Paul Sawyier, *The North Elkhorn Mill Pond*, **c. 1910**

Lake Management Plan for Lac Lavon, Dakota County, Minnesota

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with contributions from Minnesota Department of Natural Resources and Lac Lavon Residents

Funded in part by the City of Apple Valley, City of Burnsville, and Lac Lavon Residents

Comprehensive Lake Management Plan for Lac Lavon, Dakota County, Minnesota

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Lake Management Plan for
Lac Lavon, Dakota County, Minnesota

SUMMARY

Background

Lac Lavon is a 60 acre lake located in Dakota County, Minnesota with an average depth of 13 feet and a maximum depth of 32 feet. A lake management plan was prepared with the objectives to develop a plan that protects and sustains Lac Lavon water quality as well as address aquatic plant management options.

Watershed Characteristics

The lake's watershed is small, approximately 184 acres (including the lake). Land use is primarily residential (46%), with park land contributing as well.

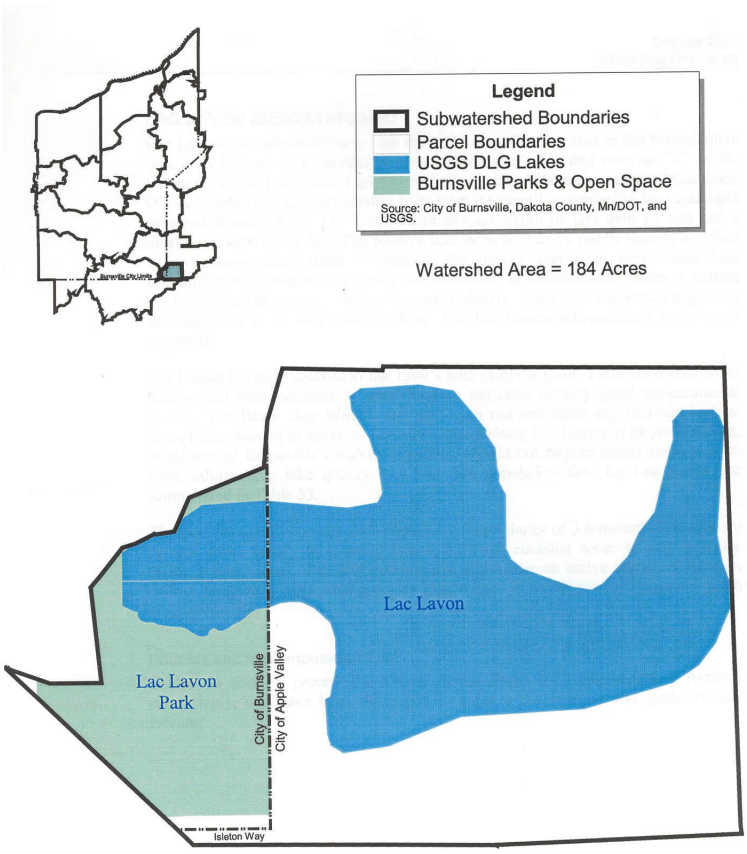


Figure 1. Lac Lavon watershed and City boundaries. The watershed areas was described to be 184 acres and that includes the lake area (source: City of Burnsville Water Resources Management Plan).

Nutrient Inputs to Lac Lavon

The nutrient input into Lac Lavon is estimated at approximately 37 pounds of phosphorus per year. This is a low amount and is one of the reasons why water clarity is good in Lac Lavon.

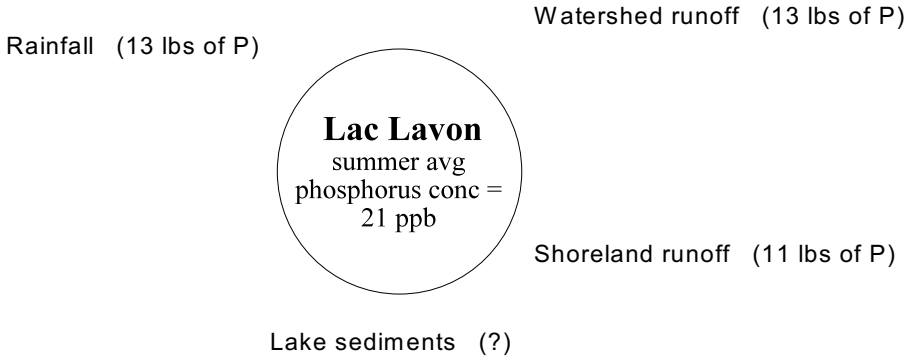


Figure 2. Sources of phosphorus (P) that feed into Lac Lavon are shown above. It is estimated that approximately 37 pounds of phosphorus enter Lac Lavon on an annual basis.

Shoreland Inventory

A summary of the inventory results is shown in Table 1. Based on our subjective criteria about 42% of the parcels in Lac Lavon shoreland area meet the natural ranking criteria for shorelines and upland areas. This is below average compared to other lakes found in the metropolitan area. In the next five to ten years proactive volunteer native landscaping could improve the natural aspects of a number of parcels.

Table 1. Summary of shoreline buffer and upland conditions in the shoreland area of Lac Lavon. Approximately 110 parcels were examined.

	Natural Shoreline Condition		Natural Upland Condition		Undevel. Photo Parcels	Shoreline Structure Present	
	>50%	>75%	>50%	>75%		riprap	wall
LAC LAVON TOTALS (no. of parcels = 110)	42% (48)	30% (33)	54% (59)	44% (48)	10% (11)	1% (1)	7% (8)

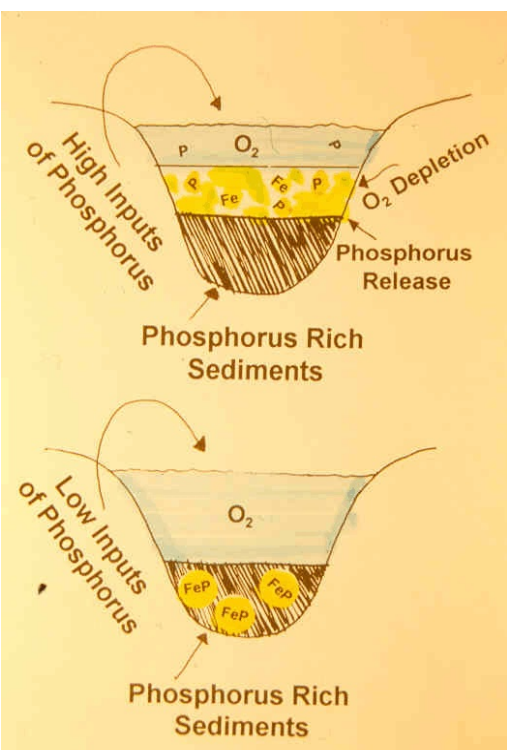
Deep Water Sediments

A special analysis was conducted on a Lac Lavon deep water sediment sample in 2004. The objective was to characterize the "available" or "mobile" phosphorus content of the deep sediments. Several types of tests were run and were different from the littoral zone sediment tests.

Sediment results, shown in Table 2, indicate Lac Lavon sediments have an extremely high mobile phosphorus content. For comparison, results from the two other eutrophic lakes are shown (Lake Volney and Alimagnet Lake). The high Lac Lavon mobile phosphorus content indicates that if oxygen becomes depleted in the bottom of the lake, there is the potential for a large amount of phosphorus to be released from the sediments. This could produce algae blooms in Lac Lavon. Currently, this phosphorus release does not appear to be occurring.

Table 2. Deep water sediment results for mobile phosphorus for Lac Lavon, Lake Volney, and Alimagnet Lake.

Core		Mobile - P ($\mu g\ cm^3$)	Al - P ($\mu g\ cm^3$)	Ca - P ($\mu g\ cm^3$)	Organic - P ($\mu g\ cm^3$)	Total P ($\mu g\ cm^3$)
Lac Lavon	0 - 10 cm	182.0	47.4	84.0	44.8	358.2
Volney - 40 ft	0 - 10 cm	31.2	3.6	53.4	38.1	126.3
Volney - 40 ft	0 - 10 cm	25.8	4.0	62.0	41.2	132.9
Volney - 50 ft	0 - 10 cm	33.0	5.3	63.1	46.9	148.4
Volney - 50 ft	0 - 10 cm	24.2	6.3	70.7	52.0	153.2
Alimagnet A	0 - 10 cm	78.0	54.9	54.4	73.7	261.0
Alimagnet B	0 - 10 cm	25.0	7.5	24.8	49.3	106.6
Alimagnet C	0 - 10 cm	15.1	4.7	13.9	30.4	64.1



Lac Lavon has a high mobile phosphorus content in the bottom sediments. What is "mobile" phosphorus? It is the phosphorus associated with solid iron compounds. This attached phosphorus can be released into the water column when oxygen is depleted in the lake bottom because the solid iron dissolves and releases phosphorus.

Lake Dissolved Oxygen and Temperature

Lac Lavon probably thermally stratifies during the summer. This means that warm water sits on top of the denser cold water during the summer. It is expected that dissolved oxygen concentrations are found throughout the water column most of the time, although there may be periods of time when oxygen is depleted on the bottom of the lake.

Lake Nutrients in the Water Column

Phosphorus concentrations in Lac Lavon water column are lower compared to other lakes in the North Central Hardwood Forest ecoregion. A three-year growing season phosphorus average is 15 ppb. A predicted lake phosphorus concentration based on ecoregion values is 25 ppb.

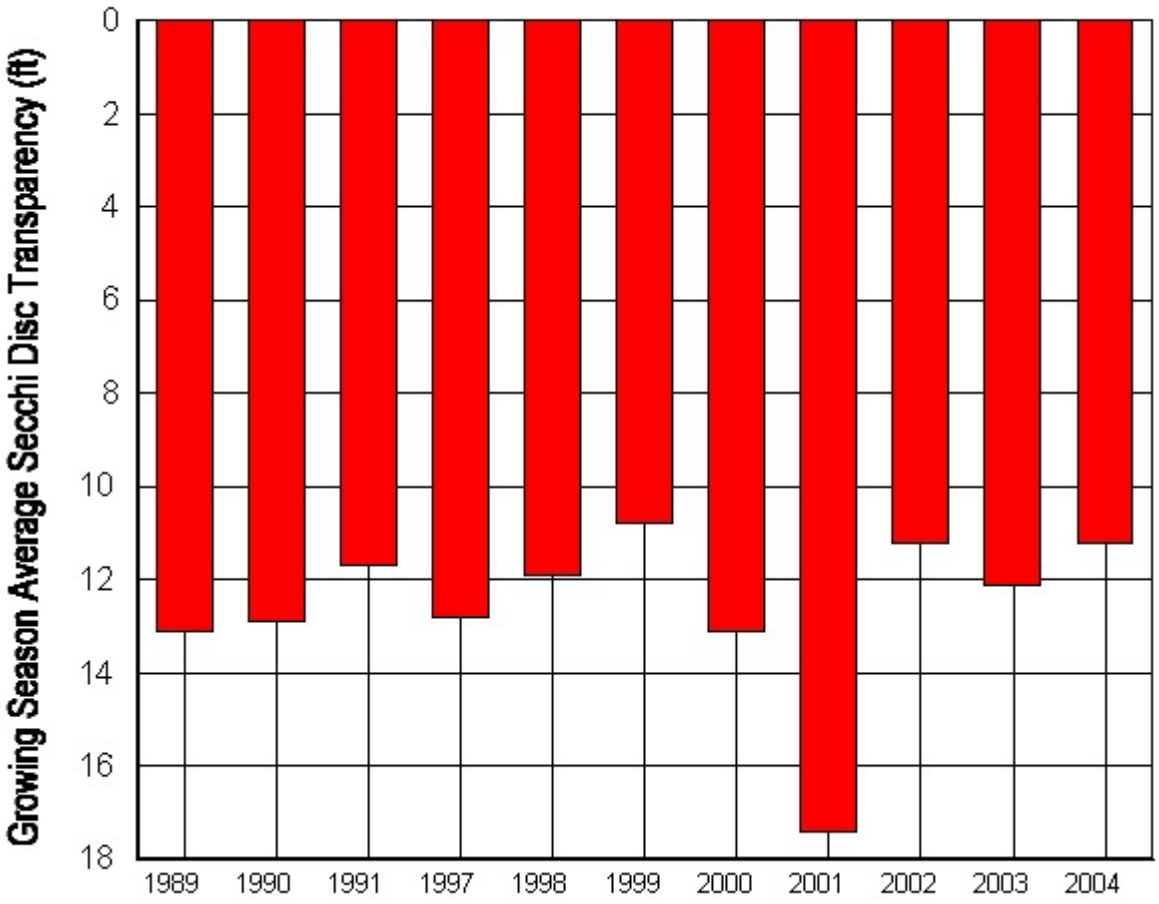


Figure 3. Growing season average Secchi disc readings from 1989-2004.

Lake Algae

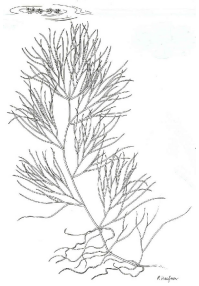
Lac Lavon has algae species that are common to lakes in this part of the state. By mid-summer algae concentrations increase slightly and water clarity decreases. Lake phosphorus levels will produce the increase in algal growth. Overall, algae has a low population density in Lac Lavon.

Lake Aquatic Plants

There are only a few stands of emergent vegetation in shallow water near the shoreline. However, when present, they are beneficial as a filter for nutrients and as fish and wildlife habitat. Aquatic plant diversity is good with 11 different submerged species identified. Three non-native submerged aquatic plants are present in Lac Lavon.

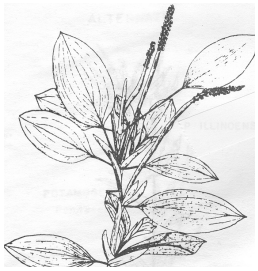
Common Native Plants in Lac Lavon

Sago Pondweed



Sago pondweed (*Stuckenia pectinata*) is found in water depths out to 11 feet deep. It can grow to the surface in water depths out to 10 feet along shoreline areas in the bay with the swimming beach and on the southwest side of the lake as well.

Illinois pondweed



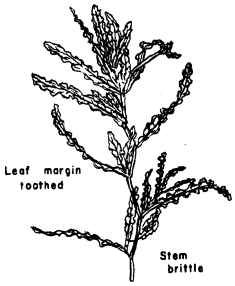
Illinois pondweed (*Potamogeton illinoensis*) is found in water depths to 10 feet. It can grow to the surface in some areas, especially by the swimming beach.

Coontail

Coontail (*Ceratophyllum demersum*) is found in several locations. Typically is not a nuisance in Lac Lavon.

Non-Native Plants in Lac Lavon

Curlyleaf pondweed



Curlyleaf pondweed (*Potamogeton crispus*) is an non-native invasive plant found in Lac Lavon. It does not produce nuisance matted conditions at this time.

Eurasian watermilfoil

Eurasian watermilfoil (*Myriophyllum spicatum*) first discovered in Lac Lavon in 1988 (source: MnDNR). It has produced nuisance conditions in some areas in some years.

Brittle naiad

Brittle naiad (*Najas minor All*) was discovered in 2002 and verified in 2004 and is a non-native plant species. It does not present nuisance growth as of 2004. Courtesy of USDA NRCS Wetland Science Institute (USDA, NRCS. 2004).

Predicting Areas of Nuisance Eurasian Watermilfoil Growth in Lac Lavon: Based on results from other studies conducted by Blue Water Science, there has been a correlation of sediment exchangeable ammonia concentrations over 10 pm with nuisance growth of Eurasian watermilfoil. Using the 10 ppm threshold as a basis for prediction, we have constructed a map showing the areas in Lac Lavon that have the potential to support nuisance milfoil growth (Figure 4). Eight out of eleven sample locations have exchangeable ammonia concentrations over 10 µg/cm^3-dry coupled with low organic matter. This combination is correlated with nuisance growth of EWM. We estimate that 11 acres of lake bottom could support matting EWM growth. Exchangeable ammonia can come from a variety of sources including runoff from fertilized yards. In other cases, lake sediments can be naturally high in nitrogen. The nitrogen source was not determined for Lac Lavon.

Table 3. Lac Lavon sediment data and ratings for potential nuisance Eurasian watermilfoil growth.

Sample Number	Water Depth at Sample Location (ft)	Lake Sediment Bulk Density (dry) grams/cm^3	NH_4 Based on Corrected Weight-Volume (µg/cm^3)	Organic Matter (%)	Potential for Nuisance EWM Growth
1	6	0.97	19.1	3.0	High
2	10	0.88	5.9	3.1/3.0	Med
3	6	1.37	6	0.5	Med
4	6	1.09	16.7	1.6	High
5	5	0.94	60.3	3.5	High
6	6	1.04	25.7	1.4	High
7	5	0.99	24.4	1.6	High
8	5	1.32	5	0.9	Low
9	6.5	0.92	15.4	2	High
10	8	0.91	25.2	2.6	High
11	8	0.92	15.2	2	High

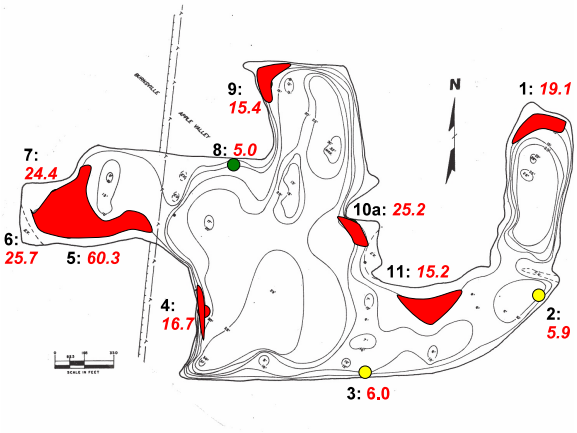


Figure 4. Areas that have the potential to support nuisance growth of Eurasian watermilfoil are shown in red shading.

Figure 5. Matting, nuisance Eurasian watermilfoil is shown above. This is a density of a "5" and this is the kind of nuisance growth predicted by high sediment nitrogen values and a sediment organic matter content less than 20%.

Main Findings of this Study

1. Lake data reinforce that lake water quality is excellent.
2. MnDNR reported another new exotic plant found in the lake, a brittle naiad.
3. Shoreland conditions and the occurrence of native shoreland vegetation are below average.
4. Shallow lake sediment fertility indicated that persistent nuisance growth of milfoil would be expected in about 11 acres. However, conditions are not as suitable to support widespread nuisance curlyleaf pondweed.
5. Use of the herbicide, Sonar, controls Eurasian watermilfoil for up to three years. However Illinois pondweed and sago pondweed can grow to the water surface in the year after the Sonar treatment.
6. Lake sediment testing revealed that there is a huge phosphorus pool in the deep sediments. This has the potential to cause algae blooms if the phosphorus is released. At the present time, the phosphorus does not appear to release during the summer.
7. Aquatic plant management options should protect water quality. Management practices have achieved main objectives as of 2004. Recommend harvesting as a plant management option.

