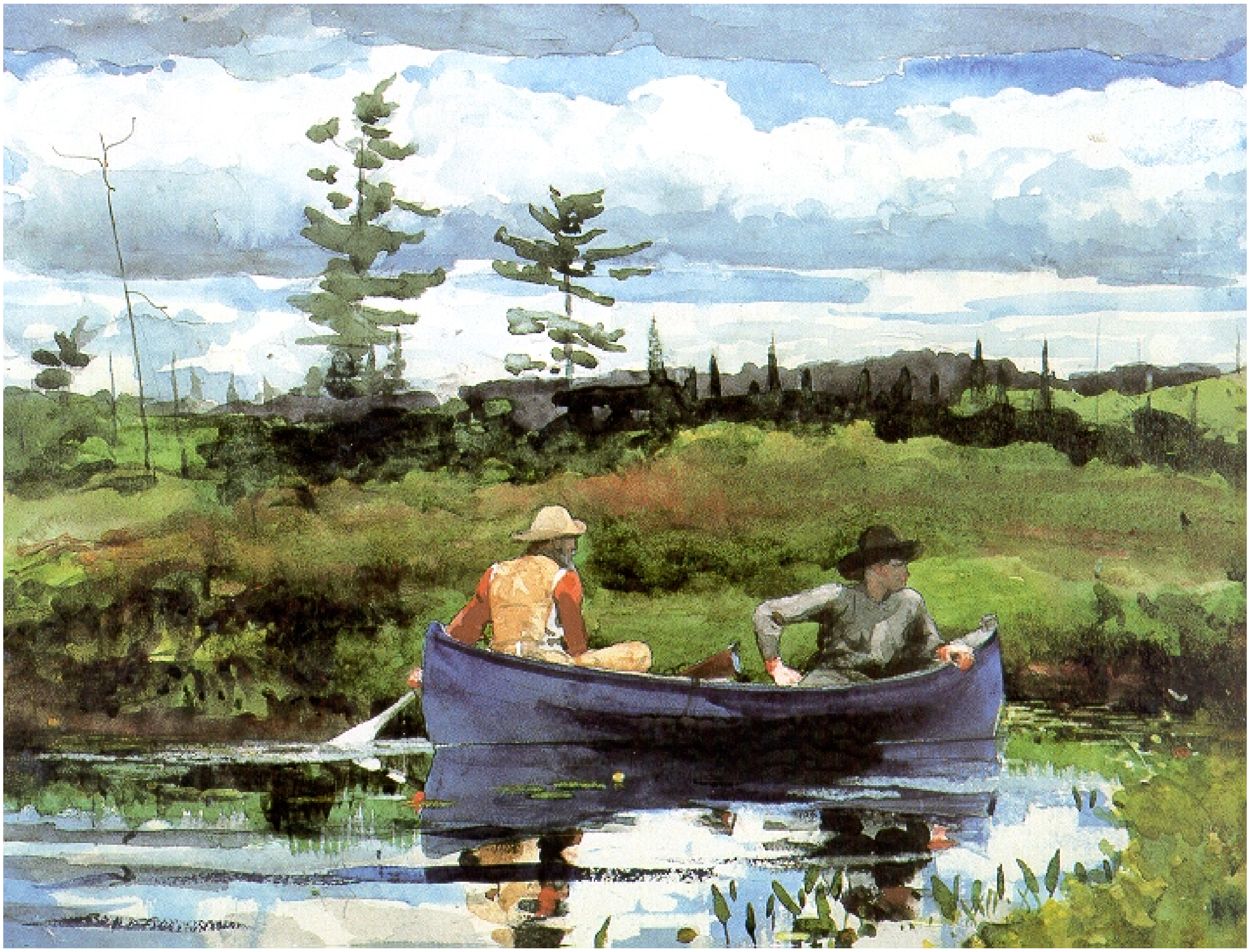

Winslow Homer: *The Blue Boat*, **1892**

Comprehensive Lake Management Plan for Ravine Lake, Washington County, Minnesota

Prepared for
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--Contents--

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Summary

Ravine Lake is a 25 acre lake with an average depth of 7 feet. A comprehensive study was conducted from 2000 through 2002 Based on these results and on other available information a lake management plan was prepared.

Important Findings of this Study:

- Ravine Lake is highly nutrient enriched and is classified as eutrophic.
- An updated lake map was constructed by the MnDNR based on aerial photography from 2000. The lake size was estimated to be 24.7 acres.
- The shoreline is 98% natural. This is a real asset for the lake and should be maintained.
- Lake sediments were found to have high fertility. If Eurasian watermilfoil invades Ravine Lake, we predict there would be up to 8 acres of matted growth.
- There appears to be an area of strong groundwater inflow in the north end of Ravine Lake. This was found using seepage meters and from a shoreline conductivity survey.
- A surprising finding was that five-year old walleyes were captured in a 2001 MnDNR fish survey even through winter dissolved oxygen measurements did not detect oxygen in the middle of the lake. We speculate that springs carry in enough oxygenated water to support some fish.
- Based on future development using either the existing watershed size or an increased watershed size, lake water quality is not predicted to get better.
- Lake management objectives center around creating active and passive recreational opportunities. Recreational fishing projects are being implemented by the MnDNR. Passive recreational activities would center primarily around sight-seeing.

Lake Management Recommendations

1. Erosion control in several stretches of steep gradient stream channels.
2. Implement stormwater management programs of the Cities within the watershed.
3. Leave the standing trees in the lake in place. They serve as wildlife habitat.
4. Continue to work with the MnDNR on fishing improvements - fishing piers and fish stocking.
5. Establish shoreline openings for visitors to get to the lake.
6. Designate the lake a non-motorized lake or a trolling motor only lake.
7. The lake strongly stratifies in summer and there is no oxygen in water deeper than 6-feet. Nutrient release from lake sediments probably occurs (based on the high winter TP when dissolved oxygen was depleted). One option is to set-up an aeration system for summer and winter aeration. Winter aeration would produce open water conditions. A second option is a lake sediment alum treatment. This is not recommended unless black bullhead numbers are dramatically reduced. The third option is no aeration and no alum. The lake will remain eutrophic and the fish population will use rise and fall depending on the severity of winterkill.

1. Introduction and Project Setting

Ravine Lake is located in the Cottage Grove Ravine. The lake is approximately 25 acres in size. This waterbody formerly existed as a Type 4 wetland, with an open area of about 6 acres but due to higher water levels in recent years, it has a lake appearance now. It is not clear whether this waterbody will continue to exist as a lake or revert back to a wetland-type system in the future due to its apparent reliance on groundwater and higher than normal groundwater levels in recent years. The maximum depth of the lake, as of August 8, 2001 was 16 feet. This depth should support a gamefish community; however, water quality will dictate which type of fishery becomes established. Currently there is no developed public boat access to the lake. A bathymetric map of the lake is shown in Figure 1.

The lake has been monitored for two years through the CAMP program. Based on data showing low water clarity and elevated phosphorus concentrations, the lake is eutrophic. This means it has moderate to high fertility levels and will support nuisance algae blooms.

The active drainage area to Ravine Lake is about 800 acres with an ephemeral inflow on the northeast side of the lake (ephemeral means a stream only flows occasionally, usually with a rainfall). There is a potentially large watershed to the northwest, but it does not appear to carry surface flow to the lake in any great quantity under normal hydrologic conditions at this time.

A comprehensive study was undertaken to better understand the ramifications of future high runoff resulting from extreme events and then design projects to improve conditions and sustain desirable water quality.

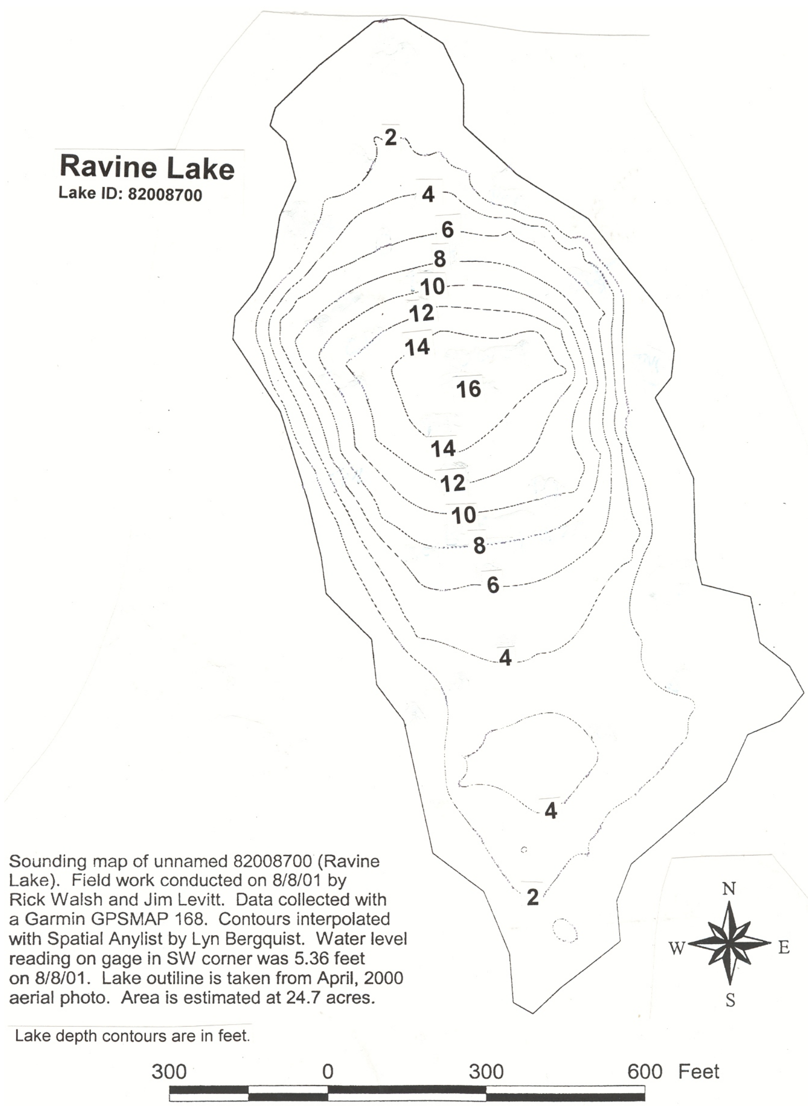
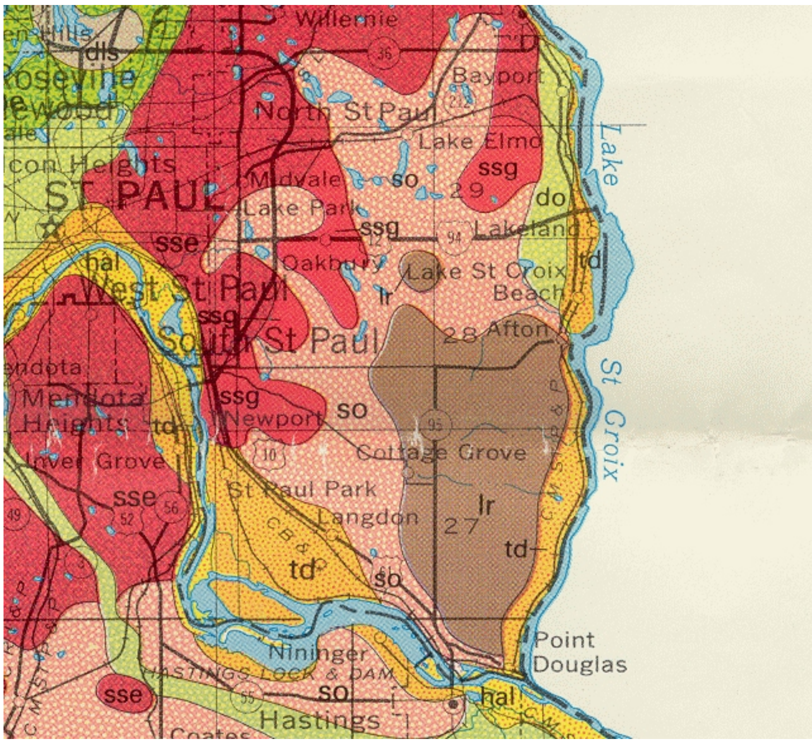


Figure 1. Bathymetric map of Ravine Lake.

2. Geology and Soils

Glacial Geology

As glaciers advanced across Minnesota they carried along material ranging from huge boulders to small sand particles. As the glaciers melted they left behind the materials that had been carried along. This material is known as drift. The Ravine Lake basin is located in a ground moraine from the Superior Lobe (Figure 2).



Legend

DEPOSITS ASSOCIATED WITH THE SUPERIOR LOBE (PLEISTOCENE, LATE WISCONSINAN) - reddish-brown noncalcareous drift; clasts predominantly igneous and metamorphic rocks of the Canadian Shield, but also present are distinctive clasts from the Superior basin, including red sedimentary rocks, amygdaloidal basalt, red rhyolite and agate.

ST. CROIX MORAINE ASSOCIATION - sandy, stony till; locally calcareous in the Twin Cities area because of incorporated local limestone bedrock.

lr	WEATHERING RESIDUUM OVER BEDROCK (PLEISTOCENE, PRE-WISCONSINAN) - Loess-covered; includes remnants of highly eroded old drift and slopewash sediment.
so	OUTWASH - undivided as to moraine association; includes scoured bedrock surfaces in meltwater channels.
ssg	Ground moraine; the contact between this unit and the equivalent unit of the Rainy lobe (rsg) is arbitarily located within a transitional zone.
sse	End moraine.
td	TERRACES (HOLOCENE TO PLEISTOCENE) - remnants of former channels and flood plains, and below the levels of adjacent moraine or outwash surfaces. Predominantly sand and gravel, but finer grained material also occurs, especially in the terraces along small tributaries of the Mississippi River. Parts of tome terraces are scoured surfaces rather than deposits.

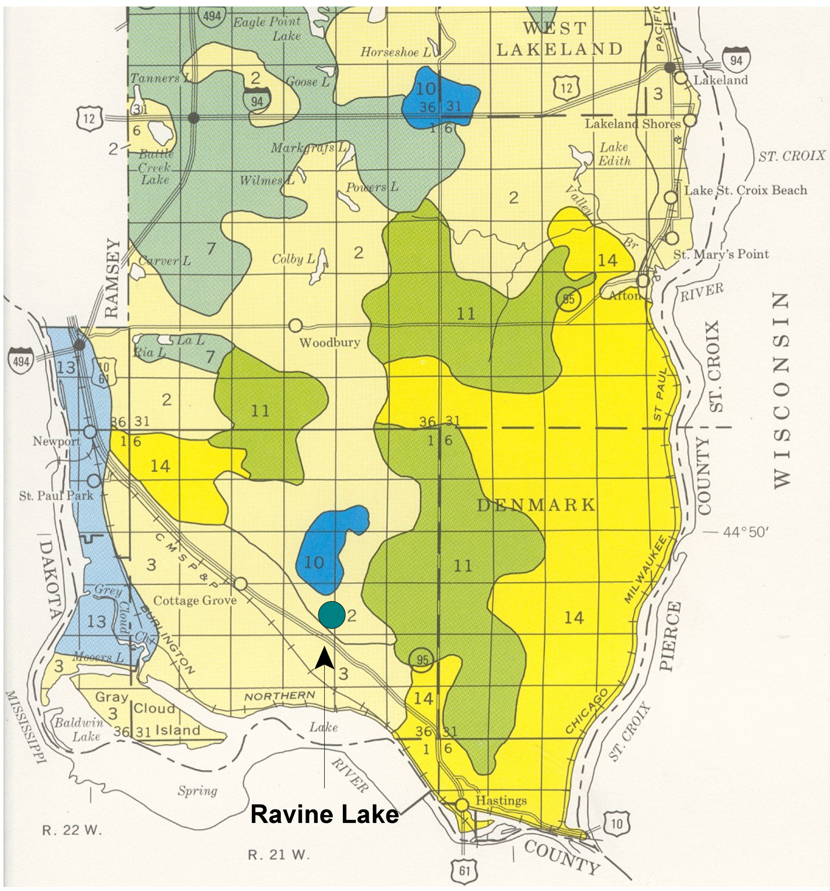
Figure 2. Geology of Ravine Lake.

Soils

The soils in the Ravine Lake watershed range from excessively drained to poorly drained soils. There are seven different soil associations represented in the Ravine Lake watershed: Antigo-Chetek-Mahtomedi; Sparta-Dickman-Hubbard, Santiago-Kingsley, Antigo-Comstock, Ostrander-Baytown-Ripon, Copaston-Sparta, and Waukegan-Baytown-Ripon.

The majority of the Ravine Lake watershed is the Antigo-Chetek-Mahtomedi and the Sparta-Dickman-Hubbard Groups (Figure 3) the soils are represented by well drained to excessively drained soils, medium to coarse texture soils, mostly on outwashed plains.

A map of soil series is shown in Figure 4. Many of the soils are rated as moderate to severe for septic tank/soil absorption systems due to wetness, poor filter, and seepage caused by slow percs. These soils may not treat wastewater as well as a more loamy soil.



Legend

2 Antigo-Chetek-Mahtomedi: Nearly level to steep, well drained to excessively drained, medium textured to coarse textured soils; mostly on outwash plains.

3 Sparta-Dickman-Hubbard: Level to moderately steep, excessively drained and somewhat excessively drained, moderately coarse textured and coarse textured soils; mostly on outwash terraces.

7 Santiago-Kingsley: Undulating to steep, well drained, medium textured and moderately coarse textured soils; on uplands.

10 Antigo-Comstock: Level to moderately sloping, well drained and somewhat poorly drained, medium textured soils; on outwash plains and glacial lake plains.

11 Ostrander-Baytown-Ripon: Nearly level to moderately sloping, well drained, medium textured soils; on upland.

13 Copaston-Sparta: Nearly level to moderately steep, well drained and excessively drained, medium textured and coarse textured soils; mostly on terraces.

14 Waukegan-Baytown-Ripon: Level to moderately sloping, well drained, medium textured soils, on uplands.

Figure 3. Soil associations for the Ravine Lake watershed.

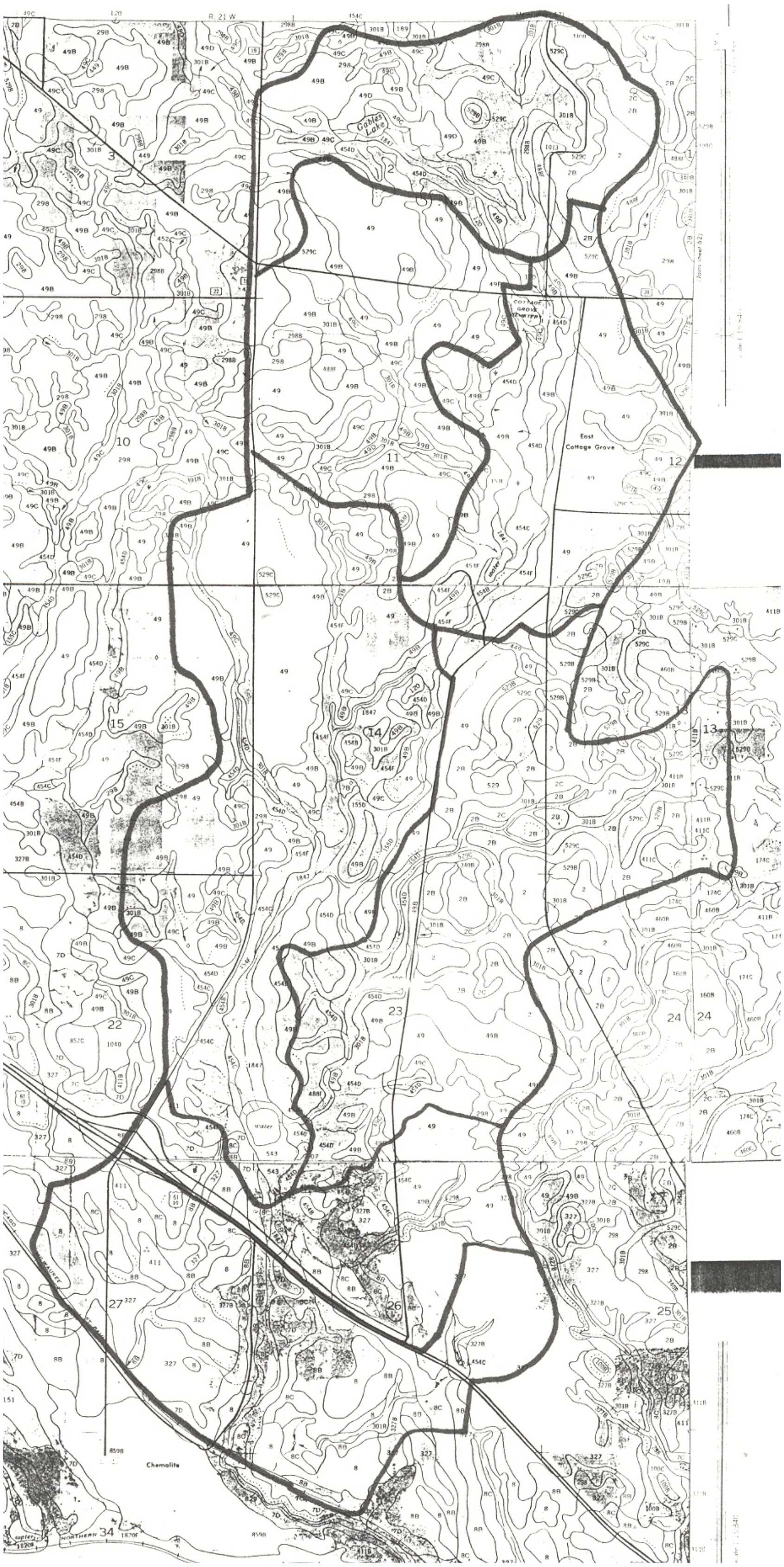


Figure 4. Representative soils around Ravine Lake.

