03
8/8/77	5	7.90	184	300	0.08	0.74
8/17/77	17	8.15	258	327	0.08	6.27
8/22/77	15	8.30	187	267	0.12	0.52
8/30/77	22	7.80	194	320	0.15	2.21
9/6/77	8	7.50	194	340	0.05	1.54
9/27/77	260	8.10	182	340	0.18	0.96

Date	Sulfate (mg/l)	Solids (mg/l)		Phosphorus (mg/l)		Aluminum (mg/l)	Algae (oounts/ml)
		Total	Diss.	Total	Diss.		
5/31/77	74.1	372	338	0.88	0.62		240
6/6/77	78.2	524	488	0.53	0.37		240
6/19/77	69.9	894	444	1.41	1.35		200
6/20/77	75.0	396	380	0.57	0.43		1970
6/27/77	75.5	358	340	0.80	0.71		
7/5/77	76.8	442	400	0.76	0.68		2130
7/11/77	65.5	404	400	1.43	1.21		3630
7/18/77	73.2	496	440	1.49	1.07		2670
7/26/77	56.2	460	370	1.31	1.17		2930
8/1/7.7	66.7	510	470	1.91	1.39		2660
8/8/77	68.4	410	288	0.22	0.10		180
8/11/77						0.04	200
8/17/77	57.9	474	442	1.06	0.83	0.06	750
8/22/77	66.0	400	320	0.28	0.18	0.03	660
8/30/77	63.5	466	422	0.47	0.25	0.03	140
9/6/77	66.1	462	422	0.27	0.20	0.03	100
9/27/77	64.1	910	368	0.86	0.11	0.21	100

Table 5. Water Quality Characteristics, Bluff Lake, Interface

Date	*Tur-bidity (FTU)*	*pH*	*Alka-linity (mg/l)*	*Hard-ness (mg/l)*	*Ni-trate (mg/l)*	*Ammo-nia (mg/l)*
8/11/77	308	8.40	308	400	0.12	9.47
8/17/77	137	7.55	323	347	0.26	13.29
8/22/77	875	7.50	220	287	0.22	1.87
8/30/77	47	7.30	237	327	0.29	6.77
9/6/77	20	7.85	232	427	0.28	6.76
9/27/77	2450	8.12	177	360	0.30	

Date	*Sul-fate (mg/l)*	*Solids (mg/l)*		*Phosphorus (mg/l)*		*Alu-minum (mg/l)*
		Total	*Diss.*	*Total*	*Diss.*	
8/11/77	48.4	2206	440	1.93	0.08	8.97
8/17/77	24.2	3446	546	11.41	0.45	1.63
8/22/77	70.5	3446	452	9.04	0.41	1.05
8/30/77	62.5	5566	440	12.94	0.47	5.45
9/6/77	60.8	5762	462	9.68	0.57	0.82
9/27/77	10.8	38488	360	0.23	0.05	29.80

counts in the lake indicate a declining trend after the alum application (figure 11), aesthetic conditions in the lake did not improve except during a very short period after the alum application. A comparison of the algal densities in Bluff Lake for the year 1975 (Kothandaraman et al., 1977) indicates that an algal bloom of the magnitude that occurred in mid-September 1975 did not recur in September 1977.

The total and dissolved phosphorus levels in the surface and mid-depth samples did not change. However, a marked drop in total and dissolved phosphorus levels was observed in the deep water samples after alum treatment. The pretreatment average values for these parameters were 1.03 and 0.83 mg/l. The post-treatment values for total and dissolved phosphorus were 0.58 and 0.31 mg/l, respectively.

No changes other than normal perturbances resulted from the alum treatment in the other water quality characteristics observed, namely, turbidity, alkalinity, hardness, nitrate, ammonia, sulfate, and solids. Even the sulfate concentrations and pH values were unaffected by the treatment. The isothermal plots of iso-dissolved oxygen concentration curves (figures 12 and 13) are similar to the ones for the corresponding period in 1975 (Kothandaraman et al., 1977).

The beneficial effects of alum treatment in Bluff Lake did not last for any appreciable length of time. This is in contrast to the experiences reported for other water bodies (Funk et al., 1977; Peterson et al., 1973; Shannon and Ludwig, 1974). Unlike the other water bodies that received alum

Table 6. Water Quality Characteristics, Bluff Lake, Bay Surface and Interface

Date	Transparency (inches)	Turbidity (FTU)	pH	Alkalinity (mg/l)	Hardness (mg/l)	Nitrate (mg/l)	Ammonia (mg/l)
Bay surface							
8/11/77	33	68	7.80	174	307	0.11	0.72
8/17/77	30	10	8.30	182	327	0.11	1.47
8/22/77	18	16	8.35	182	273	0.10	0.04
8/30/77	18	19	8.70	162	307	0.18	0.02
9/6/77	24	10	8.70	187	360	0.04	0.12
9/27/77	9	25	8.37	187	313	0.12	0.68
Bay interface							
8/11/77		174	7.90	174	273	0.08	0.67
8/17/77		417	7.60	192	333	0.26	1.52
8/22/77		30	7.70	179	320	0.12	0.50
8/30/77		1092	8.60	197	300	0.14	0.04
9/6/77		2156	8.60	182	353	0.02	0.07
9/27/77		41	8.50	298	313	0.15	0.45

	Sulfate (mg/l)	Solids (mg/l)		Phosphorus (mg/l)		Aluminum (mg/l)	Algae (counts/ml)
		Total	Diss.	Total	Diss.		
Bay surface							
8/11/77	70.7	2176	304			0.34	620
8/17/77	67.2	386	286	0.15	0.04	0.06	2720
8/22/77	64.1	384	272	0.28	0.02	0.03	3610
8/30/77	61.4	484	390	0.04	0.03	0.02	3320
9/6/77	66.1	484	418	0.16	0.02	0.03	670
9/27/77	61.2	492	352	0.22	0.08	0.03	2050
Bay interfrace							
8/11/77	58.9	954	370	2.44	1.68	2.26	
8/17/77	44.2	1322	468	1.98	0.08	0.99	
8/22/77	69.5	616	488	0.52	0.03	0.14	
8/30/77	66.0	1122	384	0.91	0.03	0.38	
9/6/77	65.3	592	436	0.36	0.05	0.07	
9/27/77	64.1	530	350	47.51	1.86	0.08	

treatment, Bluff Lake is part of a large system of lakes and is subjected to intensive recreational boating activities. On the basis of this investigation, it is concluded that nutrient inactivation as an interim means of lake restoration is not applicable to the lakes of the Fox Chain.

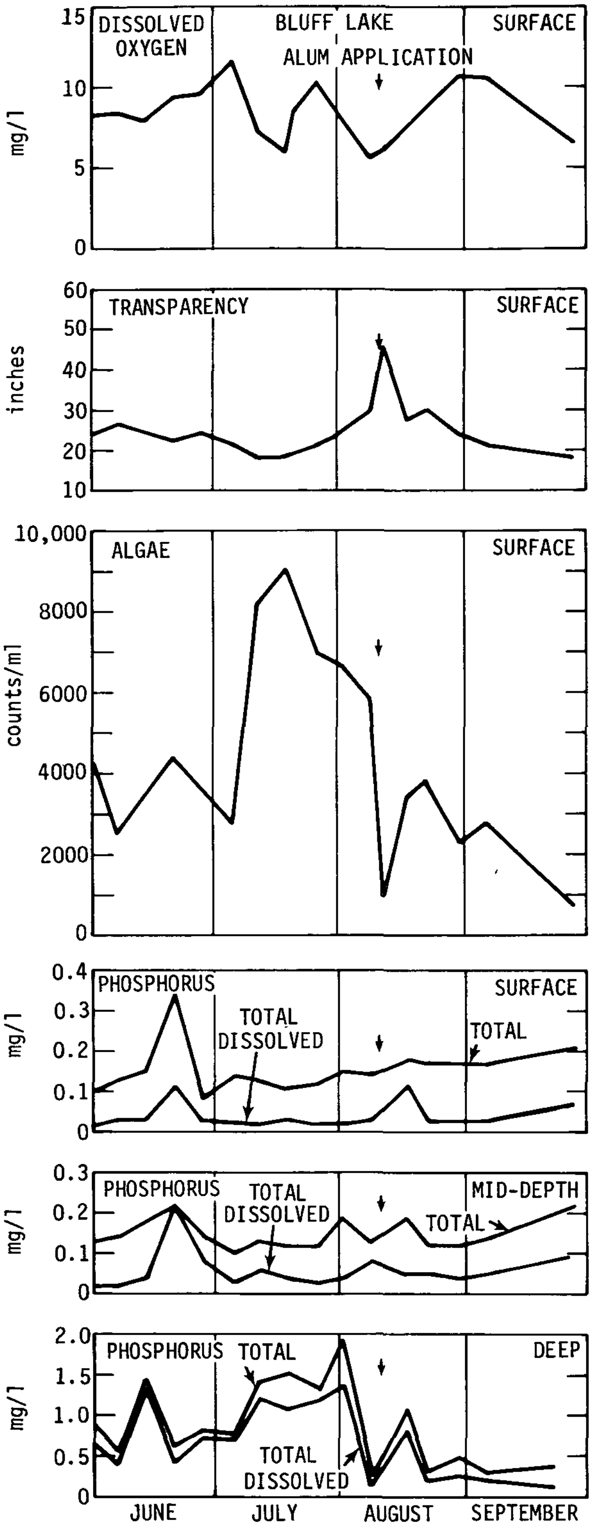

Figure 11. Bluff Lake water quality characteristics

CHEMICAL TREATMENT
IN MINEOLA BAY (FOX LAKE)

Copper sulfate was used as a chemical means of controlling algae in the Mineola Bay of Fox Lake. The chemical was applied on a contractual basis by Midas Midwest, Inc., a company authorized by the State of Illinois to apply algicides, herbicides, pesticides, etc. The dry feed technique was employed for this purpose.

The device, shown in figure 14, consists essentially of a 4-inch diameter polyvinyl chloride pipe with an enlarged bell-mouthed entry. The pipe terminates with an elbow pointing upwards. Near the front end of this pipe, a vertical pipe is joined by a 4-inch 'T' joint. Copper sulfate powder is hand dispensed through this vertical pipe. The system is attached to two pipes with ends sealed, one on each side of the chemical feed pipe, to enable it to float in water. The whole system, which is portable, is mounted on one side of a work boat with the bell-mouthed end pointing in the direction of motion. The forward motion of the boat draws the lake water through the applicator, mixed with the chemical. The copper sulfate solution is discharged at the rear end of the applicator over the water surface.

Copper sulfate was applied to the bay at the rate of 5.4 pounds per acre which is equivalent to a dosage rate of 1 mg/l to the top 2 feet of the lake waters. The chemical was applied on three calm, sunny days, June 2, June 27, and July 19, 1977. Applications commenced early at about 7 a.m. and lasted for about 3 hours.

A total of 1100 pounds of copper sulfate was applied on each occasion. The entire shoreline of the bay was treated, after which the copper sulfate was applied by criss-crossing the bay.