Recommended Lake Management Projects

1. Landscaping projects: Lac Lavon has stretches of natural shoreline conditions but is lacking along some of the developed parcels. The challenge is to protect the existing natural conditions and to enhance shorelands that lack native vegetative buffers. A volunteer lakescaping program should be implemented.

2. Aquatic plant projects: Aquatic plants are important in Lac Lavon for fish habitat and for helping sustain good water quality. Although there is good aquatic plant diversity with 11 species identified, three exotic aquatic plant species were found in Lac Lavon. Three management options were considered for addressing nuisance aquatic plant growth (Table 4). Options for implementation will be reviewed each year.

Table 4. Three options for aquatic plant management.

	Area to Be Treated	Annual Cost	3-Year Cost
1. Harvesting	15 ac x $500	$7,500	$22,500
2. Spot treatment with 2, 4D	15 ac x $425	$6,375	$19,125
3. Sonar every 3 to 4 years	whole lake	$6,000	$18,000

3. Watershed and lake monitoring program: Ongoing testing should include: Secchi disk, total phosphorus, or chlorophyll a levels in the lake. In addition, dissolved oxygen profiles should be taken through the summer months. The level of effort depends on the availability of volunteers and funding levels.

1. Introduction and Project Setting

Lac Lavon is a 60 acre lake (source: Burnsville Water Resources Management Plan) located in the Cities of Burnsville and Apple Valley in Dakota County, Minnesota (Figure 1). Lac Lavon characteristics are shown in Table 1.

The objectives of this study were to characterize existing lake conditions and to make recommendations to protect and improve the lake environment where feasible.

Table 1. Lake statistics (MnDNR 1999).

	Lac Lavon
Size (acres)	60 (Burnsville Water Resources Management Plan) (*note: MnDNR Fish Survey states the lake size is 55 acres*)
Mean depth (ft)	13
Maximum depth (ft)	32

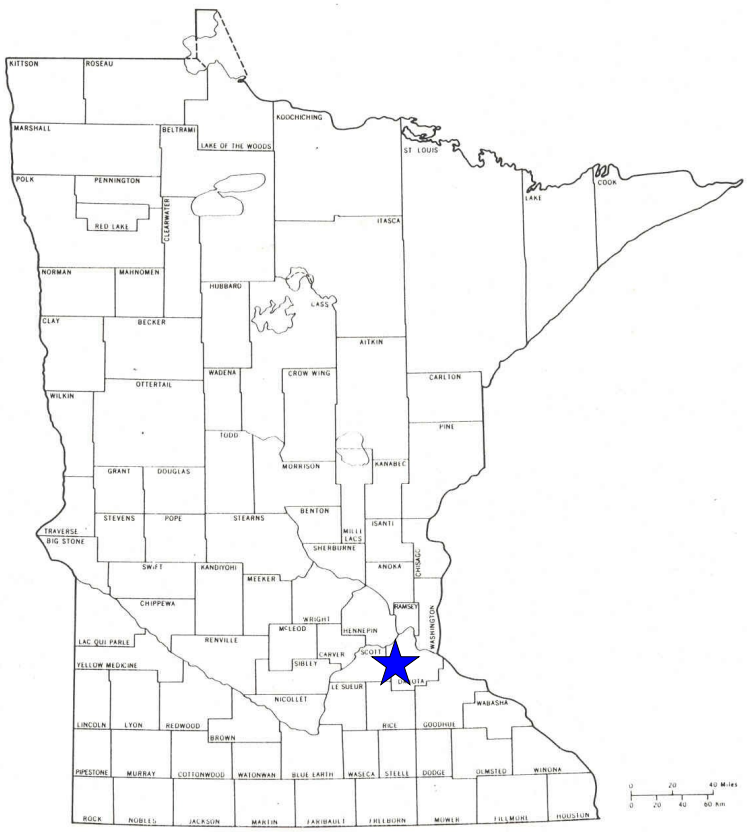


Figure 1. Lac Lavon is located in Dakota County, Minnesota.

2. Watershed Features

2.1. Drainage Area to Lac Lavon

For this study, SEH Engineers prepared a watershed map for the City of Burnsville Water Resources Management Plan. The estimated drainage area to Lac Lavon is 124 acres and when the lake surface area of 60 acres is added the total watershed area is 184 acres (source: City of Burnsville Water Plan 2002) and the watershed delineation is shown in Figure 2. The watershed to lake ratio of Lac Lavon is 2 to 1.

Lac Lavon and its watershed are located within the Cities of Apple Valley and Burnsville. Land use within the watershed is mostly residential with park abutting the west end (Burnsville Park) and the east end (Apple Valley Park).

Currently, Lac Lavon has good water quality. To ensure good water quality for years to come, conservation measures in the watershed and on the lakeshore of Lac Lavon should be considered.

Lac Lavon is a 60 acre lake that lies in both Burnsville and Apple Valley. It has a relatively small watershed area and has good water quality.

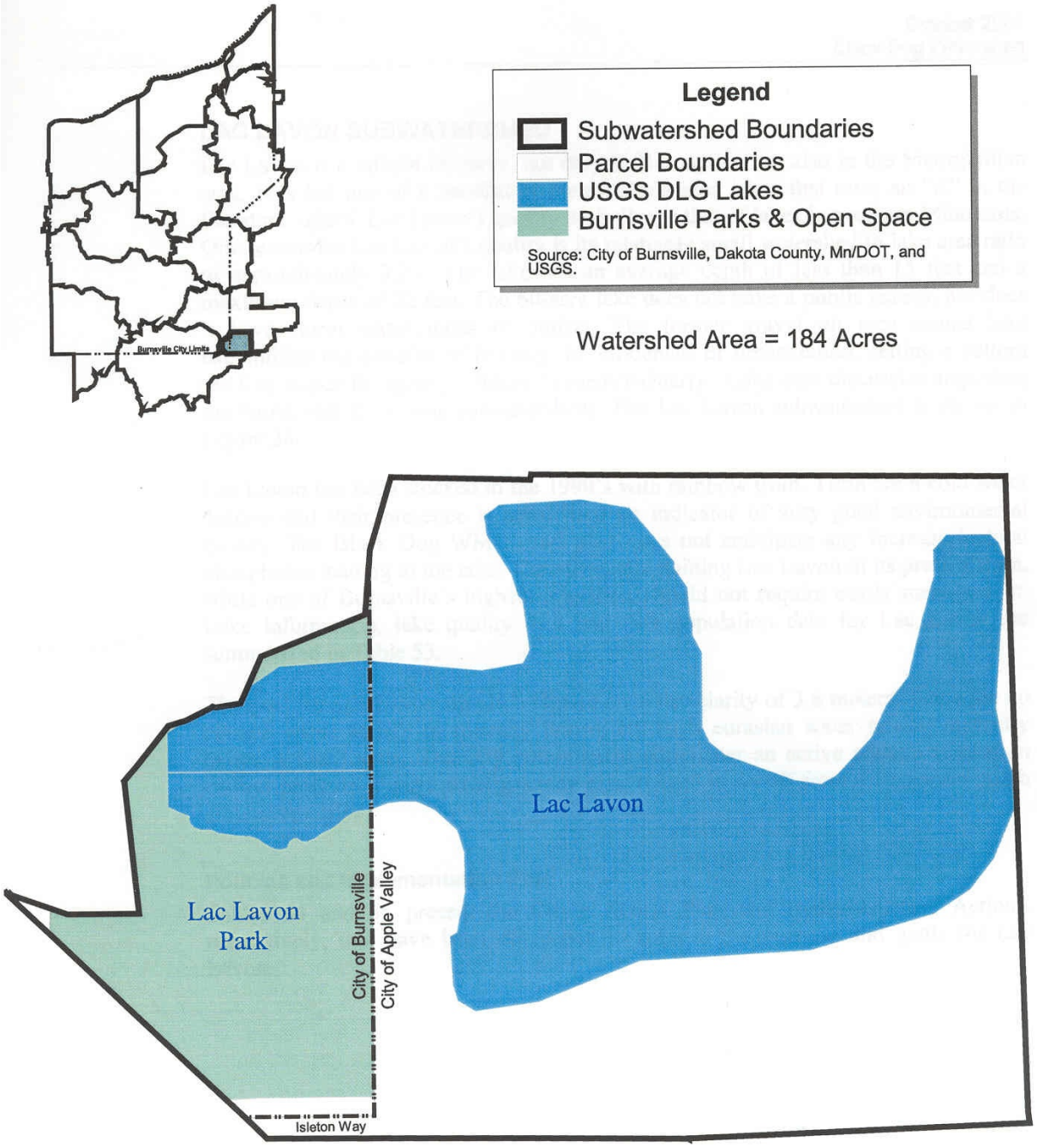


Figure 2. Lac Lavon watershed and City boundaries. The watershed area was described to be 184 acres and that includes the lake area (source: City of Burnsville Water Resources Management Plan).

2.2. Watershed Sources of Water and Nutrients to Lac Lavon

Water: The source of water to Lac Lavon is from a combination of surface runoff, rainfall, and groundwater. The amount of water flowing into Lac Lavon is estimated to be less than 1 cubic foot per second. Flows were estimated based on an average runoff amount for the Twin Cities Metropolitan area of 5.4 inches (0.45 ft) per years (Table 2).

Table 2. Average annual water flow into Lac Lavon .

Drainage area (not including the lake) (acre)	124
Average yearly runoff for Dakota County (feet)	0.45
Total water inflow (acre-feet)	55.8

This is a moderate amount of water coming into Lac Lavon. The unknown variable is groundwater. Groundwater inputs and outputs were not evaluated for this study. The volume of Lac Lavon is 780 acre-feet. If Lac Lavon completely dried up, it would take 14 years to fill by surface water runoff.

Nutrients: The primary source of phosphorus from the watershed of Lac Lavon is residential and parkland runoff. Groundwater does not appear to be a significant nutrient source, but it was not tested.

2.3. Shoreland Inventory

The shoreland area encompasses three components: the upland fringe, the shoreline, and shallow water area by the shore. A photographic inventory of Lac Lavon shoreline was conducted on September 9, 2003. 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 shorelines and uplands at the 75% natural level as well (Figure 3 illustrates the methodology).

A summary of the inventory results is shown in Table 3. Based on our subjective criteria about 42% of the parcels in Lac Lavon shoreland area meet the natural ranking criteria for shorelines and upland areas. This is below average compared to other lakes found in the metropolitan area. In the next five to ten years proactive volunteer native landscaping could improve the natural aspects of a number of parcels.

Table 3. Summary of shoreline buffer and upland conditions in the shoreland area of Lac Lavon. Approximately 110 parcels were examined.

	Natural Shoreline Condition		Natural Upland Condition		Undevel. Photo Parcels	Shoreline Structure Present	
	>50%	>75%	>50%	>75%		riprap	wall
LAC LAVON TOTALS (no. of parcels = 110)	42% (48)	30% (33)	54% (59)	44% (48)	10% (11)	1% (1)	7% (8)

A comparison of Lac Lavon's shoreland conditions to other lakes in Minnesota and Wisconsin is shown in Table 4 and in Figure 4.

Figure 3. Both of the pictures are from Lac Lavon. [top] This parcel would rate as having a shoreline with a buffer greater than 50% of the lot width and an understory with greater than 50% natural cover.
[bottom] These parcels would not qualify as having a natural shoreline buffer greater than 50% of the lot width. Also the understory in the upland area would be rated as having less than 50% natural cover.

Table 4. Summary of shoreland inventories from Lac Lavon and 20 other lakes in Minnesota and Wisconsin.

Lake	Eco-region	Date of Survey	Total Number of Parcels (#)	Undevel. Parcels % (#)	Natural Upland Condition		Natural Shoreline Condition		Parcels with Erosion % (#)	Parcels with Shoreline Structure[1] % (#)
					> 50% % (#)	>75% % (#)	> 50% % (#)	>75% % (#)		
Lac Lavon Dakota County, MN	CHF[2]	9.9.03	110	7 (8)	54 (59)	44 (48)	42 (46)	30 (33)	0	8 (9)
Alimagnet Lake Dakota Co, MN	CHF	8.6.03	108	37 (40)	54 (58)	47 (51)	69 (75)	61 (66)	0	16 (17)
Big Bear Lake Burnett Co, WI	LF[3]	9.11.02	87	13 (11)	82 (71)	62 (54)	86 (75)	76 (66)	0	9 (8)
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)
Ravine Lake Washington Co, MN		7.19.01	9	100 (9)	100 (9)	100 (9)	100 (9)	100 (9)	0	0
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)
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)
Comfort Chisago Co, MN	CHF	10.9-11.2.98	100	--	62 (62)	--	50 (50)	--	--	12 (12)

Table 4. Concluded.

Lake	Eco-region	Date of Survey	Total Number of Parcels (#)	Undevel. Parcels % (#)	Natural Upland Condition		Natural Shoreline Condition		Parcels with Erosion % (#)	Parcels with Shoreline Structure[1] % (#)
					> 50% % (#)	>75% % (#)	> 50% % (#)	>75% % (#)		
Pipe Lake/North Pipe Lake Polk Co, WI	CHF	8.03	21780	8 (17) 45 (36)	67 (144) 100 (80)	50 (108) 96 (77)	63 (137) 94 (75)	56 (121) 91 (73)	0	22 (48) 1 (1)
Big Round Lake, Polk Co, WI	CHF	8.03	74	14 (10)	27 (20)	24 (18)	39 (29)	34 (25)	1 (1)	14 (10)
Pike Chain Price & Vilas Co, WI			722	380	92 (633)	87 (626)	95 (684)	91 (654)	--	5 (34)
Plum Lake Vilas Co, WI	LF	7.26.01	225	13 (30)	75 (169)	58 (130)	81 (182)	708(158)	--	9(4)
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
Bear Oneida Co, WI	LF	6.8.99	115	6 (7)	93 (107)	78 (90)	84 (97)	77 (89)	1 (1)	8 (9)

1. Structures refer to riprap or retaining wall.
2. CHF = Central Hardwood Forest Ecoregion
3. LF = Lake and Forests Ecoregion

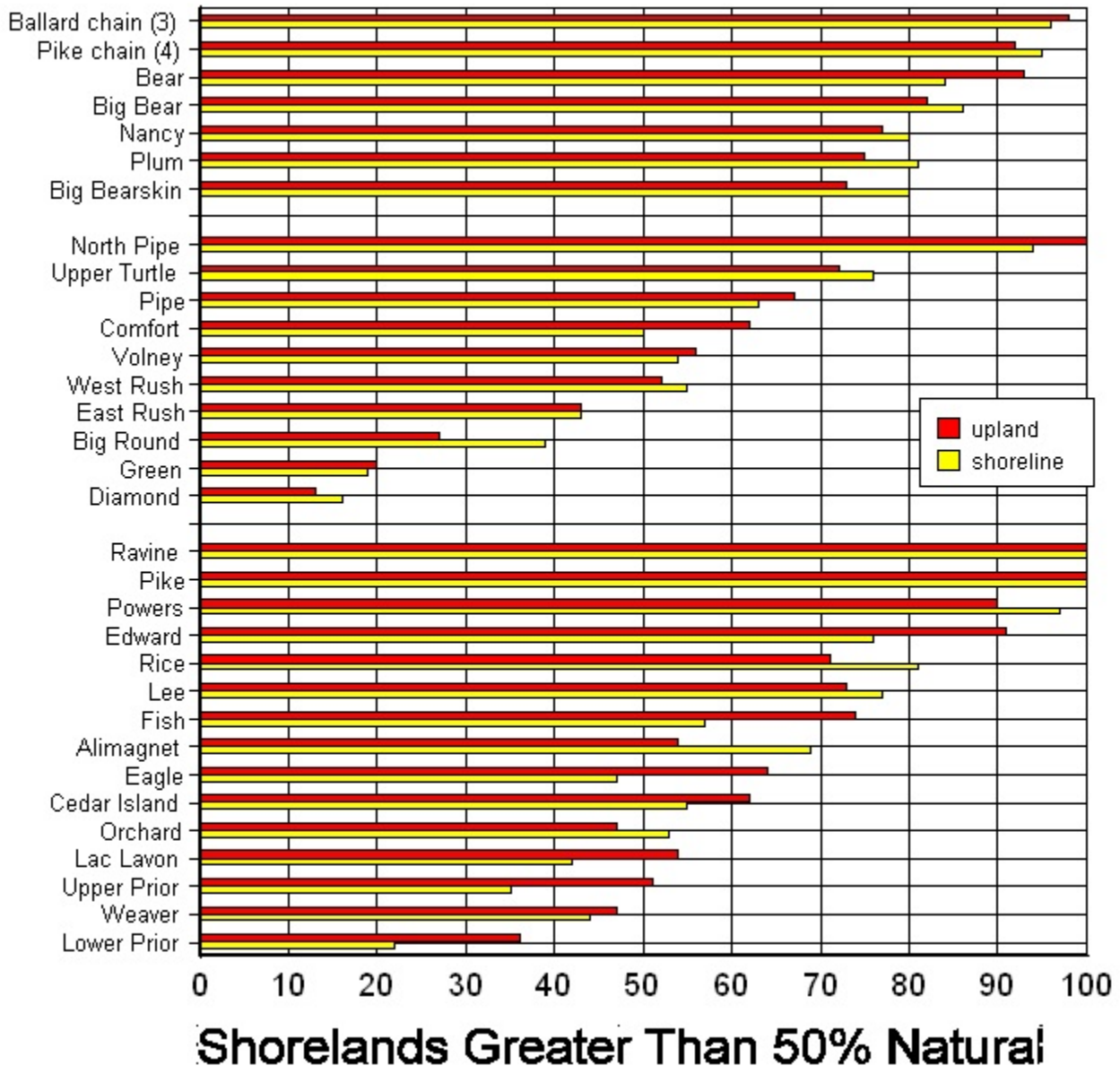


Figure 4. A summary of shoreland inventory results for lakes using an evaluation based on shoreland photographs. For each lake the percentage of shoreline and upland conditions with greater than 50% natural conditions is shown. The first tier of lakes are located in northern Wisconsin which are 4 to 5 hours from a major metropolitan area. The middle tier of lakes are about an hour's drive from the Twin Cities, and are considered to be "country" lakes. The lower tier of lakes are in the Twin City Metropolitan area and are categorized as urban lakes. Several lakes of the "urban" lakes have most of their shoreland owned by the city and there is a high percentage of natural conditions.

Lac Lavon is considered a Twin City Metropolitan lake for this inventory. Natural shoreland conditions for Lac Lavon are below average compared to the other metropolitan lakes.

2.4. Watershed Synopsis

The watershed area that drains to Lac Lavon is relatively small. The ratio of watershed area to lake area is also small This has positive ramifications for water quality.

The water quality coming into Lac Lavon was estimated based on water quality modeling. Results of the water quality modeling indicate the phosphorus content in water coming into Lac Lavon is low for urban runoff and the overall pounds of phosphorus are low because of the small watershed size.

