Comprehensive Lake Management Plan for Plum Lake, Vilas County, Wisconsin

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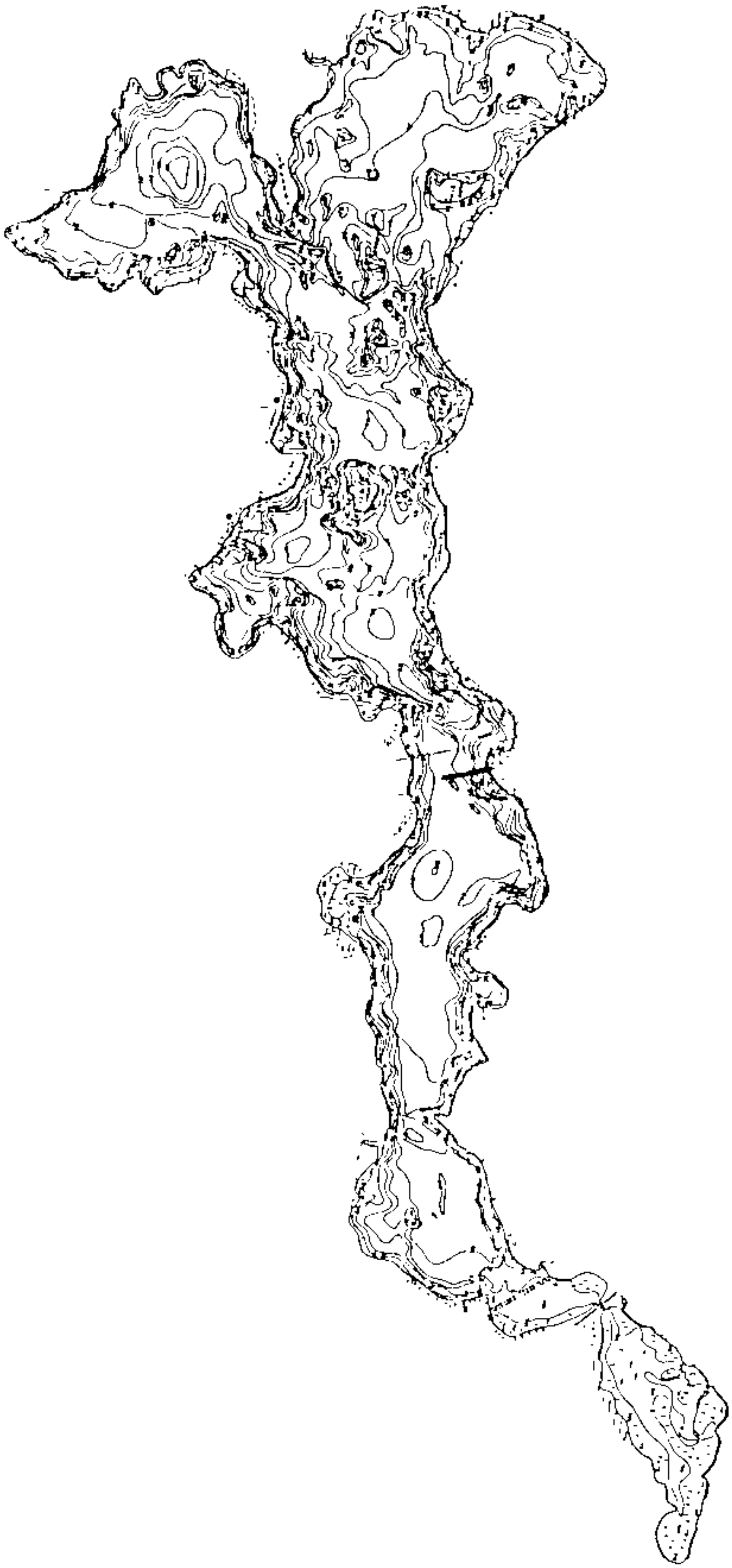


Figure 1. Map of Plum Lake.

2. Geology and Soils

Plum Lake was formed approximately 16,000 years ago during the last glacial retreat of the Wisconsin Valley glacial lobe (Figure 2). The soils deposited by the Wisconsin Valley glacier were primarily sands and loamy-sands. Beneath these soils at depths of about 50-350 feet is Precambrian bedrock that is over one billion years old. The bed rock is referred to as the North American shield.