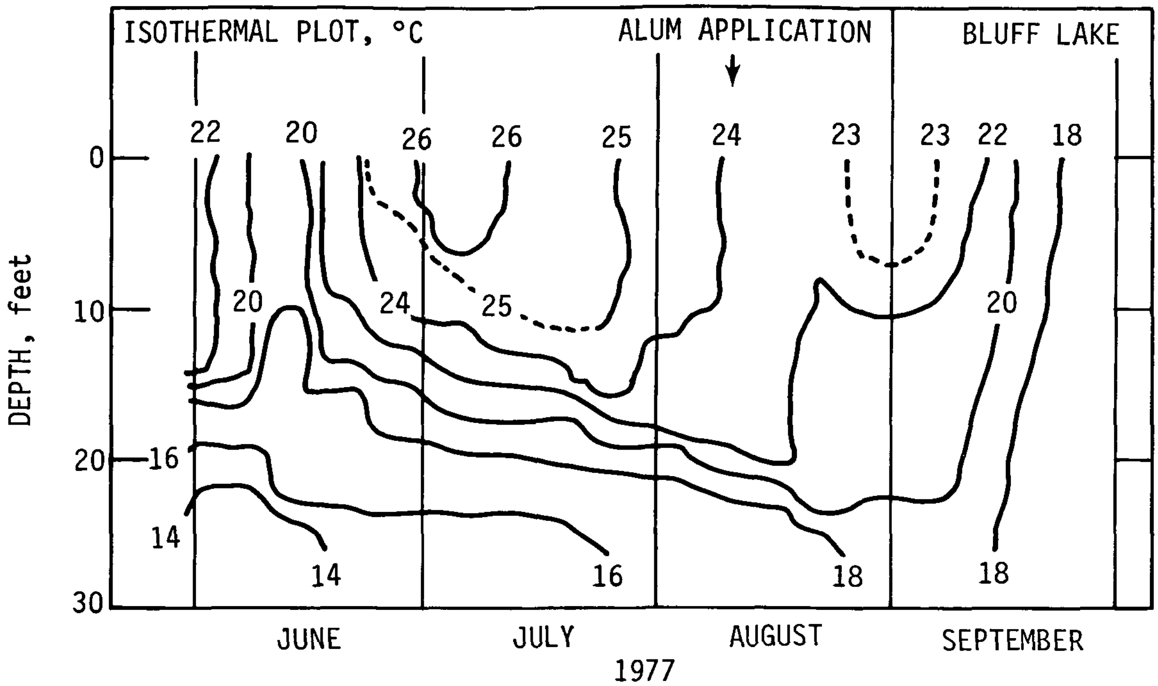

Figure 12. Isothermal plots for Bluff Lake

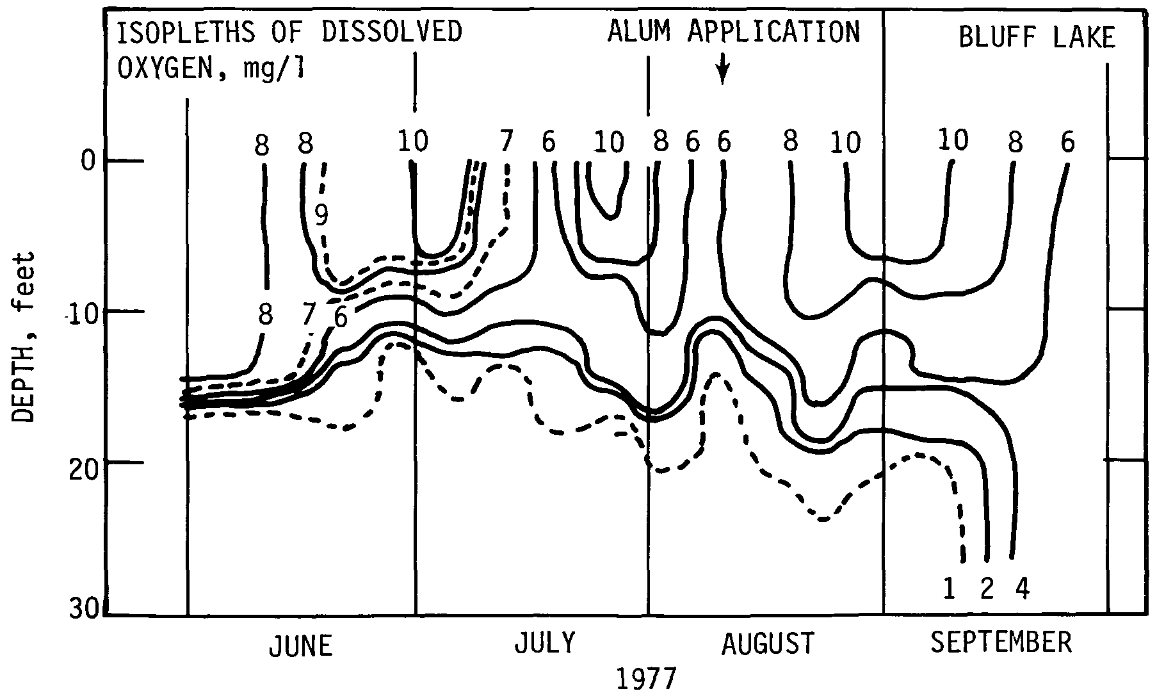

Figure 13. Iso-dissolved oxygen concentration curves for Bluff Lake

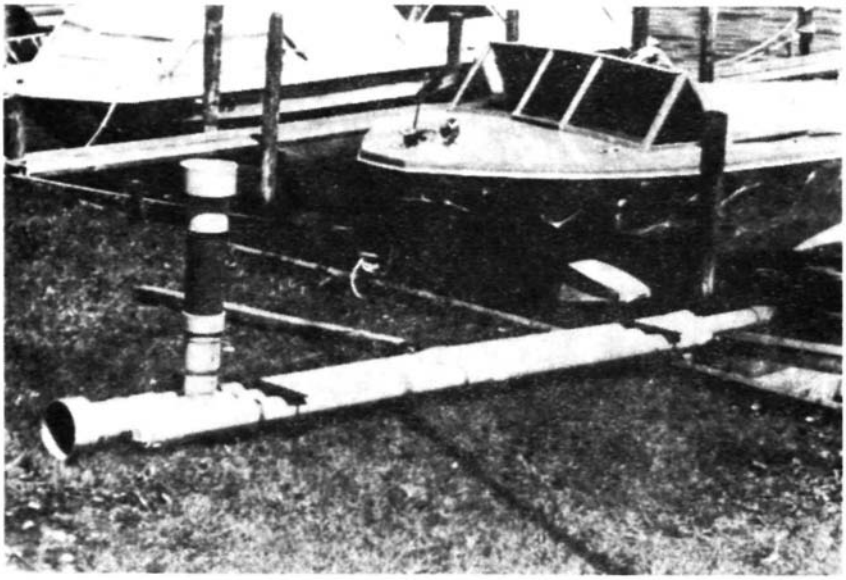

Figure 14. Copper sulfate application device

Soon after the completion of each chemical treatment, water samples for copper analysis were collected from the 8 locations shown in figure 15. Water samples were also collected from these locations on the following day fn each case. The results are shown in table 7. Except near the open waters of the bay, an average copper concentration of about 0.13 mg/l (as Cu^{++}) was observed on the days of chemical treatment. On days subsequent to chemical treatment, copper concentrations reached the limits of detectability. The mud-water interface samples obtained on three occasions (table 7) did not show any significant increase in copper accumulation in the lake bottom. Change in color of the periphytic algal growth along the shoreline from green to whitish gray was observed after the chemical treatment.

Pre- and post-treatment water quality characteristics in Mfneola Bay were monitored on a weekly schedule starting May 16, 1977. Statfon 2 in figure 15 was used as the regular water sample collection site. *In-situ* observations, water sampling methods, and chemical analyses were the same as for Bluff Lake. In addition, water samples were collected and *in-situ* observations were made at an untreated part of the Fox Lake adjacent to Mineola Bay. The depth of water at this location was about 5 feet, comparable to the regular sampling site in Mineola Bay. The results are treated as a control for comparison with the results of the copper sulfate treatment in Mineola Bay.

Water quality characteristics in Mineola Bay and for the Fox Lake control station are shown in tables 8 and 9, respectively. Figures 16 and 17 depict the temporal variations in the parameters which are significantly impacted by the chemical treatment. From figure 16, it can be seen that copper concentrations varied from 0.06 to 0.20 mg/1 on the days of copper sulfate application at the regular sampling station in Mineola Bay. On the following days it varied from 0.04 to 0.9 mg/1. On all other days the copper concentrations were either not detectable or at the threshold level of detectability.

Table 7. Copper Concentrations in Surface Samples, Fox Lake, Mineola Bay, after Copper Sulfate Application

Station	Soon after appli-cation 6/2/77	Bay after appli-cation 6/3/77	Soon after appli-cation 6/27/77	Day after appli-cation 6/28/77	Soon after appli-cation 7/19/77	Day after appli-cation 7/20/77
1	0.12	0.06	0.12	<0.03	0.11	<0.04
2	0.12	0.09	0.20	0.04	0.06	<0.04
3	0.24	0.06	0.07	0.04	0.07	<0.04
4	0.16	0.06	0.09	0.03	0.13	0.29
5	0.04	<0.04	0.11	0.04	0.04	0.06
6	0.04	<0.04	0.06	0.04	0.18	<0.04
7	0.04	<0.04	0.04	<0.03	0.18	<0.04
8	0.04	<0.04	<0.03	<0.03	0.04	<0.03
2*		0.08		0.06		0.12

*Mud-water interface samples at Station 2

The algal counts in Mineola Bay dipped significantly after each chemical treatment. However, the algal counts increased immediately thereafter. This is most likely due to the intermixing of the bay waters and the main lake caused by wind and wave action. The Mineola Bay algal counts were generally lower than those for the Fox Lake control stations.

Secchi disc transparency values did not show any differences between the treated and untreated portions of the lake. Temporal variations in surface dissolved oxygen concentrations were similar in magnitude and shape (figures 16 and 17). Temperature and dissolved oxygen profiles shown in figure 18 for these two sampling sites indicate that the lake is isothermal and that during the summer months (June and July) the lake sediments exert a higher oxygen demand than is replenished from the atmosphere.

There were no perceptible differences in the other water quality parameters (pH, alkalinity, hardness, nitrate, ammonia, sulfate, solids, and phosphate) between the treated and untreated water bodies other than the normal spatial and temporal deviations.

SUMMARY

Aluminum sulfate was applied successfully to Bluff Lake on August 9 and 10, 1977. A total of 43.2 tons of commercial liquid alum (approximately 50 percent aluminum sultate) was applied. A dosage rate of 100 mg/l as $Al_2 (S0_4)_3$ and 15.8 mg/l as Al^{3+} was used for the top 2 feet of water. Except for the immediate but transient improvement in lake transparency as assessed by secchi disc measurement, aesthetic conditions in the lake did not improve. Phosphorus concentrations in the deep waters of the lake were reduced signi-