Watershed phosphorus inputs have been estimated at 37 pounds of phosphorus per year based on a lake model that used the existing lake phosphorus concentration of 21 ppb and then back calculated to find how much phosphorus it would take to produce that lake concentration.

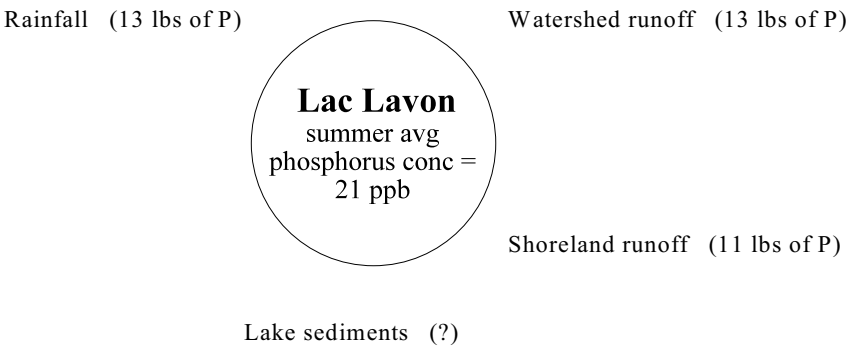


Figure 5. Sources of phosphorus (P) that feed into Lac Lavon are shown above. It is estimated that approximately 37 pounds of phosphorus enter Lac Lavon on an annual basis.

3. Lake Features

3.1. Lake Map and Lake Statistics

Lac Lavon is approximately 60 acres in size, with a watershed of 184 acres. The average depth of Lac Lavon is 13 feet with a maximum depth of 32 feet. A lake contour map is shown in Figure 6.

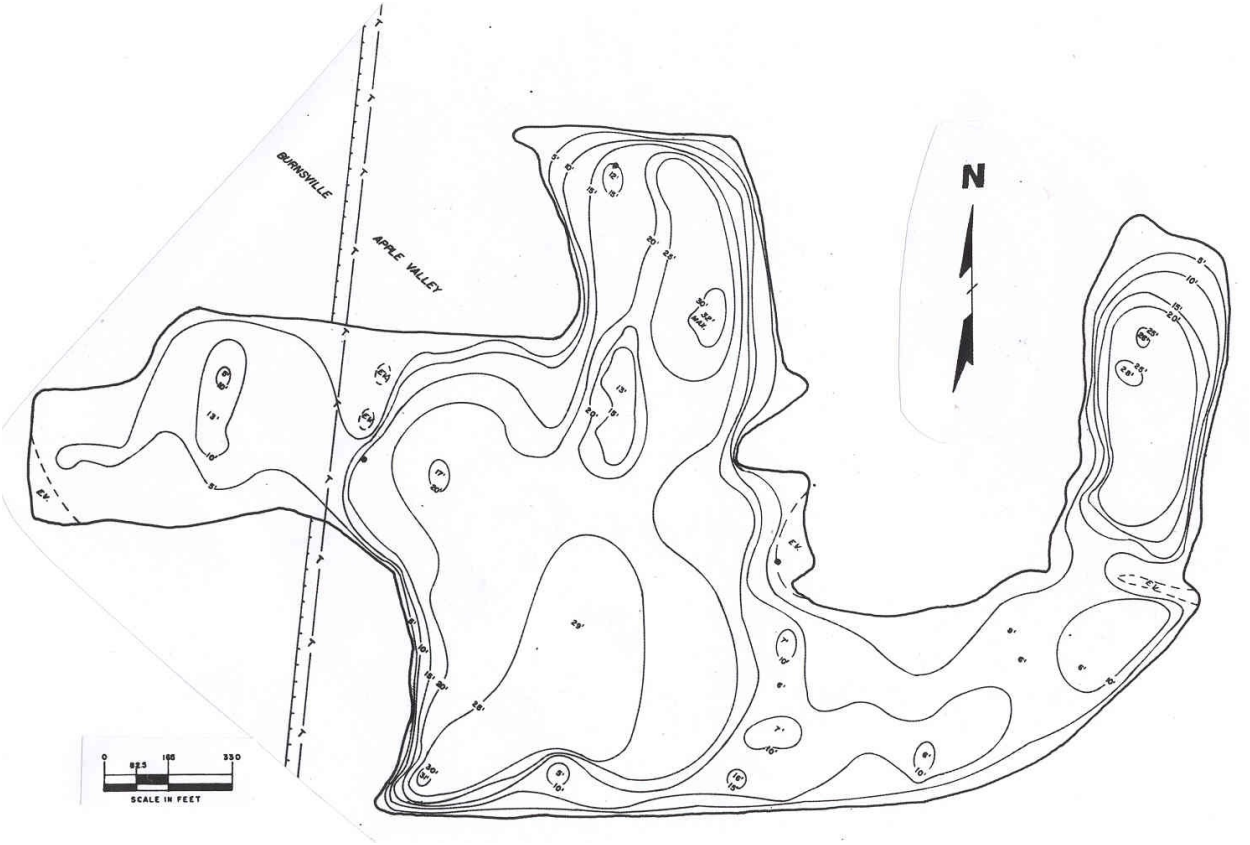


Figure 6. A bathymetric map of Lac Lavon (source: MnDNR).

3.2. Lake Sediment Status

Lake Soil Collection: A total of 11 lake sediment sites were monitored from depths ranging from 5 to 10 feet and one sample (number 12) was collected from a 28 foot depth (Figure 7). The deep water lake sediment sample was collected with an Eckman dredge. The shallower samples were collected using a modified soil auger, 5.2 inches in diameter (Figure 8). Soils were sampled to a depth of 6 inches. The lake soil from the sampler was transferred to 1-gallon zip-lock bags and delivered to a soil testing laboratory.

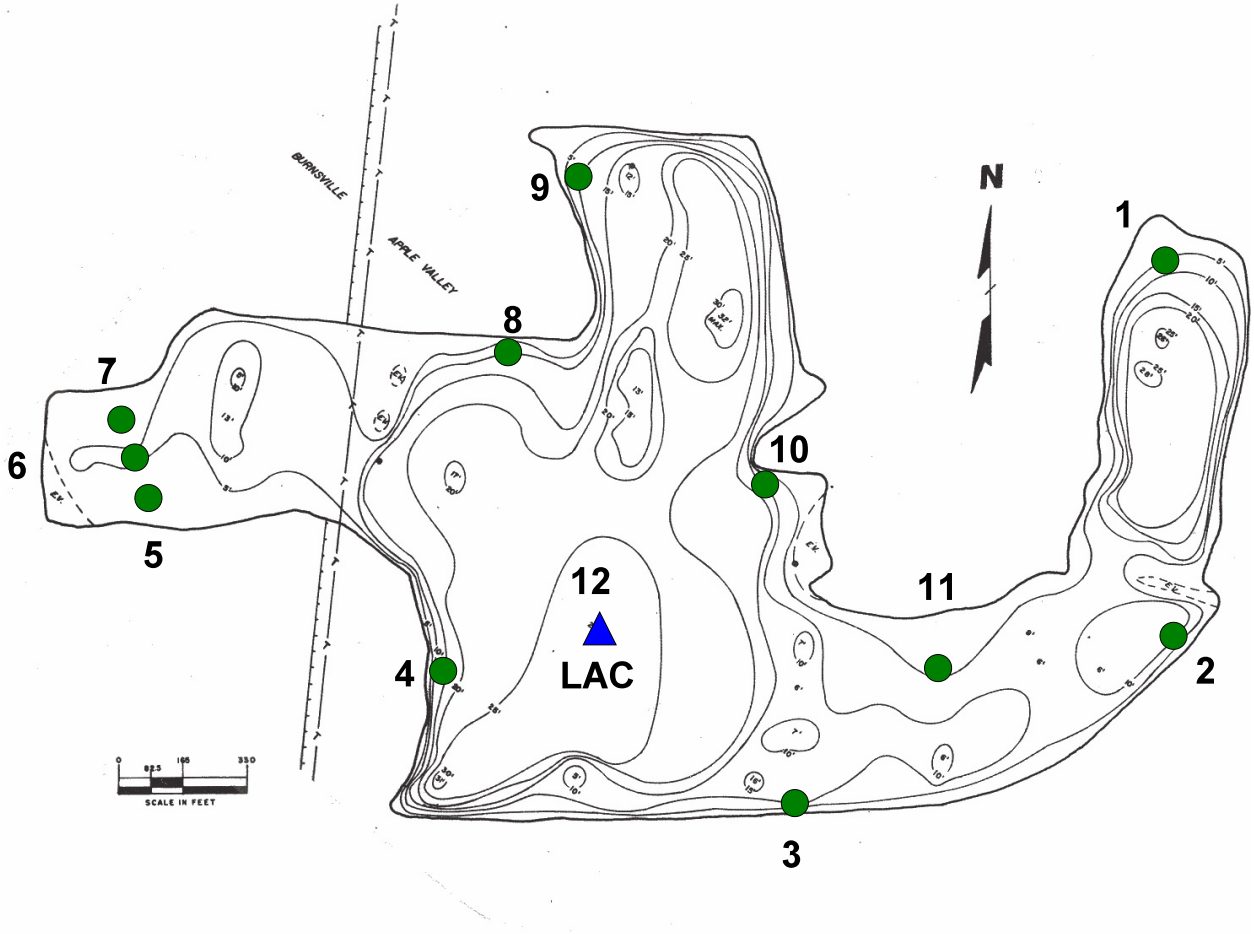


Figure 7. Lake sediment sample locations for the October 8, 2003 sediment survey.

Littoral Zone Lake Soil Analysis: At the lab, the littoral zone sediment samples were air dried at room temperature, crushed and sieved through a 2 mm mesh sieve. Sediment samples were analyzed using standard agricultural soil testing methods. Sixteen parameters were tested for each soil sample. A summary of extractants and procedures is shown in Table 5. Routine soil test results are given on a weight per volume basis.

Table 5. Soil testing extractants used by University of Minnesota Crop Research Laboratory. These are standard extractants used for routine soil tests by most Midwestern soil testing laboratories (reference: Western States Laboratory Proficiency Testing Program: Soil and Plant Analytical Methods, 1996-Version 3).

Parameter	Extractant
P-Bray	0.025M HCL in 0.03M NH_4F
P-Olsen	0.5M $NaHCO_3$
NH_4-N	2N KCL
K, Ca, Mg	1N NH_4OA_c (ammonium acetate)
Fe, Mn, Zn, Cu	DTPA (diethylenetriamine pentaacetic acid)
B	Hot water
SO_4-S	$Ca(H_2PO_4)_2$
pH	water
Organic matter	Loss on ignition at 550 C

Figure 8. Soil auger used to collect lake sediments.

Deep Water Lake Sediment Analysis: The deep water sediment sample was analyzed by Brian Husar at the University of Minnesota and several types of available phosphorus fractions were quantified. The methods were based on the Rydin and Welch approach (1999).

3.2.1. Littoral Zone Sediments

Lake sediments were sampled at 11 littoral area sites on October 8, 2003. In the littoral area, 15 parameters were analyzed for each sediment sample. Results are listed in Table 6.

The littoral zone represents the shallower area of the lake, from 0-15 feet. In this area organic matter is relatively low in the lake sediments and phosphorus concentrations are moderate. It appears nitrogen is the limiting nutrient. The sediment pH ranges from 7 to 8 putting the sediments just into the alkaline side.

Soil results indicate the lake soils are not polluted and are fairly representative of other lake sediments.

Table 6. Lac Lavon sediment characteristics and existing aquatic plants found at the sample site on October 8, 2003.

Sample Number	Water Depth at Sample Location (ft)	Sediment Characteristics	Aquatic Plant Species Found at Sediment Sample Sites				
			EWM	Chara	Naiads	Illinois pond-weed	Sago pond-weed
1	6	Soft sediment on top of sand.		1			
2	10	Fine grain gray material - soft.					3
3	6	Sand-gravel.			2	3	
4	6	Mostly sand with fine grain silt or clay.				2	2
5	5	Soft sediment (4-5 in) on top of sand.				5	
6	6	Soft sediment (4-5 in) on top of sand.	0.5			3	2
7	5	Soft sediment (4-5 in) on top of sand.	1			4	1
8	5	Grayish; sand, gravel, and fine sand.				2	2
9	6.5	Grayish to tan: fine grain sediment muck or clay.					2
10	8	Black muck (3 in) on top of gray clay.				3	
10d*		Gray material below the black muck.					
11	8	Very soft sediment, grey sediment.					4
LAC	25						

* 10d is a sediment fraction from 6 to 10 inches, at Site 10.

Table 7. Lac Lavon sediment results from the 5 to 10 foot water depth collected on October 8, 2003. Results are in µg/cm^3 (which is similar to ppm) except for bulk density (g/cm^3), OM (organic matter in %), and pH (standard units).

Sample ID	Bulk density g/cm^3	NH_4-N corrected	P_Bray corrected	P_Olsen corrected	K corrected	OM %	Ca corrected	Mg corrected	S corrected	Zn corrected	Cu corrected	Mn corrected	Fe corrected	B corrected	pH su	Mn:Fe
1	0.97	19.1	0.8	4.9	53	3	3291	281	89	2.1	8.1	25.9	219	0.3	7.5	0.12
2	0.88	5.9	0.7	6.7	92	3.1 / 3.0	3136	288	29	1.7	11.3	24.2	291	0.2	7.65	0.08
3	1.37	6.0	7.0	3.5	25	0.5	1854	98	16	0.6	1.9	16.3	98	0.1	7.9	0.17
4	1.09	16.7	0.9	6.5	31	1.6	3112	185	99	1.5	4.9	26.3	160	0.3	7.6	0.16
5	0.94	60.3	0.8	14.3	76	3.5	3422	271	151	0.9	8.7	36.3	323	0.4	7.3	0.11
6	1.04	25.7	0.9	5.3	43	1.4	3127	165	35	0.6	6.4	20.6	231	0.2	7.6	0.09
7	0.99	24.4	0.8	5.1	36	1.6	3168	194	63	0.8	9.2	28.8	275	0.2	7.6	0.11
8	1.32	5.0	1.1	2.3	38	0.9	3711	281	20	0.6	3.5	23.3	219	0.2	7.8	0.11
9	0.92	15.4	0.8	11.0	103	2.0	3264	265	16	1.5	16.5	72.1	259	0.3	7.7	0.28
10	0.91	25.2	0.8	5.4	49	2.6	2960	188	104	0.9	6.4	27.1	247	0.3	7.5	0.11
10d*	1.06	10.0	0.9	2.7	33	1.2	2955	143	76	1.0	5.4	19.5	186	0.2	7.6	0.11
11	0.92	15.2	0.8	7.1	100	2.0	3120	301	20	1.3	13.5	57.6	280	0.2	7.6	0.21

* 10d is a sediment fraction from 6 to 10 inches at Site 10.

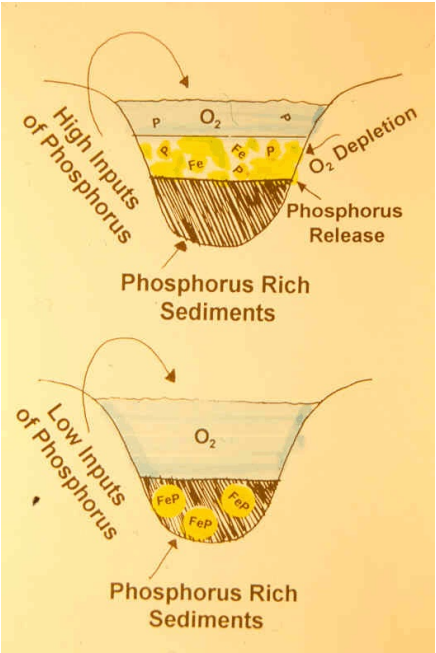
3.2.2. Deep Water Sediments

A special analysis was conducted on a Lac Lavon deep water sediment sample in 2004. The objective was to characterize the "available" or "mobile" phosphorus content of the deep sediments. Several types of tests were run and were different from the littoral zone tests.

Sediment results, for the deep water sediment sample, indicate Lac Lavon sediments have an extremely high mobile phosphorus content (Table 8). For comparison, results from the two other eutrophic lakes are shown (Lake Volney and Alimagnet Lake). The high Lac Lavon mobile phosphorus content indicates that if oxygen becomes depleted in the bottom of the lake, there is the potential for a large amount of phosphorus to be released from the sediments. This could produce algae blooms in Lac Lavon.

Table 8. Deep water sediment results for mobile phosphorus for Lac Lavon, Lake Volney, and Alimagnet Lake.

Core		Mobile - P ($\mu g\ cm^3$)	Al - P ($\mu g\ cm^3$)	Ca - P ($\mu g\ cm^3$)	Organic - P ($\mu g\ cm^3$)	Total P ($\mu g\ cm^3$)
Lac Lavon	0 - 10 cm	182.0	47.4	84.0	44.8	358.2
Volney - 40 ft	0 - 10 cm	31.2	3.6	53.4	38.1	126.3
Volney - 40 ft	0 - 10 cm	25.8	4.0	62.0	41.2	132.9
Volney - 50 ft	0 - 10 cm	33.0	5.3	63.1	46.9	148.4
Volney - 50 ft	0 - 10 cm	24.2	6.3	70.7	52.0	153.2
Alimagnet A	0 - 10 cm	78.0	54.9	54.4	73.7	261.0
Alimagnet B	0 - 10 cm	25.0	7.5	24.8	49.3	106.6
Alimagnet C	0 - 10 cm	15.1	4.7	13.9	30.4	64.1



Lac Lavon has a high mobile phosphorus content in the bottom sediments. What is "mobile" phosphorus? It is the phosphorus associated with solid iron compounds. This attached phosphorus can be released into the water column when oxygen is depleted in the lake bottom because the solid iron dissolves and releases phosphorus.

3.3. Dissolved Oxygen and Temperature

The summer dissolved oxygen and temperature profiles were not collected in this study. However, based on the lake depth, it is assumed that the water column could be thermally stratified. **Thermally stratified** means that the water column of the lake is segregated into different layers of water based on their temperature. Just as hot air rises because it is less dense than cold air, water near the surface that is warmed by the sun is less dense than the cooler water below it and it "floats" forming a layer called the *epilimnion*, or *mixed layer*. The water in the epilimnion is frequently mixed by the wind, so it is usually the same temperature and is saturated with oxygen.

Below this layer of warm, oxygenated surface water is a region called the *metalimnion*, or *thermocline* where water temperatures decrease precipitously with depth. Water in this layer is isolated from gas exchange with the atmosphere. The oxygen content of this layer usually declines with depth in a manner similar to the decrease in water temperature.

Below the thermocline is the layer of cold, dense water called the *hypolimnion*. This layer is completely cut off from exchange with the atmosphere and light levels are very low. So, once the lake stratifies in the summer, oxygen concentrations in the hypolimnion progressively decline due to the decomposition of plant and animal matter and respiration of benthic (bottom-dwelling) organisms.