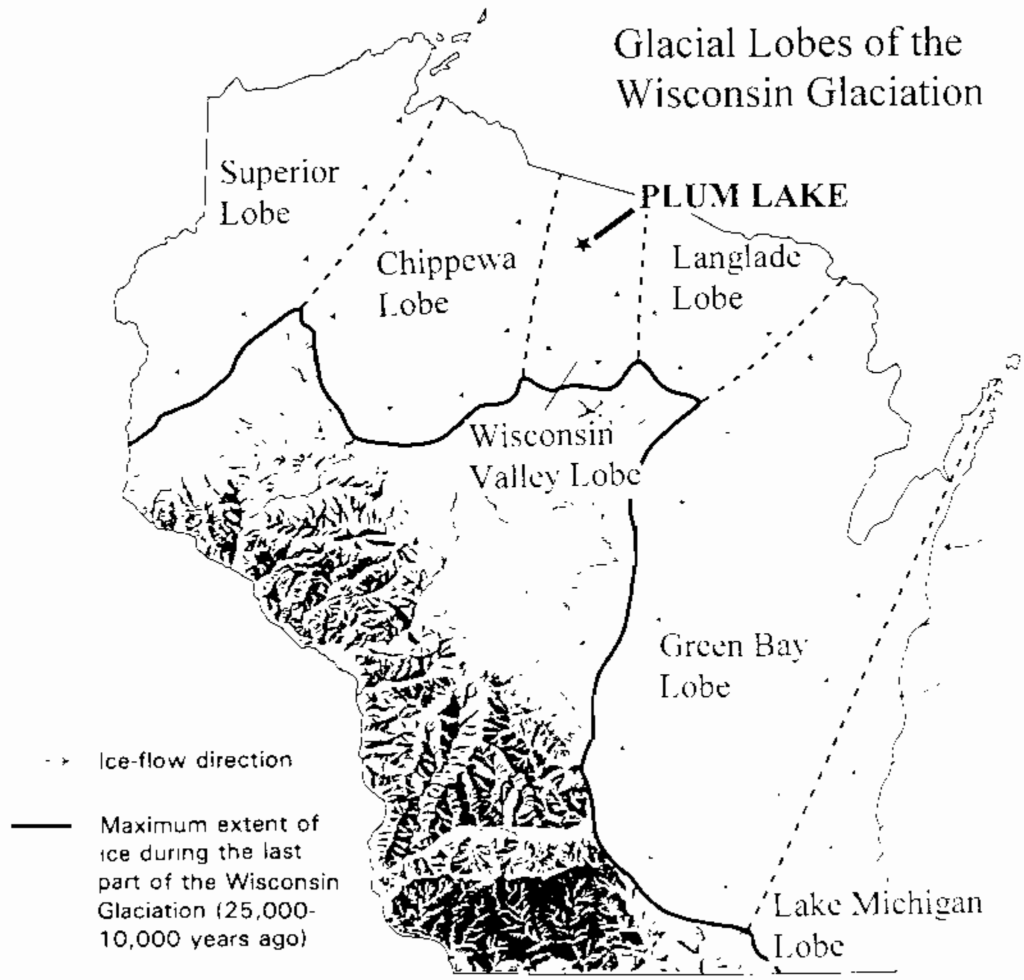


Figure 2. Glacial lobes of the Wisconsin glaciation. Plum Lake is located in the Wisconsin Valley lobe.

The soils sitting on top of glacial sands are some of the most acid (pH 5.5) and have some of the highest in available phosphorus (138 lbs/acre) of any soils in Wisconsin. Plum Lake rests in soils group (21) referred to as the Vilas, Omega, Pence group (Table 1 and Figure 3).

Table 1. Soil test data for plow layers of representative soils of Wisconsin.[1]

	Organic matter %				Available phosphorus lbs/A				Available potassium lbs/A				Soil reaction pH				Lime req T/A	Representative corresponding soil names and symbols from Soils of Wisconsin color map, 1:710,000 (Hole, 1976)[2]
	Low 0-2	Med 2-5	High >5		Low 0-50	Med 51-100	High 101-200+		Low 0-200	Med 201-400	High 400+		Low 4.5-6.5	Med 6.5-7.5	High 7.5+			
	% of soil tests			Av	% of soil tests			Av	% of soil tests			Av	% of soil tests			Av	Av	
1	0	96	4	3.7	55	31	14	60	44	48	8	279	30	69	1	6.5	0.9	[illegible]
2	0	90	10	3.9	59	28	13	55	40	52	8	239	31	68	1	6.6	0.8	[illegible]
3	35	65	0	2.2	65	25	10	51	70	27	3	175	34	65	1	6.6	0.36	[illegible]
4	28	71	1	2.3	68	21	11	50	69	28	3	183	37	62	1	6.8	0.36	[illegible]
5	4	87	9	3.8	45	45	10	71	49	45	6	222	27	71	2	6.6	0.72	[illegible]
6	0	75	25	4.5	62	26	12	53	41	54	3	224	55	45	0	6.4	1.55	[illegible]
7	35	65	0	2.2	44	37	19	70	63	35	2	138	29	69	2	6.7	0.28	[illegible]
8	20	79	1	2.4	63	27	10	52	61	37	2	188	54	45	1	6.4	1.16	[illegible]
9	50	45	5	2.7	34	39	27	87	63	34	3	184	44	55	1	6.4	0.65	[illegible]
10	94	6	0	1.5	24	33	41	102	75	21	[illegible]	146	60	39	1	6.4	[illegible]	[illegible]
11	87	10	3	1.5	16	39	45	107	84	16	0	136	69	31	0	6.0	1.51	[illegible]
12	42	55	3	1.7	48	31	21	56	73	24	1	156	61	40	1	6.0	[illegible]	[illegible]
13	52	46	2	1.8	33	38	29	87	76	21	3	162	51	49	0	6.1	[illegible]	[illegible]
14	6	80	14	[illegible]	58	25	17	57	71	22	5	175	15	60	25	6.9	[illegible]	[illegible]
15	2	90	8	4	50	25	25	65	71	29	1	[illegible]	[illegible]	[illegible]	1	6.0	0.25	[illegible]
16	3	84	13	3.8	65	20	15	54	67	29	4	176	54	45	1	6.3	2.78	[illegible]
17	28	72	0	3.8	28	26	46	113	56	36	8	201	61	39	0	6.2	0.32	[illegible]
18	16	82	2	2.9	55	31	14	59	81	18	1	145	59	41	0	6.2	1.70	[illegible]
19	3	95	2	3.2	64	26	10	52	70	28	2	163	59	40		6.3	2.50	[illegible]
20	68	32	0	1.7	15	[illegible]	47	114	63	28	9	149	16	46	8	[illegible]	1.57	[illegible]
21	13	55	12	2.3	28	9	63	139	76	[illegible]	1	170	81	19	0	5.5	1.44	[illegible]
22	2	81	17	4.1	73	19	8	39	67	30	[illegible]	184	1	73	26	[illegible]	0.04	[illegible]
23	9	83	8	1.6	96	3	1	13	59	40	1	190	67	33	0	6.3	2.09	[illegible]
24	2	68	30	5.0	29	40	31	90	35	55	10	250	4	70	26	7.2	[illegible]	[illegible]
25	0	10	90	7.0	67	24	9	50	50	46	4	214	2	42	56	[illegible]	[illegible]	[illegible]
26	0	3	97	56.2	51	23	26	90	59	20	21	200	53	39	9	6.1	0.12	[illegible]
State Total	22	73	5	2.9	50	30	20	67	70	27	3	175	40	59	[illegible]	6.5	0.91	[illegible]

[1] Wisconsin State Soil and Plant Analysis Laboratory ... Madison, Wisconsin ... Representative data were extracted from State and County summaries ... [illegible]

[2] Hole, F. D. 1976. Soils of Wisconsin ... Soil Series 12. University of Wisconsin Press.