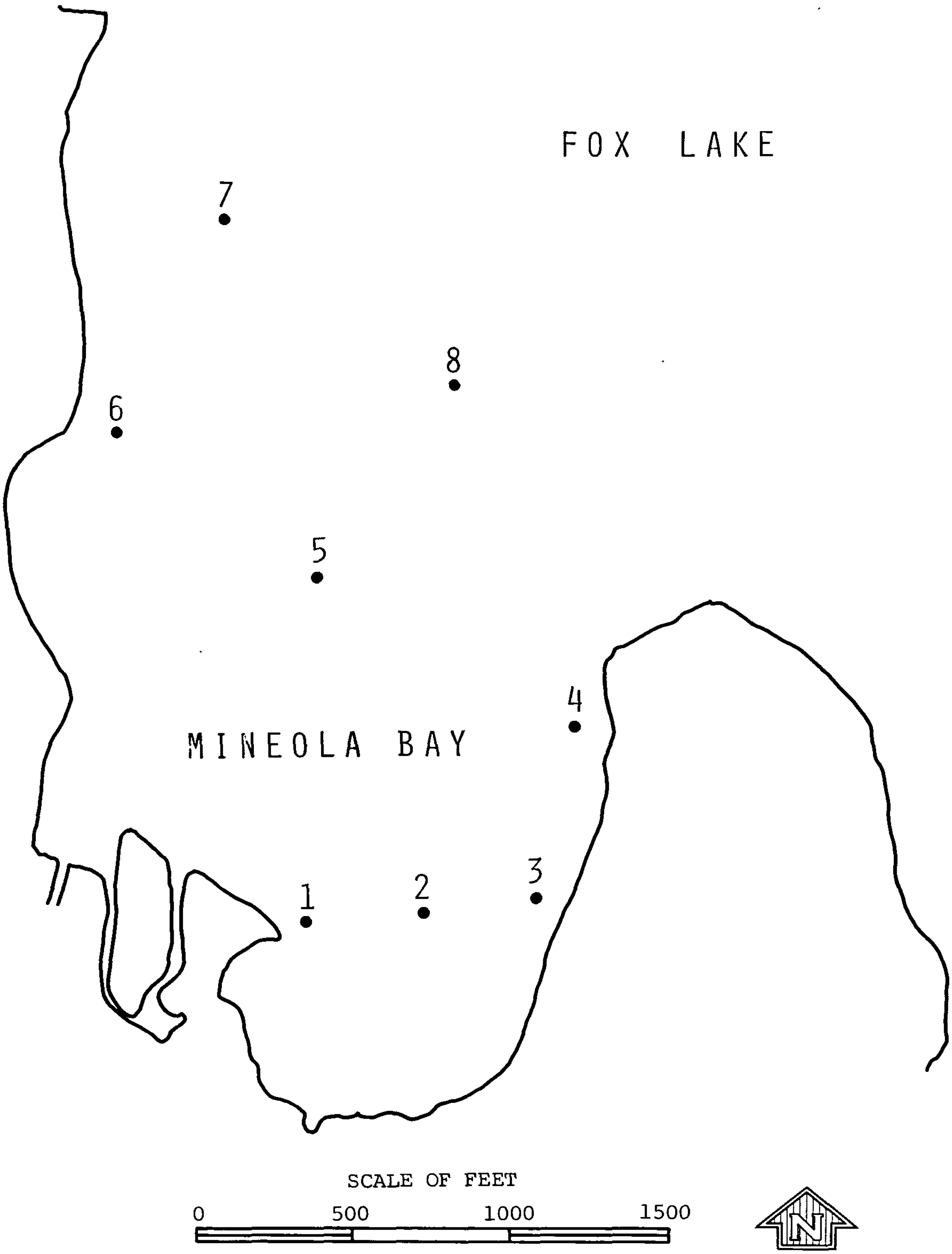

Figure 15. Sampling sites for copper analysis soon after copper sulfate application to Mineola Bay

Table 8. Water Quality Characteristics, Fox Lake, Mineola Bay

Date	Transparency (inches)	Turbidity (FTU)	pH	Alkalinity (mg/l)	Hardness (mg/l)	Nitrate (mg/l)	Ammonia (mg/l)
5/16/77	27	7	8.37	177	278	0.12	0.06
5/23/77	18	20	8.25	187	209	0.16	0.43
5/31/77	12	20	8.65	179	352	0.16	0.11
6/2/77	12						
6/3/77	12						
6/6/77	9	2	8.42	174	199	0.30	0.21
6/13/77	9	23	8.55	202	272	0.22	0.12
6/20/77	9	26	8.67	210	258	0.22	0.15
6/27/77	12	16	8.77	207	179	0.15	0.12
6/28/77	18	11	8.67	215	126	0.18	0.17
7/5/77	12	17	8.25	205	172	0.18	0.78
7/11/77	9	24	8.50	220	159	0.14	0.14
7/18/77	6	30	8.00	194	467	0.16	0.22
7/20/77	11						
7/26/77	10	24	8.70	194	113	0.13	0.09
8/1/77	6	24	8.70	202	307	0.16	0.28
8/8/77	6	29	8.40	217	320	0.14	0.28
8/17/77	9	34	8.40	197	373	0.14	0.63
8/22/77	9	26	8.20	197	273	0.16	0.03
8/30/77	9	9	8.20	197	293	0.13	0.09

Date	Sulfate (mg/l)	Solids (mg/l) Total	Diss.	Phosphorus (mg/l) Total	Diss.	Copper++ (mg/l)	Algae (counts/ml)
5/16/77	83.0	405	375	0.13	0.07	ND	2160
5/23/77	79.0	408	387	0.21	0.08	ND	1960
5/31/77	81.8	368	238	0.25	0.03	ND	3770
6/3/77							2860
6/6/77	79.1	612	456	0.21	0.04	ND	4330
6/13/77	81.6	544	472	0.39	0.15	ND	3690
6/20/77	77.8	466	394	0.39	0.17	0.04	3860
6/27/77	78.1	344	246	0.23	0.09	ND	2880
6/28/77	74.0	360	240	0.29	0.12	ND	440
7/5/77	73.9	480	388	0.28	0.13		3530
7/11/77	73.6	392	380	0.31	0.13	0.04	6060
7/18/77	66.2	668	400	0.34	0.15	ND	5870
7/20/77							3570
7/26/77	66.4	508	364	0.47	0.17	ND	
8/1/77	69.5	490	376	0.49	0.17	ND	2020
8/8/77	71.3	500	360	0.34	0.16	0.04	2180
8/17/77	66.9	474	466	0.36	0.14	ND	870
8/22/77	59.8	404	374	0.28	0.11	0.05	3430
8/30/77	60.0	466	428	0.28	0.14	ND	140

Note: Copper sulfate was applied on 6/2, 6/27, and 7/19;
ND = Not detectable, <0.03

Table 9. Water Quality Characteristics, Fox Lake, Control

Date	Trans-parency (inches)	Tur-bidity (FTU)	pH	Alka-linity (mg/l)	Hard-ness (mg/l)	Ni-trate (mg/l)	Ammo-nia (mg/l)
6/2/77	12						
6/3/77	6						
6/6/77	9	2	8.42	174	199	0.30	0.21
6/13/77	9	25	8.35	202	258	0.19	0.58
6/20/77	6	26	8.67	210	258	0.22	0.15
6/27/77	9	23	8.70	207	159	0.20	0.17
6/28/77	12	16	8.78	215	126	0.18	0.04
7/5/77	9	24	8.40	202	212	0.13	0.17
7/11/77	9	23	8.60	202	146	0.13	0.09
7/18/77	5	37	8.05	192	453	0.21	0.05
7/26/77	9	33	8.40	197	133	0.14	0.06
8/1/77	6	29	8.60	202	300	0.16	0.07
8/8/77	4	33	8.40	225	360	0.14	0.12
8/17/77	9	42	8.40	197	327	0.15	0.04
8/22/77	6	27	8.30	202	327	0.15	0.02
8/30/77	9	21	8.45	197	267	0.14	0.00

Date	Sul-fate (mg/l)	Solids (mg/l) Total	Solids Diss.	Phosphorus (mg/l) Total	Phosphorus Diss.	$Copper^{++}$ (mg/l)	Algae (counts/ml)
6/2/77							3770
6/6/77	79.1	612	456	0.21	0.04	ND	4780
6/13/77	76.7	556	246	0.31	0.06	ND	3890
6/20/77	77.8	466	394	0.39	0.17	0.04	2230
6/27/77	79.2	472	248	0.40	0.16	ND	2780
6/28/77	78.0	390	251	0.25	0.08	ND	2290
7/5/77	72.6	434	394	0.26	0.07		4500
7/11/77	71.5	430	416	0.31	0.11	0.04	9140
7/18/77	70.4	512	406	0.45	0.18	ND	4110
7/26/77	37.0	538	406	0.66	0.13	ND	2000
8/1/77	76.2	464	400	0.52	0.17	ND	1740
8/8/77	76.0	522	364	0.36	0.11	0.04	3010
8/17/77	71.4	548	452	0.45	0.14	ND	680
8/22/77	66.8	430	302	0.38	0.18	0.05	3490
8/30/77	62.3	470	418	0.29	0.13	ND	220