At the present time, it is assumed that the bottom water contains dissolved oxygen through the summer and that may explain why the mobile phosphorus is so high . . . because phosphorus is accumulating, but it remains tied up with iron.

It is recommended that temperature and dissolved oxygen profiles be conducted over the summer in the future.

3.4. Lake Water Quality Summary

Summer water chemistry data collected since 1989 includes Secchi disc, total phosphorus (TP), chlorophyll a (Chl a), and total kjeldahl nitrogen (TKN) (Table 9). Samples were collected just below the surface in the deepest area of Lac Lavon. Overall, the three water quality indicators (Secchi disc, total phosphorus, and chlorophyll a) over the years indicate Lac Lavon is in excellent shape.

Table 9. Lac Lavon summer averages (May-September)(source: Met Council CAMP program).

Date	SD (m)	SD (ft)	TP (µg/l)	TKN-N (mg/l)	CHL (µg/l)
1989					
average	4	13.1			
range	3.4 - 6.2	11.0 - 20.5			
n	12	12			
1990					
average	3.9	12.9			
range	3.2 - 4.4	10.5 - 14.5			
n	6	6			
1991					
average	3.6	11.7			
range	2.7 - 4.3	9.0 - 14.0			
n	11	11			
1997					
average	3.9	12.8	16.5	0.45	6
range	1.5 - 5.2	4.9 - 17.1	<10 - 30	0.26 - 0.6	<1.0 - 14.0
n	10	10	10	10	10
1998					
average	3.6	11.9	14.4	0.63	4.4
range	2.4 - 4.8	7.9 - 15.8	10 - 20	0.46 - 0.87	1.2 - 7.8
n	10	10	10	10	10
1999					
average	3.3	10.8	11.1	0.43	3.7
range	1.4 - 4.7	4.6 - 15.4	<10 - 20	0.37 - 0.50	1.3 - 6.8
n	10	10	10	10	10
2000					
average	4	13.1	12.2	0.40	2.5
range	2.8 - 5.9	9.2 - 19.4	<10 - 20	0.33 - 0.49	1.2 - 5.1
n	9	9	9	9	9
2001					
average	5.3	17.4	25		1.4
range	4.2 - 6.4	13.8 - 21.0	20 - 30		1 - 1.8
n	2	2	2		2
2002					
average	3.4	11.2	12.2	0.57	2.7
range	2.6 - 4.8	8.5 - 15.7	10 - 15	0.47 - 0.85	1.0 - 4.9
n	5	5	5	5	5
2003					
average	3.7	12.1	20.6	0.48	3.8
range	2.4 - 4.8	7.9 - 15.7	13 - 36	0.36 - 0.59	1.6 - 10.0
n	10	10	10	10	10
2004					
average	3.4	11.2	13.0	0.43	4.3
range	2.7 - 4.2	8.9 - 13.9	9 - 18	0.35 - 0.54	1.8 - 8.4
n	10	10	10	10	10

3.4.1. Secchi Disc Transparency

Water clarity is commonly measured with a Secchi disc. A typical seasonal pattern shows good clarity in May and June with a drop off in July, August, and September. However, rarely does the clarity even drop below 5-feet.

The seasonal average Secchi disc readings over the years are shown in Figure 9.

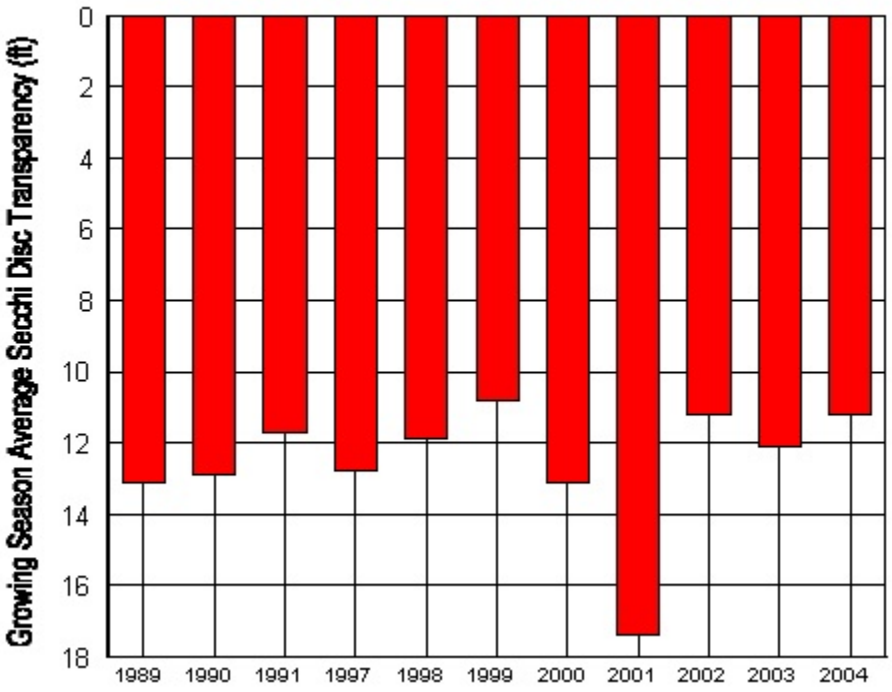


Figure 9. Growing season average Secchi disc readings from 1989-2004.

3.4.2. Total Phosphorus

Phosphorus is the nutrient more often associated with stimulating nuisance algae growth. Summer average lake phosphorus concentrations for 1997 through 2004 are shown in Figure 10. Phosphorus concentrations in Lac Lavon are low and represent some of the lowest phosphorus concentrations found in the Twin City metro area (based on CAMP data).

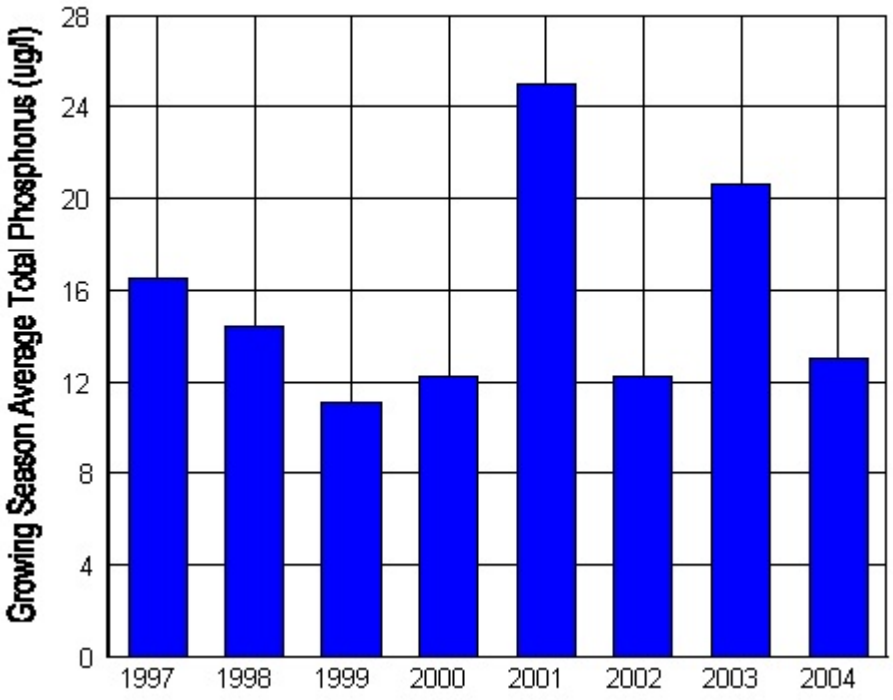


Figure 10. Summer average phosphorus concentrations (May - September) for Lac Lavon.

3.4.3. Chlorophyll and Algae

Algae are small green plants, often consisting of single cells or grouped together in filaments (strings of cells). Algae is commonly characterized by measuring the chlorophyll content in lake water. Summer average chlorophyll results for 1997 through 2004 are shown in Figure 11.

The summer average is typically less than 6 ppb. This is very low and produces excellent water clarity.

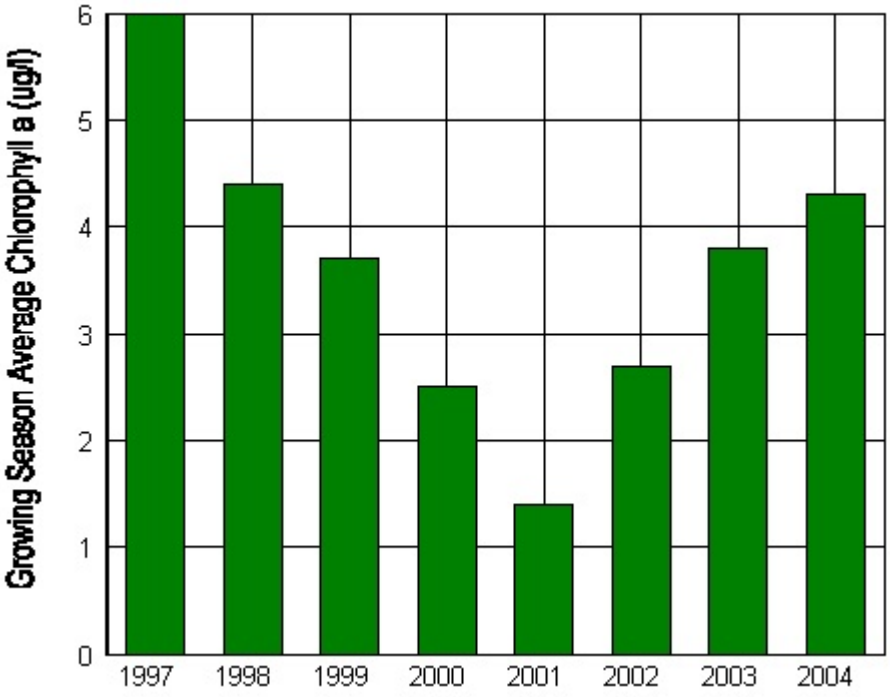


Figure 11. Summer average chlorophyll concentrations (May - September) in Lac Lavon for 1997 - 2004.

Figure 12. Examples of the type of algae found in Lac Lavon. Diatoms dominated in mid summer and although blue-green algae are present, their densities are low.

3.5. Aquatic Plant Status

Aquatic plants are very important to lakes and they are crucial for Lac Lavon. Plants act as nurseries for small fish, refuges for larger fish, and they help to keep the water clear.

Lac Lavon is a relatively new lake that was created from gravel extraction operations in the 1960s. The aquatic plant community is also relatively young, but a good diversity has developed. Currently (August 2004), Lac Lavon has eleven species of aquatic plants, with three species being non native invasive species. Eurasian watermilfoil has received the most attention since it was first discovered in 1988. The aquatic plants in Lac Lavon have been studied extensively and the Lake Association has taken an active role in aquatic plant management over the years.

Because aquatic plants in Lac Lavon are important for sustaining clear water conditions, aquatic plant management is an important lake management area.

Figure 13. Illinois pondweed is growing to the surface in Lac Lavon in September of 2003. Eurasian watermilfoil was present, but not a nuisance in 2003. It was more abundant in 2004.

3.5.1. Aquatic Plant Conditions from 1996-2004

Two aquatic plant surveys per year have been conducted in Lac Lavon from 1996 through 2004 by the MnDNR. The most recent survey results, from August 18, 2004, are summarized in Table 10. All the survey results from 1996 through 2004 are summarized in Table 11.

Table 10. Aquatic plant survey summary for 2004.

	All Stations
Number of submerged aquatic plant species found	11
Most common plants	sago pondweed and Illinois pondweed
Rarest plant	elodea
Maximum depth of plant growth	15 feet

Shallow water areas support aquatic plant growth that reaches the surface. The abundant plant growth helps sustain clear water, but can produce recreational hindrances. In the photos above, sago pondweed - a native plant, is growing up to the lake surface.

Lac Lavon Aquatic Plant Summary (based on MnDNR survey data)

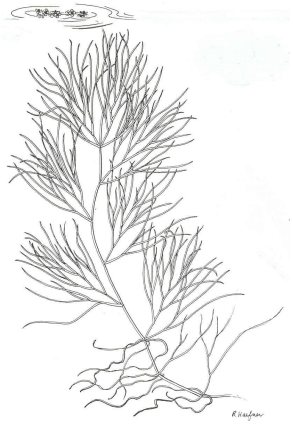
Table 11. Frequency of submerged, free floating and floating leaf macrophytes in Lac Lavon, Minnesota. Only taxa with a frequency of 10% or greater on at least one date are shown *. Twenty-four sites sampled. Maximum depth of vegetation on each date was 15 feet. Fluridone herbicide was applied on May 23, 1996, May 5, 1998, and June 5, 2002. Shaded columns with bold dates indicate approximate treatment dates.

	Frequency (%)																
Non –vascular Taxa	**May 28, 1996**	**Aug 21, 1996**	**June 12, 1997**	**Aug 27, 1997**	**May 22, 1998**	**Aug 21, 1998**	**June 17, 1999**	**Aug 20, 1999**	**May 26, 2000**	**Aug 31, 2000**	**Sept. 17, 2001**	**June 28, 2002**	**Sept. 6, 2002**	**June 13 2003**	**Aug 27, 2003**	**June 18, 2004**	**Aug 18, 2004**
Chara sp. (muskgrass)	33	42	71	75	79	96	96	100	100	100	75	75	79	88	92	88	63
Nitella sp. (stonewort)	0	0	0	0	0	0	0	17	0	0	0	0	8	0	0	0	0
Vascular Taxa																	
Ceratophyllum demersum (coontail)	46	67	17	33	29	4	4	8	17	29	54	38	42	4	17	33	33
Elodea cf *canadensis* (Canadian waterweed)	38	0	4	0	4	0	0	0	0	0	4	4	0	4	0	4	0
Myriophyllum sibiricum (northern watermilfoil)	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myriophyllum spicatum (Eurasian watermilfoil)	88	21	0	13	8	0	0	4	4	25	79	92	4	0	4	13	58
Najas flexilis (bushy pondweed)	0	0	0	63	0	0	0	17	0	46	25	0	0	0	17	8	42
Najas minor (slender naiad)	0	0	0	0	0	0	0	4	0	0	8	0	0	0	13	0	21
Potamogeton crispus (curly-leaf pondweed)	38	0	75	50	79	0	42	0	63	4	0	13	0	63	8	63	17
P. illinoensis (Illinois pondweed)	13	0	8	38	17	4	13	46	46	46	46	46	29	46	38	42	75
P. nodosus (long-leaf pondweed)	0	8	0	13	0	8	4	4	0	4	21	0	4	4	17	0	0
P .cf. *pusillus* (leafy pondweed)	21	0	25	54	8	0	0	21	17	21	4	33	4	21	38	54	33
Ranunculus cf *flabellaris* (yellow water crowfoot)	46	0	0	0	17	0	0	0	0	4	8	25	8	8	4	21	25
Stuckenia pectinata (sago pondweed)	0	13	75	83	29	8	67	54	33	75	46	42	8	83	79	63	79
Zosterella dubia (water stargrass)	13	54	54	83	83	79	46	71	67	54	33	13	46	13	29	29	42
Total number of taxa	**10**	**6**	**9**	**10**	**10**	**6**	**7**	**11**	**9**	**11**	**12**	**10**	**10**	**10**	**12**	**11**	**11**
Average number of taxa per site	3.5	2.0	3.3	5.0	3.5	2.0	2.7	3.5	3.5	4.1	4.0	3.8	2.3	3.3	3.5	4.3	4.9
Average number of native taxa per site	**2.3**	**1.8**	**2.6**	**4.4**	**2.7**	**2.0**	**2.3**	**3.4**	**2.8**	**3.8**	**3.3**	**2.8**	**2.3**	**2.7**	**3.4**		
Percent vegetated sample sites	100	92	100	100	100	100	100	100	100	100	100	100	96	100	100	100	100

Taxa that were found in Lac Lavon with a frequency of less than 10% (year(s) found): *Potamogeton natans* (June 1997) and *P. zosteriformis* (May 2000).

Common Native Plants in Lac Lavon

Sago Pondweed

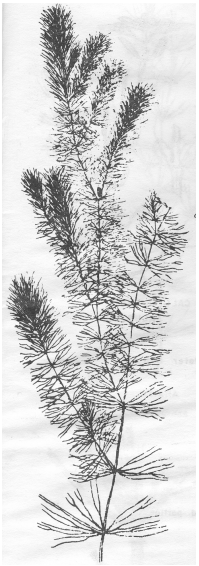


Sago pondweed (*Stuckenia pectinata*) is found in water depths out to 11 feet deep. It can grow to the surface in water depths out to 10 feet along shoreline areas in the bay with the swimming beach and on the southwest side of the lake as well.

Illinois pondweed

Illinois pondweed (*Potamogeton illinoensis*) is found in water depths to 10 feet. It can grow to the surface in some areas, especially by the swimming beach.

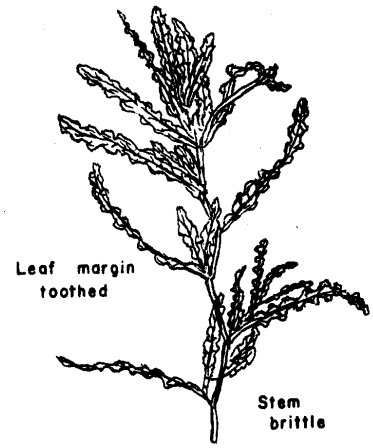
Coontail



Coontail (*Ceratophyllum demersum*) is found in several locations. Typically is not a nuisance in Lac Lavon.

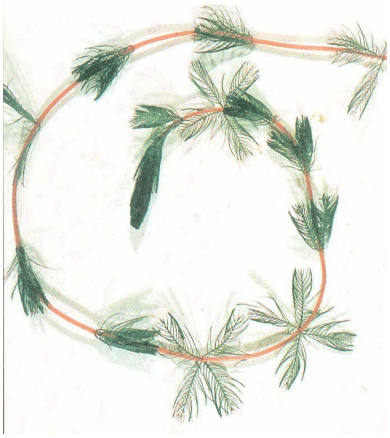
Non-Native Plants in Lac Lavon

Curlyleaf pondweed



Curlyleaf pondweed (*Potamogeton crispus*) is an non-native invasive plant found in Lac Lavon. It does not produce nuisance matted conditions at this time.