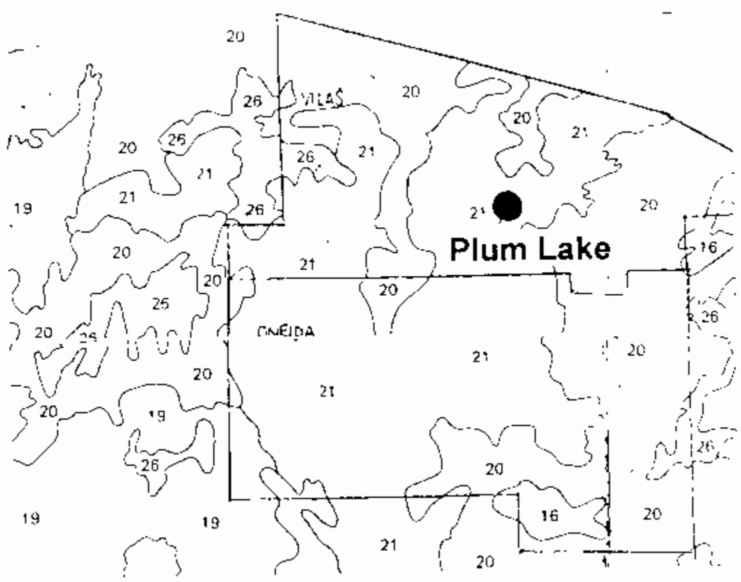


Figure 3. Plum Lake is located in a depression in soil group 21.

3. Watershed Characteristics

3.1. Land Use

The Plum Lake watershed is shown in Figure 4. The Plum Lake watershed encompasses approximately 15,310 acres. Forest lands dominate with 10,112 acres followed by wetlands (2,335 ac), other lakes (2,039 ac), Golf Course (600 ac) and then 224 acres of residential lands (Table 2).

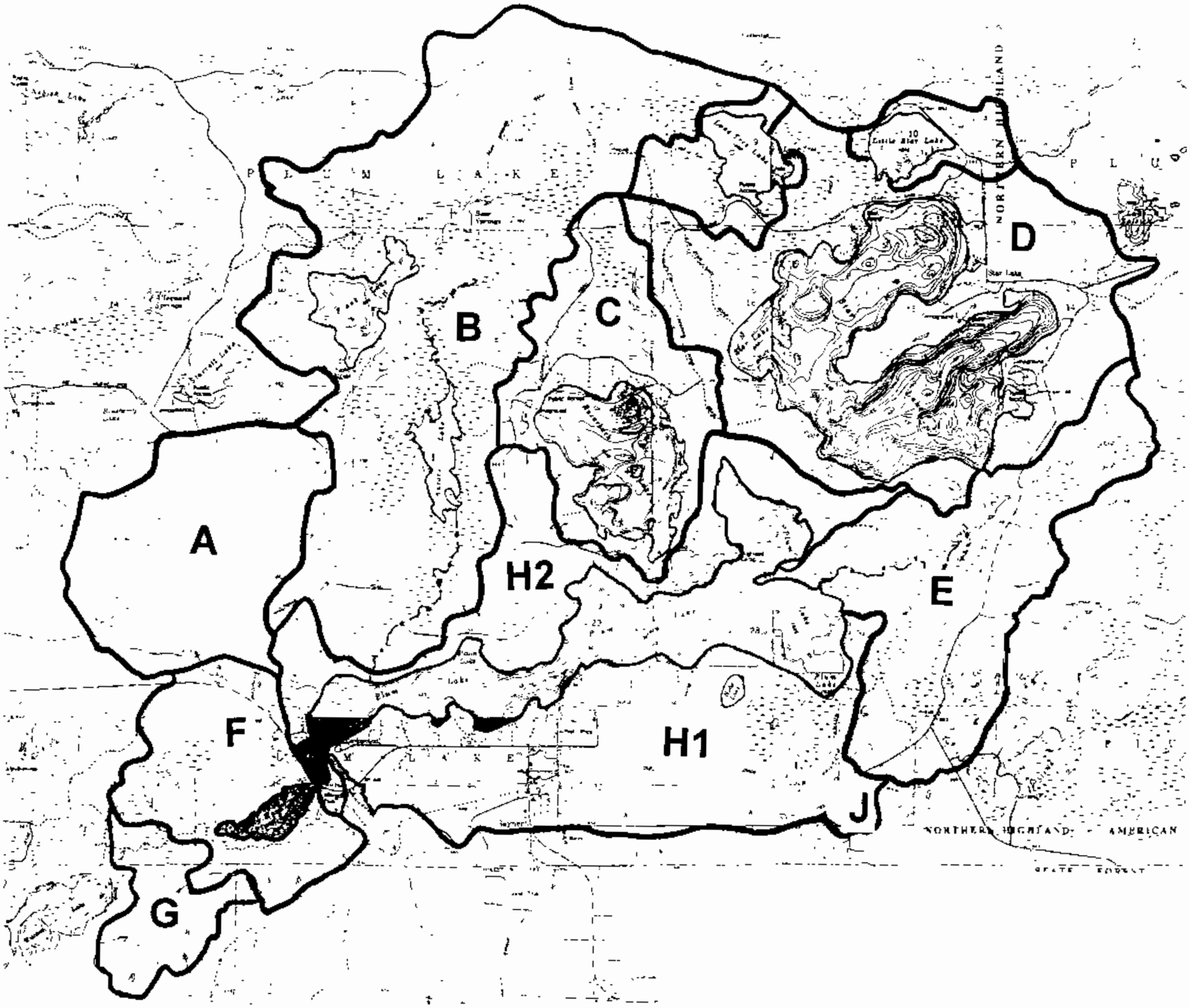
Table 2. Land use in the Plum Lake watershed. Areas presented are in acres. Numbers shown in parentheses are the percent of land use.