Note: Interface copper concentration <0.03; ND = Not detectable, <0.03

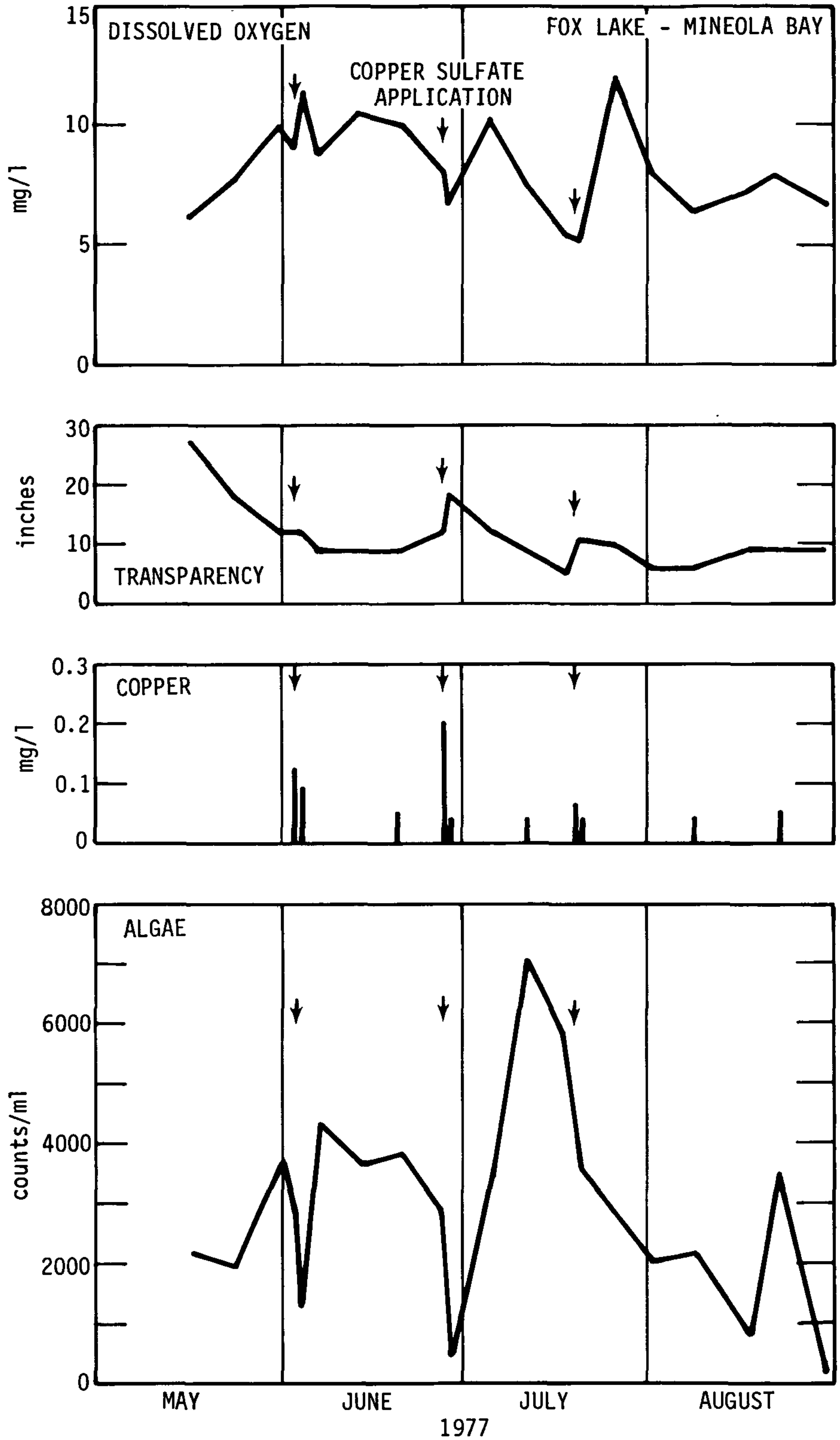

Figure 16. Fox Lake, Mineola Bay, water quality characteristics

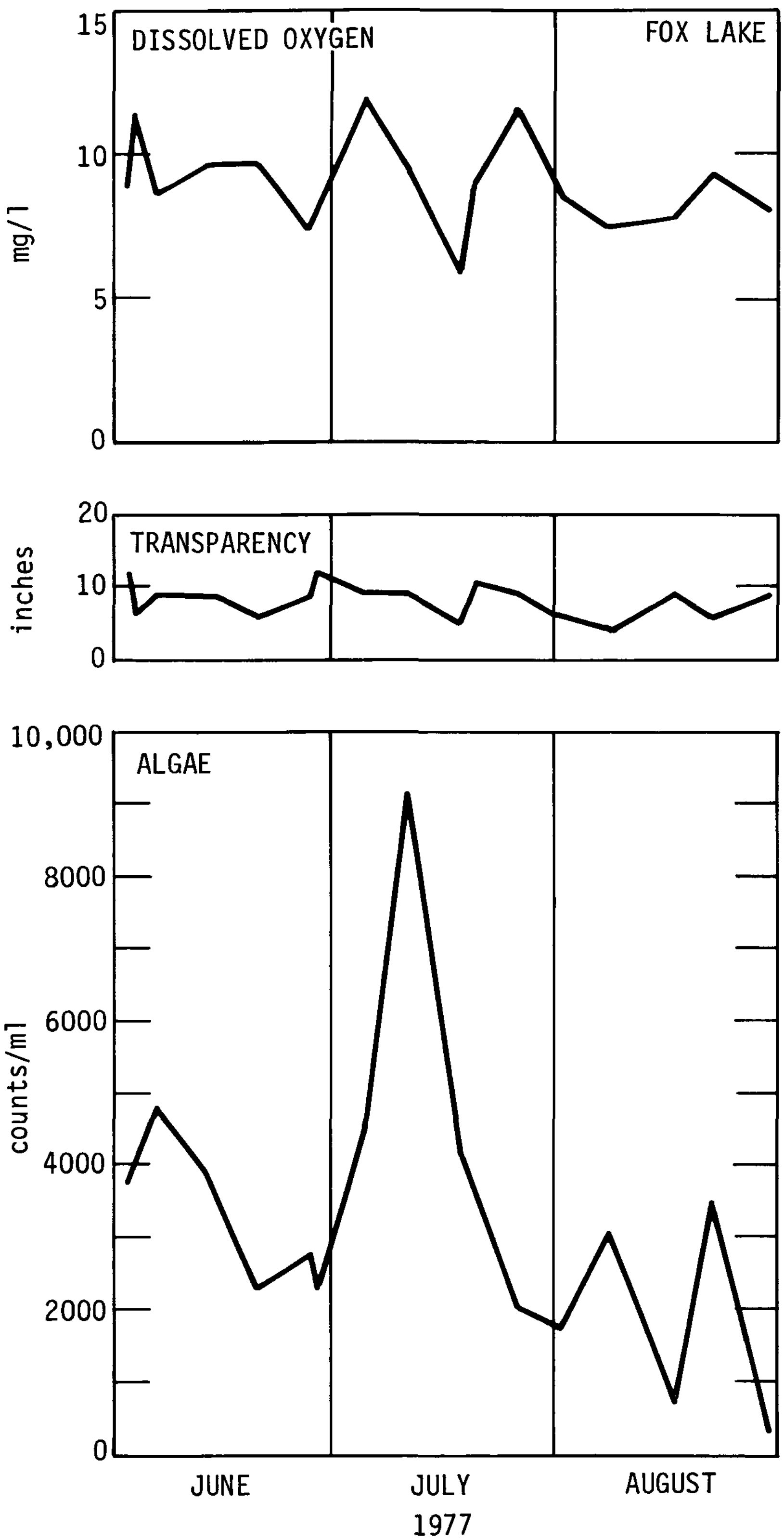

Figure 17. Fox Lake, control, water quality characteristics

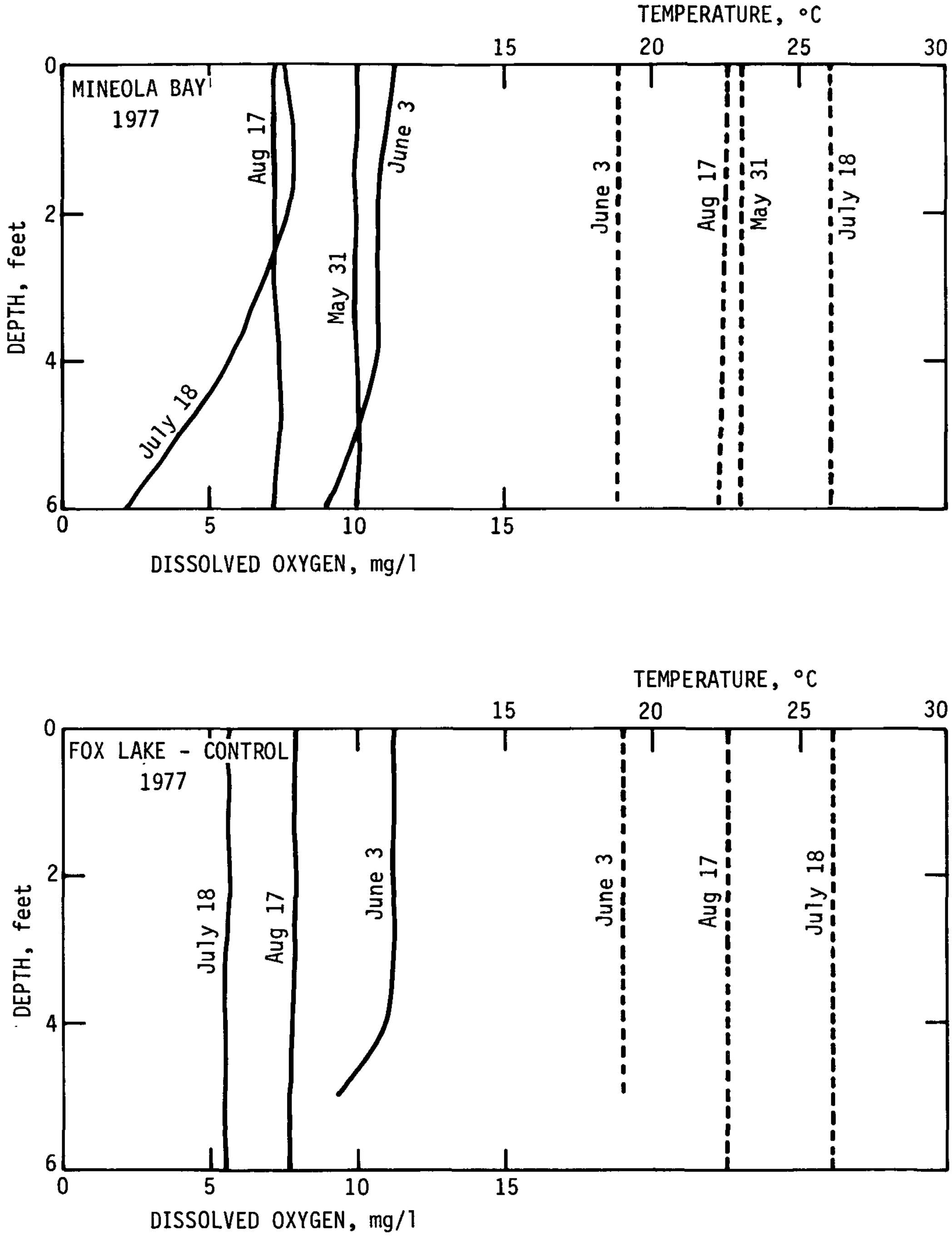

Figure 18. Temperature and DO profiles in Fox Lake

ficantly after the alum application. Generally, it is concluded that alum treatment for nutrient inactivation in the Fox Chain is not a viable technique.

Mineola Bay in the Fox Lake was chemically treated with copper sulfate on three occasions. On each occasion, a total of 1100 pounds of copper sulfate, at the rate of 5.4 pounds per acre, was applied. The algal counts decreased significantly after each treatment but tended to increase within a week. Nevertheless the algal counts observed in Mineola Bay were generally less than for the untreated part of Fox Lake adjacent to Mineola Bay. The method did not prove to be an unqualified success. As experienced with Bluff Lake, the interconnection of the Chain's waters indicated that chemical control in a small portion of the lake system is ineffective.

However, chemical treatment in combination with other in-lake restoration techniques, like aeration and destratification, hold promise. It is probable that its full potential could be realized when a comprehensive management scheme for improving the Chain's water quality is implemented.

ACKNOWLEDGMENTS

This investigation, sponsored and financially supported by the Illinois Institute for Environmental Quality, was conducted under the general supervision and guidance of Dr. William C. Ackermann, Chief of the Illinois State Water Survey.

The task of applying alum to Bluff Lake would have been extremely difficult and expensive but for the gracious gesture of Mr. Clem Haley of the Grass Lake Marina who loaned the pontoon tank barge with the outboard motor to the Water Survey without any charge. In addition, he provided space and tools and gave permission to make needed modifications to the pontoon tank. His help is sincerely appreciated and acknowledged.

Mr. William Faundre of the Harbor Marina in Bluff Lake permitted the Survey to store the bulk alum on their property and to carry out the whole operation from their dock facilities.

Mr. Charles Bernard of the Lake County Health Department was helpful in obtaining the pontoon tank, and the department loaned its boat for sampling purposes and for use during the period of alum application.

Mr. Robert Himel of the Midas Midwest, Inc., participated enthusiastically in the alum application task. He gave some valuable practical suggestions in applying alum. Midas Midwest, Inc. was contracted to apply copper sulfate to Mineola Bay.

Mr. Frank W. Novak, Lock and Dams Supervisor, Division of Water Resources, Illinois Department of Transportation, loaned to the Survey regulatory buoys, chains, and anchor weights used in Bluff Lake.

Mr. Jerry Kramarczwk of the Department of Conservation, Division of Law Enforcement, assisted in controlling the flow of boat traffic through Bluff Lake during alum application.

A few other Survey personnel participated in this investigation. Messrs. Gary Benker, David L. Hullinger, and Melbern E. Jannett performed chemical analyses of water samples. Mr. Davis B. Beuscher assisted in the identification and enumeration of algae. Mr. Robert Duffner assisted in the field work. Ms. Alice Wallner typed the initial draft. Graphics were prepared under the supervision of Mr. John Brother. Editorial assistance was provided by Mrs. Patricia A. Motherway and Mrs. J. Loreena Ivens.

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Temperature and Dissolved Oxygen Data, Bluff Lake

Depth (ft)	5/31/77 Temp	DO	6/6/77 Temp	DO	6/13/77 Temp	DO	6/20/77 Temp	DO	6/27/77 Temp	DO	7/5/77 Temp	DO
0	23.0	8.3	21.3	8.6	18.5	7.8	23.2	9.3	25.7	9.6	27.0	11.1
2	23.0	8.3	21.3	8.7	18.5	7.3	23.2	9.6	25.7	9.1	26.5	11.6
4	23.0	8.5	21.3	8.7	18.2	7.7	23.2	9.8	21.8	9.3	26.5	11.1
6	23.0	8.5	21.3	3.6	18.2	7.6	23.2	10.0	21.8	9.1	26.1	10.8
8	23.0	8.5	21.3	3.5	18.1	7.5	23.2	10.0	21.5	7.6	25.0	7.6
10	23.0	8.5	21.3	3.5	18.0	7.1	21.8	6.6	21.0	1.1	21.2	6.9
12	23.0	8.5	21.3	8.5	17.7	7.1	20.6	4.4	22.5	0.8	23.1	1.5
14	23.0	8.1	21.2	8.5	17.8	7.1	19.2	1.7	21.0	0.1	22.8	1.1
1C	18.0	0.7	18.2	0.7	17.5	3.1	17.8	1.1	19.1	0.3	21.8	1.0
18	17.0	0.3	17.5	0.1	17.2	0.5	17.3	1.0	18.7	0.2	19.5	0.8
20	15.3	0.3	15.8	0.3	17.1	0.5	17.0	1.0	17.5	0.2	18.8	0.7
22	11.0	0.3	11.0	0.3	16.5	0.2	16.6	0.7	16.5	0.2	17.0	0.7
21	11.0	0.3	13.6	0.3	11.1	0.2	16.0	0.6	16.0	0.2	16.0	0.7
26			13.2	0.3	13.5	0.2	15.0	0.6	15.5	0.2	15.2	0.7