Eurasian watermilfoil



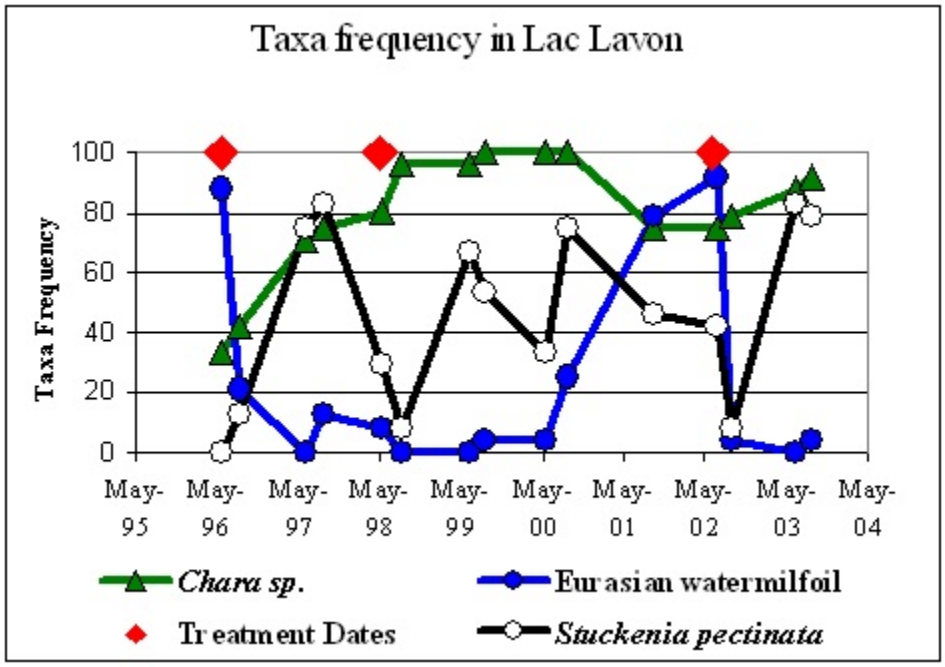
Eurasian watermilfoil (*Myriophyllum spicatum*) first discovered in Lac Lavon in 1988 (source: MnDNR). It has produced nuisance conditions in some areas in some years.

Brittle naiad

Brittle naiad (*Najas minor All*) was discovered in 2002 and identified in 2004 and is a non-native plant species. It does not present nuisance growth as of 2004. Courtesy of USDA NRCS Wetland Science Institute (USDA, NRCS. 2004).

3.5.2. Evaluation of Past Aquatic Plant Management Activities

The Lac Lavon Association has taken an active role in aquatic plant management in the lake. The main tool employed for plant management has been the use of the herbicide "Sonar". The primary plant management objective has been to control Eurasian watermilfoil which was first reported in Lac Lavon in 1988 (based on MnDNR records). Sonar has been added in the early summer in 1996, 1998, and 2002. A MnDNR report summarizing the effects of Sonar on milfoil and other plant species is found in the Appendix.



(Source: MnDNR)

September 2003. Eurasian watermilfoil in 2003 was in small bunches.

June 2004. Eurasian watermilfoil bunches had expanded in 2004, but was only a minor problem in terms of producing matting conditions.

3.5.3. Predicting Future Growth of Non-Native Invasive Plants Based on Lake Sediment Fertility

The objective of the Lac Lavon soil fertility survey was to characterize Lac Lavon soils in the littoral zone in order to better predict where nuisance areas of curlyleaf pondweed and milfoil growth could occur in the future.

Based on other lake research, it appears that the potential nuisance growth of the non-native invasion plant, curlyleaf pondweed, can be predicted in a lake based on several key sediment parameters. These parameters were analyzed in this Lac Lavon study. Although this curlyleaf evaluation method is still experimental, it has correctly predicted heavy nuisance growth for several lakes in the Central Hardwood Forest Ecoregion (McComas, unpublished).

In addition to using lake sediments to predict the growth conditions of curlyleaf pondweed, lake sediments can also be used to predict the growth characteristics of Eurasian watermilfoil.

It is well established that nitrogen is often the limiting nutrient for terrestrial plants (Wedin and Tilman 1996; Stevens et al 2004). Based on results from other lakes, it appears sediment nitrogen (as exchangeable ammonium) is important for producing heavy growth of Eurasian watermilfoil (Anderson and Kalff 1986; Barko, pers comm). There appears to be a nitrogen threshold for nuisance milfoil growth (Wakeman and Les 1994). When sediment nitrogen concentrations (as exchangeable ammonia) are greater than about 10 ppm, nuisance milfoil conditions are found in these areas in many lakes (McComas, unpublished).

Organic matter is another leading indicator for potential nuisance milfoil growth and this is probably because organic matter and nitrogen are related so when there is also high organic matter there is also high nitrogen. However, at high levels of organic matter, and 20% or greater seems to be the threshold, Eurasian watermilfoil does not exhibit nuisance growth (Barko and Smart 1986; Barko et al 1991).

Based on results from other lakes it is predicted that the combination of organic matter and high nitrogen values (as exchangeable ammonium) will sustain nuisance milfoil growth in shallow water on an annual basis unless some other factor limits growth. Limiting factors include things such as herbicide use, milfoil weevils, light penetration, sediment density, and even lake bottom slopes. When lake bottoms have moderate fertility (less than 6 ppm of exchangeable nitrogen), it is predicted that potential nuisance growth could occur in some years, but not on a continuous basis.

Predicting Areas of Nuisance Curlyleaf Pondweed Growth in Lac Lavon: Curlyleaf pondweed, is an non-native invasive aquatic plant, and can grow to nuisance conditions. Four parameters are correlated with three categories of curlyleaf pondweed growth. The means of the sediment determinations as they correlated to the three growth categories are shown in Table 12. For heavy nuisance curlyleaf growth to occur in a lake, like Lac Lavon, all four parameters from a sediment site need to be within range of the reference nuisance category. For Lac Lavon, none of the sediments tested had all four sediment characteristics that apparently are necessary to produce heavy nuisance growth of curlyleaf pondweed. No areas are predicted to support heavy curlyleaf growth in Lac Lavon although light growth is predicted to occur at 4 of the 11 sites. Ongoing aquatic plant surveys will help to characterize the curlyleaf status and check the predicted growth patterns.

Table 12. Lac Lavon sediment data and ratings for potential nuisance curlyleaf pondweed growth.

Sample ID	Bulk density (g/cm^3)	Organic Matter (%)	pH (su)	Mn:Fe Ratio	Potential for Nuisance Curlyleaf Pondweed Growth
non-nuisance	**1.04**	**5**	**6.8**	**0.22**	**Low**
light nuisance	**0.94**	**11**	**6.2**	**0.17**	**Med**
heavy nuisance	**<0.51**	**>20**	**>7.7**	**>0.64**	**High**
1	0.97	3	7.5	0.12	Low
2	0.88	3.1/3.0	7.65	0.08	Med
3	1.37	0.5	7.9	0.17	Med
4	1.09	1.6	7.6	0.16	Low
5	0.94	3.5	7.3	0.11	Low
6	1.04	1.4	7.6	0.09	Low
7	0.99	1.6	7.6	0.11	Low
8	1.32	0.9	7.8	0.11	Med
9	0.92	2	7.7	0.28	Med
10	0.91	2.6	7.5	0.11	Low
11	0.92	2	7.6	0.21	Low

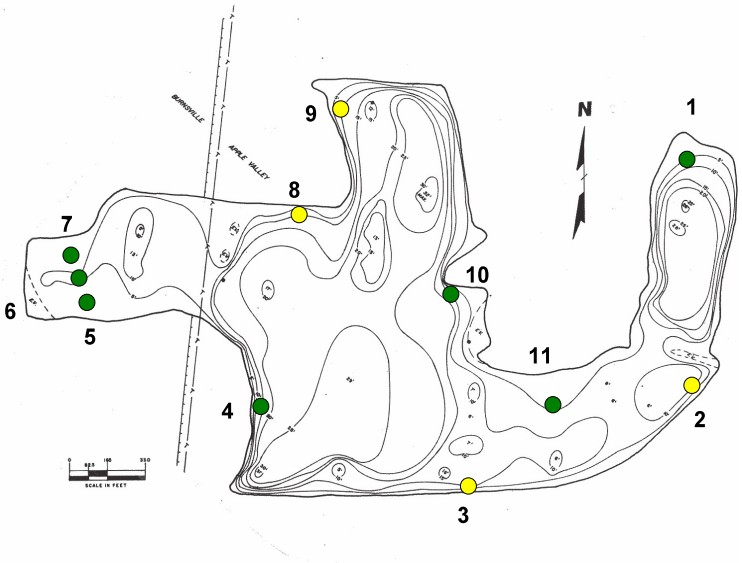


Figure 14. Sediment sample locations are shown with dots. The dot color indicates the potential for the growth characteristic of curlyleaf pondweed to grow at that site. Key: green dot = low; yellow dot = medium; red dot = high potential (no red dots were used).

Predicting Areas of Nuisance Eurasian Watermilfoil Growth in Lac Lavon: Based on results from other studies conducted by Blue Water Science, there has been a correlation of sediment exchangeable ammonia concentrations over 10 pm with nuisance growth of Eurasian watermilfoil. Using the 10 ppm threshold as a basis for prediction, we have constructed a map showing the areas in Lac Lavon that have the potential to support nuisance milfoil growth (Figure 15). Eight out of eleven sample locations have exchangeable ammonia concentrations over 10 µg/cm^3-dry coupled with low organic matter. This combination is correlated with nuisance growth of EWM. We estimate that 11 acres of lake bottom could support matting EWM growth.

Table 13. Lac Lavon sediment data and ratings for potential nuisance Eurasian watermilfoil growth.

Sample Number	Water Depth at Sample Location (ft)	Lake Sediment Bulk Density (dry) grams/cm^3	NH_4 Based on Corrected Weight-Volume (µg/cm^3)	Organic Matter (%)	Potential for Nuisance EWM Growth
1	6	0.97	19.1	3.0	High
2	10	0.88	5.9	3.1/3.0	Med
3	6	1.37	6	0.5	Med
4	6	1.09	16.7	1.6	High
5	5	0.94	60.3	3.5	High
6	6	1.04	25.7	1.4	High
7	5	0.99	24.4	1.6	High
8	5	1.32	5	0.9	Low
9	6.5	0.92	15.4	2	High
10	8	0.91	25.2	2.6	High
11	8	0.92	15.2	2	High

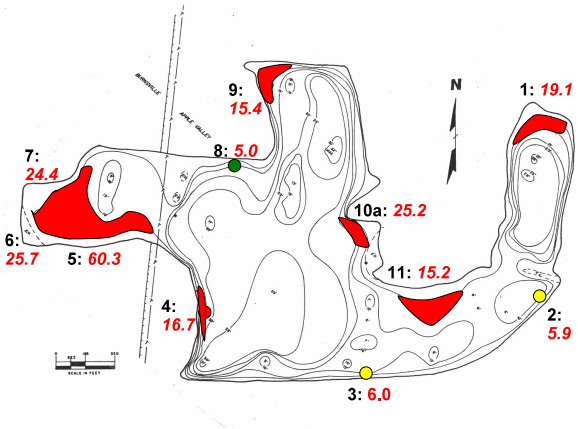


Figure 15. Areas that have the potential to support nuisance growth of Eurasian watermilfoil are shown in red shading.

Figure 16. Matting, nuisance Eurasian watermilfoil is shown above. This is a density of a "5" and this is the kind of nuisance growth predicted by high sediment nitrogen values and a sediment organic matter content less than 20%.

3.6. Fishery Status (prepared by MnDNR)

The fishery status has been summarized by the MnDNR.

Name: Lac Lavon

Nearest Town: Burnsville and Apple Valley
Primary County: Dakota

Survey Date: 08/09/1999
Inventory Number: 19-0446-00

Public Access Information

Ownership	Type	Description
City	Unknown	Beach area owned by Burnsville on west side of lake.
City	Unknown	Park on NE corner owned by Apple Valley, asphalt path to lake with pier.

Lake Characteristics

Lake Area (acres): 55.00
Littoral Area (acres): 26.00
Maximum Depth (ft): 32.00
Water Clarity (ft): 10.00

Dominant Bottom Substrate : sand, gravel, silt
Abundance of Aquatic Plants : abundant
Maximum Depth of Plant Growth (ft): 16.00

Fish Sampled up to the 1999 Survey Year

		Number of fish per net			
Species	**Gear Used**	**Caught**	**Normal Range**	**Average Fish Weight (lbs)**	**Normal Range (lbs)**
Black Bullhead	Trap net	0.1	0.7 - 16.4	0.55	0.2 - 0.6
Black Crappie	Gill net	3.0	1.0 - 4.3	0.28	0.2 - 0.5
	Trap net	1.6	0.7 - 4.3	0.27	0.2 - 0.5
Bluegill	Gill net	5.0	N/A - N/A	0.17	N/A - N/A
	Trap net	49.8	2.9 - 41.2	0.07	0.1 - 0.3
Golden Shiner	Trap net	0.1	0.5 - 3.2	0.06	0.1 - 0.3
Hybrid Sunfish	Trap net	3.1	N/A - N/A	0.19	N/A - N/A
Largemouth Bass	Gill net	0.5	0.5 - 1.5	0.34	0.4 - 1.2
	Trap net	0.1	0.4 - 2.0	0.05	0.2 - 0.9
Northern Pike	Gill net	11.5	2.7 - 9.3	2.24	1.6 - 2.9
	Trap net	0.1	N/A - N/A	1.94	N/A - N/A
Pumpkinseed Sunfish	Gill net	1.0	N/A - N/A	0.04	N/A - N/A
	Trap net	4.6	1.5 - 7.4	0.08	0.1 - 0.2
Snapping Turtle	Trap net	0.4	N/A - N/A	ND	N/A - N/A
Walleye	Gill net	1.5	0.5 - 3.8	2.98	1.1 - 2.9
White Sucker	Gill net	2.0	0.5 - 2.5	2.75	1.0 - 2.4
	Trap net	0.4	0.3 - 1.3	0.81	1.1 - 2.4

Normal Ranges represent typical catches for lakes with similar physical and chemical characteristics.

Length of Selected Species Sampled for All Gear for the 1999 Survey Year

	Number of fish caught in each category (inches)								
Species	***0-5***	***6-8***	***9-11***	***12-14***	***15-19***	***20-24***	***25-29***	***>29***	***Total***
Black Bullhead	0	0	1	0	0	0	0	0	1
Black Crappie	8	3	8	0	0	0	0	0	19
Bluegill	167	64	0	0	0	0	0	0	231
Hybrid Sunfish	11	14	0	0	0	0	0	0	25
Largemouth Bass	1	1	0	0	0	0	0	0	2
Northern Pike	0	0	1	1	9	8	4	1	24
Pumpkinseed Sunfish	36	3	0	0	0	0	0	0	39
Walleye	0	0	0	0	2	1	0	0	3

Fish Stocked by Species for the Last Five Years

Year	**Species**	**Age**	**Number**
1997	*Rainbow Trout*	Yearling	2,000
1998	*Rainbow Trout*	Yearling	1,668
1999	*Rainbow Trout*	Yearling	2,000
2000	*Rainbow Trout*	Yearling	1,000
	Tullibee (Cisco)	Adult	4,176
2001	*Smallmouth Bass*	Adult	32
2002	*Tullibee (Cisco)*	Adult	5,578

Fish Consumption Advisory

Meal Advice for Pregnant Women, Women who may become pregnant and Children under age 15

Species	less than 15"	15" to 20"	20" to 25"	25" to 30"	greater than 30"
Bluegill Sunfish	◔				
Northern Pike		◑			

Meal Advice for the General Population

Species	less than 15"	15" to 20"	20" to 25"	25" to 30"	greater than 30"
Bluegill Sunfish	◔				
Northern Pike		◔			

Symbol Key	unlimited	1 meal per week	1 meal per month	1 meal every 2 months	do not eat
Mercury	○	◔	◑		●
PCBs	□	◧	◩	◪	

Status of the Fishery (as of 08/09/1999)

Lac Lavon has been stocked with rainbow trout since 1989. Public access is available on the northeast and west shores. No gas engines are allowed on the lake. In addition to this survey, a creel survey of anglers was performed throughout 1999. Sunfish species dominated the net and angler catch in 1999, with the most common species being bluegill. Sizes of fish ranged from under 2 inches to over 7 inches in length. Largemouth bass were the next most abundant species caught by anglers, with most fish released. Net catches in this survey were low, but the nets used were not designed to effectively sample largemouth bass. Black crappie were captured in nets and by anglers in much lower numbers than sunfish, but a larger percentage of the fish were of acceptable size, with several netted fish measuring over 10 inches in length. Northern pike were the most abundant predator sampled in the nets, in higher numbers than in previous nettings. The largest fish measured over 30 inches in length. Angler catch was moderate, with most fish released. Three walleye were sampled in nets, all three near 20 inches in length. Anglers in the creel survey did not catch walleye. A few white sucker, a golden shiner, a black bullhead and three snapping turtles were captured in nets. No trout were captured. Anglers caught an estimated 171 rainbow trout during the year, with over 2/3 released.

4. Lake and Watershed Assessment

4.1. Lac Lavon Status

Lac Lavon has relatively low fertility and has lower phosphorus concentrations than many of the surrounding lakes. One way to compare the status of Lac Lavon is to compare it to other lakes in a similar setting or ecoregion.

Ecoregions are geographic regions that have similar geology, soils, and land use. The continental United States has been divided into 84 ecoregions, and there are seven ecoregions in Minnesota. A map of Minnesota ecoregions is shown in Figure 17. Lac Lavon is in the North Central Hardwood Forest ecoregion (Figure 17). Lakes in this area of the state have some of the better water quality values in the State. A range of ecoregion values for lakes in the North Central Hardwood Forest ecoregion along with actual Lac Lavon data are shown in Table 14.

Table 14. Summer average quality characteristics for lakes in the Northern Lakes and Forest ecoregion (Minnesota Pollution Control Agency, 1988).

Parameter	North Central Hardwood Forest	Lac Lavon (2003)
Total phosphorus (µg/l) - top	23 - 50	21
Algae [as Chlorophyll (µg/l)]	5 - 22	4
Chlorophyll - max (µg/l)	7 - 37	10
Secchi disc (ft)	4.9 - 10.5	12.2

This comparison indicates that the water quality of Lac Lavon is within range and sometimes better compared to the North Central Hardwood Forest ecoregion water quality values. The challenge will be to maintain Lac Lavon's water quality values within ecoregion ranges.