Land Use in the Watershed				
Forest	Wetlands	Lakes	Golf Course	Urban
10,112 (66%)	2,335 (15%)	2,039 (13%)	600 (4%)	224 (1.5%)

The Plum Lake watershed has several lakes with outlets and several that seep to Plum Lake. A listing of the water bodies is shown in Table 3.

Table 3. Other lakes in the Plum Lake watershed. For lake types the key is: DG = drainage lake (stream fed, with a stream outlet), SE = seepage lake (no stream inlets or outlets), SP = spring lake (spring fed with a stream outlet). For fish types the key is: C = common, P = present, A = abundant.

Lake	Elevation	Area	Max Depth	Public Access	Lake Type	Walleye	Muskie	Northern Pike	L.M. Bass	S.M. Bass
Lone Tree	1682	121	16	yes	SE	--	--	--	C	P
Little Star	1672	93	9	yes	DG	C	P	P	P	P
Star	1672	1,206	68	yes	DG	C	P	P	P	P
Razorback	1650	362	35	yes	SE	C	P	C	C	C
Bear Spring	1655	22	14	no	SP	--	--	--	--	--
Frank	1655	141	24	yes	SE	C	--	C	C	--
Aurora	1636	94	4	yes	DG	--	--	P	P	--
Plum	1635	1,108	57	yes	DG	C	C	P	P	P



Letter	Acres	Group
A	1,163 ac	Aurora
B	3,712 ac	Aurora
C	1,219 ac	Razorback
D	3,702 ac	Star lake
E	1,472 ac	Star Lake
F	801 ac	West Plum
G	372 ac	West Plum
H1	1,847 ac	Direct drainage
H2	997 ac	Direct drainage
J	25 ac	Drains to H1
	15,310 ac	

Figure 4. Plum Lake watershed map.

3.2. Streams

Two major streams and a number of temporary streams flow into Plum Lake: Aurora Stream enters from the north in the west end of Plum Lake and Star Creek enters from the east.

Star Creek comes from Star Lake and is a clear water stream.

Figure 5. Aurora Creek has a dark stain and comes out of Aurora Lake. The stain is actually dissolved organic compounds leaching form wetlands. The water is clean and low in fertility. These two pictures are from the summer of 1996.

Aurora Creek was sampled for phosphorus on four occasions from July 17, 2000 to August 25, 2001. Results show low phosphorus concentrations in Aurora Creek representative of natural background conditions (Table 4). This is good news for Plum Lake. It implys that there is "good" water coming into Plum Lake.

Table 4. Aurora Creek phosphorus concentrations in 2000 and 2001.

	Aurora Creek Phosphorus (ppb)	Notes
7.17.00	18	Estimated flow was about 10 cfs.
6.27.01	28	
7.27.01	23	Estimated flow was 10-15 cfs.
8.25.01	19	

Flows into Plum Lake

We estimate the Plum Lake watershed to be 15,310 acres. The average runoff for this part of Wisconsin is about 14 inches per year based on U.S. Geological Survey runoff data. With this average runoff, the annual flow into Plum Lake is about 1.17 feet from the entire watershed which is equivalent to 17,861 acre-feet of water. This is equivalent to 25 cubic feet per second (cfs) of inflow.

We estimate Aurora Creek to flow at about 10 cfs; Star Lake Creek to flow at about 10 cfs, West Plum Lake inflow at 2 or 3 cfs and groundwater inflow at 2 or 3 cfs.

3.3 Groundwater and Onsite Systems

Specific conductance or conductivity is a measure of dissolved salts in the water. The unit of measurement is microSiemans/cm^2 or micro umhos/cm^2 . . . both are used. The saltier the water the higher the conductivity. For example oceans have higher conductivity than fresh water. For the conductivity survey on Plum Lake we used a YSI (Yellow Springs Instruments) probe attached to the end of an eight-foot pole. The survey used two people. One person held the probe under the surface of the water and recorded the reading off of a conductivity meter while the other person maneuvered the boat around the perimeter of Plum Lake.

The objective was to see if there was any change in conductivity. An increase or decrease in conductivity could indicate the inflow of groundwater. The groundwater could be coming from natural flows or from septic tank drainfields.

Results are shown in Figure 6. The background or base conductivity was 78 umhos/cm. Several areas around Plum Lake had readings above background. Because of a lack of homes or because the homes are far removed from the lakeshore, it does not appear that the elevated conductivity is from septic leachate discharges. Rather, the results suggest that Plum Lake may be receiving groundwater inflows.