Table 1. Characteristics of soils series for soils in Washington County. Corn production is from Table 5, % clay, organic matter, and pH are from Table 15, and septic tank absorption field descriptions are from Table 11.

Soil Number and Name		Characteristics				
		Corn Production (bushel/ac)	Clay % (A horizon)	Organic Matter (%)	Soil Reaction pH	Septic Tank Absorption
Ravine Lake						
2	Ostrander	95	18-27	3-5	5.6-7.3	Slight
2B	Ostrander	90	18-27	3-5	5.6-7.3	Slight
2C	Ostrander	80	18-27	3-5	5.6-7.3	Slight
7D	Hubbard	--	4-10	1-2	5.1-7.3	Severe: slope
8	Sparta	50	3-10	1-2	5.1-7.3	Slight
8B	Sparta	50	3-10	1-2	5.1-7.3	Slight
8C	Sparta	--	3-10	1-2	5.1-7.3	Moderate: slope
49	Antigo	70	10-15	2-3	4.5-6.5	Slight
49B	Antigo	70	10-15	2-3	4.5-6.5	Slight
49C	Antigo	60	10-15	2-3	4.5-6.5	Moderate: slope
49D	Antigo	50	10-15	2-3	4.5-6.5	Severe: slope
298	Richwood	95	15-22	2-5	5.6-7.3	Slight
298B	Richwood	95	15-22	2-5	5.6-7.3	Slight
301B	Lindstrom	95	18-24	3-5	5.6-7.3	Slight
327	Dickman	55	10-18	2-4	6.1-7.3	Slight
327B	Dickman	50	10-18	2-4	6.1-7.3	Slight
411	Waukegan	80	18-30	2-5	5.6-7.3	Slight
411B	Waukegan	80	18-30	2-5	5.6-7.3	Slight
454B	Mahtomedi	45	5-10	<1	5.1-6.5	Slight
454C	Mahtomedi	45	5-10	<1	5.1-6.5	Moderate: slope
454D	Mahtomedi	--	5-10	<1	5.1-6.5	Severe: slope
454F	Mahtomedi	--	5-10	<1	5.1-6.5	Severe: slope
529	Ripon	75	10-18	2-4	5.6-7.8	Severe: depth to rock
529C	Ripon	65	10-18	2-4	5.6-7.8	Severe: depth to rock
543	Markey	50	--	55-85	5.6-7.8	Severe: wetness, floods, subsides
1847	Barronett, sandy substratum	70	16-22	4-6	5.1-6.5	Severe: wetness, floods, percs slowly

3. Watershed Characteristics

3.1. Land Use

The MnDNR outlined a watershed in 1988 (Figure 5). It includes both the active watershed (1) and the inactive watershed (2). The base map is from 1967 and shows that Ravine Lake is a wetland.

The watershed of Ravine Lake was more recently delineated by EOR consultants (June 2000) and is shown in Figure 6. The active watershed (Figure 6) is estimated to be about 800 acres. There is the potential for another 2,500 acres to contribute flow in the future, but at the present time this is mostly non-contributing watershed (shown as Future and Small Future Possibility areas in Figure 5).

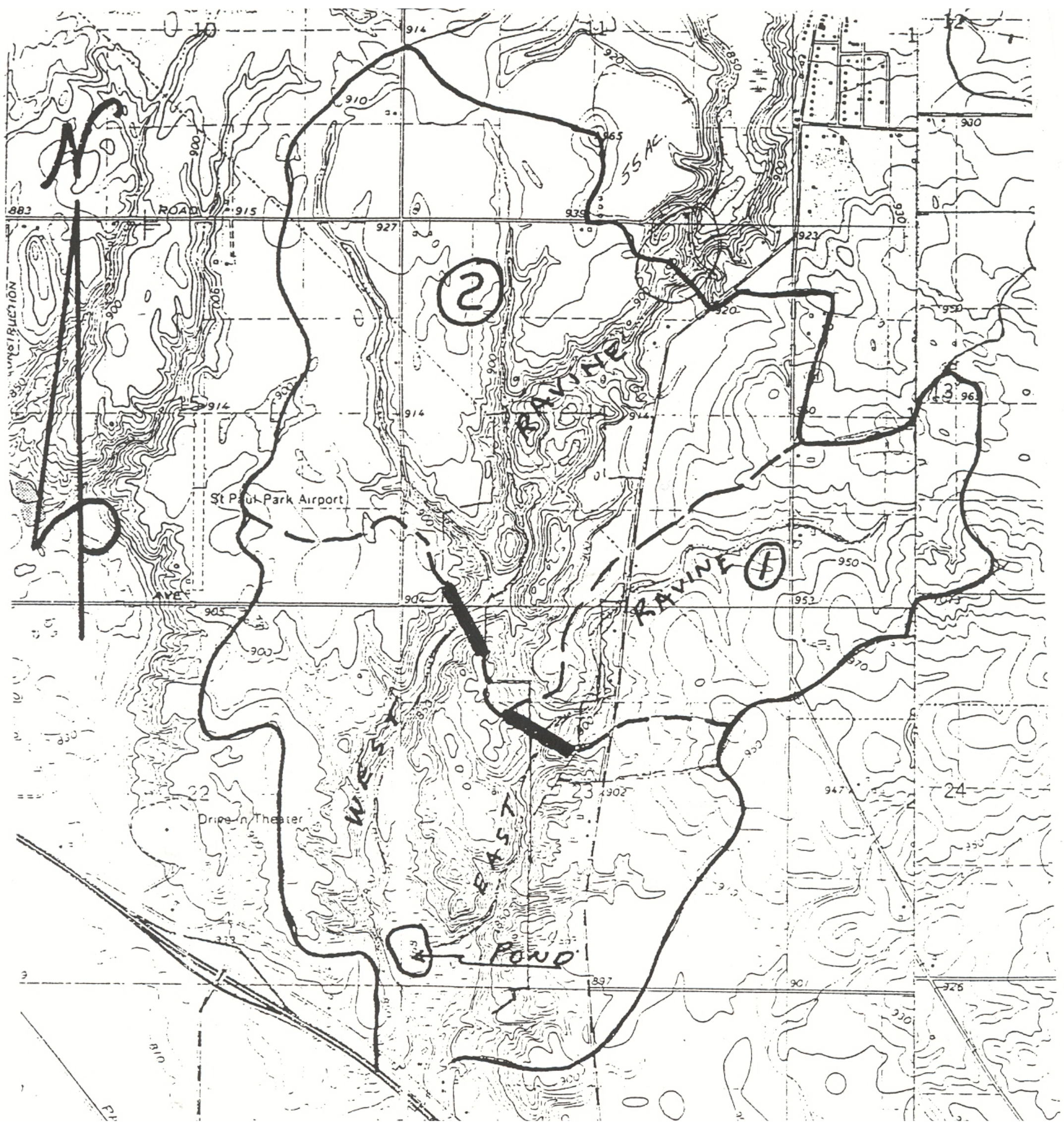


Figure 5. Ravine Lake watershed in 1988 (source: MnDNR 1988).

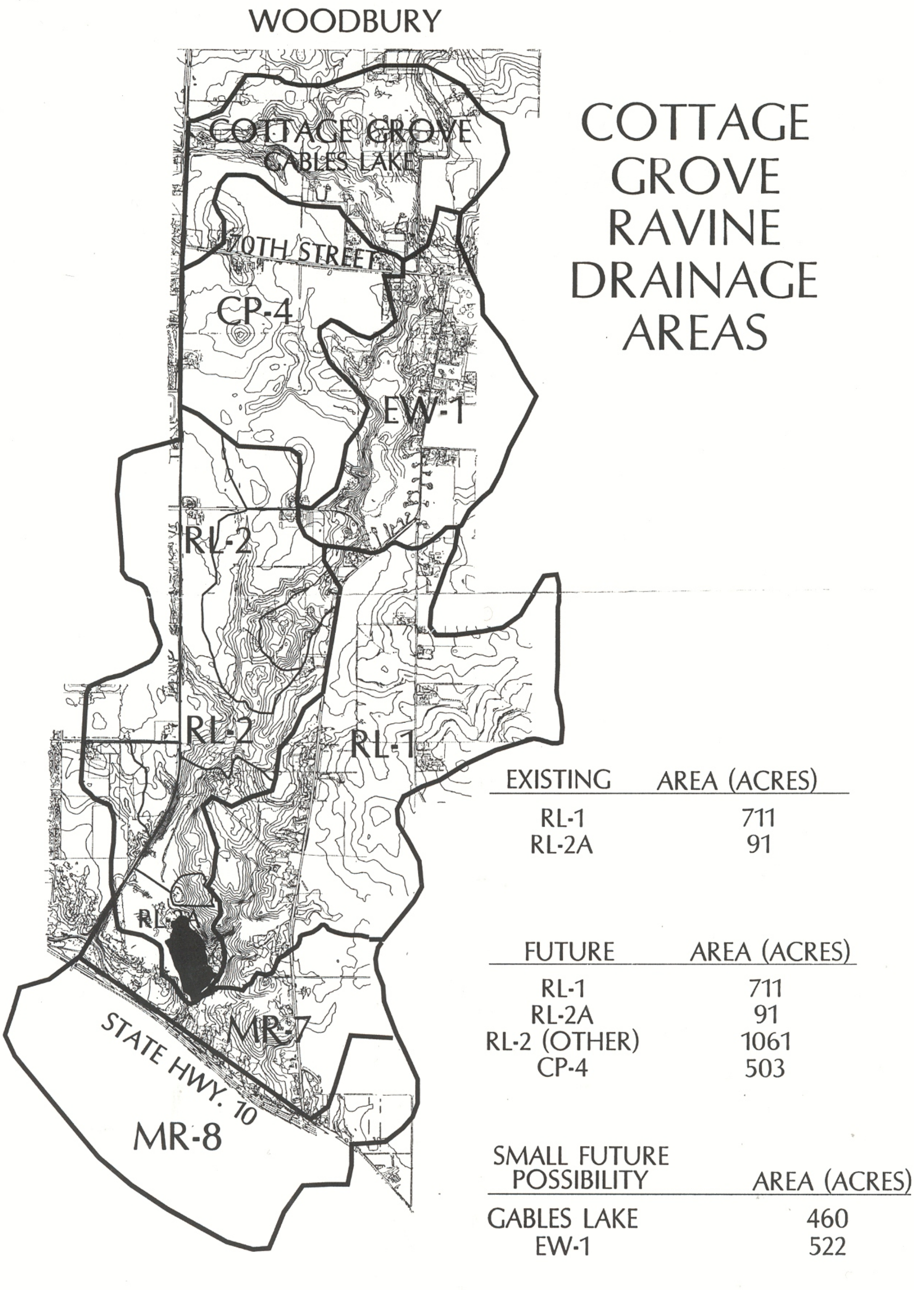


Figure 6. Ravine Lake watershed (source: EOR 2000).

3.2. Shoreland Inventory

The shoreland area encompasses three components: the upland fringe, the shoreline, and shallow water area by the shore. A photographic inventory of the 0.9 mile Ravine Lake shoreline was conducted on July 19, 2001. The objectives of the survey were to characterize existing shoreland conditions which will serve as a benchmark for future comparisons.

For each photograph we looked at the shoreline and the upland condition. Our criteria for natural conditions were the presence of 50% native vegetation in the understory and at least 50% natural vegetation along the shoreline in a strip at least 15 feet deep. We evaluated shorelands and uplands at the 75% natural level as well.

A summary of the inventory results is shown in Table 2. Based on our subjective criteria 100% of the parcels in Ravine Lake shoreland area meet the natural ranking criteria for shorelines and upland areas and there is about 98% natural shoreline. The only area without natural vegetation is along the entrance road that runs by Ravine Lake.

A contributing factor to a high percentage of Ravine Lake parcels with natural conditions is that Ravine Lake is within park setting.

Table 2. Summary of shoreline buffer and upland conditions in the shoreland area of Ravine Lake. Approximately 9 parcels were examined.

Ravine Lake	Natural Shoreline Condition		Natural Upland Condition		Undevel. Photo Parcels	Shoreline Structure Present	
	>50%	>75%	>50%	>75%		riprap	wall
TOTALS (no. of parcels = 9)	100% (9)	100% (9)	100% (9)	100% (9)	100% (9)	0% (0)	8% (1)

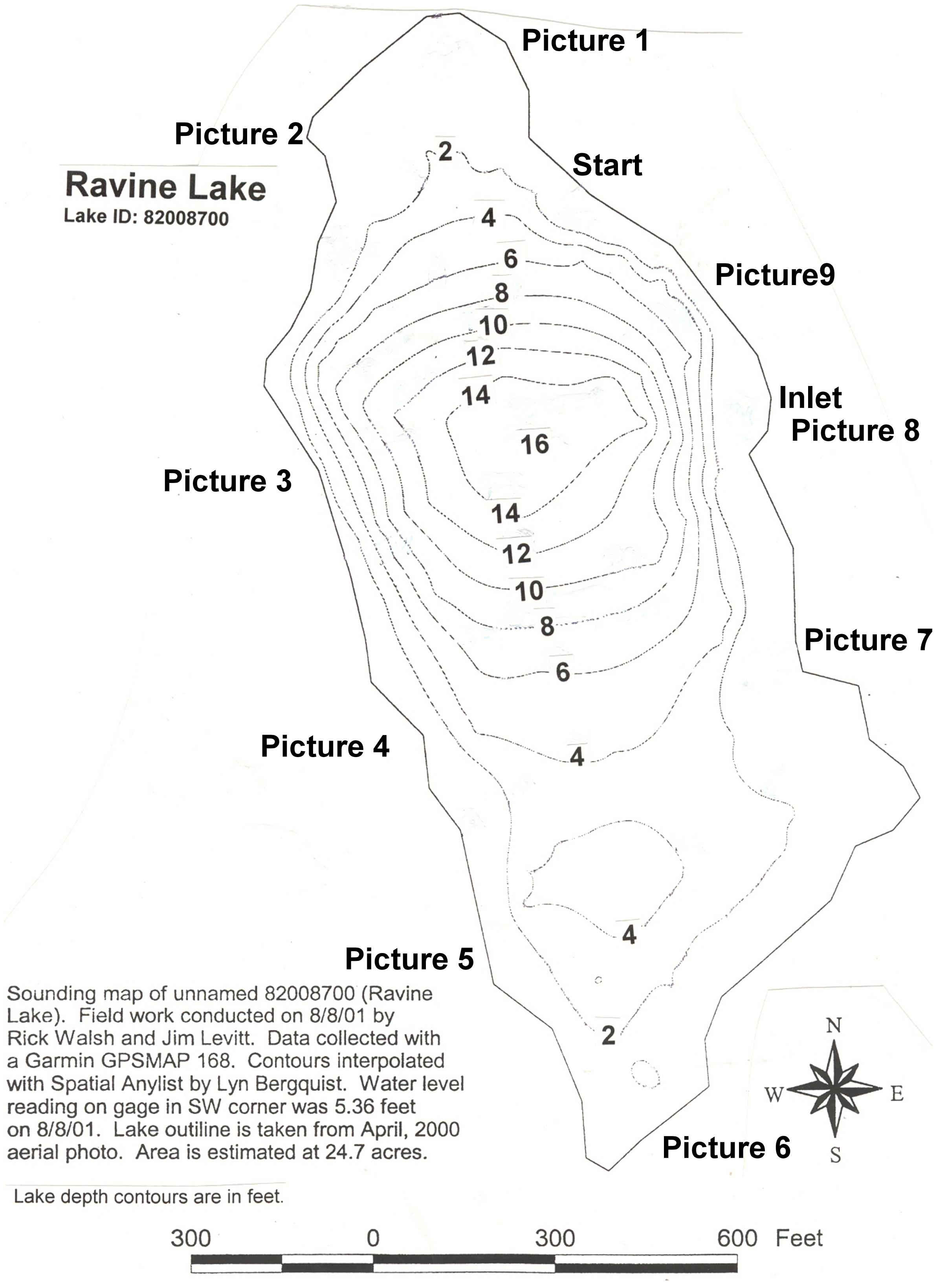
Results of individual parcel evaluations are shown in Table 3. A key to parcel locations is shown on the map on the next page.

A "parcel" represents a photo of an undeveloped shoreline area around Ravine Lake. The lake has a 0.9 miles of shoreline and 9 photos were used to characterize shoreland conditions.

Table 3. Summary of shoreland conditions for the 0.9 miles of shoreline around Ravine Lake. Nine photographs were used.

ID #	Natural Upland Condition		Natural Shoreline Condition		Shoreline Erosion		Shoreline Structure			Comments
	>50%	>75%	>50%	>75%	No	Yes*	No	Yes		
								riprap	wall	
1	X	X	X	X	X		X			
2	X	X	X	X	X		X			
3	X	X	X	X	X		X			
4	X	X	X	X	X		X			
5	X	X	X	X	X		X			
6	X	X	X	X	X		X			
7	X	X	X	X	X		X			
8	X	X	X	X	X				X	Inlet area.
9	X	X	X	X	X		X			
TOTALS	9/9 (100%)	9/9 (100%)	9/9 (100%)	9/9 (100%)	9/9 (100%)		8/9 (89%)	0/9 (0%)	1/9 (11%)	
*Slight, Moderate, Severe										

A comparison of Ravine Lake conditions to other lakes in Minnesota and Wisconsin is shown in Table 4 and Figure 7.



Key to shoreland photo parcels for Ravine Lake, July 19, 2001.

1

2

3

4

5

6

7

8

9

Table 4. Summary of shoreland inventories from Ravine Lake and 21 other lakes in Minnesota and Wisconsin.