Depth (ft)	7/11/77 Temp	DO	7/18/77 Temp	DO	7/26/77 Temp	DO	8/1/77 Temp	DO	8/8/77 Temp	DO	8/11/77 Temp	DO
0	26.6	7.1	27.0	5.9	25.0	10.2	21.1	8.0	21.0	5.7	23.8	6.1
2	26.0	7.1	27.0	5.8	25.0	10.2	21.1	8.0	21.0	5.7	23.8	6.1
1	26.0	7.0	26.9	5.7	25.0	10.0	21.1	8.0	21.0	5.6	23.8	6.2
6	25.7	7.2	26.9	5.5	25.2	9.8	21.1	8.0	21.0	5.6	23.8	6.2
8	25.5	6.6	26.8	5.2	25.0	5.8	21.2	7.9	21.0	5.6	23.8	6.1
10	25.0	6.1	26.8	5.1	25.0	1.5	21.2	7.0	21.0	1.7	23.5	2.9
12	21.5	1.7	25.0	2.1	21.8	1.6	21.0	6.0	23.6	1.6	23.2	1.6
11	23.8	3.1	21.0	1.1	21.5	1.2	23.8	5.5	23.6	1.0	23.1	1.2
16	21.9	0.9	21.6	1.1	21.0	1.2	23.8	5.2	23.5	0.1	23.1	0.8
18	19.9	0.7	19.6	1.0	20.8	0.1	22.2	1.5	23.1	0.1	22.8	0.1
20	18.0	0.7	18.2	1.0	19.5	0.3	19.6	1.2	21.1	0.1	21.0	0.1
22	16.7	0.7	17.6	1.0	17.5	0.3	17.6	0.8	18.1	0.1	18.5	0.1
21	16.0	0.7	16.0	1.0	16.5	0.3	16.8	0.7	16.8	0.1	17.0	0.1
26	15.2	0.7	15.8	1.0	16.0	0.3	16.2	0.7	16.2	0.1	16.0	0.5
27							16.0	0.6				

Depth (ft)	3/17/77 Temp	DO	8/22 /77 Temp	DO	8/30/77 Temp	DO	9/6/77 Temp	DO	9/27/77 Temp	DO
0	23.5	7.5	22.2	8.8	23.6	10.7	23.0	10.6	17.1	6.1
2	23.5	7.7	22.2	8.8	23.6	10.7	23.0	10.9	17.1	6.1
1	23.5	7.7	22.2	8.8	23.1	10.8	23.0	10.8	17.1	6.1
6	23.2	7.6	22.2	8.8	23.2	10.1	23.0	10.1	17.1	6.0
8	23.2	7.5	22.2	8.4	22.2	8.0	22.5	9.2	17.3	6.0
10	23.2	7.5	22.0	8. 2	22. 2	7.1	22.0	7.6	17.2	6.0
12	23.1	7.3	21.1	6.5	21.8	5.8	21.8	7.3	17.2	6.0
11	22.8	3.7	21. 0	6.2	21.6	5.1	21.8	7.0	17.2	6.0
16	22.8	2.0	21.0	6.2	21.2	3.1	21.5	3.7	17.2	6.0
18	28.8	2.0	21.0	5.8	21.0	2.0	21. 3	2.1	17.0	6.0
20	22.5	1. 2	20.8	1.7	20.2	1.2	21.0	0.8	17.0	6.0
22	20.0	0.7	20.2	1.3	20.2	0.8	20.5	0.1	17.0	5.8
21	17.5	0.5	20.0	1.3	19.8	0.1	19.2	0.3	17.0	5.0
26	17.0	0.5	17.0	0.9	19.2	0.1	19.0	0.2	17.0	1.6

Note: Temperature in degrees Celsius; Dissolved oxygen in mg/l

Algal Types and Density, Bluff Lake

(Density in counts/ml)

Date	Surface					Mid-depth					Deep					Bay area				
	B-G	G	D	F	0	B-G	G	D	P	0	B-G	G	D	P	0	B-G	G	D	F	0
5/31/77	470	3290	420	170	0	0	2150	170	80	0	0	80	160	0	0					
6/6/77	1320	830	250	60	0	1640	1010	700	0	0	110	70	60	0	0					
6/13/77	1960	920	550	0	0	1240	110	560	0	0	110	50	10	0	0					
6/20/77	2580	1160	350	0	0	1420	1330	160	0	0	1110	110	120	0	0					
6/27/77	2170	660	670	0	0	2660	330	190	0	0										
7/5/77	1980	620	140	10	0	1610	80	160	0	0	1620	170	350	0	0					
7/11/77	4310	2770	1100	0	0	2220	2210	880	0	0	830	1810	970	0	0					
7/18/77	4240	4470	350	0	0	2370	1610	90	0	0	1010	1190	170	0	0					
7/20/77																3800	980	210	30	0
7/26/77	1230	2130	560	0		1980	2130	380	0	0	910	1710	270	0	0					
8/9/77	3990	2360	270	0	0	2070	1270	170	0	0	1270	1210	150	0	0					
8/10/77	1520	0	280	20	0	211)0	90	60	0	0	110	30	50	0	0					
8/11/77	4960	510	370			2290	120	260	0	0	60	50	90	0	0	170	90	60	0	0
8/17/77	21)80	560	280	110	0	710	20	220	0	0	190	180	80	0	0	1860	630	230	0	0
8/22/77	1720	1900	150	1)0	0	110	280	130	0	0	210	310	150	0	0	2180	510	620	0	0
8/30/77	1680	500	80	10	0	130	10	10	0	0	80	30	30	0	0	2100	250	970	0	0
9/6/77	1160	510	1010	0	30	250	370	120	0	0	10	50	10	0	0	230	210	230	0	0
9/27/77	960	1)00	130	0	0	310	150	110	0	0	60	0	30	0	0	1170	580	300	0	0

Note: B-G = blue-greens; G = greens; D - diatoms; F = flagellates;
and 0 = others

Temperature and Dissolved Oxygen Data, Bluff Lake Bay Area

Depth (ft)	7/20/77 Temp	DO	8/11/77 Temp	DO	8/17/77 Temp	DO	8/22/77 Temp	DO
0	28.8	8.4	23.2	6.4	24.0	8.6	23.5	11.9
1	28.8	8.4	23.2	6.3	23.8	8.5	23.4	12.4
2	28.8	8.4	23.5	6.3	23.8	8.5	23.2	12.6
3	28.6	8.4	23.5	6.3	23.5	8.5'	23.2	12.6
4	28.3	8.4	23.5	6.3	23.2	7-6	23.1	12.3
5	28.3	7.5	23.5	6.3	23.0	7.2		

Depth (ft)	8/30/77 Temp	DO	9/6/77 Temp	DO	9/27/77 Temp	DO
0	24.8	16.0	24.0	12.0	17.0	5.7
1	24.8	16.0	24.3	12.1	17.0	5.6
2	24.6	15.9	24.0	12.2	17.0	5.6
3	24.2	14.2	23.7	12.2	17.0	5.6
4	23.8	12.6	23.5	11.4	17.0	5.6
5	23.8	12.0	22.5	8.2	17.0	5.6

Note: Temperature in degrees Celsius; Dissolved oxygen in mg/1

Temperature and Dissolved Oxygen Data, Fox Lake, Mineola Bay

Depth (ft)	5/16/77 Temp	5/16/77 DO	5/23/77 Temp	5/23/77 DO	5/31/77 Temp	5/31/77 DO	6/2/77 Temp	6/2/77 DO	6/3/77 Temp	6/3/77 DO
0	22.8	6.2	24.8	7.6	22.9	10.0	19.5	9.0	19.1	11.2
1	22.8	5.9	24.6	8.0	23.0	10.0	19.5	9.0	19.1	11.0
2	22.4	6.6	24.0	7.5	23.0	10.0	19.5	9.0	19.1	10.8
3	22.2	6.0	23.7	6.7	23.0	10.0	19.5	9.0	19.1	11.0
4	22.2	6.0	23.0	5.6	23.0	10.0	19.5	8.8	19.1	10.6
5	22.0	5.2	23.0	5.3	23.0	10.0	19.5	8.3	19.1	9.8
6	21.2	4.6	22.9	5.2	23.0	10.0			19.1	9.0
7					23.0	10.0				

Depth (ft)	6/6/77 Temp	6/6/77 DO	6/13/77 Temp	6/13/77 DO	6/20/77 Temp	6/20/77 DO	6/27/77 Temp	6/27/77 DO	6/28/77 Temp	6/28/77 DO
0	20.7	3.8	17.8	10.4	23.4	10.0	24.2	7.8	25.0	8.0
1	20.8	8.7	17.8	10.4	23.6	10.2	24.2	7.8	25.0	7.7
2	20.8	8.7	17.6	10.5	23.6	10.6	24.2	7.8	25.0	7.3
3	20.7	8.7	17.5	10.5	23.6	10.7	24.2	7-9	24.8	6.6
4	20.7	8.7	17.5	10.5	23.6	11.0	24.2	7.7	24.8	6.3
5	20.7	8.7	17.5	10.4	23.6	11.0	24.1	7.8	24.5	5.0
6	20.7	8.7	17.2	8.0	23.6	10.8	24.0	6.9	24.2	2.3

Depth (ft)	7/5/77 Temp	7/5/77 DO	7/11/77 Temp	7/11/77 DO	7/18/77 Temp	7/18/77 DO	7/20/77 Temp	7/20/77 DO	7/26/77 Temp	7/26/77 DO
0	27.0	10.2	26.0	7.5	26.1	5.4	27.5	5.1	25.0	12.0
1	27.0	10.2	26.0	7.7	26.1	5.4	27.5	5.0	25.0	12.1
2	27.0	10.2	25.9	7.7	26.1	5.4	27.2	4.9	25.0	12.1
3	27.0	10.2	25.2	7.2	26.1	5.3	27.0	4.9	25.0	12.0
4	26.8	10.2	25.0	5.6	26.1	5.3	27.0	3.9	25.0	12.0
5	26.8	9.8	24.6	3.5	26.1	5.3	26.8	3.8	25.0	11.2
6	26.0	7.1	24.5	2.2	26.1	3.9	26.5	2.2	25.0	10.0

Depth (ft)	8/1/77 Temp	8/1/77 DO	8/8/77 Temp	8/8/77 DO	8/17/77 Temp	8/17/77 DO	8/22/77 Temp	8/22/77 DO	8/30/77 Temp	8/30/77 DO
0	24.2	9.4	23.2	6.3	22.5	7.3	21.6	7.9	23.9	6.6
1	24.2	9.4	23.2	6.3	22.5	7.3	21.6	7.9	23.9	6.6
2	24.2	9.4	23.2	6.3	22.5	7.3	21.6	7.8	23.9	6.6
3	24.2	9.4	23.2	6.1	22.5	7.5	21.4	7.9	23.8	6.4
4	24.2	9.4	23.2	6.1	22.5	7.5	21.4	7.9	23.4	6.3
5	24.2	9.4	23.2	5.5	22.5	7.5	21.0	7.7	22.9	5.3
6	24.0	5.5	23.2	4.1	22.2	7.3	20.9	7.1	22.4	4.6

Note: Temperature in degree Celsuis; Dissolved oxygen in mg/l

Temperature and Dissolved Oxygen Data, Fox Lake, Control

Depth (ft)	6/2/77 Temp	6/2/77 DO	6/3/77 Temp	6/3/77 DO	6/6/77 Temp	6/6/77 DO	6/13/77 Temp	6/13/77 DO	6/20/77 Temp	6/20/77 DO
0	19.0	8.9	19.1	11.2	21.0	8.6	18.0	9.6	23.4	10.0
1	19.0	8.9	19.1	11.2	21.0	8	18.0	9.6	23.6	10.2
2	19.0	8.7	19.1	11.2	21.0	8 6	17.8	9.7	23.6	10.6
3	19.0	8.7	19.1	11.2	21.0	8 8	17.8	9.7	23.6	10.7
4	19.0	8.7	19.1	11.0	21.0	8 8	17.8	9.7	23.6	11.0
5	18.9	8.7	19.1	11.0	21.0	8 8	17.8	9.7	23.6	11.0
6	18.9	8.7	19.1	9.4	21.0	8 8			23.6	10.8
7					21.0	7 6				
8					21.0	7 8				
						8				