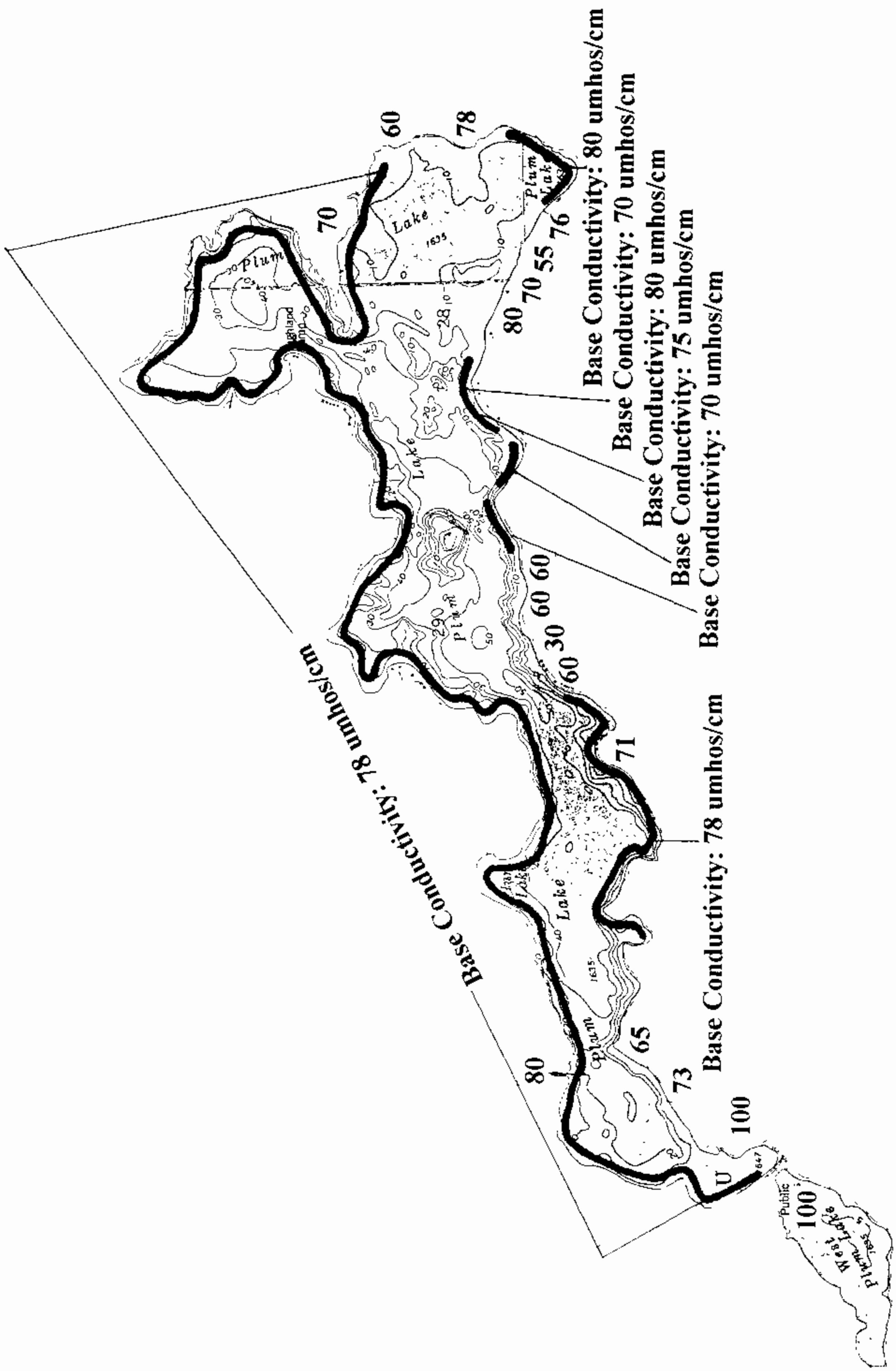
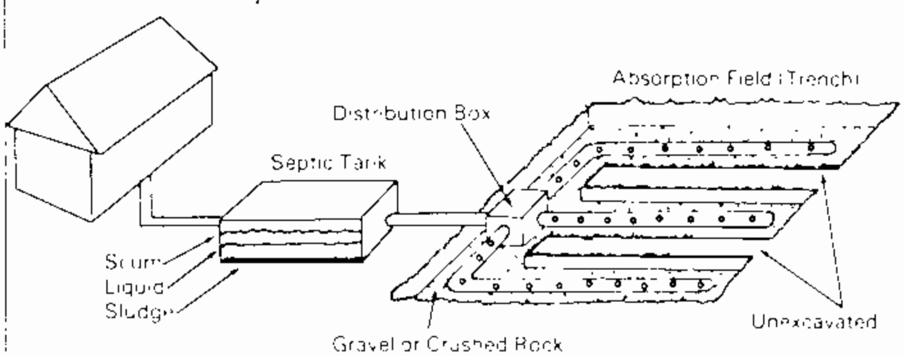


Figure 6. Plum Lake conductivity survey, August 19, 1996.

Sewage bacteria break up some solids in tank. Heavy solids sink to bottom as sludge. Grease & light particles float to top as scum. Liquid flows from tank through closed pipe and distribution box to perforated pipes in trenches; flows through surrounding crushed rocks or gravel and soil to ground water (underground water). Bacteria & oxygen in soil help purify liquid. Tank sludge & scum are pumped out periodically. Most common onsite system.



Septic tank and soil absorption trench.
Of the conventional types of septic tank soil absorption systems, the trench-style soil absorption field is the preferred system. A typical cost is $3,000 to $4,000 for the complete system.

Figure 7. Typical onsite wastewater treatment system found in the Plum Lake watershed.

3.4. Shoreland Inventory

The shoreland area encompasses three components: the upland fringe, the shoreline, and shallow water area by the shore. A photographic inventory of the Plum Lake shoreline was conducted on July 26, 2001. The objectives of the survey were to characterize existing shoreland conditions which will serve as a benchmark for future comparisons.

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

A summary of the inventory results is shown in Table 5. Based on our subjective criteria over 75% of the parcels in Plum Lake shoreland area meet the natural ranking criteria shorelines and upland areas. This is good for a lake in northern Wisconsin. However in the next 10 years there could be pressure to reduce natural conditions. Proactive volunteer native landscaping should maintain existing conditions and improve other parcels.

Table 5. Summary of buffer and upland conditions in the shoreland area of Plum Lake. Approximately 225 parcels were examined.