Lake	Eco-region	Date of Survey	Total Number of Parcels (#)	Undevel. Parcels % (#)	Natural Upland Condition > 50% % (#)	Natural Upland Condition >75% % (#)	Natural Shoreline Condition > 50% % (#)	Natural Shoreline Condition >75% % (#)	Parcels with Erosion % (#)	Parcels with Shoreline Revetment % (#)
Ravine Lake Washington Co, MN	CHF	7.19.01	12	100 (12)	100 (12)	100 (12)	100 (12)	100 (12)	0 (0)	8 (1)
Diamond Lake Kandiyohi Co, MN	CHF	8.13 & 14.02	344	2 (7)	13 (44)	11 (39)	16 (56)	12 (42)	1 (5)	49 (168)
Green Lake Kandiyohi Co, MN	CHF	9.19.01	721	1 (9)	20 (146)	12 (88)	19 (140)	14 (100)	0	62 (446)
Orchard Lake Dakota Co, MN	CHF	9.17.01	109	4 (4)	47 (51)	30 (33)	53 (58)	32 (35)	0	54 (59)
Rush Lake Chisago Co, MN	CHF	9.16.00	524	11 (58)	48 (253)	28 (147)	51 (267)	38 (201)	1 (3)	18 (92)
West Rush	CHF	9.16.00	332	12 (40)	52 (171)	31 (103)	55 (184)	43 (142)	1 (2)	15 (50)
East Rush	CHF	9.16.00	192	9 (18)	43 (82)	23 (44)	43 (83)	31 (59)	1 (1)	22 (42)
Comfort Chisago Co, MN	CHF	10.9-11.2.98	100	--	62 (62)	--	50 (50)	--	--	12 (12)
Maple Grove Lake Summary, MN	CHF	9.30 - 10.12.99	644	14 (89)	67 (431)	48 (312)	60 (385)	48 (310)	1 (3)	20 (129)
Cedar Island	CHF	9.30 - 10.12.99	93	5 (5)	62 (58)	35 (33)	55 (51)	39 (36)	0	22 (21)
Eagle	CHF	9.30 - 10.12.99	90	14 (13)	64 (58)	52 (47)	47 (42)	41 (37)	0	35 (32)
Edward	CHF	9.30 - 10.12.99	34	12 (4)	91 (31)	88 (30)	76 (26)	71 (24)	6 (2)	3 (1)
Fish	CHF	9.30 - 10.12.99	170	7 (12)	74 (126)	44 (75)	57 (97)	41 (70)	1 (1)	20 (34)
Pike	CHF	9.30 - 10.12.99	9	56 (5)	100 (9)	100 (9)	100(9)	100 (9)	0	0
Rice	CHF	9.30 - 10.12.99	137	33 (45)	71 (97)	64 (87)	81 (111)	74 (102)	0	19 (25)
Weaver	CHF	9.30 - 10.12.99	111	5 (5)	47 (52)	28 (31)	44 (49)	29 (32)	0	14 (16)
Powers City of Woodbury, MN	CHF		30	90 (27)	90 (27)	90 (27)	97 (29)	97 (29)	0	0
Upper Prior Scott Co, MN	CHF	9.30-10.12.99	366	10 (37)	51 (187)	36 (132)	35 (128)	31 (113)	4 (15)	46 (168)
Lower Prior Scott Co, MN	CHF	9.24-30.99	691	10 (66)	36 (249)	24 (166)	22 (152)	17 (117)	5 (35)	54 (373)
Plum Lake Vilas Co, WI	LF	7.26.01	225	13 (30)	75 (169)	58 (130)	81 (182)	708(158)	--	9(4)
Bear Oneida Co, WI	LF	6.8.99	115	6 (7)	93 (107)	78 (90)	84 (97)	77 (89)	1 (1)	8 (9)
Nancy Lake Washburn Co, WI	LF	9.21.00	217	19 (41)	77 (167)	65 (141)	80 (174)	72 (156)		5 (11)
Big Bearskin Oneida Co, WI	LF	8.10.99	130	--	73 (95)	63 (82)	80 (104)	67 (87)	--	0
Ballard chain Vilas Co, WI	LF	7.23.99	110	--	98 (108)	96 (106)	96 (106)	95 (105)	--	0

* CHF = Central Hardwood Forest Ecoregion
** LF = Lake and Forests Ecoregion

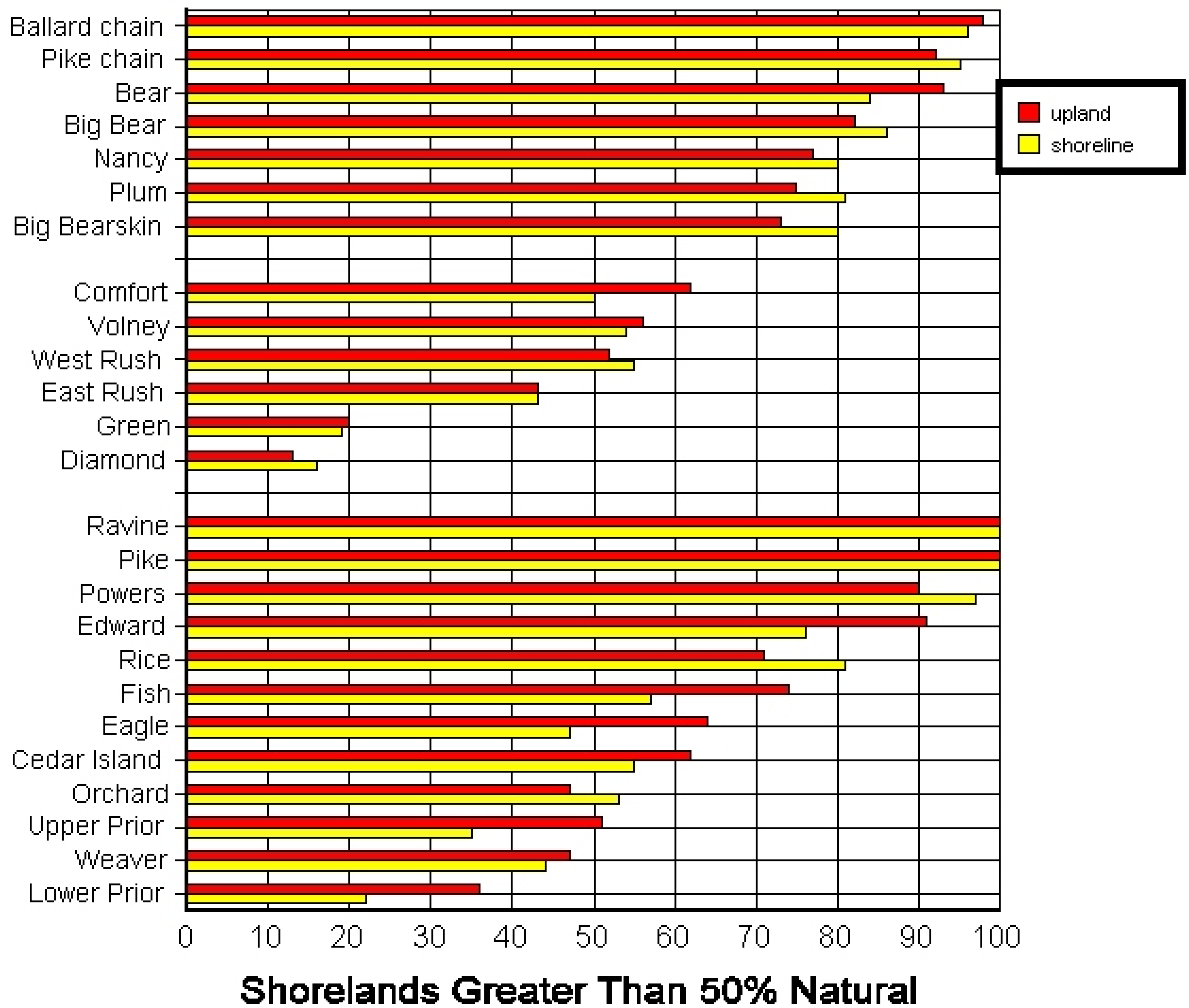


Figure 7. A summary of shoreland inventory results for lakes using an evaluation based on shoreland photographs. For each lake the percentage of shoreline and upland conditions with greater than 50% natural conditions is shown. The first tier of lakes are located in northern Wisconsin. The lower tier of lakes are in the Twin City Metropolitan area and are considered urban lakes. Although several lakes are "urban" lakes most of the shoreland is owned by the city and there is a high percentage of natural conditions. The middle tier of lakes are about an hour's drive from the Twin Cities, and are not considered to be urban lakes, they are "country" lakes.

Ravine Lake is a Twin City Metropolitan lake. It's natural shoreland conditions are above average compared to the other metropolitan lakes.

3.3. Groundwater

Groundwater inflows (also referred to as springs) were evaluated using two methods. The first was with a conductivity survey and the second was with the use of seepage meters.

Conductivity survey results are shown in Figure 8. Two general areas of inflow are proposed based on conductivity readings that are below background readings of 241. The general areas of groundwater inflow appear to be the north end and the lower east end.

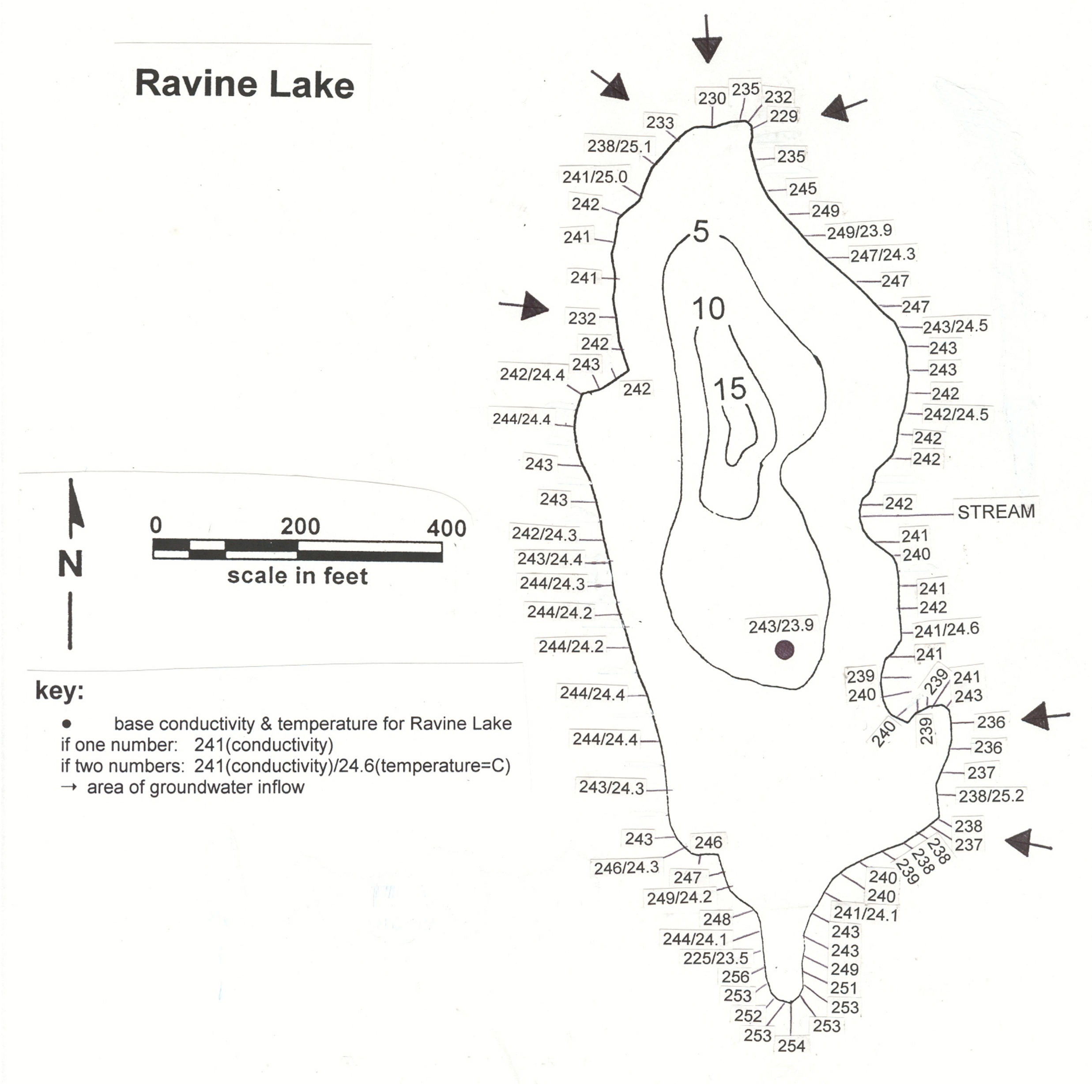


Figure 8. Conductivity survey conducted on August 14, 2001.

The volume of groundwater entering the north end of Ravine Lake was checked on October 26, 2001 (Table 5).

Table 5. Ravine Lake groundwater results for October 26, 2001. Seepage meter is 23 inches in diameter, which is equivalent to 0.266 meters^2.

	Minutes	Quantity of Water Collected (ml)	Seepage Rate	
			ml/min	liters/day/m^2
Seepage Meter 1 10:30 am - 12:40 pm	130	28	0.22	1.2
Seepage Meter 2 10:30 am - 12:40 pm	130	4	0.03	0.2
Seepage Meter 3 10:30 am - 11:30 am	60	58	0.97	5.2
Seepage Meter 3 11:30 am - 12:40 pm	70	7	0.1	0.54
Seepage Meter 4 10:30 am - 12:40 pm	130	359	2.76	14.9
Average	104	91	0.82	4.4

Average seepage volume for 5 tests was 4.4 liters/day/m^2. If we take 2000 meters of shoreline out 10 meters into the lake then a daily groundwater inflow would be 88 m^3/day or 32,120 meters^3/yr.

Based on a lake size of 25 acres and an average depth of 7 feet, the lake volume is approximately 175 acre-feet or 215,845 m^3. Estimated annual groundwater inputs represent about 15% of the lake volume.

This average groundwater velocity entering Ravine Lake would be approximately 1.65 cm/day which is somewhat a typical velocity. Seepage meter 4 had the highest velocity at 5.64 cm/day.

If this groundwater flow rate occurred over the winter and if groundwater was entering Ravine Lake at 10 mg of dissolved oxygen per liter, it would maintain dissolved oxygen at 4 mg/l for a small area of 16m x 16m x 1m. This could be large enough to allow some fish to overwinter in Ravine Lake, even if the rest of the lake lost all its oxygen. It this case, incoming groundwater would serve as a type of natural winter aeration.

3.4. Streams and Ravines

No perennial streams flow into Ravine Lake, but there is interesting evidence of ephemeral stream flow that has probably been occurring for thousands of years.

A recent pictural history of the main inflow (from 1994 to 2001) is shown in Figure 9.

The stream channel has cut through bedrock indicating that at times, flow must have been substantial.

For this study period, flows were flashy and were not measured, but water samples were collected from pools left after a storm event. Results are shown in Table 6. Nutrient concentrations are elevated compared to an ecoregion stream value of about 150 ppb.

Figure 9. All three pictures are stream channels in a steep gradient on the northeast side of Ravine Lake and are in subwatershed RL-1, the active watershed.
[top] October 1994
[middle] June 2000.
[bottom] July 2001.

Table 6. Phosphorus and suspended solid concentrations in a Ravine Creek pool and the lake inlet area.

	6.15.01	7.19.01
Ravine Creek Pool		
Total phosphorus (ppb)	626	201
Total suspended solids (mg/l)	210	10
Chloride (mg/l)	6.9	--
Lake Inlet Area (backwater to lake)		
Total phosphorus (ppb)	--	127

Figure 10. Stream channel leading into Ravine Lake referred to as the lake inlet area in Table 6. Both pictures are in a low gradient setting at the bottom of the ravine. The top picture is in June 2000 and the bottom picture is from June 2001.

A minor mystery was discovered over the course of the project. A small pond about 100 meters from Ravine Lake had a distinctive brown color. Examination of water samples under the microscope showed that the color was due to clay-size soil particles (Figure 11). The source of the particles was not determined.

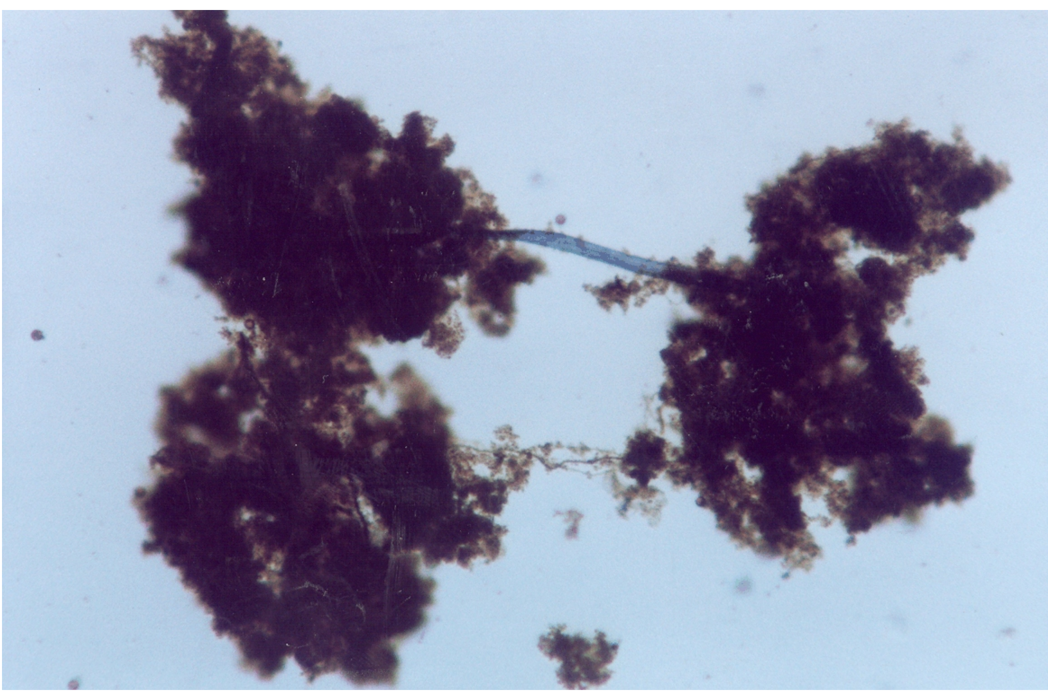
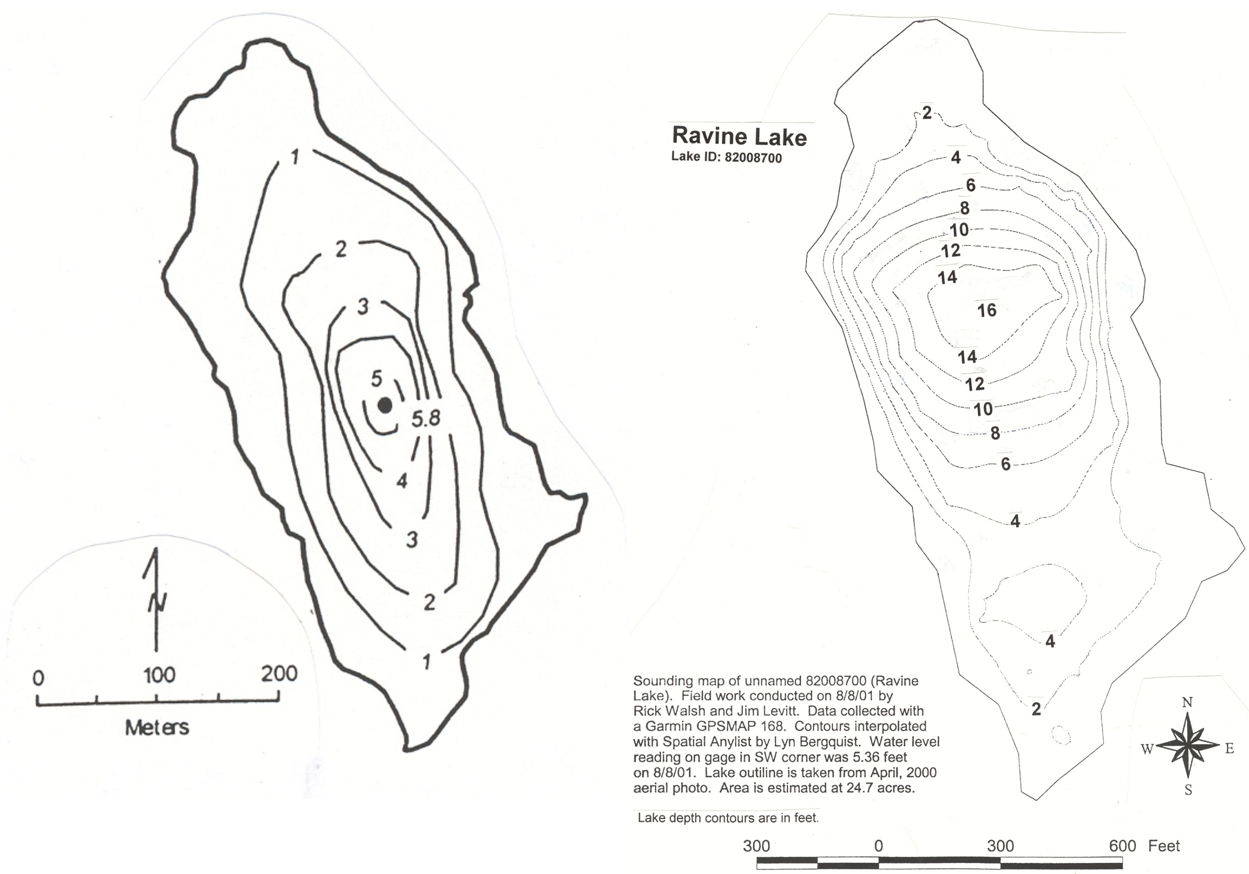


Figure 11. [top] A small pond about 100 meters from Ravine Lake had a brownish color. [bottom] Particles observed under a microscope at 625x. They appear to be soil particles.