Depth (ft)	6/27/77 Temp	6/27/77 DO	6/28/77 Temp	6/28/77 DO	7/5/77 Temp	7/5/77 DO	7/11/77 Temp	7/11/77 DO	7/18/77 Temp	7/18/77 DO
0	24.0	7.4	25.0	8.0	27.8	11.9	25.8	9.4	26.1	5.8
1	21.0	7.4	25.0	7.7	27.8	11.8	25.7	9.4	26.1	5.8
2	24.0	7.5	25.0	7.3	27.8	11.8	25.7	9.6	26.1	5.8
3	24.0	7.5	24.8	6.6	27.5	11.5	25.5	9.6	26.1	5.8
4	24.0	7.5	24.8	6.3	27.5	11.3	25.4	9.4	26.1	5.8
5	24.0	7.4	24.5	5.0	27.2	11.0	25.0	9.3	26.1	5.8
6			24.2	2.3	27.0	8.1	24.8	6.4	26.1	5.7

Depth (ft)	7/20/77 Temp	7/20/77 DO	7/26/77 Temp	7/26/77 DO	8/1/77 Temp	8/1/77 DO	8/8/77 Temp	8/8/77 DO	8/17/77 Temp	8/17/77 DO
0	28.0	8.8	25.0	11.4	24.0	8.2	23.4	7.4	22.5	7.8
1	28.0	8.7	25.0	11.4	24.0	8.2	23.4	7.4	22.5	7.8
2	28.0	8.7	25.0	11.4	24.0	8.4	23.4	7.4	22.5	7.8
3	27.9	8.5	25.0	11.4	23.8	8.3	23.4	7.4	22.5	7.8
4	27.9	8.3	25.0	11.2	23.8	8.3	23.4	7.4	22.5	7.8
5	27.6	7.2	24.8	11.0	23.8	8.3	23.4	7.4	22.5	7.8
6	27.3	5.9			23.7	7.3	23.4	6.9	22.5	7.8

Depth (ft)	8/22/77 Temp	8/22/77 DO	8/30/77 Temp	8/30/77 DO
0	22.0	9.4	24.2	8.0
1	22.0	9.4	24.2	8.3
2	21.9	9.4	24.0	8.5
3	21.5	9.3	24.0	8.5
4	21.0	8.8	23.1	7.2
5	20.8	8.1	22.8	6.6

Note: Temperature in degrees Celsius; Dissolved oxygen in mg/l

Algal Types and Density, Fox Lake

(Density in counts/ml)

Date	Mineola Bay B-G	G	D	P	0	Control B-G	G	D	P	0
5/17/77	160	1360	500	80	50					
5/21/77	420	1400	150	0	0					
6/2/77	310	1340	1090	80	0	560	1950	1170	90	0
6/3/77	430	320	480	0	0	400	610	560	0	0
6/6/77	160	1530	2640	0	0	260	1830	2690	0	0
6/13/77	980	1190	1520	0	0	810	1710	1370	0	0
6/20/77	940	1310	1500	60	0	400	650	1170	10	0
6/27/77	850	1150	870	0	0	1640	1000	160	0	0
6/28/77	230	120	80	0	0	850	580	870	0	0
7/5/77	670	120	2740	0	0	1290	790	2430	0	0
7/11/77	4200	190	440	1110	120	6790	380	170	1800	0
7/18/77	3200	1910	760	0	0	2190	1390	530	0	0
7/20/77	2690	580	300	0	0					
7/26/77						1340	410	240	0	0
8/1/77	1550	360	90	10	0	970	600	180	0	0
8/8/77	1240	210	670	60	0	1820	280	910	0	0
8/17/77	670	130	70	0	0	310	150	220	10	0
8/22/77	1210	1650	580	0	0	1470	1460	560	0	0
8/30/77	80	30	20	10	0	70	80	80	0	0

Note: B-G = blue-greens; G = greens; D = diatoms; F = flagellates; and O = others

Water Quality Characteristics, Lake Catherine, Surface

Date	Trans-parency (inches)	Tur-bidity (PTU)	pH	Alka-linity (mg/l)	Hard-ness (rag/1)	Ni-trate (mg/l)	Am-monia (mg/l)	Sul-fate (rag/1)	Solids (mg/l) Total	Solids (mg/l) Diss	Phosphorus (mg/l) Total	Phosphorus (mg/l) Diss	Algae (cts/ml)
5/16/77	69	1	9.05	162	221	0.26	0.10	38.8	313	215	0.05	0.02	2610
5/23/77	57	1	8.67	169	211	0.12	0.01	36.7	271	261	0.05	0.03	3090
5/31/77	12	1	8.71	151	272	0.26	0.05	18.1	238	206	0.06	0.02	2190
6/6/77	39	2	8.52	161	265	0.32	0.07	18.5	176	110	0.06	0.02	570
6/13/77	45	3	8.15	182	258	0.13	0.11	17.1	392	370	0.06	0.02	5660
6/20/77	33	1	8.65	169	305	0.11	0.02	18.6	310	301	0.15	0.01	6080
6/27/77	35	6	8.68	169	258	0.11	0.07	52.7	262	201	0.05	0.02	3110
7/5/77	33	7	8.25	167	199	0.10	0.06	56.6	350	302	0.06	0.01	3020
7/11/77	33	6	8.35	169	225	0.11	0.12	53.5	320	320	0.06	0.02	2790
7/18/77	33	1	8.00	169	233	0.11	0.21	53.0	338	282	0.06	0.02	2180
7/26/77	39	1	8.35	156	267	0.14	0.09	51.1	386	316	0.06	0.02	
8/1/77	39	3	8.10	169	300	0.07	0.05	59.2	118	231	0.07	0.03	1180
8/8/77	15	3	8.30	161	327	0.08	0.11	59.8	112	170	0.03	0.02	2590
8/17/77	60	5	8.10	161	293	0.06	0.11	55.2	311	228	0.05	0.02	3520
8/22/77		3	8.20	172	260	0.31	0.07	50.7	276	216	0.01	0.02	1880
8/30/77	51	3	7.90	167	293	0.17	0.01	52.6	116	360	0.04	0.01	610
9/6/77	39	1	8.30	172	267	0.01	0.05	57.6	108	388	0.05	0.01	700

Water Quality Characteristics, Lake Catherine, Mid-depth

Date	Tur-bidity (PTU)	pH	Alka-linity (mg/l)	Hard-ness (mg/l)	Ni-trate (mg/l)	Am-monia (mg/l)	Sul-fate (mg/l)	Solids (mg/l) Total	Solids (mg/l) Diss	Phosphorus (mg/l) Total	Phosphorus (mg/l) Diss	Algae (cts/ml)
5/16/77	2	8.72	171	213	0.17	0.10	10.2	335	291	0.06	0.01	1820
5/23/77	1	8.23	182	221	0.18	0.50	33.1	252	210	0.15	0.13	1160
5/31/77	2	8.16	177	265	0.11	0.21	15.3	256	221	0.08	0.05	1290
6/6/77	2	8.26	172	278	0.26	0.19	13.0	518	158	0.08	0.03	550
6/13/77	3	8.11	177	325	0.12	0.37	16.9	396	361	0.08	0.05	2260
6/20/77	2	8.22	177	331	0.13	0.29	17.1	378	338	0.18	0.15	7390
6/27/77	3	7.87	182	291	0.11	0.37	51.8	282	206	0.10	0.07	2910
7/5/77	5	7.97	161	199	0.16	0.51	50.8	320	310	0.05	0.01	110
7/11/77	3	8.00	167	166	0.12	0.15	52.0	316	300	0.05	0.02	680
7/18/77	2	7.70	177	207	0.09	0.28	18.0	321	278	0.05	0.03	2950
7/26/77	3	7.90	187	113	0.07	0.19	51.0	382	306	0.05	0.01	
8/1/77	1	8.25	169	210	0.08	0.12	59.6	101	228	0.13	0.03	810
8/8/77	3	7.90	161	273	0.07	0.10	59.8	386	238	0.05	0.02	630
8/17/77	3	7.85	172	267	0.06	0.22	50.5	336	260	0.08	0.04	2520
8/22/77	1	8.30	172	260	0.13	0.06	53.1	270	216	0.01	0.01	2520
8/30/77	3	8.10	167	253	0.09	0.01	52.8	101	371	0.01	0.01	210
9/6/77	3	8.20	177	280	0.01	0.07	55.7	112	391	0.05	0.03	130

Water Quality Characteristics, Lake Catherine, Deep

Date	Turbidity (FTU)	pH	Alkalinity (mg/1)	Hardness (mg/1)	Nitrate (mg/1)	Ammonia (mg/1)	Sulfate (mg/1)	Solids (mg/1) Total	Solids (mg/1) Diss	Phosphorus (mg/1) Total	Phosphorus (mg/1) Diss	Algae (cts/ml)
5/16/77	4	7.79	189	243	0.15	0.87	34.4	329	288	0.37	0.34	250
5/23/77	3	7.95	199	293	0.11	1.97	31.3	246	232	0.44	0.40	140
5/31/77	2	7.16	174	331	0.09	2.06	36.7	244	234	0.51	0.44	220
6/6/77	37	7.78	197	298	0.25	1.71	39.2	646	432	0.49	0.35	180
6/13/77	2	7.57	205	298	0.11	2.50	34.6	406	364	0.60	0.52	190
6/20/77	4	8.15	187	298	0.13	0.73	39.2	380	318	0.24	0.21	4410
6/27/77	3	7.15	212	265	0.11	2.59	40.0	298	210	0.61	0.53	2530
7/5/77	4	7.30	210	225	0.08	4.80	40.3	318	306	0.56	0.49	70
7/H/77	13	7.65	207	205	0.11)	1.38	41.4	346	346	0.51	0.35	710
7/18/77	18	7.50	220	340	0.11	3.21	43.2	430	304	0.82	0.58	1810
7/26/77	3	7.35	227	240	0.07	2.27	35.6	396	316	0.89	0.72	810
8/1/77	5	8.35	222	313	0.08	1.51	39.2	426	224	0.93	0.79	170
8/8/77	4	7.70	210	300	0.10	4.01	39.8	460	212	1.09	0.87	100
8/17/77	4	7.10	253	313	0.09	4.53	21.5	338	284	1.10	0.93	210
8/22/77	3	7.95	237	280	0.11	1.54	33.8	332	230	0.88	0.67	800
8/30/77	3	7.50	217	320	0.12	4.35	31.6	462	368	1.11	0.88	140
9/6/77	4	7.10	252	333	0.01)	4.96	33.3	418	404	1.26	0.85	170

Temperature and Dissolved Oxygen Data, Lake Catherine

Depth	5/16/77		5/23/77		5/31/77		6/6/77		6/13/77	
(ft)	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
0	21.1	7.8	23.9	9.2	23.0	8.6	21.2	8.6	18.2	8.5
2	21.1	6.8	23.8	8.6	23.0	8.1	21.1	8.6	18.1	8.2
4	21.1	6.6	23.5	7.9	23.0	7.2	21.0	8.7	18.0	8.1
6	21.0	6.0	23.1	7.1	23.0	6.6	21.0	8.7	18.0	8.1
8	20.9	5.1	23.1	6.9	23.0	5.8	21.0	8.7	17.9	8.1
10	20.0	1.9	22.5	6.0	23.0	5.1	21.0	9.0	17.8	8.0
12	18.0	1.9	20.9	1.9	21.8	1.1	21.0	9.0	17.6	7.6
14	16.6	1.6	17.1	5.1	17.9	3.9	19.2	5.9	17.1	7.3
16	15.8	1.3	15.1	1.8	16.1	3.8	17.8	3.2	17.2	6.5
18	15.1	1.1	11.6	1.2	15.0	3.7	17.2	2.2	16.9	5.8
20	11.3	3.7	12.1	1.0	11.0	3.1	15.5	0.9	16.1	0.7
22	13.3	2.7	12.1	3.1	13.3	2.8	13.2	0.6	13.1	0.1
24	11.8	2.7	12.0	2.6	12.1	2.2	11.8	0.1	12.2	0.3
26	11.2	1.7	11.2	2.0	11.5	2.0	11.0	0.3	11.3	0.1
28	10.8	1.6	10.9	1.8	11.0	1.8	10.8	0.3	10.7	0.3
30	10.7	1.1	10.8	1.6	10.6	1.6	10.8	0.3	10.5	0.3
32	10.2	1.1	10.2	1.5	10.2	1.5	10.3	0.3	10.5	0.3
31	10.0	1.3	10.1	1.1	10.0	1.1	10.0	0.3	10.1	0.3
36	10.0	1.3	9.9	1.3	10.0	1.1	10.0	0.3	9.8	0.3
37	9.9	1.1								
38			9.9	1.3	10.0	1.1	10.0	0.3	9.8	0.2
40							10.0	0.3		