Plum Lake	Natural Shoreline Condition		Natural Upland Condition		Undevel. Photo Parcels	Shoreline Structure Present	
	>50%	>75%	>50%	>75%		riprap	boathouse
TOTALS (no. of photos = 225)	182 (81%)	158 (70%)	169 (75%)	130 (58%)	30 (13%)	9 (4%)	27 (12%)

A comparison of Plum Lake conditions to other lakes in Wisconsin and Minnesota is shown in Figure 8.

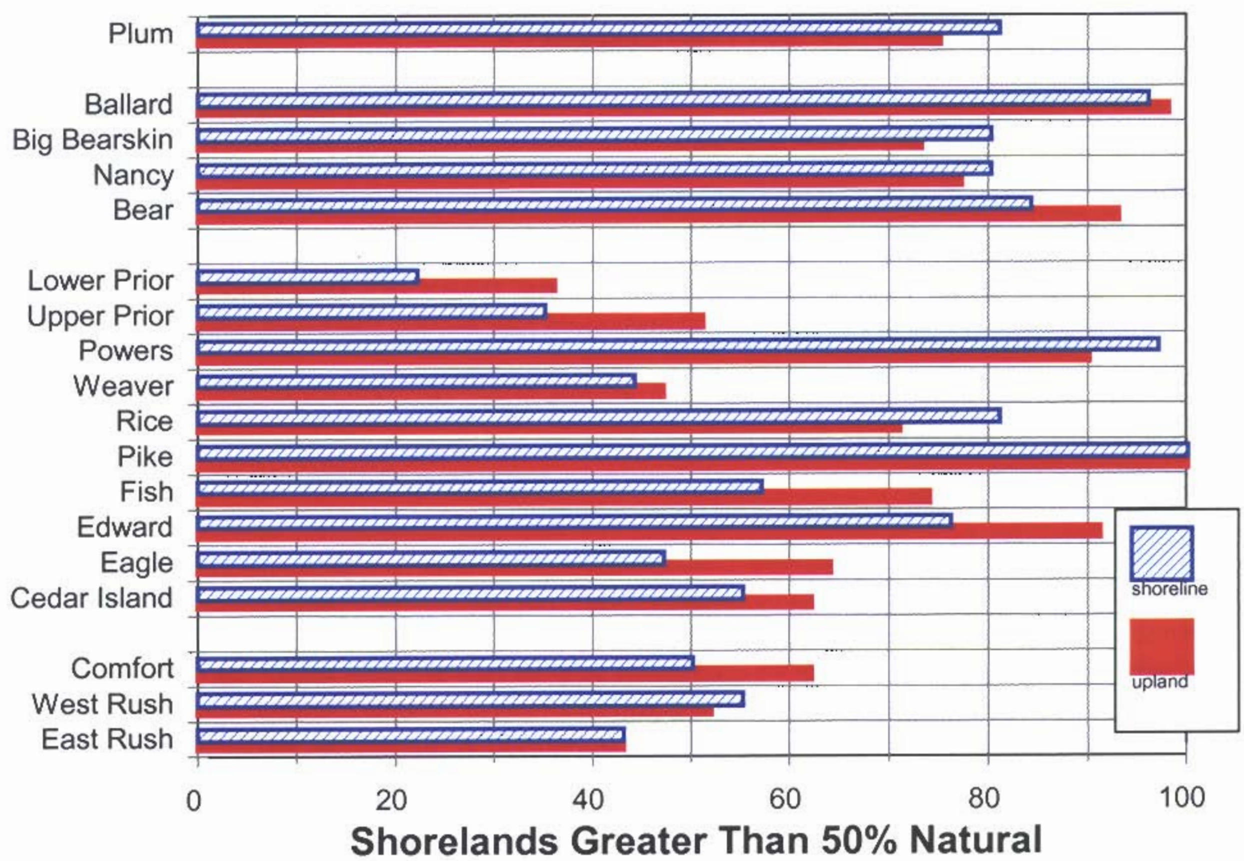


Figure 8. A summary of shoreland inventory results for 18 lakes using an evaluation based on shoreland photographs. For each lake the percentage of shoreline and upland conditions with greater than 50% natural conditions is shown.

4. Lake Characteristics

Plum Lake is approximately 1,108 acres in size, with a watershed of 15,310 acres. The average depth of Plum Lake is 6.2 meters (20 feet) with a maximum depth of 17.4 meters (57 feet) (Table 6). A lake contour map was shown in Figure 1. Plum Lake is located in an area of Wisconsin that is dominated by forests.

Table 6. Plum Lake Characteristics

Area (Lake):	1,108 acres (448 ha)
Mean depth:	20 feet (6.2 m)
Maximum depth:	57 feet (17 4 m)
Volume:	22,549.1 acre-feet (2,780 1 Ha-M)
Fetch:	8.2 mile (13.2 km)
Watershed area:	15,310 acres (6,196 ha)
Watershed: Lake surface ratio	14:1
Public accesses (#): 1	
Inlets: 2 Outlets: 2	

4.1. Dissolved Oxygen and Temperature in Plum Lake

The summer dissolved oxygen and temperature profiles are shown in Figure 9.

A profile was obtained each month from June to August, 1996. By examining the profiles, one can learn a great deal about the condition of a lake and the habitat that is available for aquatic life.

All three profiles show that the lake was thermally stratified in the summer of 1996. **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.

The 5 June profile indicates that the epilimnion extended to a depth of about 7 ft. and that oxygen was present at all depths. By 26 July, the surface waters had warmed considerably and the epilimnion descended to about 16 ft. There was a steep decline in temperature and oxygen from 16 to 27 ft in the thermocline. Below 27 ft (in the hypolimnion), the water was devoid of oxygen. Most fish species have trouble tolerating oxygen concentrations less than about 4 ppm, so anglers are advised not to drop a line much lower than 24 ft in mid to late summer. The 19 August profile was quite similar to the July profile. The only slight difference was that the decline in oxygen concentrations in the metalimnion was slightly more rapid.