4. Lake Characteristics

Lake Basin

Ravine Lake is a 25 acre lake with sandy shorelines. The northern region of the basin is deeper than the southern portion. The bottom contours were revised based on MnDNR readings taken on August 8, 2001 (Figure 12). The average depth is about 7 feet.



Lake contour map up to 2000 | **Revised lake contour map (June 2, 2000)**

Figure 12. Ravine Lake maps. (left) Original contour map used by Met Council in the CAMP reports and (right) a revised lake map produced by the MnDNR.

4.1. Lake Sediments

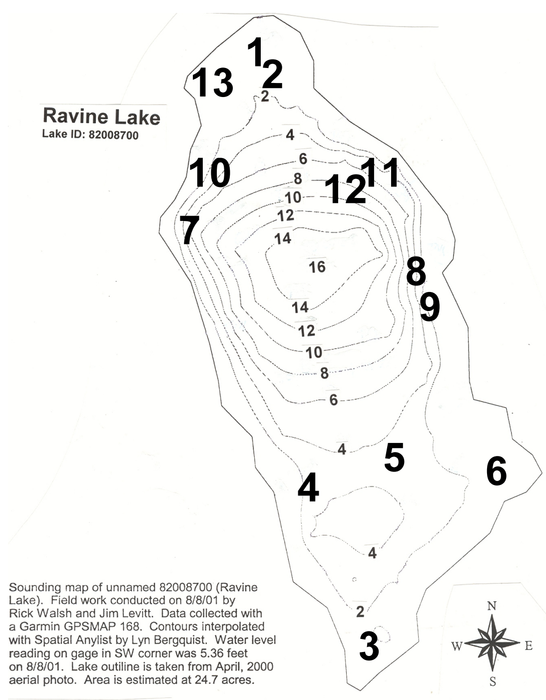
Ravine Lake sediments were sampled on October 26, 2001. The objective was to characterize sediment fertility. Analysis were conducted on dry sediments using conventional agricultural soil tests. Results are shown in Table 7. Lake sediments were elevated for both phosphorus and nitrogen.

Table 7. Ravine Lake soil data. Samples were collected on October 26, 2001. Soil chemistry results are reported as ppm except for organic matter (%) and pH (standard units). Results are given on a volume basis unless otherwise noted.

Field Description	Sample ID	weight of 5 g scoop grams	wt corr Factor	by wt. Ammonia ppm	by vol Ammonia ppm	by wt Bray P Value ppm	by vol Bray P Value ppm	by wt Olsen P Value ppm	by vol Olsen P Value ppm	by vol K ppm
3 ft.	R1	3.170	1.577	83.66	53.04	31.5	20.0	89.7	56.9	74
3 ft.	R2	2.681	1.865	81.63	43.77	42.8	23.0	92.6	49.7	68
3.5 ft.	R3	4.243	1.178	29.68	25.18	45.4	38.5	45.9	39.0	40
4 ft.	R4	3.273	1.528	24.68	16.15	14.8	9.7	13.5	8.8	59
5.5 ft.	R5	1.954	2.559	22.69	8.87	3.6	1.4	34.9	13.6	33
4.5 ft.	R6	3.465	1.443	17.98	12.46	18.0	12.5	14.0	9.7	62
4.8 ft (flooded area)	R7	3.879	1.289	18.40	14.28	20.4	15.8	9.4	7.3	47
6 ft.	R8	3.838	1.303	43.65	33.50	2.3	1.8	41.4	31.8	82
2 ft (in front of flow)	R9	4.994	1.001	10.30	10.28	39.5	39.5	15.8	15.8	29
8 ft.	R10	3.096	1.615	33.52	20.75	4.4	2.7	41.8	25.9	124
3 ft.	R11	2.887	1.732	37.09	21.41	24.5	14.2	36.9	21.3	48
6.5 ft.	R12	2.865	1.745	29.89	17.13	2.1	1.2	32.2	18.4	87
2.5 ft.	R13	2.983	1.676	191.31	114.14	38.2	22.8	117.3	70.0	42

Station ID	by vol Zinc ppm	by vol Sulfur ppm	by vol Iron ppm	by vol Copper ppm	by vol Mn ppm	by vol Boron ppm
R1	0.94	146.8	103	0.16	5.1	1.18
R2	1.64	86.5	104	0.20	5.0	1.24
R3	3.36	7.9	110	1.50	50.0	0.59
R4	3.78	169.4	98	3.08	47.8	1.35
R5	2.48	63.0	100	1.34	49.0	1.12
R6	3.42	45.7	101	2.48	43.0	0.85
R7	3.54	9.7	96	1.86	42.9	0.82
R8	2.88	104.7	98	3.24	63.9	0.71
R9	1.36	80.2	89	1.44	36.5	1.01
R10	2.40	96.0	97	3.98	47.7	0.43
R11	2.56	22.9	104	0.74	13.8	0.66
R12	2.12	99.9	96	3.32	26.9	1.67
R13	1.08	53.5	103	0.32	3.1	0.63

Station ID	by wt OM %	by vol OM %	Water pH	by vol Ca ppm	by vol Mg ppm	by vol Na ppm
R1	19.94	12.64	5.8	4320	770	88
R2	25.95	13.92	5.7	4640	695	92
R3	6.52	5.53	6.1	2720	365	88
R4	24.70	16.17	6.3	5680	1455	106
R5	42.84	16.74	7.1	9920	710	20
R6	19.45	13.48	7.2	6400	705	20
R7	7.99	6.20	7.2	3040	390	90
R8	6.96	5.34	7.0	5200	505	92
R9	2.99	2.99	7.1	3360	275	102
R10	11.78	7.29	7.3	10000	630	100
R11	32.02	18.49	6.5	8320	725	32
R12	16.40	9.40	7.2	10240	525	94
R13	20.51	12.24	6.0	4000	475	94



Sounding map of unnamed 82008700 (Ravine Lake). Field work conducted on 8/8/01 by Rick Walsh and Jim Levitt. Data collected with a Garmin GPSMAP 168. Contours interpolated with Spatial Anylist by Lyn Bergquist. Water level reading on gage in SW corner was 5.36 feet on 8/8/01. Lake outline is taken from April, 2000 aerial photo. Area is estimated at 24.7 acres.

Lake depth contours are in feet.

4.2. Dissolved Oxygen and Temperature

Somewhat surprisingly, shallow Ravine Lake has a strong temperature stratification and is devoid of oxygen below six feet in the middle of the summer.

This strong temperature stratification can occur in eutrophic, sheltered lakes. What is a little surprising is that Ravine Lake is surrounded by a large area of undeveloped land, but yet symptoms of enhanced eutrophication are evident.

The biological oxygen demand must be strong in the bottom waters and sediments and probably explains why dissolved oxygen is lacking in the bottom of Ravine Lake.

Table 8.

Depth (ft)	Water Temperature (F)	Dissolved Oxygen (ppm)
0	86.0	11.5
1	86.0	11.4
2	86.0	11.2
3	86.0	10.9
4	86.0	10.6
5	83.1	7.5
6	80.2	0.2
7	78.3	0.2
8	73.6	0.2
9	71.4	0.2
10	68.7	0.2
11	66.6	0.2
12	65.3	0.2
13	62.8	0.2
14	61.7	0.2
15	60.8	0.2

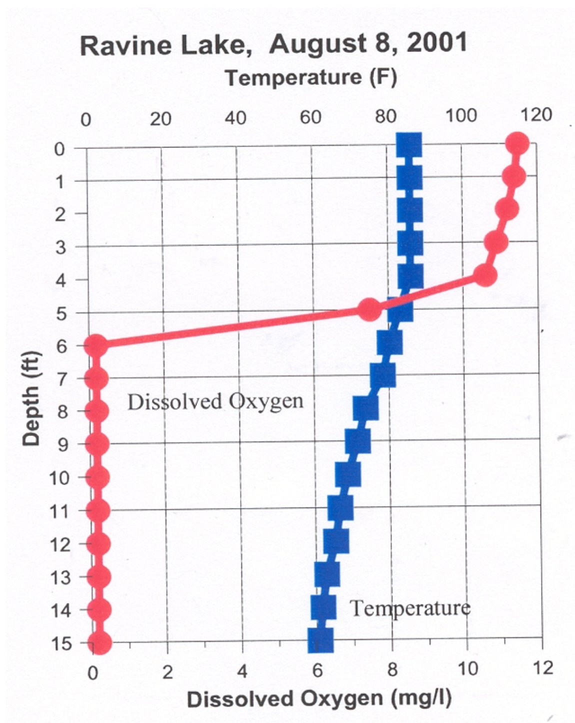


Figure 13. Dissolved oxygen/temperature profile for Ravine Lake, collected August 8, 2001.

4.3. Water Clarity, Phosphorus and Nitrogen

There is not much known about the water quality of Ravine Lake prior to 1998. Water quality data from 1998 collected through the CAMP program shows it is clearly eutrophic, meaning it is highly fertile (Table 9). Phosphorus concentrations over 40 µg/l indicate a lake is eutrophic. Average summer phosphorus levels were higher in 1998 than 1999 and around 100 ppb in 2000 and 2001 (Table 10). In 1998, 200, and 2001 the water clarity summer average was around 2.0 feet. Transparency was better in 1999 primarily because June was such a good month (Tables 9 and 10).

Table 9. Water quality data for Ravine Lake for 1998, 1999, 2000, and 2001 from the CAMP program.

Month	Week*	Total Phosphorus (µg/l)				Secchi Disc (meters)				Chlorophyll a (µg/l)			
		1998	1999	2000	2001	1998	1999	2000	2001	1998	1999	2000	2001
April	2	--	--	40	--	--	--	1.1	--	--	--	6	--
	3	--	--	--	40	--	--	--	1.4	--	--	--	7
	4	--	50	40	--	--	0.5	0.9	--	--	31	10	--
May	1	--	--	--	60	--	--	--	0.7	--	--	--	41
	2	--	30	--	--	--	1.3	--	--	--	3	--	--
	3	60	--	--	70	1.3	--	--	0.7	4	--	--	33
	4	130	20	70	40	0.6	1.3	1.5	1.3	15	5	4	6
June	2	--	30	60	--	--	1.5	0.5	--	--	3	13	--
	3	200	--	80	100	0.4	--	0.7	0.3	42	--	17	11
	4	--	40	--	110	--	2.6	--	0.3	--	9	--	33
July	1	100	--	--	--	0.7	--	--	--	8	--	--	--
	2	140	100	--	110	0.6	0.3	--	0.3	13	33	--	20
	3	130	--	100	--	0.5	--	0.4	--	7	--	30	--
	4	140	70	--	110	0.8	1	--	0.4	10	13	--	49
August	1	--	70	110	--	--	0.7	0.4	--	--	32	41	--
	2	220	--	--	140	0.6	--	--	0.2	18	--	--	54
	3	--	90	120	130	--	0.5	0.4	0.3	--	14	40	43
	4	280	60	--	--	0.5	0.7	--	--	5	28	--	--
September	1	--	--	150	140	--	--	0.3	0.3	--	--	45	63
	2	--	100	80	--	--	0.7	0.5	--	--	10	46	--
	3	--	110	--	130	--	1.4	--	0.2	--	8		46
	4	190/ 170	80	90	--	0.4/ 0.4	1	1.1	--	29/ 27	62	5	--
October	1	--	--	--	100	--	--	--	0.4	--	--	--	30
	2	80	90	80	--	0.6	0.9	0.9	--	15	18	13	--

* Week 1: days 1-7; Week 2: days 8-14; Week 3: days 15-21; Week 4: days 22-31

Table 10. Water quality growing season (May-Sept) averages for Ravine Lake. Data were collected by the City of Cottage Grove for the Metropolitan Council.

	Total Phosphorus (ppb)	Chlorophyll a (ppb)	Secchi Disc (feet)
1998	154	18	2
1999	62	17	3.6
2000	92	24	2.3
2001	108	38	1.4

CAMP water quality data are shown graphically in Figure 14. The pattern for Ravine Lake is fairly well established. Seasonal averages indicate that it is hypereutrophic.

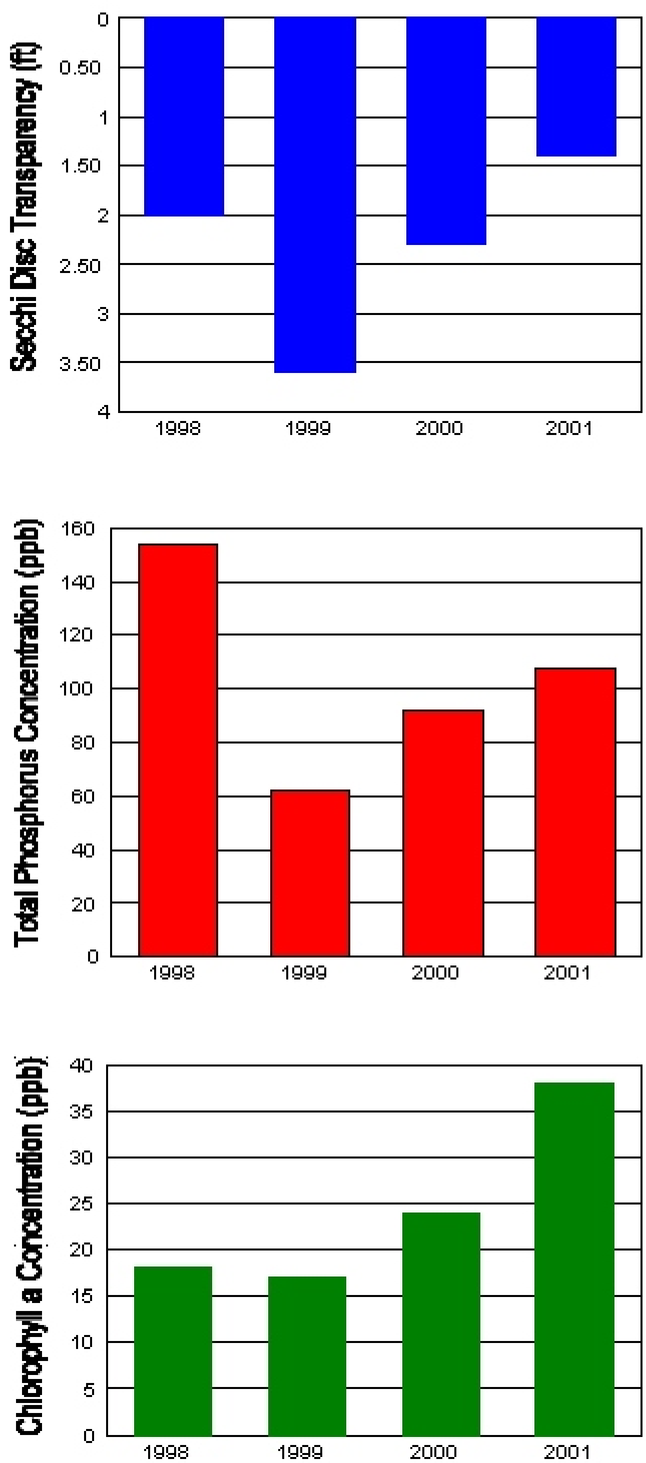


Figure 14. CAMP data water quality summer averages for 1998-2001.

The cause of poor transparency was further established in June 2000. Phosphorus concentrations and secchi disc measurements along with suspended solids measurements were taken on one date in June 2000. The low clarity was found to be caused primarily by algae. However, suspended silt and clay concentrations were present and contribute to the poor clarity to a degree (Table 11).

Table 11. Water quality data for Ravine Lake, June 2, 2000.

	North	South	Notes
Secchi disc (ft)	2.9	2.6	
Secchi disc (m)	0.9	0.8	
Total phosphorus (µg/l)	60	60	moderate levels, but still eutrophic
Total suspended solids (mg/l)	7	10	
Total solids (mg/l)	2540	2780	
Total volatile solids (mg/l)	1460	1840	

Using an observation by the MnDNR from 1988 and using other August readings, it appears Ravine Lake has had poor water quality since at least 1988 (Table 12).

Table 12. Comparison of secchi disc, total phosphorus, and chlorophyll for the month of October for 1994, 1998, 1999, 2000, and 2001.

	Secchi Disc Transparency		Total Phosphorus	Chlorophyll a
	(feet)	(meters)	(ppb)	(ppb)
(1988 - July)	1	0.3	--	--
1994	2.2	0.7	120	36
1998	2	0.6	80	15
1999	3	0.9	90	18
2000	0.9	0.3	80	13
2001	1.3	0.4	100	30

Special Winter Sampling

Ravine Lake water quality was monitored in February and March of 2001. On February 1, water clarity was good and phosphorus was low (Table 13). A disturbing finding was there was little oxygen left in this part of the lake in February.

In March, the phosphorus concentration had increased ten-fold in the lake and dissolved oxygen was very low. The phosphorus in the water column must have been released from the lake sediments. Nitrogen levels were high, but not excessively high (Table 13).

Table 13. Winter water quality results for Ravine Lake.

	February 1, 2001	March 22, 2001
Transparency (Ft)	13.8	--
Dissolved oxygen - top (ppb)	0.5	2.2
- bottom	0	0.4
Total Phosphorus (ug/l)	36	440
Ammonia-nitrogen (ug/l)	--	1,200
Nitrate-nitrogen (ug/l)	--	1,380
Total Kjeldahl nitrogen (ug/l)	--	1,500
Chlorophyll a (ug/l)	1.4	--

Figure 15. Matt Moore, Watershed Administrator, checks dissolved oxygen levels in Ravine Lake on February 1, 2001.

Trophic State Index

Three water quality parameters, secchi disc transparency, phosphorus, and chlorophyll, are referred to as trophic indicators. They are used to classify a lake as eutrophic (fertile), mesotrophic, or oligotrophic (infertile). In addition, all three parameters are closely correlated. If transparency is high, phosphorus and chlorophyll are low. If transparency is low, phosphorus and chlorophyll are high. Mathematical equations are used to convert water quality data into a *Trophic State Index*. Low trophic state index (TSI) numbers indicate oligotrophic conditions and TSI numbers over 50 indicate eutrophic conditions. Water quality data for 1998, 1999, 2000, and 2001 has been converted to TSI numbers (Table 14). The TSI results show Ravine Lake is eutrophic.

The TSI numbers can be used another way. Because the three parameters are strongly correlated, converting data to TSI should produce similar TSI values. If numbers are different then another factor may be influencing the lake water quality. The TSI values are graphed in Figure 16. In 1998, chlorophyll values were lower then expected based on secchi disc and phosphorus values. This may indicate that suspended solids may have reduced clarity and increased phosphorus levels but did not effect algae. In 1999, 2000, and 2001non-algal turbidity was possibly a factor but not as significant as 1998.

Table 14. Trophic State Index values for total phosphorus, chlorophyll a, and secchi disc data for Ravine Lake.