Depth	6/20/77		6/27/77		7/5/77		7/11/77		7/18/77	
(ft)	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
0	22.5	8.9	27.5	9.6	27.5	9.2	25.9	7.2	26.6	6.0
2	22.5	8.9	26.5	9.5	27.2	9.3	25.9	6.6	26.8	6.1
4	22.1	8.6	26.0	9.8	27.0	9.3	25.9	6.6	26.8	6.0
6	22.1	8.7	25.5	10.0	27.0	9.3	25.8	6.7	26.6	6.1
8	22.1	8.7	25.0	9.5	26.8	7.3	25.6	6.6	26.6'	6.1
10	22.2	8.6	24.0	7.5	21.5	6.6	25.0	5.6	26.5	6.0
12	22.2	8.5	22.0	4.9	22.5	6.1	24.0	3.1	26.0	3.6
11	19.0	6.1	21.0	3.1	22.0	5.2	22.0	1.4	23.8	0.9
16	17.9	1.5	19.2	2.3	21.2	3.6	21.0	0.7	22.2	0.8
18	17.0	2.7	17.0	1.2	19.5	2.2	20.0	0.7	20.2	0.8
20	16.2	0.9	15.8	0.8	19.0	0.9	16.7	0.7	18.3	0.8
22	15.0	0.6	11.0	0.5	17.5	0.8	15.0	0.7	14.2	0.9
21	13.3	0.3	13.1	0.5	11.2	0.8	13.7	0.7	13.2	0.9
26	11.2	0.3	12.0	0.5	13.1	0.8	12.7	0.7	12.6	0.9
28	11.0	0.2	11.1	0.5	12.5	0.7	11.4	0.7	12.0	0.9
30	10.9	0.3	10.8	0.4	12.0	0.7	11.0	0.7	11.4	1.0
32	10.9	0.2	10.5	0.1	11.2	0.7	10.8	0.7	11.0	1.0
31	10.1	0.2	10.2	0.3	10.8	0.6	10.4	0.9	10.9	1.0
36	10.2	0.2	10.2	0.3	10.2	0.6	10.4	0.9		
38	10.0	0.2			10.0	0.7				

Temperature and Dissolved Oxygen Data, Lake Catherine (Concluded)

Depth (ft)	7/26/77 Temp	DO	8/1/77 Temp	DO	3/8/77 Temp	DO	8/17/77 Temp	DO	8/22/77 Temp	DO
0	24.8	7.1	21.7	7.7	21.0	7.3	22.8	7.0	21.6	7.3
2	24.8	7.1	21.7	8.0	21.0	7.3	22.8	6.5	21.6	7.3
4	24.8	7.1	21.7	8.0	21.0	7.3	22.8	6.5	21.6	7.3
6	24.8	7.1	21.7	7.8	21.0	7.3	22.8	6.5	21.6	7.3
8	24.8	7.1	21.7	7.8	21.0	7.3	22.8	6.5	21.6	7.3
10	24.8	6.8	21.3	7.8	21.0	7.3	22.5	6.2	21.6	7.3
1?	24.8	6.8	24.3	7.8	21.0	7.3	?2.5	6.2	21.6	7.2
14	24.0	1.5	24.0	7.1	21.0	7.3	22.5	6.1	21.6	7.2
16	21.5	0.5	22.6	3.6	23.8	0.7	22.2	6.0	21.2	6.6
18	19.5	0.1	22.0	0.7	21.1	0.6	22.0	3.8	21.0	1.1
20	17.0	0.3	18.0	0.6	15.8	0.5	20.2	1.5	20.5	1.6
22	16.0	0.3	16.3	0.6	15.3	0.5	17.5	0.9	18.0	1.3
24	13.8	0.3	11.0	0.7	11.2	0.1	15.0	0.6	15.0	0.9
2'	13.0	0.3	13.9	1.1	13.2	0.1	13.0	0.1	13.5	0.9
28	12.2	0.1	12.1	0.9	12.0	1.0	12.5	0.1	12.8	0.7
30	11.8	0.1	11.8	0.9	11.1	1.0	12.0	0.1	12.0	0.7
32	11.5	0.1	11.2	0.9	11.0	1.1	11.0	0.1	11.6	0.5
31	11.0	0.1	11.0	0.8	10.9	1.1	11.0	0.1	11.2	0.6
36	11.0	0.1	10.8	0.3	10.6	1.3	11.0	0.3	11.0	0.1
37										
38	10.8	0.1	10.6	0.8			11.0	0.3		

Depth (ft)	8/30/77 Temp	DO	9/6/77 Temp	DO
0	23.1	8.1	23.5	8.8
2	23.0	8.2	23.3	8.8
1	23.0	8.3	23.1	8.9
6	23.0	8.3	23.0	8.8
8	22.8	8.1	22.8	8.6
10	22.1	8.0	22.1	8.0
12	22.1	7.9	22.1	6.9
11	22.0	6.1	22.0	6.5
16	21.8	5.8	22.0	1.9
18	21.2	2.1	21.9	3.7
20	19.1	0.6	21.1	1.6
22	13.1	0.3	21.1	1.2
24	16.2	0.3	20.9	0.6
26	11.6	0.3	19.1	0.3
28	13.0	0.3	17.9	0.3
30	12.2	0.3	15.1	0.2
32	11.6	0.3	11.1	0.2
34	11.1	0.3	11.2	0.2
36	11.0	0.3		

Note: Temperature In degrees Celsius; Dissolved oxygen in zng/1

Algal Types and Density, Lake Catherine

(Density in counts/ml)

Date	Strface					Hid-depth					Deep				
	B-C	G	D	F	O	B-G	G	D	F	O	B-G	G	D	F	O
5/l6/77	400	1530	400	240	0	0	710	0	670	0	0	140	70	50	0
5/23/77	230	2470	390	0	0	320	180	660	0	n	30	110	0	0	0
5/31/77	530	1760	0	0	0	250	850	190	0	0	40	150	40	0	0
6/6/77	190	380	0	0	0	150	330	70	0	0	60	110	20	0	0
6/13/77	2340	640	1701	480	0	1250	410	350	250	0	110	50	10	10	0
6/20/77	2750	1460	1900	0	0	2380	250	4760	0	0	2060	430	1920	0	0
6/27/77	1350	1160	630	0	0	1530	1250	130	0	0	1080	690	580	180	0
7/5/77	860	1430	7140	0	0	50	50	50	0	0	10	40	30	0	0
7/11/77	1740	680	370	0	0	240	310	140	0	0	120	470	130	0	0
7/16/77	1470	460	200	50	0	870	1350	390	340	0	1110	330	290	70	0
7/26/77											610	160	40	0	0
8/1/77	2990	820	370	0	0	650	110	90	0	0	70	70	20	0	0
8/8/77	1700	460	210	220	0	500	HO	80	0	0	90	10	10	0	0
8/17/77	2160	580	670	0	0	1910	200	410	0	0	80	20	110	0	0
8/22/77	1950	2090	840	0	0	1161	650	710	0	0	240	100	470	0	0
8/30/77	250	240	130	0	0	80	30	70	30	0	40	60	50	0	0
9/6/77	1410	230	30	0	0	60	50	30	0	0	30	90	50	0	0

Note: B-3=blue-green; G=green; D=diatom; F=flagellates; and O=others

Water Quality Characteristics, Channel Lake, Surface

Date	Transparency (inches)	Turbidity (FTU)	pH	Alkalinity (mg/l)	Hardness (mg/l)	Nitrate (mg/l)	Ammonia (mg/l)	Sulfate (mg/l)	Solids (mg/l) Total	Solids (mg/l) Diss	Phosphorus (mg/l) Total	Phosphorus (mg/l) Diss	Algae (cts/ml)
5/16/77	60	1	8.96	177	218	0.32	0.09	18.2	325	321	0.06	0.03	990
5/23/77	15	6	8.87	177	199	0.15	0.08	11.9	295	272	0.08	0.01	2803
5/31/77	33	5	8.81	159	238	0.09	0.01	18.1	262	230	0.10	0.03	3507
6/6/77	27	1	8.51	167	238	0.15	0.25	50.7	661	158	0.09	0.03	770
6/13/77	36	1	8.51	171	238	0.12	0.18	53.0	398	371	0.10	0.03	3310
6/20/77	33	8	8.67	167	311	0.12	0.09	18.9	372	330	0.12	0.03	3690
6/27/77	27	8	8.62	161	205	0.08	0.09	53.1	272	200	0.07	0.03	3590
7/5/77	33	9	8.15	162	199	0.11	0.23	51.8	551	306	0.08	0.02	710
7/11/77	2D	6	8.15	161	116	0.12	0.09	55.1	328	320	0.07	0.03	2690
7/18/77	27	6	7.95	162	253	0.11	0.30	57.6	351	306	0.10	0.02	1890
7/26/77	29	5	8.25	167	107	0.11	0.10	59.8	102	300	0.06	0.02	2910
8/1/77	32	6	8.10	161	253	0.08	0.11	59.6	112	261	0.16	0.03	3660
8/8/77	39	1	8.30	167	287	0.08	0.22	61.3	102	190	0.05	0.02	2120
8/17/77	54	6	8.00	172	307	0.06	0.30	57.5	362	256	0.07	0.02	800
8/22/77	18	1	8.20	171	267	0.10	0.12	57.1	300	196	0.07	0.02	5190
8/30/77	36	5	8.50	177	217	0.10	0.10	56.9	116	358	0.08	0.02	820
9/6/77	27	9	8.50	171	267	0.01	0.13	58.0	444	390	0.10	0.02	210

Water Quality Characteristics, Channel Lake, Mid-depth

Date	Turbidity (FTU)	PH	Alkalinity (mg/l)	Hardness (mg/l)	Nitrate (mg/l)	Ammonia (mg/l)	Sulfate (mg/l)	Solids (mg/l) Total	Solids (mg/l) Diss	Phosphorus (mg/l) Total	Phosphorus (mg/l) Diss	Algae (cts/ml)
5/16/77	1	8.21	181	218	0.27	0.11	16.2	317	277	0.09	0.06	720
5/23/77	2	8.33	192	253	0.23	0.30	11.9	271	258	0.08	0.01	550
5/31/77	2	7.97	187	215	0.20	0.37	18.0	262	262	0.10	0.08	970
6/6/77	1	8.13	167	219	0.07	0.13	18.9	181	138	0.09	0.02	660
6/13/77	3	8.15	172	232	0.12	0.18	53.0	108	384	0.08	0.03	2850
6/20/77	6	8.01	151	311	0.13	0.16	17.6	332	312	0.27	0.15	2770
6/27/77	1	7.89	161	205	0.08	0.31	54.8	312	228	0.06	0.03	2010
7/5/77	5	7.90	172	192	0.11	0.18	51.8	338	311	0.06	0.02	110
7/11/77	8	8.05	161	179	0.11	0.13	56.1	298	201	0.07	0.02	900
7/18/77	1	7.75	172	187	0.10	0.15	56.6	338	291	0.06	0.02	2150
7/26/77	3	7.75	171	133	0.10	0.11	56.8	388	306	0.11	0.05	2680
8/1/77	3	7.95	179	217	0.08	0.11	60.1	132	210	0.10	0.03	1910
8/8/77	3	8.15	167	293	0.09	0.20	56.1	381	256	0.08	0.05	
8/17/77	1	8.00	162	280	0.08	0.23	57.9	321	268	0.07	0.02	610
8/22/77	1	8.20	179	260	0.09	0.09	51.2	288	228	0.08	0.02	3180
8/30/77	5	8.25	171	280	0.13	0.03	56.9	128	368	0.09	0.02	170
9/6/77	5	8.10	171	287	0.01	0.10	58.6	128	378	0.09	0.02	170