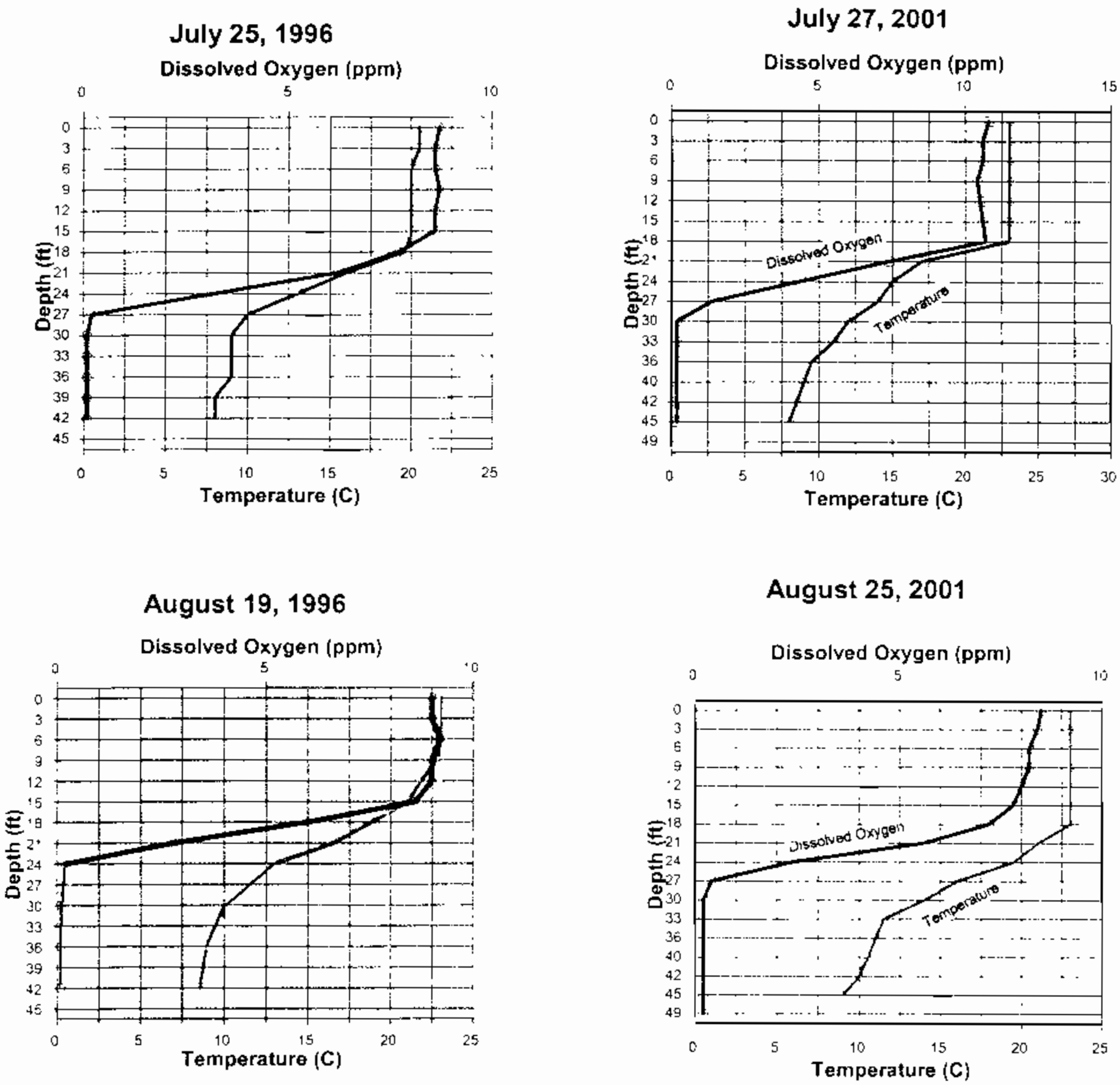


Figure 9. Dissolved oxygen (DO)/temperature profiles for the summers of 1996 and 2001. Dissolved oxygen data are shown with squares and temperature with circles.

Table 7. Plum Lake secchi disc transparency and temperature and dissolved oxygen data for 1996 and 2001.

Secchi Disc	June 5, 1996 10.0 ft		July 25, 1996 16.5 ft		August 19, 1996 12.5 ft	
Depth (ft)	**Temp (°C)**	**DO (mg/l)**	**Temp (°C)**	**DO (mg/l)**	**Temp (°C)**	**DO (mg/l)**
0	16.5	10.4	20.5	8.7	23.0	9.0
3	16.5	10.4	20.5	8.6	23.0	9.0
6	16.5	10.4	20.0	8.6	23.0	9.2
9	--	--	20.0	8.7	22.8	9.0
12	15.0	10.6	20.0	8.6	21.8	9.0
15	14.0	10.8	20.0	8.6	21.0	8.6
18	13.0	10.1	19.6	7.7	18.8	6.0
21	12.0	9.0	16.0	6.2	16.5	2.8
24	10.5	7.4	13.0	3.2	13.0	0.2
27	9.5	6.0	10.0	0.2	--	--
30	9.0	5.4	9.0	0.1	10.0	0.1
33	8.0	4.5	9.0	0.1	--	--
36	8.0	4.0	9.0	0.1	9.0	0.1
39	8.0	3.6	8.0	0.1	--	--
42	7.5	2.9	8.0	0.1	8.5	0.1
45	7.0	1.0	--	--	--	--