	TP	Chl a	SD
1998			
May 21	60	45	56
May 28	66	55	67
June 18	69	63	73
July 2	64	51	65
July 9	67	54	67
July 16	66	50	70
July 29	67	52	63
Aug 13	70	56	67
Aug 27	72	47	70
Sept 24	69	60	73
Sept 26	68	59	73
Oct 8	62	55	67
1999			
April 30	59	61	70
May 14	55	43	56
May 27	51	47	56
June 10	55	42	54
June 24	57	51	46
July 14	64	61	77
July 22	61	54	60
Aug 5	61	61	65
Aug 17	63	55	70
Aug 26	60	60	65
Sept 9	64	52	65
Sept 16	65	50	55
Sept 30	62	66	60
Oct 14	63	56	62

	TP	Chl a	SD
2000			
April 14	57	48	59
April 28	57	53	62
May 23	65	44	54
June 8	63	56	70
June 19	67	59	65
July 19	71	64	73
Aug 3	72	67	73
Aug 16	73	67	73
Sept 1	76	68	77
Sept 14	67	69	70
Sept 29	69	47	59
Oct 11	67	56	62
2001			
April 18	57	50	55
May 4	63	67	65
May 16	65	65	65
May 30	57	49	56
June 15	71	54	77
June 29	72	65	77
July 13	72	60	77
July 25	72	69	73
Aug 8	75	70	83
Aug 21	74	68	77
Sept 6	75	72	77
Sept 18	74	69	83
Oct 4	71	64	73

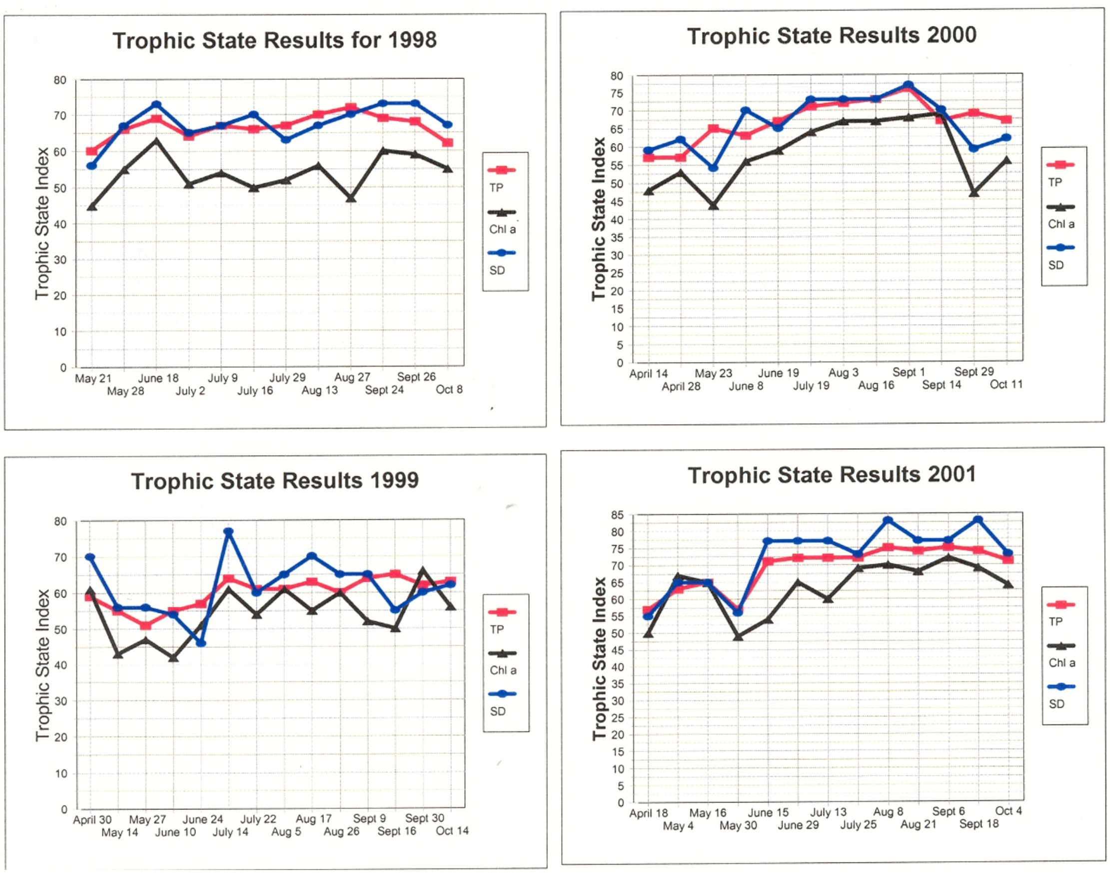


Figure 16. Water quality data from the 1998 through 2001 CAMP program were converted to Trophic State Index values and graphed. Chlorophyll (chl a) has been lower than expected compared to total phosphorus (TP) and secchi disc (SD) values.

4.4. Algae and Zooplankton

Algae in Ravine Lake in 2001, was a mix of blue-greens, greens, and diatoms (Figure 17). Aphanezomenon sp. was a dominant blue-green algae in August.

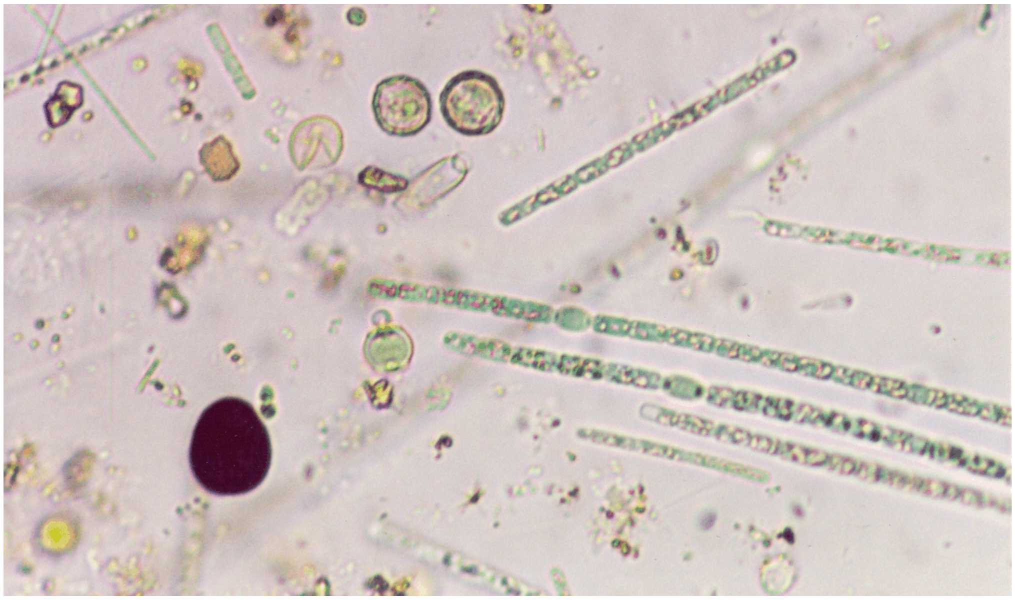


Figure 17. Ravine Lake algae from August 9, 2001. A mix of blue-green algae along with green algae and diatoms were present.

Zooplankton are in the crayfish family (Crustacea) and are an important component in the lake's food web. Zooplankton feed on algae, and in turn are fed upon by small fish. The zooplankton community found in 2000 and 2001 was typical of zooplankton assemblage typically found in small lakes (Table 15).

Table 15. Zooplankton counts for the summers of 2000 and 2001.

	6.2.00	9.12.00	8.9.01	10.26.01
Daphnids	327	38	14	2
Big	37	11	8	0
Little	0	12	6	1
Ceriodaphnia	0	0	0	0
Bosmina	290	11	0	1
Chydorus	0	5	0	0
Copepods	56	38	90	22
Calonoids	13	25	20	19
Cyclopoids	27	10	18	1
Nauplii	16	3	52	2
Rotifers	0	2	8	64
TOTAL	383	78	112	88

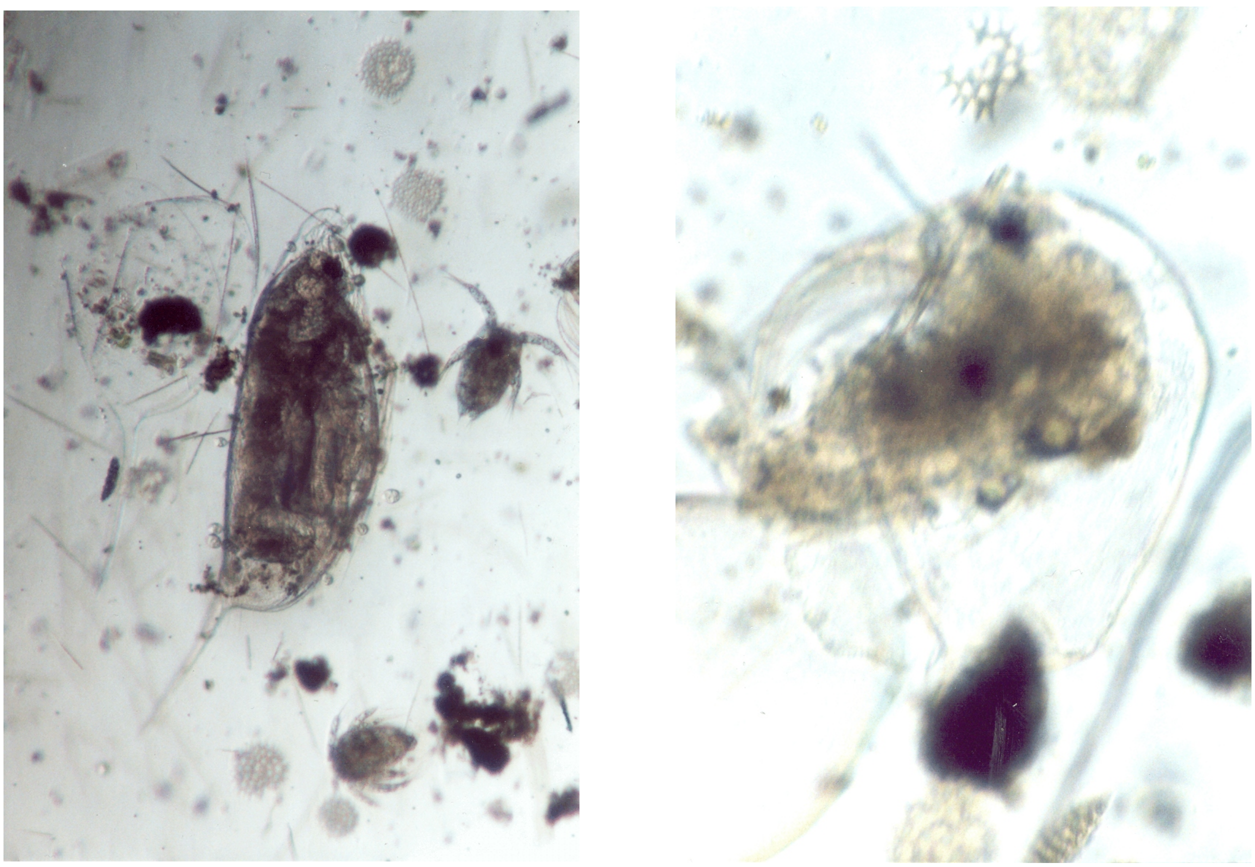


Figure 18. [left] A daphnia along with two smaller zooplankton that look like spiders which are nauplii. [right] An example of a Bosmina zooplankton, the dominant species in the June 2000 sample.

4.5. Aquatic Plants

Shoreland Plant Survey, 2000: A site visit was conducted on June 1, 2000 by Barbara Delaney, former Senior Ecologist and Botanist for the Minnesota DNR Natural Heritage Program and Elizabeth Gould, Botanist with EOR, to characterize shoreland and shallow water plants. The following is their report:

> The shoreland area and shallow water areas have a sandy substrate. Several aquatic plant species were observed including at least three Potamogeton*,* or pond-weeds. Flatstem pondweed (*Potamogeton zosteriformis),* leafy pondweed (*P. foliosus),* and Sago pondweed *(P. pectinatus*), all frequent at the northwest end of the lake. Additional aquatic plant species include two duckweeds (*Lemna minor, Spirodela polyrhiza*) and water meal (*Wolfia columbiana).*
>
> The lake beach community develops in areas exposed between the spring highwater mark and normal lake levels. Annual species such as smartweeds and beggars-ticks, as well as a species of grass, have colonized the mud flats and sand flats.
>
> *Disturbance Indicators:* The lake community is more notable for its lack of disturbance indicators rather than their presence. While reed canary grass does occur sporadically around the perimeter of the lake, most of the colonizing species in the mud- and beach-flat communities are apparently native. Similarly, the pondweeds identified are native species. Aggressive, non-native species such as curly pondweed or Eurasian water milfoil were not observed.
>
> *Wildlife Value:* The lake setting provides excellent wildlife habitat. There are numerous snags (standing dead timber) and dead fall around the perimeter of the lake. The dead fall provides excellent basking opportunities for turtles. The low-gradient shoreline, coupled with the downed logs, creates shallow pools for frog and salamander breeding. Wading birds, including great blue heron and green-backed heron, frequent the shoreline. Shorebirds forage on the mudflats and at the water's edge, and around most of the site, the adjacent woodlands persists up to the shoreline, and provides cover for a variety of bird species. The pondweeds are excellent duck food, and wood ducks, teal, and mallards all use the site.

Aquatic Plant Survey, 2001: An aquatic plant survey was conducted on Ravine Lake on June 15, 2001 by Blue Water Science.

Eight transects were made at different locations around Ravine Lake. A transect started at the weedline and headed into shore (Figure 19). Two depths on each transect were sampled with a rake to assess the aquatic plant composition. The amount of plants on the rake determined the density of each species at that location. Low density rated a “1" and a high density was a “5".

Five submerged aquatic plant species were identified (Table 16). Overall plant density is relatively low in Ravine Lake (Table 17).

Aquatic plant coverage is shown in Figure 19. Aquatic plants were found out to water depths of around 5 feet (Figure 19). Ravine Lake is below the theoretical 40% bottom coverage that has been found (in Florida by Dr. Dan Canfield) to sustain clear water.

Table 16. Ravine Lake aquatic plant occurrences and densities for the June 15, 2001 survey based on 8 transects and 2 depths, for a total of 16 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-2 feet (n=8)			Depth 3-4 feet (n=8)			All Stations (n=16)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Coontail (*Ceratophyllum demersum*)	--	--	--	1	13	0.5	1	6	0.5
Elodea (*Elodea canadensis*)	2	25	0.8	2	25	1.3	4	25	1
Flatstem pondweed (*P. sp*)	3	38	1	2	25	0.8	5	31	0.8
Sago pondweed (*P. pectinatus*)	4	50	1.3	1	13	1	5	31	1.2
Stringy pondweed (*P. pusillus*)	2	25	2.5	3	38	0.7	5	31	1.4
Filamentous algae	1	13	2	--	--	--	1	6	2

Table 17. Individual transect data for Ravine Lake for June 15, 2001.

	T1		T2		T3		T4	
	0-2	3-4	0-2	3-4	0-2	3-4	0-2	3-4
Coontail								
Elodea			0.5			1	1	
Flatstem pondweed			1		1	1	0.5	
Sago pondweed					1		1	
Stringy pondweed	3	0.5	2			0.5		
Filamentous algae	2							

	T5		T6		T7		T8	
	0-2	3-4	0-2	3-4	0-2	3-4	0-2	3-4
Coontail		0.5						
Elodea		1.5						
Flatstem pondweed				0.5				
Sago pondweed			1				2	1
Stringy pondweed		1						
Filamentous algae								

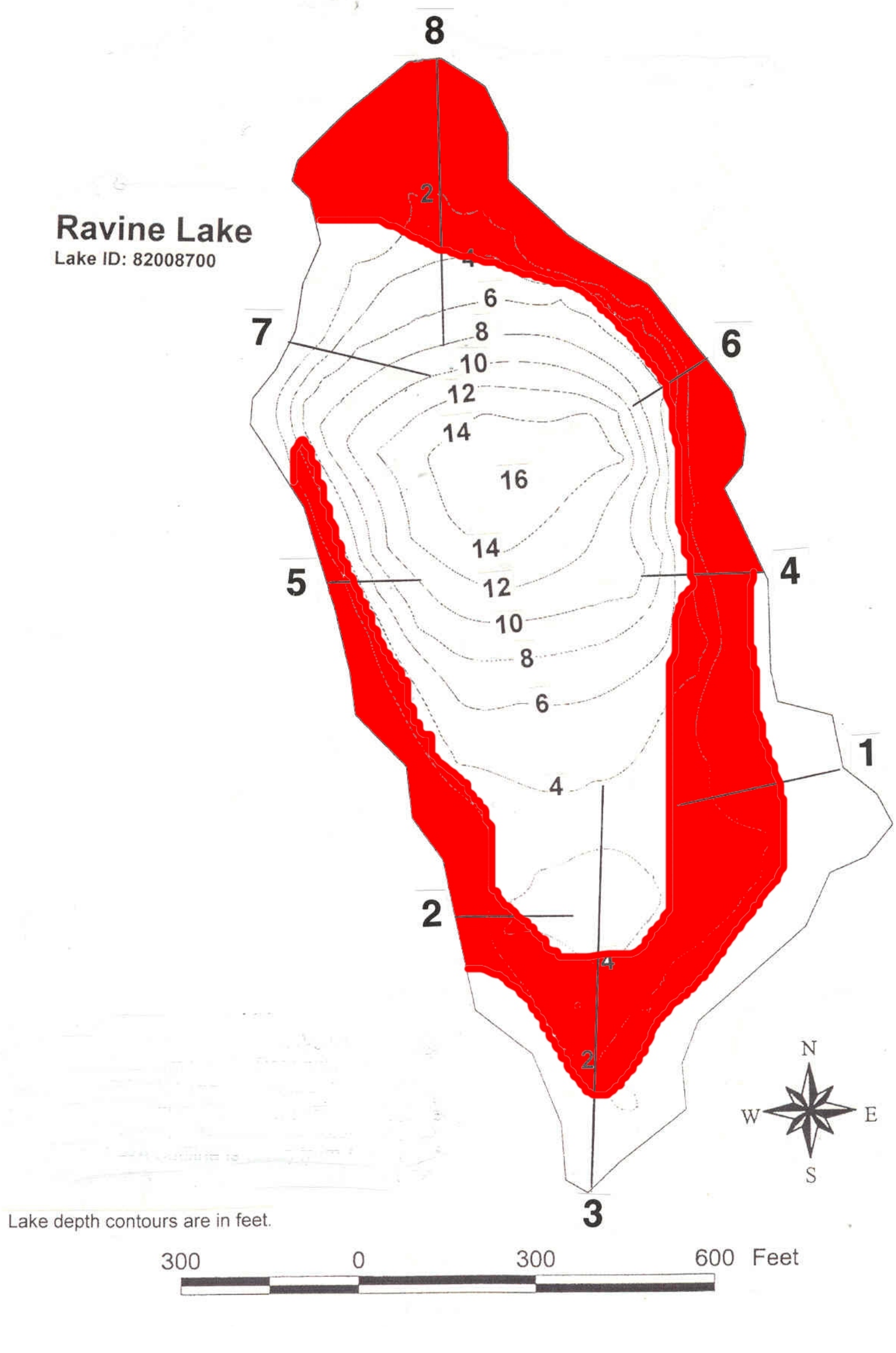
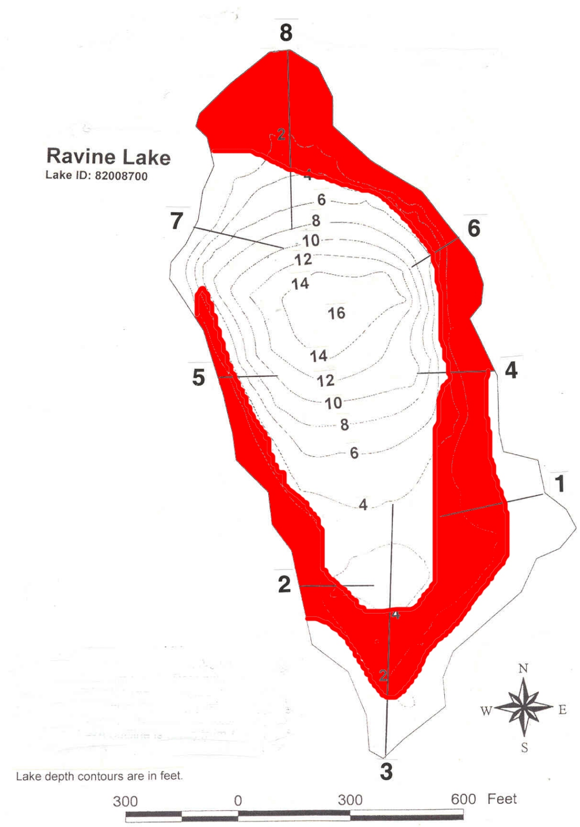


Figure 19. Transect map and aquatic plant coverage for Ravine Lake on June 15, 2001.