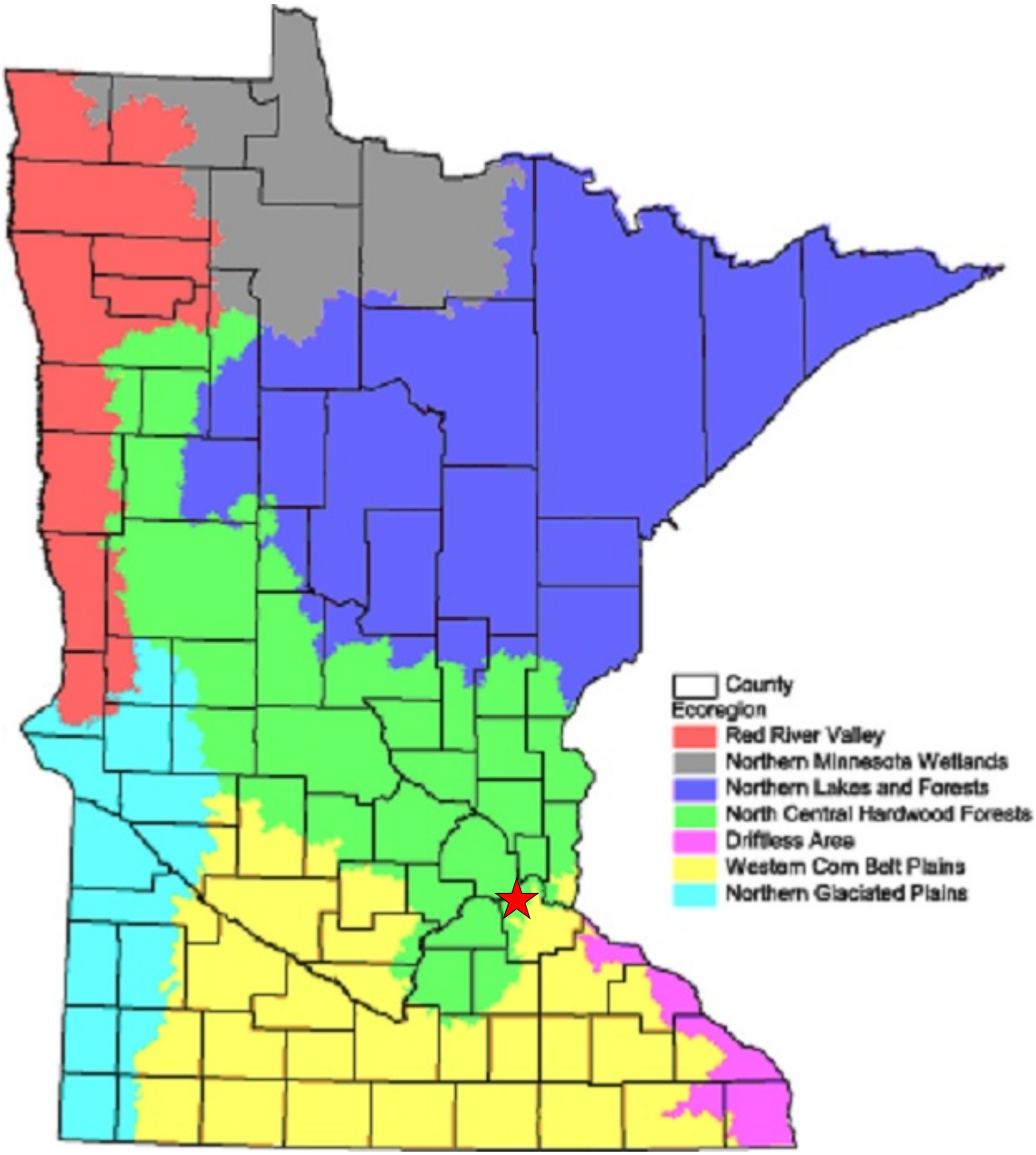


Figure 17. Ecoregion map for Minnesota. Areas that are green are within the North Central Hardwood Forests Ecoregion. Lac Lavon , located in Dakota County is officially in the North Central Hardwood Forest Ecoregion.

4.2. Setting Water Quality Goals and Aquatic Plant Goals for Lac Lavon

Water quality in Lac Lavon is good compared to ecoregion ranges. The water quality status can be further refined when an ecoregion lake model is used. A lake model is a mathematical equation that uses phosphorus inputs along with lake and watershed characteristics to predict what a lake phosphorus concentration should be. Once a lake phosphorus concentration is determined, then seasonal water clarity and algae concentrations can be calculated as well.

A Lac Lavon model was run based on ecoregion runoff values (which are 150 ppb in runoff) for the North Central Hardwood Forest Ecoregion. The results were then compared to existing observed lake conditions. The results are shown in Figure 18.

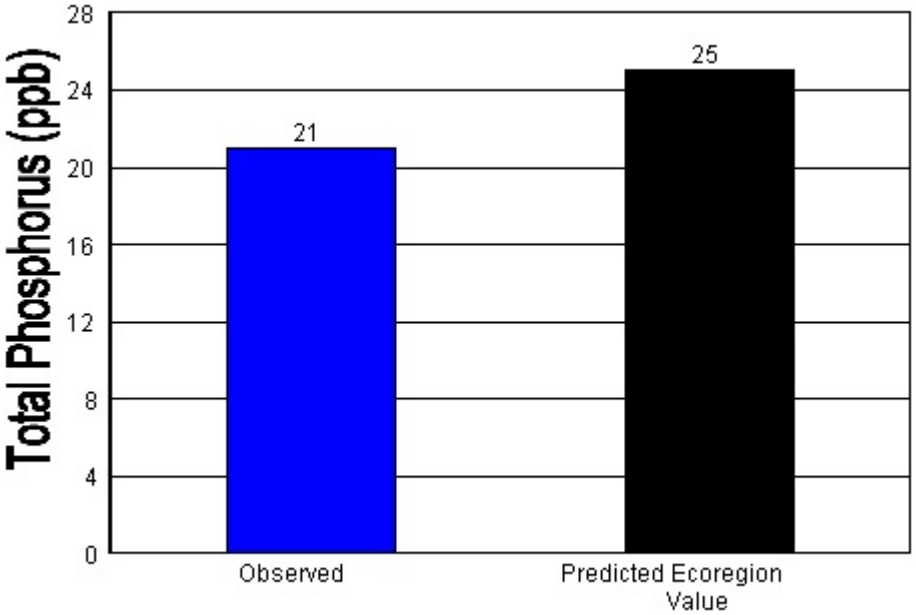


Figure 18. Comparison of total phosphorus conditions for Lac Lavon in 2004 to predicted conditions for a lake the size of Lac Lavon situated in the Central Hardwood Forest (CHF) ecoregion.

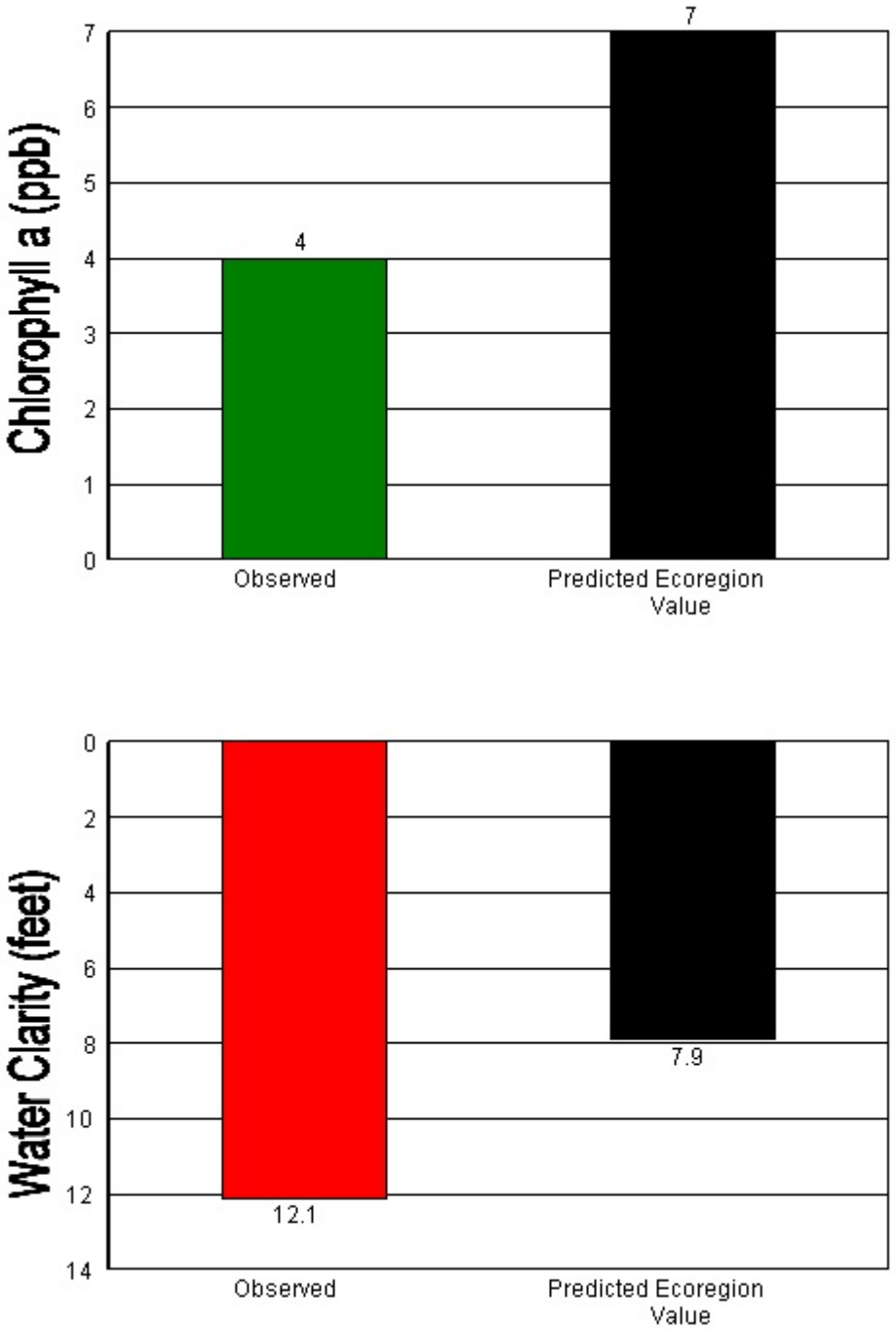


Figure 19. Comparison of chlorophyll a and water clarity conditions for Lac Lavon in 2003 to predicted conditions for a lake the size of Lac Lavon situated in the Central Hardwood Forest ecoregion.

4.3. Lake Management Strategy

Lac Lavon is a seepage lake with some urban drainage. The watershed to lake surface ratio of 2 to 1 is low for glacial seepage lakes (seepage lakes have no major streams, are largely groundwater fed, and generally have a watershed to lake ratio of 10 to 1 or less). The phosphorus loading associated with a Central Hardwood Forest Ecoregion lake model indicated Lac Lavon should have higher phosphorus concentrations and lower water clarity than what has been observed. This means the lake has better water quality than would be expected.

Therefore, in terms of water clarity Lac Lavon is in a protection mode. This means that projects and programs should be designed to maintain the good water quality currently exhibited.

However, the sediment sample at the deep station indicated there is a lot of phosphorus that has accumulated in the deep areas of the lake. Currently, this phosphorus does not come into the water column. Significant algae blooms could occur if it did.

One of the factors that is keeping phosphorus locked up in the sediments is the oxygenated bottom waters. If the bottom water experiences extended depletion of the dissolved oxygen, combined with a lake turnover, phosphorus could be released from the lake sediments and make its way into the upper water. If this occurs, an expensive remediation project such as a sediment alum treatment that would tie up the phosphorus could be considered. It is not needed at this time.

Although water quality is above average, there has been nuisance growth of aquatic plants since about 1988. The lake residents have taken an active management role targeting Eurasian watermilfoil control. They have used the herbicide flouridone (trade name Sonar) for Eurasian watermilfoil control on three occasions since 1996.

Therefore, lake management activities, and especially aquatic plant management activities, should be designed to minimize any oxygen decline in the bottom waters. Therefore, judicial use of herbicides should be considered.

Based on this strategy, a list of lake management projects has been prepared and are listed in the next section.

5. Lake Project Ideas for Protecting the Lake Environment (which includes water quality and wildlife)

Project ideas for Lac Lavon are geared toward long-term protection of water quality.

A list of projects has four main components:

1. Shoreland projects.
2. Aquatic plant projects.
3. Watershed and lake monitoring program.

Details for these projects are given in the next few pages.

Project 1. Shoreland Projects

For existing properties it is important to either maintain or to improve the natural vegetative buffer. The vegetative buffer is located in the shoreland area.

The shoreland area is valuable for promoting a natural lake environment and a natural lake experience for lake users. The shoreland is defined as the upland area about 300 to 1,000 feet back from the shoreline, and out into the lake to about the end of your dock (Figure 20). A shoreland with native vegetation offers more wildlife and water quality benefits than a lawn that extends to the lake's edge. A summary of attributes and functions of native plants in the shoreland area is shown in Table 15.

Figure 20. Cross section of the lake shoreland habitat.

Table 15. Attributes and functions of native plants in the shoreland area (Source: Henderson and others, 1999. Lakescaping for Wildlife and Water Quality. MnDNR).

Important functions of plants in and around lakes

Submergent and emergent plants

- Plants produce leaves and stems (carbohydrates) that fuel an immense food web.
- Aquatic plants produce oxygen through photosynthesis. The oxygen is released into lake water.
- Submerged and emergent plants provide underwater cover for fish, amphibians, birds, insects, and many other organisms.
- Underwater plants provide a surface for algae and bacteria to adhere to. These important microorganisms break down polluting nutrients and chemicals in lake water and are an important source of food for organisms higher in the food chain.
- Emergent plants break the energy of waves with their multitude of flexible stems, lessening the water's impact on the bank and thus preventing erosion.
- Plants stabilize bottom sediments, which otherwise can be resuspended by currents and wave action. This reduces turbidity and nutrient cycling in the lake.

Shoreline and upland plants

- Shoreline and upland plants provide food and cover for a variety of birds, amphibians, insects, and mammals above the water.
- The extensive root systems of shoreline plants stabilize lake-bank soils against pounding waves.
- Plants growing on upland slopes that reach down to the lake hold soil in place against the eroding forces of water running over the ground, and help to keep lake water clean.
- Upland plants absorb nutrients, like phosphorus and nitrogen, found in fertilizers and animal waste, which in excessive concentrations are lake pollutants.

Improving Upland Native Landscape Conditions: In the glacial lake states, three broad vegetative groups occur: pine forests with a variety of ground cover species including shrubs and sedges: hardwood forests with a variety of understory species, including ferns: and tallgrass prairie with a variety of grasses as well as bur oaks and willow trees. Residences around Lac Lavon are in the hardwood forest group.

Reestablishing native conditions in the shoreland area not only improves stormwater runoff quality, it also attracts a variety of wildlife and waterfowl to the shoreland area. Benefits multiply when other neighbors naturalize because the effects are cumulative and significant for water quality and wildlife habitat.

When installing native vegetation close to the shoreline residents are actually installing a buffer. A buffer is a strip of native vegetation wide-

enough to produce water quality and wildlife improvements. Much of the natural vegetative buffer has been lost in shoreland areas with development where lawns have been extended right down to the shore.

Lawns are not necessarily bad for a lake. However they can be over fertilized and then runoff carries phosphorus to the lake. Also, lawns function as a low grade open prairie, with poor cover for wildlife and a food supply that is generally poor, except for geese who may find it attractive. Replacing lawn areas with native landscaping projects reduces the need for fertilizer, reduces the time it takes to mow, increases the natural beauty of a shoreland area, and attracts wildlife.

Lawns do not make very good upland buffers. With runoff, short grass blades bend and do not serve as a very effective filter. Tall grass that remains upright with runoff is a better filter. Kentucky bluegrass (which actually is an exotic grass) is shallow-rooted and does not protect soil near shorelines as well as deep-rooted native prairie grasses, shrubs, or other perennials. Grass up to the shoreline offers poor cover, so predators visit other hiding areas more frequently reducing the prey food base and limiting predator populations in the long run. Also with short ground cover, ground temperatures increase in summer, evapotranspiration increases and results in drying conditions, reducing habitat for frogs and shoreline dependent animals.

Buffer Strip Considerations: A functional upland buffer should be at least 15 feet deep. With this you start getting water quality and wildlife habitat benefits. But a 25 foot deep buffer is recommended. In the past, before lakeshore development, buffers ringed the entire lake. For lakeshore residents it is recommended the length of the buffer extend for 75% of the shoreline, although 50% would produce buffer benefits.

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, you won't be mowing over their dens. An occasional den shouldn't produce muskrat densities that limit desirable aquatic vegetation.

Several types of buffers can be installed or propagated that offer nutrient removal as well as wildlife benefits. Examples include:

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, Diamond 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 initial step for lake residents to get started is to simply make a commitment to try something. Just what the final commitment is evolves as they go through a selection process. The next step in the process is to conduct a site inventory. On a map with lot boundaries, house and buildings, driveway, turf areas, trees, shrubs, and other features are drawn. If there is a chance, the property is checked during a rainstorm. Look for sources of runoff and even flag the routes. Find out where the water from the roof goes, and see if there are temporary ponding and infiltration areas. Are the paths down to the lake eroding? Then the next step is to consider a planting approach.

Native Landscaping for Buffers: Three Approaches: Native landscaping efforts can be put into three categories:

1. Naturalization
2. Accelerated Naturalization
3. Reconstruction

1. Naturalization: With this approach, the resident is going to allow an area to go natural. Whatever is present in the seedbank is what will grow. If they want to install a buffer along the shoreline, let a band of vegetation grow at least 15 feet deep from the shoreline back and preferably 25 feet or deeper. Just by not mowing will do the trick. Residents can check how it looks at the end of the summer. It will take up to three years for flowers and native grasses to grow up and be noticed. Residents can also select other spots on their property to “naturalize”.

2. Accelerated Naturalization: After developing a plant list of species from the area, residents may want to mimic some features right away.

They can lay out a planting scheme and plant right into existing vegetation. Several Minnesota nurseries can supply native plant stock and seeds. The nurseries can also help select plants and offer planting tips. Wildflowers can be interspersed with wild grasses and sedges. Mulch around the new seedlings. With this approach lake residents can accelerate the naturalization process.

3. Reconstruction: To reestablish a native landscape with the resident's input and vision, another option is to reconstruct the site with all new plants. Again plant selection should be based on plants growing in the area. Site preparation is a key factor. Residents will want to eliminate invasive weeds and eliminate turf. This can be done with either herbicides or by laying down newsprint or other types of paper followed by 4 to 6 inches of hardwood mulch. Plantings are made through the mulch. This is the most expensive of the three native landscaping categories. Residents can do the reconstruction all at once, or phase it in over 3 to 5 years. This allows them to budget annually and continue evolving the plan as time goes by.

Also mixing and matching the level-of-effort categories allows planting flexibility. Maybe a homeowner employs naturalization along the sides of the lot and reconstruction for half of the shoreline and accelerated naturalization for the other half. Examples of the three approaches are shown on the next page.

A book that covers the shoreland improvements is "Lakescaping for Wildlife and Water Quality" by Carrol Henderson and others and is available from the Minnesota Department of Natural Resources for $21 (651.296.6157).

1. Naturalization: The easiest way to implement a natural shoreline setting is to select an area and leave it grow back naturally.

2. Accelerated Naturalization: To accelerate the naturalization, plant shrubs, wild flowers, or grasses into a shoreland area.