Water Quality Characteristics, Channel Lake, Deep

Date	Turbidity (FTU)	pH	Alkalinity (mg/l)	Hardness (mg/l)	Nitrate (mg/l)	Ammonia (mg/l)	Sulfate (mg/l)	Solids (mg/l) Total	Solids (mg/l) Diss	Phosphorus (mg/l) Total	Phosphorus (mg/l) Diss	Algae (cts/ml)
5/16/77	2	8.21	187	248	0.20	0.35	50.5	332	326	0.13	0.11	110
5/23/77	3	8.09	197	194	0.11	1.11	12.1	305	281	0.21	0.21	280
5/31/77	22	7.50	199	331	0.09	1.39	11.8	361	286	0.19	0.31	320
6/6/77	3	7.91	194	278	0.23	1.36	18.1	510	168	0.28	0.22	380
6/13/77	16	7.82	197	278	0.12	1.66	17.1	191	388	0.12	0.28	720
6/20/77	10	8.09	235	252	0.12	0.58	50.0	352	328	0.27	0.20	2360
6/27/77	3	7.71	210	245	0.12	1.81	52.9	520	215	0.13	0.36	190
7/5/77	119	7.35	225	238	0.10	8.63	13.1	531	352	0.79	0.69	110
7/11/77	3	7.50	222	232	0.10	2.03	60.3	312	328	0.61	0.51	3110
7/18/77	7	7.10	217	427	0.12	0.88	51.2	396	382	0.69	0.56	890
7/26/77	3	7.10	234	127	0.07	3.72	15.6	130	330	0.96	0.75	160
8/1/77	1	7.65	245	317	0.08	51.6	15.7	162	272	1.39	1.16	230
8/8/77	3	7.50	242	313	0.10	1.52	38.7	156	272	0.88	0.77	110
8/17/77	35	7.40	172	333	0.08	5.80	29.5	506	120	1.20	1.05	130
8/22/77	3	8.50	212	313	0.08	2.05	13.1	356	211	0.93	0.88	180
8/30/77	3	7.50	270	233	0.13	6.82	38.2	150	106	1.38	0.31	200
9/6/77	37	7.45	232	327	0.09	5.27	19.0	618	106	1.06	0.73	130

Temperature and Dissolved Oxygen Data, Channel Lake

Depth (ft)	5/16/77 Temp	Do	5/23/77 Temp	DO	5/31/77 Temp	DO	6/6/77 Temp	DO	6/13/77 Temp	DO
0	21.8	7.7	23.2	10.5	23.5	9.0	20.9	8.5	18.8	7.8
2	21.8	8.1	23.1	10.8	23.5	9.0	20.9	8.1	18.7	7.8
1	21.4	7.9	23.1	10.0	23.5	9.0	20.9	8.1	18.3	7.8
6	21.0	7.2	23.0	9.6	23.5	8.1	20.9	8.3	18.2	7.7
8	20.9	6.8	22.8	8.1	23.5	8.0	20.9	8.1	18.2	7.7
10	20.8	6.2	22.1	7.2	23.5	7.9	20.9	8.3	18.1	7.7
12	19.8	6.0	21.1	6.1	22.5	1.1	20.9	3.1	18.0	7.6
14	17.7	5.3	19.5	6.2	20.9	2.0	20.9	8.3	17.9	7.1
16	16.4	5.1	18.1	5.1	18.0	1.5	20.1	8.1	17.8	7.1
18	16.4	1.7	16.1	5.0	17.5	1.1	19.6	5.9	17.8	7.1
20	15.2	1.5	15.8	1.1	15.7	1.2	17.8	2.6	17.7	7.1
22	15.0	4.0	15.0	1.2	15.0	1.0	17.0	0.7	17.5	7.0
24	11.9	3.9	15.0	3.7	11.8	1.0	15.0	0.7	17.1	6.0
26	11.7	3.1	11.1	3.1	11.0	0.8	11.0	0.3	15.9	0.8
28	11.0	3.2	11.0	2.3	13.5	0.5	13.3	0.3	15.0	0.7
30	13.7	2.1	13.1	2.0	13.5	0.5	13.0	0.3	13.5	0.6
32	13.2	1.9	13.1	1.7	13.0	0.1	12.9	0.3	13.0	0.1
34	13.0	1.1	12.0	1.5	12.8	0.1	12.8	0.3	12.9	0.3
36	12.1	1.1			12.5	0.3				

Depth (ft)	6/20/77 Temp	DO	6/27/77 Temp	DO	7/5/77 Temp	DO	7/11/77 Temp	DO	7/18/77 Temp	DO
0	22.6	9.2	26.0	9.5	27.0	10.0	26.0	7.2	26.6	5.9
2	22.6	9.2	25.5	9.5	26.5	10.0	25.9	7.3	26.6	5.8
1	22.6	9.1	25.0	9.7	26.2	9.9	25.9	7.3	26.6	5.8
6	22.7	9.1	21.8	9.9	26.0	9.8	25.7	7.3	26.6	5.8
8	22.7	9.1	21.5	9.1	25.5	9.1	25.5	6.9	26.6	5.7
10	22.7	9.1	21.2	6.1	25.0	9.1	25.1	6.7	26.6	5.6
12	21.7	8.4	21.5	3.1	21.5	7.3	25.0	6.0	26.6	5.6
11	18.2	5.1	19.8	1.5	23.0	5.6	23.2	1.1	26.1	5.5
16	18.0	1.0	18.2	1.1	21.5	2.6	22.1	0.7	26.1	1.1
18	17.1	2.8	18.0	0.7	20.8	1.6	20.5	0.8	21.0	1.1
20	17.1	1.7	17.2	0.5	20.1	1.0	19.0	0.7	19.1	1.0
22	17.0	1.6	17.0	0.1	18.0	0.8	17.9	0.7	18.2	1.0
21	16.8	0.7	16.5	0.1	17.0	0.8	17.0	0.7	17.2	1.0
26	16.2	0.6	16.0	0.3	16.5	0.8	16.2	0.7	16.8	1.0
28	15.0	0.3	15.0	0.3	16.0	0.7	15.1	0.7	16.6	1.0
30	11.0	0.3	11.0	0.2	15.2	0.5	11.8	0.7	15.2	1.0
32	13.8	0.3	13.5	0.2	11.5	0.1	11.2	0.7		
31					13.8	0.1	11.0	0.7		
36					13.5	0.1				
38					13.2	0.1				

Temperature and Dissolved Oxygen Data, Channel Lake (Concluded)

Depth (ft)	7/26/77 Temp	7/26/77 DO	8/1/77 Temp	8/1/77 DO	8/3/77 Temp	8/3/77 DO	8/17/77 Temp	8/17/77 DO	8/22/77 Temp	8/22/77 DO
0	21.8	7.0	21.7	8.1	23.8	7.8	22.8	6.5	22.0	6.7
2	21.8	6.9	21.7	8.1	21.0	7.6	22.8	5.3	22.0	6.7
4	21.8	6.6	21.7	8.5	21.0	7.6	22.8	6.1	22.0	6.6
6	21.8	6.5	21.7	8.1	21.0	7.6	22.8	5.9	22.0	6.1
8	21.8	6.1	21.1	8.3	21.0	7.6	22.8	5.8	22.0	6.1
10	21.8	6.1	21.2	8.2	21.0	7.6	22.8	5.7	22.0	6.1
12	21.8	6.1	21.0	6.7	21.0	7.5	22.8	5.7	22.0	6.1
14	21.8	6.3	23.8	6.6	21.0	7.1	22.8	5.6	22.0	6.1
16	21.0	1.5	23.8	6.1	21.0	7.3	22.8	5.5	21.9	6.0
18	21.8	0.6	23.1	3.2	23.1	2.1	22.8	5.5	21.8	6.0
20	20.0	0.1	21.2	1.2	22.2	1.5	22.5	5.3	21.2	1.6
22	18.0	0.3	18.5	0.8	18.7	1.5	22.1	5.1	21.0	1.1
21	17.0	0.3	17.8	0.7	17.1	1.6	19.0	0.6	20.9	1.1
26	16.2	0.3	16.1	0.7	16.2	1.6	17.5	0.1	18.9	2.1
28	15.2	0.1	15.9	0.7	15.2	1.7	16.0	0.1	16.2	1.1
30	11.5	0.1	11.8	0.7	11.2	1.7	15.0	0.1	15.0	1.3
32	11.0	0.1	11.2	0.7	11.0	1.7	11.1	0.3	11.6	1.1
34	11.0	0.1	11.0	0.7					11.1	1.1
36			11.0	0.7						

Depth (ft)	8/30/77 Temp	8/30/77 DO	9/6/77 Temp	9/6/77 DO
0	23.5	3.8	23.3	9.1
2	23.3	8.8	23.3	9.3
1	23.1	8.9	23.0	9.3
6	23.0	8.8	22.5	7.8
8	22.8	8.6	22.2	6.7
10	22.1	8.0	22.1	6.1
12	22.1	6.9	22.0	6.2
11	22.0	6.5	22.0	6.2
16	22.0	1.9	22.0	1.8
18	21.9	3.7	22.0	5.2
20	21.1	1.6	21.8	1.9
22	21.1	1.2	21.5	1.2
21	20.9	0.6	21.1	0.6
26	19.1	0.3	20.5	0.3
28	17.9	0.3	17.0	0.2
30	15.1	0.2	16.0	0.2
32	11.1	0.2	11.5	0.2
31	11.2	0.2	11.5	0.2

Note: Temperature in degrees Celsius; Dissolved oxygen in mg/l

Algal Types and Density, Channel Lake

(Density in counts/ml)

Date	Surface B-G	G	D	F	O	Mid-depth B-G	G	D	F	O	Deep B-G	G	D	F	O
5/16/77	330	600	0	50	0	0	620	0	0	100	0	110	0	0	30
5/23/77	MO	2080	270	0	10	0	470	70	0	10	0	260	0	0	30
5/31/77	1070	2290	140	10	0	230	740	0	0	0	10	150	160	0	0
6/6/77	390	370	20	0	0	360	80	220	0	0	590	170	120	0	0
6/13/77	2490	450	200	200	0	1840	600	160	250	0	450	130	140	0	0
6/20/77	2080	550	1060	0	0	1310	560	900	0	0	1630	140	600	0	0
6/27/77	1980	1110	200	0	0	890	1140	0	0	0	100	70	20	0	0
7/5/77	320	280	140	0	0	40	60	40	0	0	30	30	70	0	0
7/11/77	1380	350	890	70	0	330	320	250	0	0	1380	860	750	130	0
7/18/77	1620	140	140	0	0	1700	370	230	150	0	580	230	60	20	0
7/26/77	2470	170	300	0	0	1480	220	710	260	0	90	60	10	0	0
8/1/77	2860	220	590	0	0	1190	320	440	0	0	170	40	20	0	0
8/8/77	1920	230	90	170	0						90	40	10	0	0
8/17/77	320	260	200	20	0	330	50	250	0	0	20	20	90	0	0
8/22/77	3290	1410	490	0	0	1460	1350	370	0	0	150	190	140	0	0
8/30/77	360	350	110	0	0	110	40	30	0	0	80	90	30	0	0
9/6/77	80	90	30	0	0	90	50	40	0	0	30	70	30	0	0

Mote: B-G=blue-green; G=green; D=dlatom; F=flagellates; and O=others