Example of the type of aquatic plants found in Ravine Lake is shown in Figure 20. Stringy pondweed, elodea, and sago pondweed were the most common plant species.

Figure 20. Stringy pondweed and filamentous algae sampled from Transect 1 during the aquatic plant survey on Ravine Lake.

Sonar graphs from a Lowrance X-16 depth finder used on transects during the aquatic plant survey are shown in Figure 21. Plant growth is sparse on the transects.



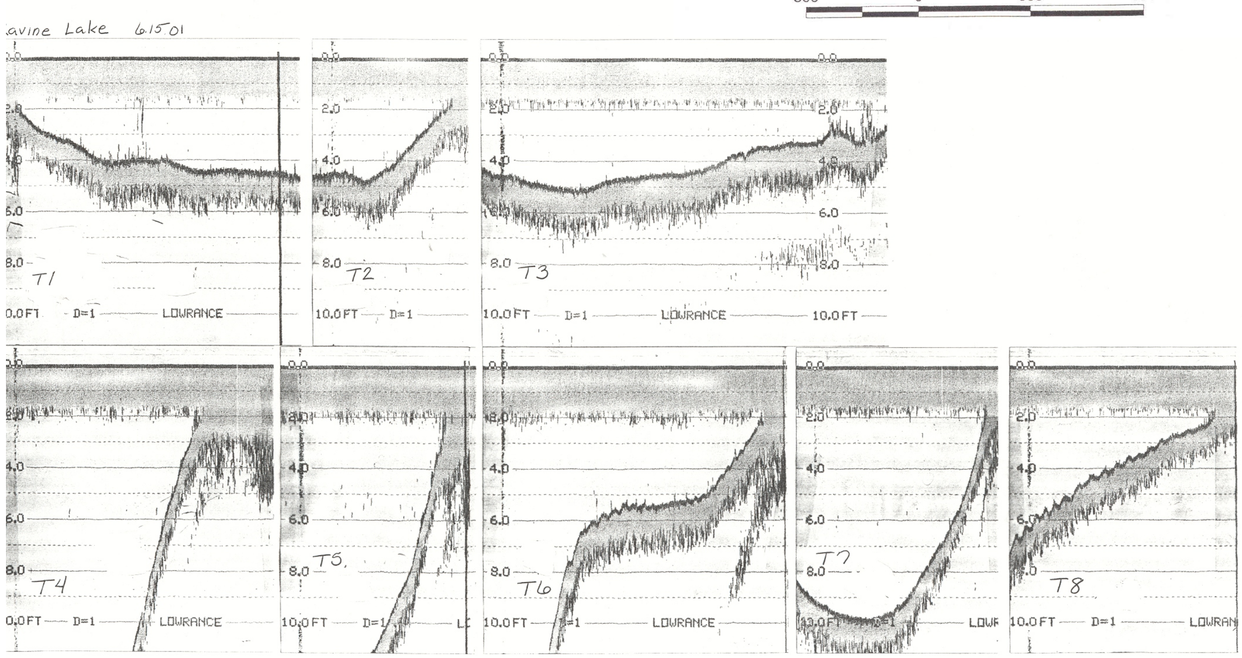


Figure 21. Sonar graphs of lake bottom over the eight transects used in the aquatic plant survey.

4.6. Fish

Notes on the first lake investigation, in 1961, indicated Ravine Lake has had some type of fish for some time. The MnDNR conducted a fish survey in 2001. Results are summarized in Table 18. Fish were sampled using trapnets (Figure 22) and gill nets.

Table 18. Fisheries data from the MnDNR fish survey conducted on August 8, 2001.

Species	Gear Used	Number of fish per set		Average Fish Weight (lbs)	Normal Range (lbs)
		Caught	Normal Range		
Black bullhead	gillnet	23.5	8-90	0.1	0.14-0.37
	trapnet	28.0	2.5-70.2	ND*	0.14-0.47
Goldfish	gillnet	1.0	NA**	0.16	NA
	trapnet	0.3	NA	0.02	NA
Green sunfish	gillnet	10.5	0.8-13.0	0.07	NA
	trapnet	10.4	0.35-3.75	0.09	0.08-0.19
Largemouth bass	trapnet	0.1	0.2-1.1	5.18	0.30-1.00
Walleye	gillnet	5.5	2.25-17.75	1.89	0.74-2.12
	trapnet	0.4	0.29-1.33	1.58	0.71-2.20
Painted turtle	trapnet	25.5	NA	ND	NA
Snapping turtle	trapnet	0.6	NA	ND	NA

*ND = no data
**NA = not available

Figure 22. Standard MnDNR trapnet being hauled into a boat. Fish are measured, weighed, and returned to the lake.

Ravine Lake was netted for the first time in 2001 to get current fish population information. The water level in Ravine Lake has been rising in recent years - creating more deep water compared to the 1960's when the depth was reported at 9 feet. Current lake size is 25 acres and maximum depth is 16 feet. The lake is fringed with flooded timber. There is no formal access, but carry-in access is possible from the parking lot. Limited shore fishing is also available.

Black bullheads were the most abundant species sampled. Lengths ranged from 7 to 10 inches, with an 8 inch average. Walleye were sampled in moderate numbers. Most fish were between 15 and 20 inches. The walleyes are fish that survived from a fry stocking in 1995, when the lake was used as a DNR rearing pond. One largemouth bass was sampled - it was 19 inches long and weighed 5.25 pounds and estimated to be 7 years old. Green sunfish were abundant - lengths ranged from 1.5 to 6.5 inches. Painted turtles were also abundant (Table 18).

Representative survey activities are shown in Figures 23 and 24.

Figure 23. [top] Fish are weighed.
[bottom] Fish are measured.

Figure 24. [top] Walleye was captured in a gillnet.
[bottom] Turtles were abundant. Here is a snapping turtle, but painted turtles were much more common.

5. Lake and Watershed Assessment

5.1. Watershed and Lake Status

Ravine Lake receives runoff from a watershed that has steep slopes, basically the runoff runs through a ravine. Although the total watershed area is about 3,300 acres, it appears only 800 acres actively drain to Ravine Lake. The other 2,500 acres do not appear to drain to Ravine Lake at this time.

The 800 acre watershed is referred to as the “active” watershed. The active watershed to lake area ratio is still 32 to 1 which is rather high and atypical for a glacial lake. This implies that Ravine Lake does not have a conventional glacial lake ice block origin, rather it is some type of depression enhanced with a blocked outlet and receives runoff from an unusually large watershed.

The dominant land use for the 800 acre watershed is in a pasture/grass category, which includes parkland and open space as well.

Even with this type of land use surrounding the lake, Ravine Lake still exhibits eutrophic conditions. The large contributing watershed delivers phosphorus at a mass loading that causes eutrophic conditions. In addition, the lake water column probably receives phosphorus from the lake sediments.

5.2. Watershed and Lake Models

A lake model for Ravine Lake was computed based on nutrient inputs under existing conditions from an 800 acre watershed. A summary of the model inputs and results is shown below in Table 19. The predicted phosphorus concentration from the Canfield-Bachman model for an artificial lake was 85 µg-P/l. The observed summer average concentration for 1998-2001 was 90 ppb. The observed lake phosphorus concentration was similar for the artificial lake model although all 13 lake models predict a eutrophic condition in Ravine Lake based on the 800 acre watershed. The Canfield-Bachman artificial lake model was the model selected as the model to work with watershed simulations and lake responses.

Table 19. Preliminary lake model simulation based on an 800 acre watershed and estimating land use. Input data are shown on the next two pages and the model predications are shown on the third page.

Ravine Lake

<u>Hydrologic and Morphometric Data</u>

Tributary Drainage Area: 786.0 acre
Total Unit Runoff: 3.5 in.
Annual Runoff Volume: 229.3 acre-ft
Lake Surface Area <As>: 25 acre
Lake Volume <V>: 175 acre-ft
Lake Mean Depth <z>: 7.0 ft
Precipitation - Evaporation: 0.0 in.
Hydraulic Loading: 229.3 acre-ft/year
Areal Water Load <qs>: 9.2 ft/year
Lake Flushing Rate <p>: 1.31 1/year
Water Residence Time: 0.76 year
Observed spring overturn total phosphorus (SPO): 57 mg/m^3
Observed growing season mean phosphorus (GSM): 106 mg/m^3
% Phosphorus Reduction: 0%

NON-POINT SOURCE DATA

Land Use	Acre (ac)	Low	Most Likely	High	Loading %	Low	Most Likely	High
		Loading (kg/ha-year)				Loading (kg/year)		
Row Crop AG	0.0	0.50	1.00	3.00	0.0	0	0	0
Mixed AG	50	0.30	0.80	1.40	21.8	16	20	28
Pasture/Grass	500	0.10	0.30	0.50	65.3	20	61	101
HD Urban	0.0	1.00	1.50	2.00	0.0	0	0	0
MD Urban	50	0.30	0.50	0.80	2.0	8	2	16
Rural Residential	100	0.05	0.10	0.25	4.4	2	4	10
Wetlands	84	0.10	0.10	0.10	3.7	3	3	3
Forest	0.0	0.05	0.09	0.18	0.0	0	0	0
Lake Surface	25.0	0.10	0.30	1.00	2.9	1	3	10

POINT SOURCE DATA

Point Sources	Water Load (m^3/year)	Low (kg/year)	Most Likely (kg/year)	High (kg/year)	Loading %
User Defined 1	0.0	0.0	0.0	0.0	0.0
User Defined 2	0.0	0.0	0.0	0.0	0.0
User Defined 3	0.0	0.0	0.0	0.0	0.0
User Defined 4	0.0	0.0	0.0	0.0	0.0
User Defined 5	0.0	0.0	0.0	0.0	0.0
User Defined 6	0.0	0.0	0.0	0.0	0.0

SEPTIC TANK DATA

Description		Low	Most Likely	High	Loading %
Septic Tank Output (kg/capita-year)		0.3	0.5	0.8	
# capita-years	0.0				
% Phosphorous Retained by Soil		98	90	80	
Septic Tank Loading (kg/year)		0.00	0.00	0.00	0.0

TOTALS DATA

Description	Low	Most Likely	High	Loading %
Total Loading (lb)	112.3	204.9	373.3	100.0
Total Loading (kg)	51.0	92.9	169.3	100.0
Areal Loading (lb/ac-year)	4.49	8.20	14.93	0.0
Areal Loading (mg/m^2-year)	503.62	918.63	1673.66	0.0

[Land use breakdown for the 800 acre watershed is estimated above. The dominant land use is the pasture/grass category, which includes parkland and open space as well. The total predicted annual phosphorus loading to Ravine Lake is 204.9 pounds of phosphorus per year.]

Phosphorus Prediction and Uncertainty Analysis Module

Observed spring overturn total phosphorus (SPO): 57.0 mg/m^3
Observed growing season mean phosphorus (GSM): 90.0 mg/m^3
Back calculation for SPO total phosphorus: 50 mg/m^3
Back calculation GSM phosphorus: 50 mg/m^3
% Confidence Range: 70%
Nurenberg Model Input - Est. Gross Int. Loading: 0 kg

Lake Phosphorus Model	**Low** Total P (mg/m^3)	**Most Likely** Total P (mg/m^3)	**High** Total P (mg/m^3)	**Predicted** -Observed (mg/m^3)	**% Dif.**
1. Walker, 1987 Reservoir	55	101	183	44	77
2. Canfield-Bachmann, 1981 Natural Lake	84	136	218	79	139
3. Canfield-Bachmann, 1981 Artificial Lake	59	85	118	28	49
4. Rechow, 1979 General	34	61	112	-45	-42
5. Rechow, 1977 Anoxic	143	261	475	155	146
6. Rechow, 1977 water load<50m/year	81	148	270	42	40
7. Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A
8. Walker, 1977 General	104	190	346	133	233
9. Vollenweider, 1982 Combined OECD	66	107	175	26	32
10. Dillon-Rigler-Kirchner	47	86	157	29	51
11. Vollenweider, 1982 Shallow Lake/Res.	57	96	163	15	18
12. Larsen-Mercier, 1976	96	175	320	118	207
13. Nurnberg, 1984 Oxic	50	92	167	-14	-13

Lake Phosphorus Model	**Confidence** Lower Bound	**Confidence** Upper Bound	**Parameter** Fit?	**Back** Calculation (kg/year)	**Model** Type
Walker, 1987 Reservoir	61	163	FIT	46	GSM
Canfield-Bachmann, 1981 Natural Lake	42	392	FIT	28	SPO
Canfield-Bachmann, 1981 Artificial Lake	26	245	FIT	39	SPO
Rechow, 1979 General	36	101	FIT	76	GSM
Rechow, 1977 Anoxic	162	418	FIT	18	GSM
Rechow, 1977 water load<50m/year	88	243	P Pin	31	GSM
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	98	337	FIT	24	SPO
Vollenweider, 1982 Combined OECD	54	190	FIT	37	ANN
Dillon-Rigler-Kirchner	53	138	P	54	SPO
Vollenweider, 1982 Shallow Lake/Res.	49	170	FIT	45	ANN
Larsen-Mercier, 1976	112	277	P Pin	26	SPO
Nurnberg, 1984 Oxic	50	158	P	51	ANN

[Thirteen different lake models are run with this lake model program using the same input data. Results vary. The Canfield-Bachman artificial lake model (model #3) is appropriate for this application. The Dillon-Rigler-Kirchner model (model #10) is sometimes used as well.]

Ths lake model was also run using the full 3,300 acre watershed under existing land use. Predicted lake results for the 800 acre and the 3,300 acre watershed are shown in Table 20.

Table 20. Predicted Ravine Lake phosphorus concentrations based on existing land use and showing results for an 800 acre watershed and a 3,300 acre watershed.

	800 acre watershed	3,300 acre watershed
Estimated P load:	205 pounds	880 pounds
3) Canfield Bachman Artificial Lake	85 ppb	119 ppb
10) Dillon-Rigler-Kirchner	86 ppb	159 ppb

The best fit of the model run was using an 800 acre watershed and the Canfield-Bachmann artificial lake model. The lake model predicted a lake phosphorus concentration of 85 ppb and 90 was the observed concentration. When using the larger watershed acreage, the predicted lake phosphorus concentration is 119 ppb, which is higher than the observed 90 ppb. It appears that the 800 acre watershed contributions can account for the observed lake conditions.

Matt Moore, South Washington Watershed District Administrator, stands by a culvert in subwatershed RL-2, located in the northwest portion of the subwatershed. Not much, if any, runoff from this part of the watershed makes it to Ravine Lake.

5.3. What Will Ravine Lake Look Like in the Future?

Lake models can be run that estimate what a lake phosphorus concentration would be if runoff phosphorus concentrations were at ecoregion values. Ecoregion stream phosphorus values are about 150 ppb. Two lake models were run using a small and a large watershed and using ecoregion stream concentrations of 150 ppb. Results are shown in Table 21.

Table 21. Predicted Ravine Lake phosphorus concentrations using an ecoregion model.

	Estimated Phosphorus Loading	Ecoregion Lake Phosphorus Concentration*
Ecoregion phosphorus conc with an 800-acre watershed	65kg or 149 lbs	72
Ecoregion phosphorus concentration with a 3,300-acre watershed	263 kg or 585 lbs	91

* using a Canfield-Bachman artificial lake model

Results indicate that the Ravine Lake with the 800 acre watershed would have slightly better water quality at ecoregion watershed loading rates compared to the observed lake concentration, although the lake would still be eutrophic.

Because the watershed area to lake ratio is high for either the 800 acre or the 3,300 acre watershed we would predict eutrophic conditions even if Ravine Lake had ecoregion stream runoff loads entering the lake.

Although Ravine Lake will have midsummer algae blooms and probably not be a desirable swimming lake, it will support an adequate fishery and a substantial wildlife base.

6. Lake Management Projects

The objective of the lake management program is to maintain a lake environment that is the best it can be at a reasonable cost. Modeling results indicate that even at ecoregion runoff values Ravine Lake will still be eutrophic. The recommended projects help ensure that the lake environment is optimized although it will still be eutrophic.

Lake management projects are grouped into two categories: watershed projects and lake projects. Three projects address watershed topics and four projects are geared to the lake (Table 22).

Table 22. List of management projects.

	Costs
1. Erosion control in Ravine Stream channels.	$65/foot of streambank improvement.
2. Stormwater management in developing areas.	Incorporated into existing programs.
3. Preserving natural shoreland areas around Ravine Lake.	Maintenance costs are only costs needed.
4. Coordinate fish projects for Ravine Lake with Washington County Parks.	$30,000 or more depending if a fishing pier is installed.
5. Winter and summer aeration system	$12,000 for winter aeration, $35,000 if summer aeration is installed.
6. Alum sediment treatment in the future.	$20,000
7. Designate the lake a non-motorized (carry-in only) lake.	n/c

Project 1. Erosion control in ravine stream channels

Because of a steep gradient, ravines will experience erosion. The question is when is erosion excessive?

Several stretches of "Ravine Stream" show bank cutting that probably could be controlled.

Listed below are ravine erosion control ideas excerpted from the "Lake and Pond Management Guidebook" written by Steve McComas (2003).

1.4 GULLY AND STREAMBANK EROSION CONTROL

Streams and ravines are natural channels that convey water to lakes and ponds. These channels are stable when hydrologic conditions such as rainfall, climate, watershed size and runoff have remained constant for some time.

Even streams with low base flow can cause significant bank erosion. (From USDA)

But when any of the hydrological parameters change, the channel configuration will change to find a new equilibrium. This often results in streambank or gully erosion, bringing excessive amounts of sediments and nutrients into a lake.

Steps can be taken to control streambank and gully erosion. The trick is to select the right combination of projects to produce a successful and sustainable solution. These projects require specialized expertise, generally organized at the community level. However, volunteers can help install the improvements.

A streambank or gully improvement project is a three-step process. The first step is to determine the causes of excessive erosion. The next step is to select the correct projects to fix the problem; and the final step is to install the projects.

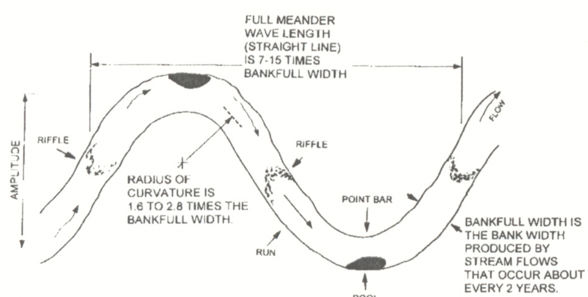
If there is a streambank or ravine erosion problem, use a checklist to determine the sources of the problem:

- Have watershed conditions changed recently? For example, are more new homes being built, with new storm sewers or water diversions resulting in more or less flow down the channel?
- Is bank or gully erosion coming from overbank flows? Check culvert outfalls that discharge over stream banks and the downspout locations on homes near the stream or ravine.
- Are there springs in the hillside?
- What kind of groundcover exists in the area? Are there bare spots?
- What is the condition of the streamside canopy? Is it lined with trees supporting a full canopy? Or do openings allow sunlight to reach the banks or gully?