3. Restoration: This involves removing existing vegetation through the use of paper mats and/or mulching and planting a variety of native grasses, flowers, and shrubs into the shoreland area.

Examples of three shoreland management options.

Project 2. Aquatic Plant Projects

A high priority lake protection recommendation is to maintain healthy native aquatic plant communities in Lac Lavon. Currently, Lac Lavon has a variety of emergent and submergent aquatic plant growth. Aquatic plants are vital for helping sustain clear water conditions and contribute to fish habitat.

The challenge is to maintain and/or protect native submerged aquatic plants in Lac Lavon. Several plant improvement ideas are given below:

- Maintaining good shoreland conditions can promote improved plant distribution.

- Over the years approximately 10 - 15 acres of lake area have supported nuisance aquatic plant growth. Only the minimum amount of plants should be removed to improve navigation and lake use. Plants are important fish habitat and help keep the water clear.

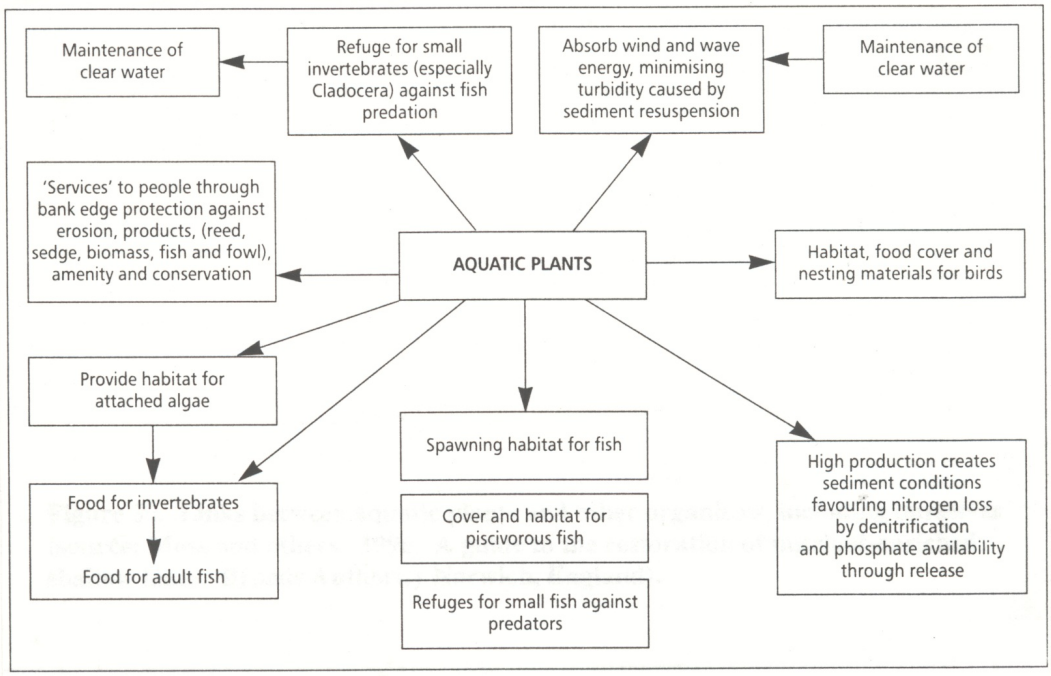


Figure 21. Links between aquatic plants and other organisms, including ourselves (source: Moss and others. 1996. A guide to the restoration of nutrient-enriched shallow lakes. Broads Authority Norwich, England).

A. Managing Non-native Invasive Plants:

Curlyleaf pondweed: Currently curlyleaf pondweed has a moderate density in Lac Lavon. Sediment sample results indicate curlyleaf should not exhibit widespread heavy growth characteristics although light nuisance to non-nuisance growth could occur. Control action is probably unnecessary at this time.

Figure 22. The above condition is an example of a heavy growth of curlyleaf pondweed in Crystal Lake in Burnsville. Lac Lavon does not have this type of curlyleaf growth. Heavy growth of curlyleaf pondweed is correlated with several key sediment parameters including sediment bulk density, organic matter, pH, and the Mn:Fe ratio.

Eurasian watermilfoil: At the end of 2004, there was minor nuisance milfoil growth. It is recommended that in 2005, lake residents monitor increases in milfoil distribution and map the beds on a scale from 1 to 5 with 5 being a bed that is topping out.

The whole lake treatment using the herbicide fluridone has been implemented on three previous occasions. The herbicide has reduced the nuisance occurrence of Eurasian watermilfoil for up to three years. This continues to be a plant management option for Lac Lavon.

In 2005, and in following years, spot treatments with a 2, 4-D herbicide may be warranted in channels or areas where boating may be hindered. Mechanical harvesting is another option for cutting channels but herbicide use is probably cheaper at this time ($300-$500 per acre).

It appears that spot treatments or harvesting will address milfoil control objectives. Stopping the spread of milfoil will be difficult and spot treatment may slow it down, but probably will not contain it. Other lake groups have tried to contain milfoil and stop its spread, but have not been successful.

Long-term control may be assisted by lowering runoff nitrogen inputs to Lac Lavon. Homeowners and lawn maintenance companies should use the minimum amount of nitrogen fertilizer for lawn care. Also, keep grass clippings out of the lake. These actions may reduce nitrogen levels in the long run and help reduce the incidence of nuisance growth of Eurasian watermilfoil.

Figure 23. Nuisance, matted Eurasian watermilfoil growth in a bay on White Bear Lake. In some years, milfoil growth has reached the water surface causing recreational hindrances.

Brittle Naiad: Lac Lavon is the only lake in the State of Minnesota with a documented occurrence of the non-native brittle naiad (*Najas minor*). The brittle naiad was first reported in the U.S. in 1934. It ranges from Vermont to Oklahoma and is found in Iowa. Like its other close cousins in the naiad genus, it is an annual plant.

The distribution of the brittle naiad in Lac Lavon is limited. It is most abundant in the northwest lobe across from the fishing pier.

At this time it does not appear that special management action is needed.

Figure 24. Najas minor All. Robert H. Mohlenbrock. USDA NRCS. 1995. *Northeast wetland flora: Field office guide to plant species.* Northeast National Technical Center, Chester, PA. Courtesy of USDA NRCS Wetland Science Institue (USDA, NRCS. 2004).

B. Managing Native Nuisance Plants:

Native aquatic plants are the foundation for good water clarity in Lac Lavon. However, in some years, one or two species can grow to the surface and create a surface matting condition which hinders navigation and boat use on the lake. In these cases selective harvesting in the form of cutting channels through the mats would be an option.

For example, Illinois pondweed can be a pesky nuisance in some areas in some years (see Figure 25). Otherwise the growth of native plants should be protected.

Figure 25. Illinois pondweed at a density of a "4" and "5" (where it is topping out) at the swimming beach in 2003.

In summary, three options are appropriate for aquatic plant management in Lac Lavon (Table 16). Mechanical harvesting is the first choice.

Table 16. Three options for aquatic plant management.

	Area to Be Treated	Annual Cost	3-Year Cost
1. Harvesting	15 ac x $500	$7,500	$22,500
2. Spot treatment with 2, 4D	15 ac x $425	$6,375	$19,125
3. Sonar every 3 to 4 years	whole lake	$6,000	$18,000

Figure 26. Buttercup surfacing June, 2004. Most native plants do not grow to nuisance conditions.

Project 3. Watershed and Lake Monitoring Program

Options for a lake monitoring program are outlined in Table 17. It will be important to track the dissolved oxygen conditions in the bottom of Lac Lavon. In addition it would be beneficial to collect bottom water samples in June, July, and August to gage the magnitude of phosphorus release. If phosphorus release is high (bottom concentration is 10 times the surface concentration) remedial action, such as a sediment alum treatment may be considered. Currently, the monitoring program does not call for watershed monitoring. The lake monitoring program is designed to be flexible to accommodate the volunteer work force and a fluctuating budget.

Table 17. Lac Lavon water quality monitoring program.

Category	Level	Alternative	Labor Needed	Cost/Year
A. Dissolved oxygen	1	Check dissolved oxygen in Lac Lavon every two weeks in January, February, and March depending on winter conditions.	Moderate	$0
	2	Check dissolved oxygen in Lac Lavon every one to two weeks in December, January, February, and March, depending on winter conditions and collect phosphorus samples.	Moderate	$0
	3	Check dissolved oxygen once per month from May - September (initial cost of meter: $1,000).	Moderate	$0
B. Water clarity	1	Secchi disc taken at spring and fall turnover.	Low	$0
	2	Secchi disc monitoring once per month May - October.	Low-moderate	$0
	3	Secchi disc monitoring twice per month, May - October.	Moderate	$0
C. Water chemistry	1	Spring and fall turnover samples are collected. Selected parameters for analysis include: TP and chlorophyll.	Low	$200
	2	Spring and fall turnover samples are collected. Standard package of parameters is analyzed.	Low	$600
	3	Sample for phosphorus and chlorophyll once per month from May - September (surface water only).	Low-moderate	$300
	4	Sample for phosphorus and chlorophyll twice per month from May - October.	Moderate	$600
	5	Sample for phosphorus, chlorophyll, Kjeldahl-N, nitrate-nitrite-N, and ammonia-N once per month (May-October)	Moderate	$960
	6	Sample for phosphorus, chlorophyll, Kjeldahl-N, nitrate-nitrite-N, and ammonia-N twice per month (May-October).	Moderate	$1,920
D. Special samples or surveys	1	Special samples: suspended solids, BOD, chloride, turbidity, sampling bottom water, and other parameters as appropriate. Aquatic plant surveys, etc.	--	$100-$3,000

For the next few years, a recommended program consists of Level A3, Level B3 and Level C4 annually. This is basically the CAMP program and is sponsored by the Cities of Burnsville and Apple Valley. An aquatic plant survey (Level D1) is currently being conducted annually by the MnDNR.

6. References

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Appendix

A. MnDNR Plant Summary and 2004 Plant Survey Data (June 18 and August 18)
B. Blue Water Science Plant Survey Data for September 9, 2003

Minnesota Department of Natural Resources
Eurasian watermilfoil Management Case Study
Lac Lavon: Results of three treatments over eight years

Prepared by Wendy Crowell and Nick Proulx Minnesota Department of Natural Resources Ecological Services, Box 25, 500 Lafayette Rd. St. Paul MN 55155 wendy.crowell@dnr.state.mn.us 651-282-2508. April 1, 2005.

Treatment Strategy: Repeated whole lake fluridone treatments with Sonar ™ A.S at a low rate (6 to 10 ppb fluridone)

Lake: **Lac Lavon**, Dakota County, Division of Waters number 19044600
55 acres with 26 acres less than 15 feet deep

Problem and Management Objectives:

In 1988, Eurasian watermilfoil, hearafter called milfoil, was discovered in Lac Lavon, a private waterbody where the Minnesota Department of Natural Resources (DNR) does not regulate the destruction of aquatic vegetation. By 1996 milfoil had become the dominant plant in the lake, which created problems for lakeshore homeowners, users of the City of Apple Valley's park and users of the City of Burnsville's beach and park who wished to swim, boat, or fish in the lake. The objective of the treatment in 1996 was to eliminate milfoil from Lac Lavon. The 1996 fluridone treatment reduced the amount of milfoil in the lake, but did not eradicate it. Because the 1996 treatment was guaranteed to eradicate milfoil from the lake it was treated again in 1998, which removed the plant for one year. Nevertheless, by 1999 milfoil was again found in Lac Lavon. By June 2002 the lake was again dominated by milfoil, which was causing nuisance conditions (Table 1). The objective of the 2002 treatment was to alleviate the nuisances caused by milfoil for several years following treatment. In 2003, milfoil was not detected during the spring survey, however the late summer survey did show milfoil had returned to Lac Lavon at low levels.

Treatments:

Lac Lavon was treated with fluridone in 1996, 1998, and 2002. In 1996 five and a half gallons of Sonar ™ A.S. were applied to Lac Lavon. Five gallons were applied on May 23, and another half gallon was applied 21 days after the first treatment (Figure 1). In 1998 five gallons of Sonar ™ A.S. were applied to Lac Lavon. Two and a half gallons were applied on May fifth and another two and a half gallons were applied 15 days after the first treatment (Figure 2). In 2002 five gallons of Sonar ™ A.S were applied to Lac Lavon. Two and a half gallons were applied on June fifth and an additional two and a half gallons were applied 27 days after the first treatment (Figure 3).

Cost:

The cost for the treatment in 1996 was $21,000, or approximately $380 per acre. This included the cost of the herbicide, application and fluridone concentration monitoring, and a guarantee to eliminate milfoil. The 1998 treatment was done at no cost, under a guarantee from the 1996 treatment to eradicate milfoil for the 1996, 1997 and 1998 seasons. The total cost for the 2002 treatment was $16,375. This included the cost of the herbicide, the application, and the fluridone concentration and plant monitoring. This is approximately $270 per acre.

Figures 1 - 3. Fluridone concentrations were measured either with an immunoassay technique developed by SePro Corp. (FastTest™) or using a gas chromatograph (GC). Fast Test™ data are shown with open circles; GC are solid circles. Treatment dates are shown with diamonds on the horizontal axis (◆).

Figure 1. Fluridone Concentration in Lac Lavon, 1996

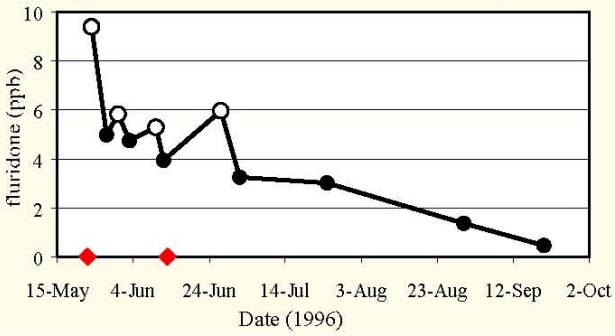


Figure 2. Fluridone Concentration in Lac Lavon, 1998

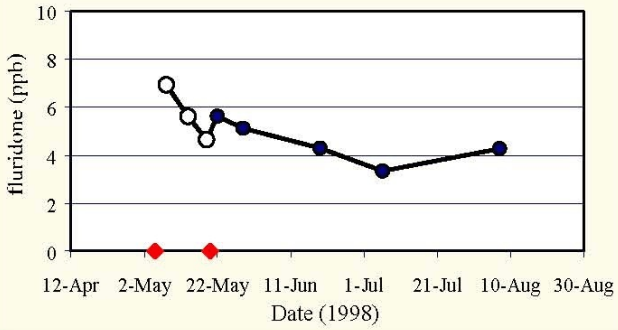
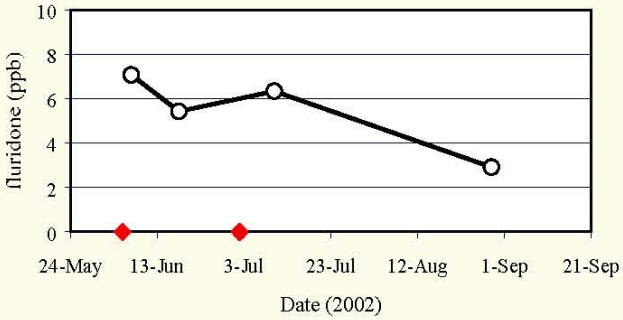


Figure 3. Fluridone Concentration in Lac Lavon, 2002



Fluridone Concentrations:

Both the initial fluridone concentration and the length of time plants are exposed to fluridone affect the results of a fluridone treatment. In 1996 the initial fluridone concentration one day after treatment was 9.6 ppb. The additional bump treatment maintained the concentration of fluridone above 3 ppb for 60 days after treatment (Figure 1).

In 1998 the initial fluridone concentration three days after treatment was 6.9 ppb. The additional bump treatment maintained the concentration of fluridone above 3 ppb for 90 days after treatment (Figure 2).

In 2002 the initial fluridone concentration three days after treatment was 7.1 ppb. The additional bump treatment maintained the concentration of fluridone above 2.9 ppb for 80 days after treatment (Figure 3).

Methods:

The Lac Lavon surveys are performed in the spring and late summer (only once in 2001). Twelve transects are scattered around the lake, located by landmarks, with varying number of sample sites per transect (Figure 4, Table 2). The sampling sites are identified along each transect by a predetermined depth of water and total 24 (Table 2). At each sampling site four plant grapple throws and one visual observation(s) are made to determine plant species presence and relative abundance. Each grapple toss is rotated from port to starboard from both the bow and stern of the boat. These aquatic plant surveys were completed by Minnesota Department of Natural Resources Exotic Species Program Staff.

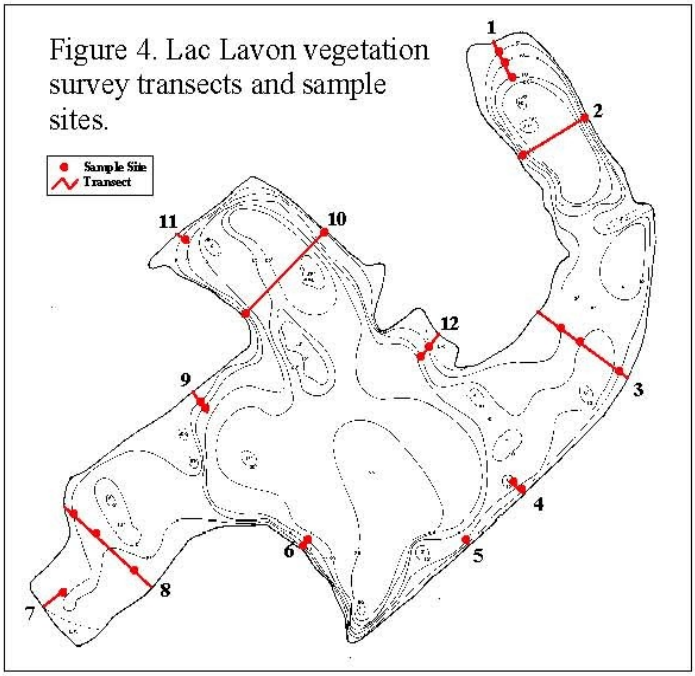


Figure 4. Lac Lavon vegetation survey transects and sample sites.

Results:

The effect of fluridone was determined by examining how the distribution of individual aquatic plant species, diversity of plant species, and relative abundance changed following treatment. The distribution of individual species was estimated by the species frequency, which is the percentage of sampling sites (n = 24) at which the plant was present. Diversity of plant species was estimated by the average number of plant taxa per sampling site. Relative abundance is determined by summing the presence of a given species at each sample site (four grapple throws). In some cases, plants could be identified to the level of genus, but not species. Consequently, they are reported as "taxa," which includes both genus and species.