Then the checklist moves into the channel:

- Examine similar stream stretches that are not eroding. What is the stream width, water depth, vegetation cover, water flow rate, slope or gradient, sediment size in the streambed, and existing bank material?
- Then, examine stream stretches with erosion problems; gather the same information collected in the good stretch and make comparisons.

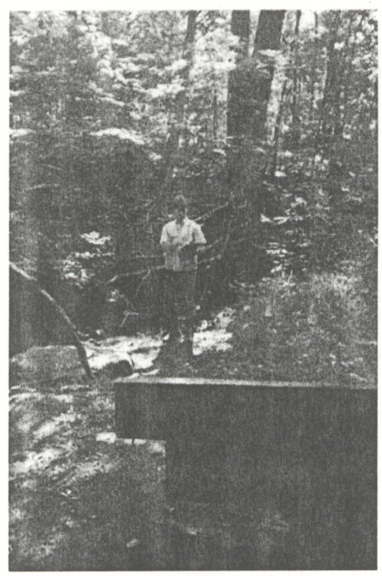
From this information, apply the "rules of the river." The bends in a stream are referred to as meanders. The relationship between the width of the stream and the distance between meanders has been well documented.



A few "rules of the river" are illustrated above. If the stream meanders are not in a stable configuration, then it is helpful to remeander the stream if possible. Once the meander is stable, then streambank erosion control methods will be effective. (Adapted from Newbury, R.W. and Gaboury, M.N., Stream Analysis and Fish Habitat Design—A Field Manual, *Newbury Hydraulics Ltd., Gibsons, British Columbia, Canada, 1993.)*

This urban stream suffered damage from overland runoff coming from nearby roof downspouts. Redirecting overland flow will reduce streambank erosion.

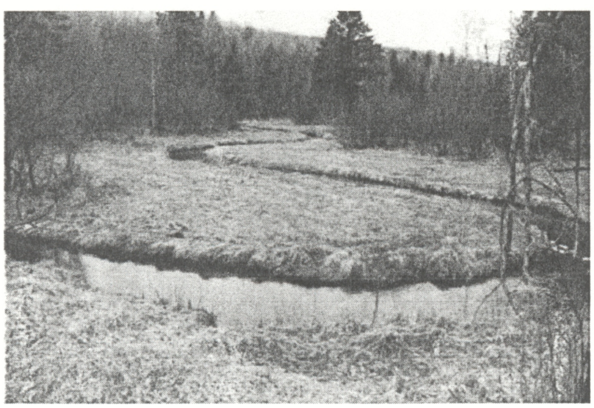
When hydrologists apply the "rules of the river," they can determine if the meanders are stable or how they will meander in the future. Severe bank erosion is really the result of the stream working to reestablish equilibrium with flow and site conditions.



To fix eroding streambank problems, first check stream channel characteristics and see if the stream complies with the "rules of the river." The problem with this urban stream was an increase in stormwater runoff, coupled with some misplaced flow diversion structures. The change in hydrology resulted in aggressive erosion.

An increase in flow due to an increase in impervious surfaces in this urbanizing watershed was largely responsible for the bank cutting in this situation. The channel needs to be remeandered to achieve stability. Then the banks can be reshaped and revegetated.

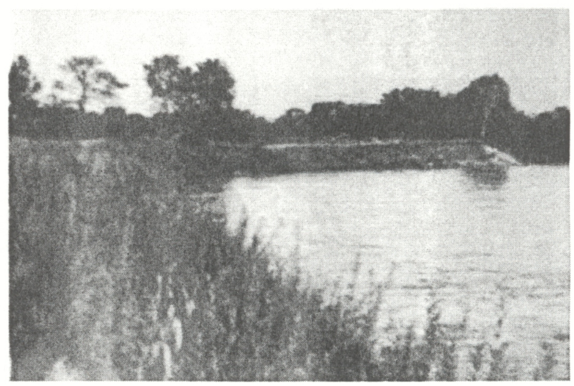
For some stream improvement projects, the first task is to remeander it using a backhoe or bulldozer. Then, the new curves in the stream should be relatively stable because they are now in equilibrium with the flow. As a result, stabilization has a better chance of success.



Under stable flow conditions, a stream channel and meanders will be relatively stable and minimal streambank erosion will occur.

Vegetation was used in the 1930s for stabilization, but gave way to rock and concrete in succeeding decades. However, in the 1990s, vegetation made a comeback and was used in combination with rock or the equivalent to stabilize streambanks and gullies.

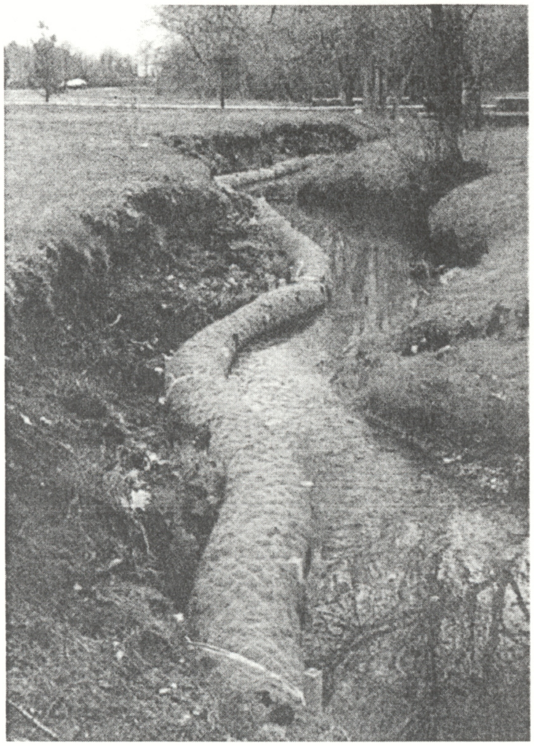
That's History...



"Streambank erosion control project: (top) Existing conditions in 1937. (bottom) Same bank in 1938. Improvements included protecting toe of slope with riprap, reshaping the bank, brush-matted and planted with willows." (From Edminster et al., 1949.)

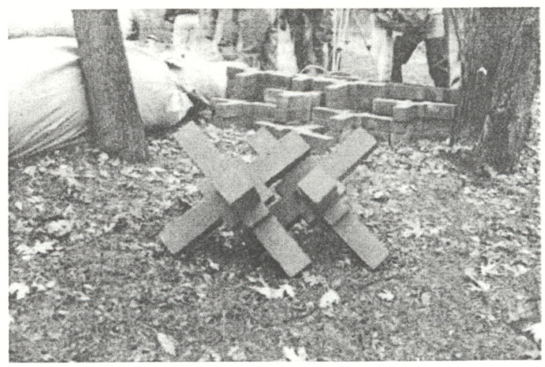
Structural protection, such as root wads, native stone, or cement A-jacks, is commonly used at the base of the bank, called the toe, up to the waterline. Then a combination of bank reshaping and vegetation is used above the waterline.

With training, volunteers can help install biostabilization practices outlined below.



Coir fiber rolls can be used to stabilize the toe of a streambank. Bank reshaping and reseeding will complete the stabilization project. Coir fiber rolls are composed of loose coconut fiber from coconut husks, held together with coir fiber netting. In higher energy environments, rock is used. (From Don Knezick, Pinelands Nursury, Columbus, NJ. With permission.)

Here is the same stream 1 year later. Vegetation is growing up through the rock, which will actually increase stability.



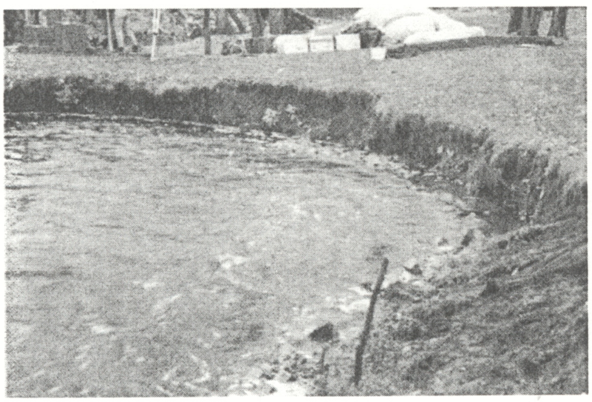
Another type of structural toe protection is the use of A-jacks. They are a good energy dissipater. As with rock riprap, they are permanent.

Rock can be used to stabilize the toe of a streambank where there are high flows.

A-jacks interlock and will not roll as easily as rock riprap. Eventually, soil and other materials will fill in behind the A-jacks.

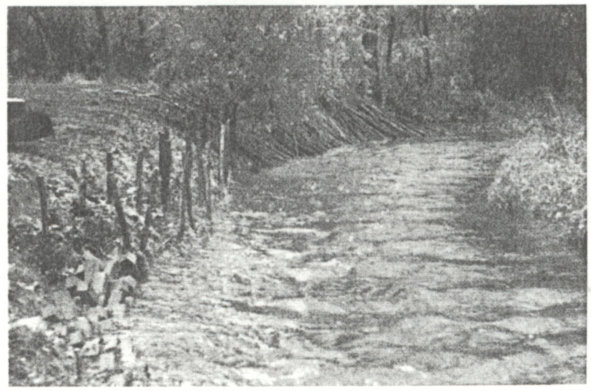
To stabilize the toe below the waterline, consider the following options:

- Coir fiber rolls (2 to 3 years of protection, then vegetation should be in place to stabilize the bank)
- Root wads (long-term protection)
- Natural stone (long-term protection)
- A-jacks (long-term protection)



After toe protection is in place, the next step is to reshape the unstable bank.

Reshaping the bank can be done by hand or with equipment. In this case, a backhoe is reshaping the streambank, followed by the placement of willow posts. An auger on the end of a bobcat drills holes for the willow posts.



Willow posts and willow stakes are used to help stabilize streambanks. Their root systems stabilize the soil. Willows are often acquired from river floodplain areas. They are left soaking in water until they are used. They should be cut and inserted into the ground as soon as possible.

After inserting the willow posts, they can be cut off at 1 to 2 feet above the ground. Erosion control matting is laid down on the reshaped banks to reduce erosion.

To stabilize the bank *above* the waterline, you can:

- Reshape the bank.
- Remove some of the canopy to allow sunlight to reach the bank (unless it is a trout stream; then you want shade).
- Install erosion control fabric with native plantings.
- Insert willow posts or stakes for erosion control.
- Use wattles (same as live fascines). A wattle or live fascine is a bundle of willow twigs (6 to 8 inches in diameter and 6 to 8 feet long) staked on the slope contour with spacing of the rows 3 to 5 feet apart up the slope.

Gully erosion is another form of streambank erosion. The keys to stabilization are to stop head cutting, reduce the gradient, and revegetate.

Reducing the gradient in gullies or ravines reduces the erosive force of the water flows. Grade control structures such as this rock weir reduce flow velocities and allow a streambank to reestablish vegetation and stabilize. The rock weir is constructed in the shape of an arc with the high point oriented upstream.

To control gully or ravine erosion, take the same basic approach with a couple of additional considerations:

- Stopping the head cutting is a key element. Consider diversion as a first option.
- Consider using rock weirs or check dams to flatten the gradient; these grade controls slow the water velocity.

That's History...

"Series of loose rock dams in a farm gully." (From Ayres, Q.C., *Soil and Erosion Control*, McGraw-Hill, New York, 1936.)

Reducing erosion may allow vegetation to become established in the head cut area. However, if a dense canopy is preventing understory growth, you may have to partially remove the canopy.

Removing some of the overlying dense forest canopy in gullies or ravines allows sunlight to penetrate to the ravine soils and reestablish ground cover.

Project 2. Stormwater management in developing areas

Residential development will increase in the watershed in the future. Because several cities have land in the watershed, the Watershed District is in a good position to facilitate stormwater management operations in the Ravine Lake watershed.

This management framework is already being implemented and should continue into the future. This is a critical component to maintaining the fish and wildlife aspects of Ravine Lake. Because Ravine Lake is eutrophic, standard watershed practices represent a sufficient level of effort for managing the Ravine Lake water resource.

Project 3. Preserving natural shoreland areas around Ravine Lake

A functional upland buffer should be at least 15 feet wide. With this you start getting water quality and wildlife habitat benefits. But a 25 foot wide buffer is recommended. Most of the Ravine Lake shoreline is well buffered.

A buffer strip can address two problem areas right away. Geese are shy about walking through tall grass because of the threat of predators. There will always be a few who charge right through but it is a deterrent for most of them. Also, muskrats shouldn't be a problem. They may burrow into the bank, but generally not more then 10 feet. With a buffer going back 15 to 25 feet, there won't be mowing over their dens and an occasional den shouldn't produce muskrat densities that limit desirable aquatic vegetation.

Ravine Lake has three primary buffer types:

Tall grass, sedge, flower buffer: Provides nesting cover for mallards, blue-winged teal and Canada geese. Provides above ground nesting habitat for sedge wrens, common yellow throat and others.

Shrub and brush buffer: Provides nesting habitat for lakeside songbirds such as yellow warblers, common yellowthroat, swamp sparrows, and flycatchers. It also provides significant cover during migration.

Forested buffers: Provides habitat for nesting warblers and yellow-throated vireo, green herons, woodducks, hocked mergansers, and others. Upland birds such as red-winged blackbirds, orioles, and woodpeckers use the forest edge for nesting and feeding habitat.

Even standing dead trees, which are referred to as snags, have a critical role. When they are left standing they serve as perching sites for kingfishers and provide nesting sites for herons, egrets, eagles, and ospreys. In the midwest over 40 bird species and 25 mammal species use snags. To be useful, they should be at least 15 feet tall and 6-inches in diameter.

The shoreland area around Ravine Lake should be protected. A fishing pier and walk-in access points can be placed to minimize shoreland disruption.

Project 4. Coordinate fish projects for Ravine Lake (from MnDNR)

The following is a listing of some of the potential things that could be done to make Ravine a more viable fishing resource. This is not an exhaustive list and should not be taken as a list of action items or "must do" tasks. The list was compiled by the MnDNR.

What	When	Who
Year 1		
Stock black crappies.	Late April or early May.	DNR
Designate and "clear" fishing sites along shore.	Spring or early summer.	DNR & county
Article in local press.	Spring.	County
Signage/postings at lake and other appropriate places.	Spring,	DNR & county
Include Ravine in the "Fishing Downtown" web page on DNR site.	Late winter or spring.	DNR
Include in Park & Rec web page on county website??	Late winter or spring.	County
Year 2 and Beyond		
Continued panfish stocking.	Annual or multi-annual.	DNR
Stock other species.	When appropriate.	DNR
Fishing pier or shore structures.	When appropriate.	DNR & county
Monitor winter DO.	Monthly in winter.	DNR
Winter aeration.	If needed.	DNR & county
Alum or rotenone reclamation.	When appropriate based on outcome of drainage modification.	DNR & county

Project 5. Winter and summer aeration system

Winter aeration is an option for sustaining the lake fishery. One of the findings of this study was that incoming groundwater apparently aerates a small volume of lake and keeps some fish alive.

If winter aeration is considered, I would recommend the diffusion aerator style. Listed below are several winter aeration options excerpted from the "Lake and Pond Management Guidebook", written by Steve McComas (2003).

Summer aeration could theoretically be employed to reduce internal phosphorus release. If winter aeration is to be employed, it should be sized to accommodate the possibility of employing a summer aeration option.

4.4.4.3 Winter Aeration

Aerating the lake or pond in the winter is a direct way to maintain dissolved oxygen levels in a lake. A typical winter aeration system operates for about 2 months or longer over the winter, depending on specific lake and weather conditions.

The objective of a winter aeration project is not to aerate the entire lake, but rather to set up an oxygen-rich refuge in part of the lake to allow fish to survive the ice-covered days until breakup. As a rule of thumb, at least 10% of the volume of the lake should be aerated to prevent winterkill. When the ice breaks up, the wind-mixing action quickly re-aerates the entire lake.

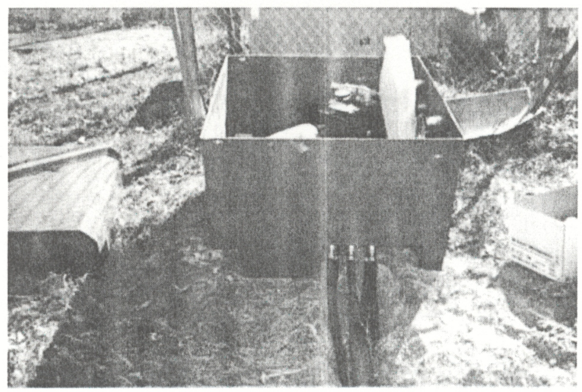
That's History…

Winter aeration efforts in the 1930s attempted to reaerate a portion of the lake volume. The same basic approach is used today. (From Hubbs, C.L. and Eschmeyer, R.W., The Improvement of Lakes for Fishing, *Bulletin of the Institute for Fisheries Research (Michigan Department of Conservation),* No. 2, University of Michigan, Ann Arbor, 1937.)

How do you know if winter aeration is necessary? Consulting past records of fishkills is one way. Also, are there old fish in the lake? If there are, this indicates winterkill may occur infrequently. If no data are available, measure dissolved oxygen levels throughout a winter. If oxygen levels rapidly decline and approach 2 mg/L or less, the lake is potentially a winterkill lake and is an aeration candidate. Aeration is probably too late for that year, but plan ahead and have a system ready to go for the following winter.

You may need an aeration permit, so check with state agencies before using aeration. You will probably need liability insurance; typical coverage ($500,000) starts at about $400 for a basic policy.

Several types of aeration systems are available.



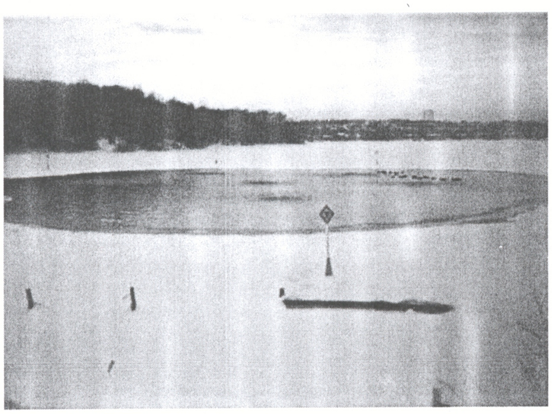
Like the conventional aeration systems described in Chapter 2, the air compressors used for winter aeration are contained in onshore housing, with air lines going out into the lake to diffuser heads.

4.4.4.3.1 Diffusion or Bubbler Aerators

Diffusion aerators release compressed air at the lake bottom. The air bubbles push water upward and open up a hole in the ice that exposes the upwelling lake water to the atmosphere for reaeration. These are the same aerators described in Chapter 2 for algae control.

Winterkill prevention aeration systems are sized according to lake conditions. For example, a 100-acre eutrophic lake will use two 1-hp air compressors to operate six diffuser heads clustered in a star-shaped pattern with a diffuser in the middle. The diffuser heads are spaced about 100 feet apart and located near the shore. A standard diffuser head will open about a 50-foot radius hole in the ice. If the diffuser heads are grouped together, you will open one large hole (about 300 × 200 feet) in the ice. Be sure to place warning signs at public access points and around the open water.

Winter diffuser aeration system operating on a 75-acre lake. An aerial view shows seven diffuser heads spread around the lake with the intent of aerating small pockets in the lake. (From H.B. Huller, Company Nature Reserve, Vadnais Heights, MN.)



This winter diffuser aeration system has grouped together six diffuser heads and opened up a large hole in a 100-acre lake. For winter aeration, creating one large opening in the ice is better than creating several smaller ones.

The cost for a system like this is about $13,000. It is usually not configured to be effective for summer algae control. Rarely is the same diffuser aeration system used in summer and winter. Summer aerators are used to destratify a lake, implying it has some depth, making winterkill unlikely. Winter aeration is used in shallow lakes. These lakes probably do not stratify during the summer and, thus, would not need summer aeration. If shallow lakes have summer algae blooms, implementing phosphorus reduction techniques other than aeration are likely necessary.

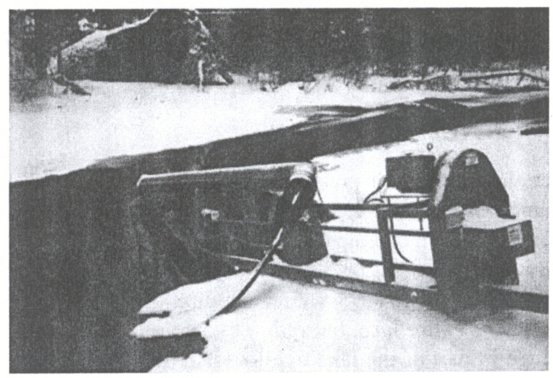
Solar-powered diffusion aerators may work for ponds if they have enough bubbling action to keep a hole open, but are underpowered for large lakes.

4.4.4.3.2 Pump and Baffle Aerators

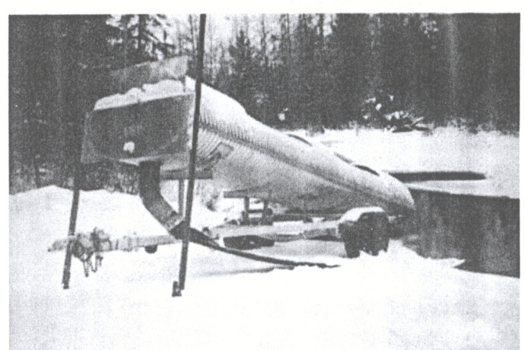
Another aeration system, designed just for winter use, is a pump and baffle aerator. It extracts oxygen-poor water from the nearshore area and pumps it to the top of a chute located on shore. As the water cascades over a set of baffles in the chute, it reaerates, while also releasing nasty gases such as hydrogen sulfide and methane. The reoxygenated water is returned to another area of the lake away from the intake, creating a zone of oxygen-rich water that fish will find and occupy.

A typical pump and baffle system has a 4-, 6-, or 8-inch pump that usually runs off a 5- to 30-horsepower electric motor. Gasoline-powered pumps can also be used. An intake line is placed in the lake and lake water is sucked in by the pump and discharged through a pipe or discharge hose to the top of the chute or the flume. The chute, which is often enclosed, ranges from 2 to 3 feet wide and 12 to 16 feet long. Several wooden boards in the chute act as baffles. As water runs down, the turbulence helps reaerate the lake water.

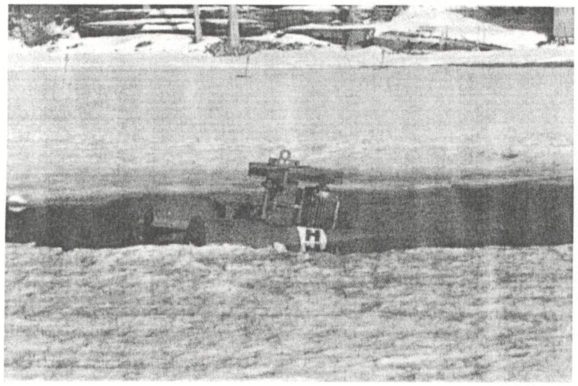
The pump and baffle system has a significant safety feature: only a small area of the lake, at the intake and at the discharge, is open during operation. Another feature of the pump and baffle is its mobility. The chute is mounted on a trailer and can be moved from one lake to another or to different areas around the lake.



The pump-and-baffle system can be temporary or permanent. This is a temporary installation. The intake is placed in shallow water and water is pumped up to a baffle component. In this case, the objective was to boost oxygen levels in a stream that was leaving a lake low in oxygen. Then the reaerated stream water flowed into the downstream lake and gave it an oxygen boost. (From Frank Splitt, Ballard Lake, WI.)



The water flows over boards inside this tube. The reaerated water was returned to the stream. This was a Crisifulli Company setup. (From Frank Splitt, Ballard Lake, WI.)



Another style of pump-and baffle-system uses an intake mounted on a floating platform. The hydraulic pump delivers low oxygenated lake water to the baffle component.

Lake water goes in at the top of the baffle and cascades back into the lake. (From City of Lakeville, Minnesota.)

When the pump-and-baffle system is built into a hillside and uses natural rock for baffles, it mimics a bubbling brook. It looks natural and is a permanent setup, but can cost $30,000 or more.

Reaeration occurs as water tumbles down the hillside. There is some open water at the discharge site.

All major pieces of equipment are on shore, so there is no need to worry about the system falling through the ice.

This system works well in lakes of 200 acres or less. For large lakes, you would probably need additional systems.

During its operation, you should check the system at least once a day to make sure the equipment is operating properly. Because of its exposure to frigid winter temperatures, the system can freeze up at the intake, in the flume, or at the discharge to the lake. Sometimes, the chute or the flume gets top-heavy from ice buildup and falls over.

An important operating step is to determine the pumping rate of the lake water. The goal is to add reaerated water to the lake at just the right velocity to create a pool of oxygen-rich water. However, if the inflow velocity is too slow, not enough water will be introduced to create a large enough oxygen-rich pool.

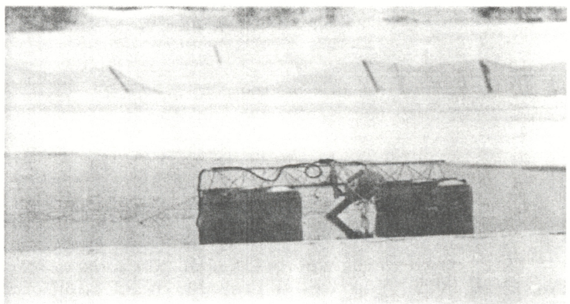
Conversely, if too much water is pumped and the discharge velocity is too high, it may entrain too much oxygen-poor lake water. That could result in slightly elevated oxygen levels in a large volume of water (e.g., from 1.0 to 1.5 ppm), rather than fulfilling the objective of producing highly oxygenated levels in a smaller volume.

When the aim is to aerate 10% of the volume of the lake, you can estimate a pumping requirement. For example, if a lake has a surface area of 100 acres with an average depth of 6 feet, the lake's volume is 600 acre-feet of water. You want to aerate 10% of the volume, or 60 acre-feet, roughly 19.5 million gallons of water.

Although this sounds like a lot, a pump with a 6-inch-diameter intake can handle 2.3 million gallons a day.

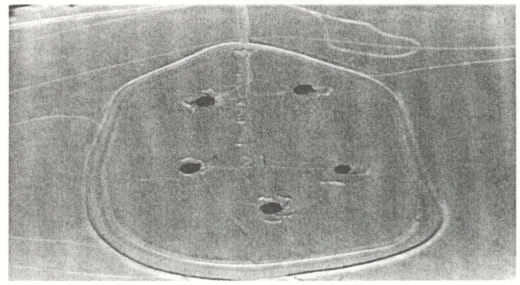
Theoretically, in 10 days, this pump and baffle system could create a suitable refuge and then maintain it.

One manufacturer of a pump and baffle system is the Crisafulli Pump Company, Inc., (Crisafulli Drive, Glendive, MT 59330; Tel: 406-365-3393). They can supply the entire rig, which starts at about $13,000. A typical system runs off a 10- to 20-hp motor with a 6- or 8-inch pump that delivers between 1600 and 3000 gallons per minute. Electrical costs average about $5 to $12 per day. If two or more pumps are needed, costs double.



This is a jet aerator. It shoots a water jet, creating moving water, and maintains open water. These aerators are prone to freezing up and create thin ice conditions at uncertain distances from the open water.

There are no guarantees that winter aeration will work in every case. Early ice-up and heavy snows will produce severe winterkill conditions. In the lake above, winter aeration did not keep dissolved oxygen levels high enough, and there was a fishkill, resulting in a fish buffet for area wildlife.



The question of dredging or aerating for winterkill protection occasionally arises. For large lakes, it is cheaper to aerate. (From Minnesota Department of Natural Resources.)

4.4.4.4 Dredge Deeper Holes

Another way to prevent winterkill is by dredging. Winterkill can usually be avoided for lakes or ponds on the edge of the snow belt, such as central Illinois and Indiana, if 25% of the lake area is 8 to 10 feet or deeper. In northern states where the winter is harsher, 25% of the pond or lake should be at least 15 feet deep.

In rare cases, it may be feasible to dredge 10 feet or deeper to create additional volume, which will hold more dissolved oxygen in the lake. It may be cheaper to dredge than to run a winter aeration system for the next 25 years.

Dredging should be considered only if sedimentation rates are low—$^1/_8$ inch per year or less. Otherwise, the deep holes will fill in too rapidly, resulting in a loss of volume and bringing on winterkill conditions once again.

Dredging alone may not prevent winterkill. You should still try to reduce phosphorus to curb algal blooms, which in turn will lower the oxygen consumption in the lake and increase the odds that the fish will live through the winter.

Dredging costs range from $3 to $12 or more per cubic yard, depending on site conditions and whether hydraulic or mechanical equipment is used. Dredging options are described in Chapter 5.

Project 6. Alum sediment treatment in the future

It appears that phosphorus release from lake sediments occurs in winter and in summer. An alum sediment treatment would theoretically reduce phosphorus release from lake sediments. This is a future option. If lake conditions get so bad during the summer due to excessive algal blooms, an alum treatment could reduce the intensity of the algae blooms, although the lake model predicts that eutrophic conditions would still persist.

An alum treatment would probably only be effective for 2 or 3 years because of the large watershed load that enters on an annual basis. Summer aeration is an option to consider as well but that requires an annual expense as well.

2.5.3 Buffered Alum for Sediment Treatments

> **That's History...**
>
> A man clarified water by stirring with a long cane: "I found that the cane had been pierced with small holes and that it was full of powdered alum. This alum, in dissolving, clarified the water. This means of clarifying water I found had been used in China for centuries." General William Sibert of the U.S. Army in China in 1914.
>
> — **World of Water, 2000**

When it is known that phosphorus release from lake sediments is a significant source of phosphorus to the lake, alum can also be used as a one-time dose to curtail phosphorus release from lake sediments. Lake testing is typically required to make that determination.

Aluminum sulfate plus calcium compounds creates buffered alum. When buffered alum is applied to the lake surface, it forms a nontoxic precipitate that scavenges phosphorus as it settles through the water. The precipitate will also eliminate sediment turbidity in a lake, although only for a short while.

After the precipitate, which is also called a "floc," settles into the sediments, the aluminum and calcium compounds continue to tie up the phosphorus as it is released from lake sediments, thus reducing the amount of phosphorus in the water column originating from lake sediments. Lowering the lake phosphorus concentration should result in less algal and filamentous algal growth.

This approach treats the sediment and does not reduce phosphorus that comes in with runoff. In lakes where phosphorus inputs are low from watershed runoff but are high from lake sediments, buffered alum can be used as an alternative to herbicides for controlling algae. One dose can be effective for several years.

Straight alum is often used in large projects when large quantities are required. For example, a 300-acre lake might use over 200,000 gallons of alum (300-acre lake at 700 gallons per acre). In these cases, the lake chemistry has been tested and the amount of alum that can be safely added is known. Using alum without buffering compounds in large quantities in lakes with low buffering capacities has been known to lower the water pH, causing fish kills due to toxic free aluminum present because of the low pH. Buffered alum products are safer for lakes and ponds and are available at the retail level.

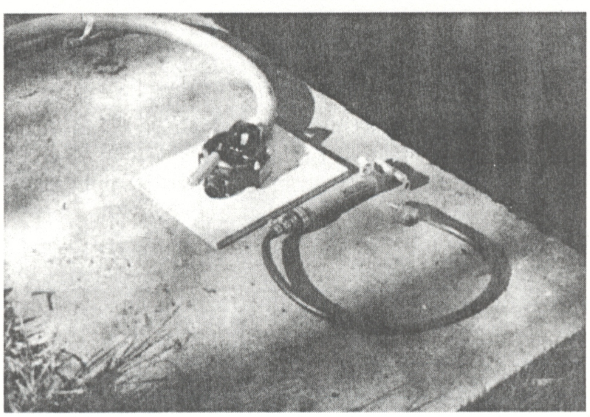
Buffered alum in dry form is easily shipped and handled. The dry alum can be mixed with lake water for application to the water surface. The calcium in the alum maintains a pH above 6 and ensures a good aluminum precipitate. Preliminary water testing for pH adjustments is usually unnecessary for small-scale projects because the manufacturers' special formula for buffered alum does not produce the acidity that straight alum does.

- Buffered alum is most effective when sediments in the lake supply significant amounts of phosphorus
- If a pond or lake has a significant stream or creek inflow, phosphorus entering from the watershed will still produce algal blooms
- Although buffered alum should control blue-green algae and possibly filamentous algae, it will not control rooted aquatic plants because

they get most of their phosphorus from sediments in the lake that are not affected by the alum

The minimum recommended dose is about 100 pounds of buffered alum per lake-acre. In some cases, commercial applicators will apply 500 pounds or more of dry alum per lake-acre, based on testing for alkalinity and sediment phosphorus availability. For lakes larger than 60 acres, liquid alum is typically used and applied at 300 gallons or more per lake-acre. On this scale, it is suggested that lake groups contract with a commercial applicator.

For small lakes or ponds, a distribution system for a buffered alum application can be constructed from PVC pipe. The buffered alum is mixed into a slurry in a pail and pumped through the manifold into the lake.



Hand pumps pump the alum slurry through the manifold.

One person directs the boat, and another pumps the buffered alum into the water.

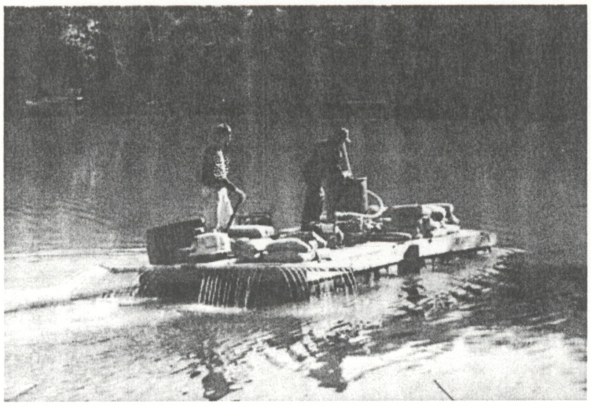
The alum floc settles out of the water column in a couple of hours.

2.5.3.1 Applying Buffered Alum to Small Lakes

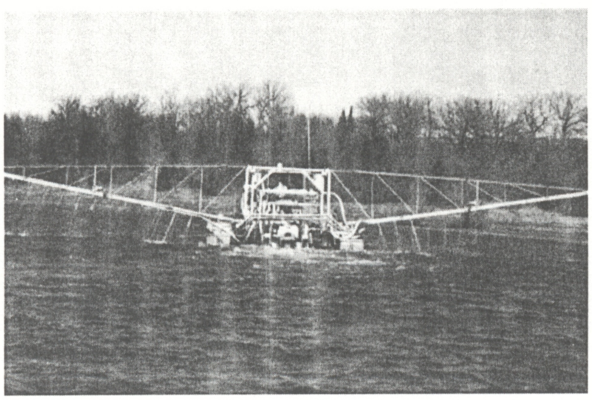
If using a dry, powdered alum that is not in slow-release pellet form, you can distribute the powdered buffered alum from the end of a flat-bottomed boat, a fishing boat, or a pontoon.

Add 20 pounds to a small garbage can about one-third full of water (it is better to add dry alum to water than to add water to dry alum). After the alum and water are mixed, pump the mixture through a manifold system to the lake surface. You can make a manifold system from $^3/_4$-inch PVC plumbing pipe. Drill $^1/_8$-inch holes 4 inches apart into the distribution pipe, which should be about 6 feet wide.

You can use a brass bailing pump to transfer the liquid alum from the garbage can to the manifold. However, your arm is going to get tired if your pond is larger than 1 surface acre. For lakes or ponds larger than several acres, use a hand-operated diaphragm pump to pump the liquid alum through the manifold. One advantage of hand operation is that you can easily vary the application rate to coincide with boat speed.



For alum applications in ponds over 4 acres in size, a scaled-up delivery system will be more efficient. Here, a commercial applicator mixes dry alum with lake water to make a slurry that is then pumped through a manifold in the rear of the alum barge.



When the lake size reaches more than 60 or 70 acres, you may want to call in the professionals. This alum barge uses liquid alum that is pumped out to arms that are 80-feet wide. A GPS unit keeps the barge on track. This outfit can do 50 acres per day or more.

A commercially prepared buffered alum mixture, called DePhos-A, is available in powdered form from Aquatic Eco-Systems (1767 Benbow Court, Apopka, FL 32703; Tel: 877-347-4788; www.aquaticeco.com). The mixture costs about $95 per 40-pound pail. Typical costs for applying the mixture to a 4-acre pond range from $300 to over $700 per surface acre, depending on labor costs, mode of application, and equipment needed.

That's History…

One of the first lake alum treatments used in the United States to control runoff pollution occurred in California in 1951 and 1952 in Stone and Franklin reservoirs. The objective was to remove suspended solids. "Turbidities at the reservoir [caused by turbid inflows] increased from less than 5 units to more than 50 units. Consumer complaints of turbid water—more than 3000 the first week—flooded the department switchboards. Jar tests showed that an alum dosage of 85 ppm would produce a satisfactory floc. Treatment of Lower Franklin Reservoir [32 acres in surface area] with 30 tons of powered alum started one evening and concluded 24 hours later. The laborers poured the alum from a slit in the sack directly into the propeller wash of the boat. This provided sufficient rapid mixing to form a floc.... and by the following day the turbidity of the water being served in the distribution system had dropped from 54 units to 14 units. The total cost of this treatment was $2700."

— Ree, 1963

2.5.4 Calcium Compounds

Algae and turbidity can be removed from water using calcium compounds, such as calcium hydroxide (i.e., lime) or calcium carbonate (limestone). The use of these relatively common compounds avoids the stigma of using herbicides or aluminum compounds. But to succeed, you must apply heavy doses of calcium several times each season. A recommended dose is about 150 pounds of calcium hydroxide per acre-foot. Combining the lime and the limestone in a one-to-one mix is even more effective.

That's History…

Experiments using a calcium compound, lime, were conducted in 1950 to remove phosphorus from wastewater effluent. Investigators found they could get 80% phosphorus removal with 530 ppm of unslaked lime, but too much sludge (from by-products of lime and other components) was produced to be practical.

— Drake and Owens, 1950

Apply the compounds to a pond or small lake as a slurry—an insoluble but watery mixture—or in dry form.

Project 7. Designate the lake a non-motorized (carry-in only) lake

The setting of Ravine Lake, tucked away in a regional park location, and the fact that it is small and relatively shallow lends itself to a natural lake approach. This type of lake should feature the natural resource aspects both in the shoreland area and in the lake. Along these lines, a non-motorized rule would help maintain a peaceful and natural setting.

Appendix A. Lake Data

MNLEAP - Minnesota Lake Eutrophication Analysis Procedure

Lake Name: Ravine
Watershed Area: 800 Acres
Mean Depth: 7 ft
Lake Outflow: 0.42 hm3/yr
Residence Time: 0.5 years
Areal Water Load: 4.20 m/yr

Ecoregion: CHF
Surface Area: 25 Acres
TP Load: 65 kg/yr
Avg TP Inflow: 154 ug/L
Chiaudani/Vighi TP: NA ug/L
P Retention Coef: 0.53

Variable	Observed	Predicted	Std Error	Residual	T-test
TP (ug/L)	108	72	20	0.17	1.23
Chlr a (ug/L)	38.0	34.2	18.7	0.05	0.17
Secchi (m)	0.4	1.0	0.4	-0.35	-2.04

Note: Residual = Log10(Observed/Predicted)
T-test for signifigant difference between observed & predicted

Chlrophyll A Interval Frequencies (%)

ppb	Observed	Case A	Case B	Case C
10	99%	99%	98%	93%
20	86%	81%	79%	71%
30	60%	51%	51%	51%
60	12%	8%	10%	18%

Case A = within year variation considered
Case B = within year + year-to-year variation
Case C = Case B + Model Error

Carlson's Trophic Status Index

Avg TSI = 70
TP TSI = 72
Chlr a TSI = 67
Secchi TSI = 72