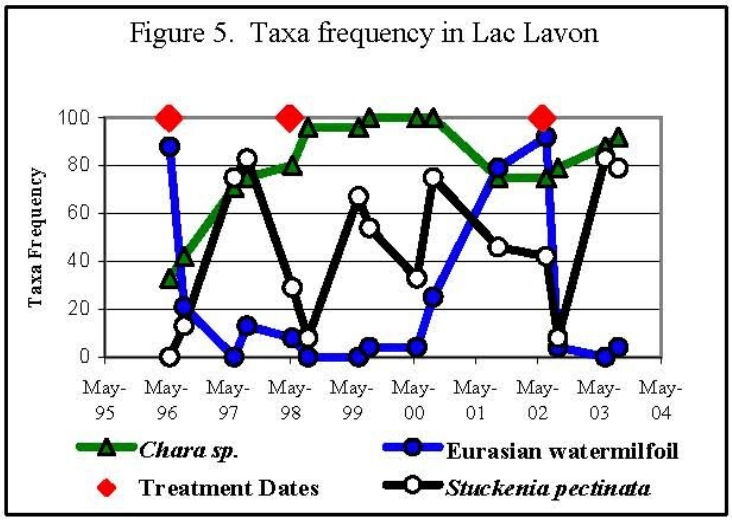
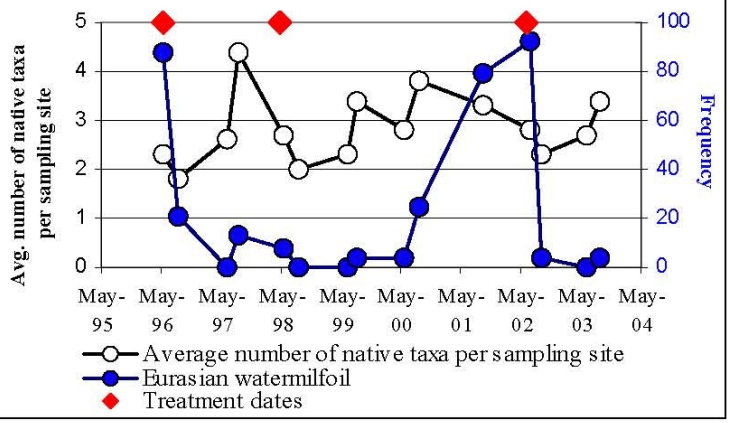


Figure 5. Taxa frequency in Lac Lavon

The 1996 treatment significantly reduced the amount of milfoil in Lac Lavon for at least two years following treatment (Figure 5, Table 1). After two years, in 1998, Lac Lavon was again treated even though milfoil was not causing a nuisance. The purpose of this treatment was to eliminate milfoil from the lake. This objective was not achieved. Milfoil occurred in 8% of areas sampled in May of 1998. By August of 1999 it was found in 4% of areas sampled, and a year later, milfoil increased to 25%. Milfoil increased again in September 2001 to 79% of areas sampled. In the spring of 2002 Lac Lavon was treated a third time and by August, milfoil was reduced to 4%. Milfoil was absent in spring of 2003, but returned at low levels (4%) in August 2003 (Table 1, Figure 5).

The Sonar ™ A.S. treatments reduced the distribution of some native taxa in Lac Lavon. For example, the frequency of *Myriophyllum sibiricum* was reduced to zero following the 1996 treatment and has not been found in Lac Lavon since that time. *Elodea* cf *canadensis* declined from 38% following the 1996 treatment and has not been found above 4% in the lake since the initial treatment (Table 1). Finally,

Figure 6. Average number of native taxa per sampling site and Eurasian watermilfoil frequency



Ranunculus cf *flabellaris* has declined after each treatment and has not returned to its original frequency of 46%. Absence of additional fluridone treatments, it is uncertain if these native species will return to pre-treatment levels of abundance. The distribution of some native taxa increased following the treatments. For example, *Chara* sp., *Stuckenia pectinata* and *Zosterella dubia* generally increased following treatment (Table 1, Figure 5). Of particular note, *Stuckenia pectinata* (Sago pondweed) is one of the first native plant species to increase in abundance after a fluridone treatment (Figure 5) and in some instances can become quite dense (personal observation). In the years following the 1996, 1998, and 2002 treatments the average number of native taxa per sampling station increased (Table 1, Figure 6). This increase appears to be related to the abundance of milfoil within Lac Lavon. A general decline occurs in the average number of native taxa per sampling site when milfoil reaches 50 – 65% frequency and an increase in the native taxa per site occurs after each fluridone treatment reduces the milfoil to well below 10% (Table 1, Figure 6).

Another invasive aquatic exotic present in Lac Lavon is *Potamogeton crispus* (curly-leaf pondweed). This plant is the first to emerge in the spring, where it has the potential to cause nuisances, and dies back in the summer. Its frequency increased two out of the three years after treatment (Table 1 – Spring dates only, Figure 7). The final pieces of information collected during these surveys were density ratings. When summarized, the density rating analysis correlates well with plant frequency and no additional trends were revealed.

Figure 7. Curly-leaf pondweed frequency in Lac Lavon

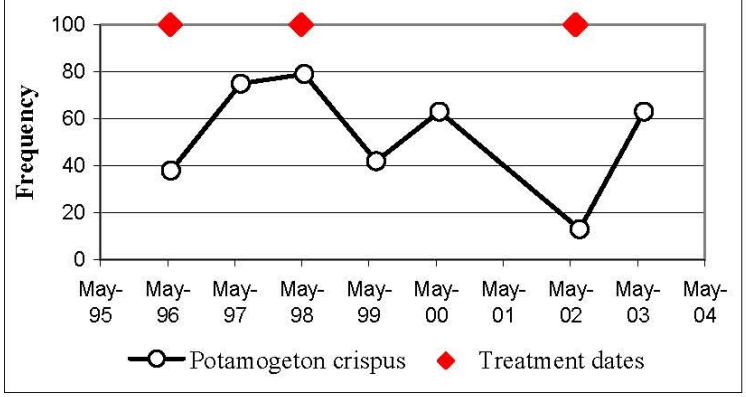


Table 1. Frequency of submerged, free floating and floating leaf macrophytes in Lac Lavon, Minnesota, to which fluridone herbicide was applied on May 23, 1996, May 5, 1998, and June 5, 2002. Only taxa with a frequency of 10% or greater on at least one date are shown *.
Twenty-four sites sampled. Shaded columns with bold dates indicate approximate treatment dates. Maximum depth of vegetation on each date was 15 feet.

	Frequency (%)														
Non –vascular Taxa	**May 28 1996**	August 21 1996	June 12 1997	August 27 1997	**May 22 1998**	August 21 1998	June 17 1999	August 20 1999	May 26 2000	August 31 2000	Sept. 17 2001	**June 28 2002**	Sept. 6 2002	June 13 2003	August 27, 2003
Chara sp. (muskgrass)	33	42	71	75	79	96	96	100	100	100	75	75	79	88	92
Nitella sp. (stonewort)	0	0	0	0	0	0	0	17	0	0	0	0	8		
Vascular Taxa															
Ceratophyllum demersum (coontail)	46	67	17	33	29	4	4	8	17	29	54	38	42	4	17
Elodea cf *canadensis* (Canadian waterweed)	38	0	4	0	4	0	0	0	0	0	4	4	0	4	0
Myriophyllum sibiricum (northern watermilfoil)	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
***Myriophyllum spicatum* (Eurasian watermilfoil)**	**88**	**21**	**0**	**13**	**8**	**0**	**0**	**4**	**4**	**25**	**79**	**92**	**4**	**0**	**4**
Najas flexilis (bushy pondweed)	0	0	0	63	0	0	0	17	0	46	25	0	0	0	17
Najas minor (slender naiad)	0	0	0	0	0	0	0	4	0	0	8	0	0	0	13
Potamogeton crispus (curly-leaf pondweed)	38	0	75	50	79	0	42	0	63	4	0	13	0	63	8
P. illinoensis (Illinois pondweed)	13	0	8	38	17	4	13	46	46	46	46	46	29	46	38
P. nodosus (long-leaf pondweed)	0	8	0	13	0	8	4	4	0	4	21	0	4	4	17
P .cf. *pusillus* (leafy pondweed)	21	0	25	54	8	0	0	21	17	21	4	33	4	21	38
Ranunculus cf *flabellaris* (yellow water crowfoot)	46	0	0	0	17	0	0	0	0	4	8	25	8	8	4
Stuckenia pectinata (sago pondweed)	0	13	75	83	29	8	67	54	33	75	46	42	8	83	79
Zosterella dubia (water stargrass)	13	54	54	83	83	79	46	71	67	54	33	13	46	13	29
Total number of taxa	**10**	**6**	**9**	**10**	**10**	**6**	**7**	**11**	**9**	**11**	**12**	**10**	**10**	**10**	**12**
Average number of taxa per site	3.5	2.0	3.3	5.0	3.5	2.0	2.7	3.5	3.5	4.1	4.0	3.8	2.3	3.3	3.5
Average number of native taxa per site	**2.3**	**1.8**	**2.6**	**4.4**	**2.7**	**2.0**	**2.3**	**3.4**	**2.8**	**3.8**	**3.3**	**2.8**	**2.3**	**2.7**	**3.4**
Percent vegetated sample sites	100	92	100	100	100	100	100	100	100	100	100	100	96	100	100

- Taxa that were found in Lac Lavon with a frequency of less than 10% (year(s) found): *Potamogeton natans* (June 1997) and *P. zosteriformis* (May 2000).

Table 2. Lac Lavon sample sites for depth.

Transect #	**Shoreline Landmarks**	**Sample Depth - feet**		
1	Left of sign in water – "Do not swim"	5	10	15
2	House with shrub line on east. House with walls on the west	8 East	8 West	
3	House with a gazebo on the east side, Beige house on the west	5 East	10 Center	5 West
4	In front of a small group of willows by a rock pile	5	15	
5	Grey house with retaining wall – one tier holding pea gravel, the other sand	10		
6	Grey house with large birdhouse in backyard, Floyd security sign	6	15	
7	North of the chain linked fence that divides public land with private (East). 90 feet to the left of the chain link fence on the West side	5 East	10 Center	5.5 West
8	West side of public beach	7		
9	Weeping willow near shore, with a row of shrubs running adjacent to lake	6	12	
10	Dock in front with small sand beach (south). Grey house with brown brick path (north)	6 North	6 South	
11	Beach next to culvert	8		
12	Two tiered retaining wall, with swing set	5	12	
TOTAL	**12 transects, 24 sites**			

Lac Lavon Lake Plant Survey
Date: June 18, 2004

Minnesota DNR, Section of Ecological Services, Exotic Species Program

Name(s): Proulx, Pavlowich

Entered: WC 10.1.04

Proofed WC/NP 10.7.04

Corrected WC 10.7.04

Number of taxa found
Maximum depth of plants
Secchi Depth

Blank cells=0, species not found
Density estimated from rake throw or visual estimation
Mean density computed by transforming visual estimates to numerical values (r = 1, o = 2, c = 3, a = 4)

		Non-vascular	Vascular													
Transect	Depth (ft)	Chara sp.	Ceratophyllum demersum	Najas flexilis	M. sibiricum	Myriophyllum spicatum	P. crispus	P. pectinatus	P. nodosus	P. illinoensis	Ranunculus cf flabellaris	P. cf pusillus	Elodea canadensis	P. natans	Zosterella dubia	All Plants
1	5.0	4					1	2			2					4
1	10.0	4														1
1	15.0	3														1
2 East	8.0	1						3							3	3
2 West	8.0	4														1
3	5.0	1	1			1	3	2			1	2			2	8
3	10.0	1	1				3					4				4
3	5.0		1				4			1	3	4				5
4	5.0							3		1		3				3
4	15.0	1					1					4				3
5	10.0	1		1			2	1				3				5
6	6.0	4						2		4					1	4
6	15.0	2														1
7south	5.0	4	4				3	1				3			1	6
7center	10.0	3	4					1		4		2			1	6
7north	5.5	3	2				1	1				1				5
8	7.0	2	3			1	1	1		3			2			7
9	6.0	3				1	2			3	1	4			2	7
9	12.0	4					1									2
10west	6.0	3		1			1	3	1	1					1	7
10east	6.0	4						2		4	1					4
11	8.0						3	4	1	1		1				5
12	5.0	3					4	4		3		4				5
12	12.0	3	1				3	1				1				5
Total Sites:	24															
# of occurrences		21	8	2	0	3	15	15		10	5	13	1	0	7	Avg. # of Plants/site
% occurrence		88%	33%	8%	0%	13%	63%	63%		42%	21%	54%	4%	0%	29%	4.3
average density (max=4)		2.42	0.71	0.08	0.00	0.13	1.38	1.29		1.04	0.33	1.50	0.08	0.00	0.46	

Lac Lavon Lake Plant Survey
Date: August 18, 2004

Minnesota DNR, Section of Ecological Services, Exotic Species Program

Name(s): Wendy Crowell, Amber Ellering

Entered: Oct 1.04 WC

Proofed WC/NP 10.7.04

Corrected WC 10.7.04

Number of taxa found =
Maximum depth of plants =
Secchi Depth = 8.5 feet

Blank cells=0, species not found
Density estimated from rake throw or visual estimation
Mean density computed by transforming visual estimates to numerical values (A=4, C=3, S=2)

		Nonvascular	Vascular											
Transect	Depth (ft)	Chara sp.	Ceratophyllum demersum	Myriophyllum spicatum	Najas minor	Najas flexilis	P. crispus	P. pectinatus	P. illinoensis	Ranunculus cf flabellaris	P. natans	P. cf pusillus	Zosterella Dubia	All Plants
1	5.0	4		1	4	2		2	1			1	3	8
1	10.0	4												1
1	15.0	3												1
west 2	8.0	4			1									2
east 2	8.0	4		1		1		1					1	5
east 3	5.0	4	2	4		3		2	1	1			4	8
3	10.0		1					3	2	1				4
west 3	5.0	1				2		3	2	1			3	6
4	5.0	2		1	1	4		2	1				4	7
4	11.0							4				2		2
5	10.0	4				2		4	1	1		1	4	7
6	6.0	4		1	1	3			4	1				6
6	15.0	2							2			1		3
east 7	5.0	4	3	4				2	4					5
7	7.0		4	2	1	1		1	3	1			2	8
west 7	5.0		4	2				1	3			1	1	6
8	7.0		4	4			1	1	1				1	6
9	6.0	4		1		1	2	1	1					6
9	12.0						1	1	1					3
South 10	6.0			2		3		2	3			1		5
North 10	6.0	1		1				4	4					4
11	8.0		2	1			1	2				1		5
12	5.0	1	1	1				3	3				1	6
12	12.0							1	1			1		3
Total Sites:	24													
# of occurrences		15	8	14	5	10	4	19	18	6	0	8	10	Avg. # of Plants/site
% occurrence		63%	33%	58%	21%	42%	17%	79%	75%	25%	0%	33%	42%	4.9
average density (max=4)		1.92	0.88	1.08	0.33	0.92	0.21	1.67	1.58	0.25	0.00	0.38	1.00	

Blue Water Science Plant Survey, September 9, 2003

Table B1. Lac Lavon aquatic plant occurrences and densities for the September 9, 2003 survey based on 20 transects and 3 depths, for a total of 60 stations. Density ratings are 1-5 with 1 being low and 5 being most dense. Survey was conducted by Blue Water Science.

	Depth 0-5 feet (20 stations)			Depth 6-10 feet (20 stations)			Depth 11-15 feet (20 stations)			All Depths (60 stations)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Coontail (*Ceratophyllum demersum*)	6	30	1.5	4	21	2.8	3	16	1.7	13	22	1.9
Chara (*Chara sp*)	6	30	2.3	5	26	3	1	5	1	12	21	2.5
Eurasian watermilfoil (*Myriophyllum spicatum*)	2	10	0.8	--	--	--	--	--	--	2	3	0.8
Naiads (*Najas sp*)	3	15	1	2	11	0.8	--	--	--	5	9	0.9
Nitella (*Nitella sp*)	--	--	--	1	5	3	2	11	0.5	3	5	1.3
Illinois pondweed (*Potamogeton illinoensis*)	13	65	3	8	42	2	2	11	2	23	40	2.6
Floatingleaf pondweed (*P. natans*)	4	20	0.9	--	--	--	--	--	--	4	7	0.9
Stringy pondweed (*P. pusillus*)	1	5	0.5	--	--	--	--	--	--	1	2	0.5
Sago pondweed (*Stuckenia pectinata*)	16	80	2.1	13	68	2.6	5	26	1.8	34	59	2.3
Water stargrass (*Zosterella dubia*)	10	50	1	3	16	1	2	11	0.5	15	26	0.9
Filamentous algae	--	--	--	1	5	1	1	5	1	2	3	1

Table B2. Individual transect data for Lac Lavon for September 9, 2003. Survey was conducted by Blue Water Science.

	T1			T2			T3			T4	T5			T6			T7		
	0 -5	6 -10	11-15	0 - 5	6-10	11-15	0 -5	6 -10	11-15	0 - 5	0 -5	6 -10	11-15	0 -5	6 -10	11-15	0 - 5	6 -10	11-15
Coontail	2	3	1	1			1	2	1	3				1				4	3
Chara																			
Eurasian watermilfoil																			
Naiads															0.5				
Nitella																			
Illinois pondweed				5						4	2			1	3			1	3
Floatingleaf pondweed														1					
Stringy pondweed	0.5																		
Sago pondweed				1	2	1				5	3	4	2	1	2	2	2		
Water stargrass	0.5						1				1			1			1	0.5	0.5
Filamentous algae												1							
No plants																			

	T8			T9			T10			T11			T12			T13			T14		
	0 -5	6 -10	11-15	0 -5	6 -10	11-15	0 -5	6 -10	11-15	0 -5	6 -10	11-15	0 -5	6 -10	11-15	0 -5	6 -10	11-15	0 - 5	6 -10	11-15
Coontail													1	2							
Chara	1																3		1		
Eurasian watermilfoil										0.5			1								
Naiads	1	1											1								
Nitella			0.5			0.5		3													
Illinois pondweed		1		5	4	1	5	2		5			1	2.5		2	1.5		0.5	1	
Floatingleaf pondweed																1			0.5		
Stringy pondweed																					
Sago pondweed	1			3	1		2	1		3				3.5		3	3.5		2	3	
Water stargrass	1	0.5	0.5	1																	
Filamentous algae						1															
No plants									X		X	X			X			X			X

	T15			T16			T17			T18			T19			T20		
	0 -5	6 -10	11-15	0 -5	6 -10	11-15	0 -5	6 -10	11-15	0 -5	6 -10	11-15	0 -5	6 -10	11-15	0 - 5	6 -10	11-15
Coontail																		
Chara					2		3	2	1	2			3	5		4	3	
Eurasian watermilfoil																		
Naiads	1																	
Nitella																		
Illinois pondweed				3			1			5								
Floatingleaf pondweed																1		
Stringy pondweed																		
Sago pondweed	2	3	3	1	2		1	3	1	2	2			4	4	2		
Water stargrass	1						1	2		1								
Filamentous algae																		
No plants						X						X						X