Secchi Disc	June 27, 2001 15.0 ft		July 27, 2001 14.0 ft		August 25, 2001 17.0 ft	
Depth (ft)	**Temp (°C)**	**DO (mg/l)**	**Temp (°C)**	**DO (mg/l)**	**Temp (°C)**	**DO (mg/l)**
0	22.4	9.4	23.0	10.8	23.0	8.5
3	--	--	23.0	10.6	23.0	8.4
6	22.0	9.4	23.0	10.6	23.0	8.2
9	21.5	9.4	23.0	10.4	23.0	8.2
12	20.1	9.3	23.0	10.5	23.0	8.0
15	18.6	9.6	23.0	10.6	23.0	7.8
18	18.3	9.0	23.0	10.7	23.0	7.2
21	16.5	7.5	17.0	7.4	21.0	5.6
24	13.3	6.3	15.0	4.4	19.5	2.4
27	11.6	2.8	14.0	1.4	16.0	0.4
30	10.5	1.4	12.0	0.2	14.0	0.2
33	10.1	0.9	11.0	0.2	11.5	0.2
36	9.5	0.5	9.5	0.2	11.0	0.2
40	9.0	0.4	9.0	0.2	10.5	0.2
42	--	--	8.5	0.2	10.0	0.2
45	--	--	8.0	0.2	9.0	0.2
49	--	--	--	--	--	0.2

The historical data from Plum Lake are somewhat sparse, but they show that conditions today are quite similar to conditions in the past. The secchi transparency has consistently been between 10-20 ft, which is a good indication that the lake is not being degraded. Continued protection of the lake and its watershed should ensure clean, clear water for the future.

Table 8. Temperature/dissolved oxygen profiles from earlier studies.

Date	Temperature		Dissolved Oxygen		Depth Where DO < 1 mg/l
	Top	Bottom	Top	Bottom	
4.26.77	52.0	42.0	11.0	3.9	Bottom
6.27.89	21.0	8.0	9.5	2.4	Bottom
7.19.89	22.5	7.5	8.1	0.2	36
8.16.89	21.0	8.0	8.4	0.2	30
8.30.89	20.5	8.5	8.3	0.2	30
10.30.89	10.0	8.0	10.4	7.7	Bottom
6.5.96	16.5	7.0	10.4	1.0	45
7.25.96	20.5	8.0	8.7	0.1	27
8.19.96	23.0	8.5	9.0	0.1	24
6.27.01	22.4	9.0	9.4	0.4	33
7.27.01	23.0	8.0	10.8	0.2	30
8.25.01	23.0		8.5	0.2	27

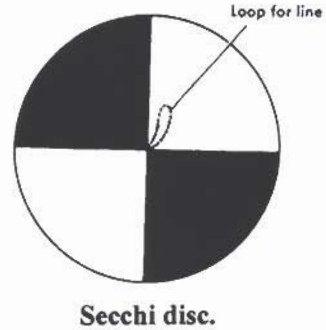
4.2. Secchi Disc Transparency

The Secchi disc transparency had an average summer depth of 4.0 meters (13.0 feet) in 1996. This is good water clarity and about average for this part of the state (based on ecoregion averages).

Table 9. Plum Lake Secchi disc readings over the years. Results are shown in feet. "R" represents a replicate reading.

	1969	1977	1989	1990	1993		1994		1995	1996		1997	1998	1999		2000		2001	
	Site 1	Site 1	Site 1	Site 1	Site 1	Site 2	Site 1	Site 2	Site 1	Site 1	Site 1 R	Site 1	Site 1	Site 1	Site 2	Site 1	Site 1 R	Site 1	Site 1 R
April																			
1																			
2																			
3																			
4		11.0											9.88						
May																			
1							10.0		8.75				11.75	11.25	11.25	9.75			
2							9.0		9.50				16.0					11.0	
3							12.0		10.0	8.0			13.50	19.25	19.25	13.25		13.5	
4							16.5		12.63	10.6		10.25	18.25	15.75	15.75	14.6		27.25	
June																			
1							18.75				10.0	14.0		15.75	15.75				
2					14.0	11.25	16.25		19.5	11.0		17.75	13.25	14.0	14.0	17.0		22.50	
3						14.25	15.88		21.0			16.75		14.5	14.5	15.25		16.25	
4			15.0			12.0							11.25	16.75	16.75			17.75	15.0
July																			
1				14.25	13.5	12.25				15.0		16.25	11.50	12.75	12.75	13.75		17.0	
2							15.25		18.5	15.5			14.5					19.0	
3			14.0	16.25	14.0	11.25	14.5	14.0	15.25	14.5				15.5	15.5		10.5		
4					15.0	12.5	14.0		15.5	14.5	16.5	18.5	15.25	17.0	17.0	15.5		16.75	14.0
August																			
1				13.0	13.0	11.5	14.5		16.5	15.0				13.5	13.5	15.5		15.75	
2	20.0				14.5				19.75	13.5		16.0	13.5	14.75	14.75	15.25		17.75	
3			15.0	14.0	16.5	14.0	12.0	10.5	20.5	15.75	12.5			17.0	17.0	13.75		17.0	
4			14.0		13.25	14.5	11.63			14.0			13.5	16.75	16.75			13.0	17.0
September																			
1					13.0		11.5		18.0				13.0	19.0				16.0	
2						13.0		15.0	16.25			16.0	14.0						
3						15.0			14.5	12.25			15.5						
4					10.25				12.0	10.25		13.75	12.5			13.0		15.4	
October																			
1									14.25									15.25	
2									9.75	10.13		13.25	10.5			10.25		10.25	
3									10.0										
4			11.0																
Avg			14.5	14.4	13.5	13.0	13.5	13.2	16.2	12.2	12.8	15.0	13.6	15.3	15.3	14.2	10.5	17.1	15.3

Picture of a Secchi disc. A Secchi disc is used to determine the water clarity in water environments. The more clear the water the greater the depth you can see the Secchi disc.



Secchi disc.

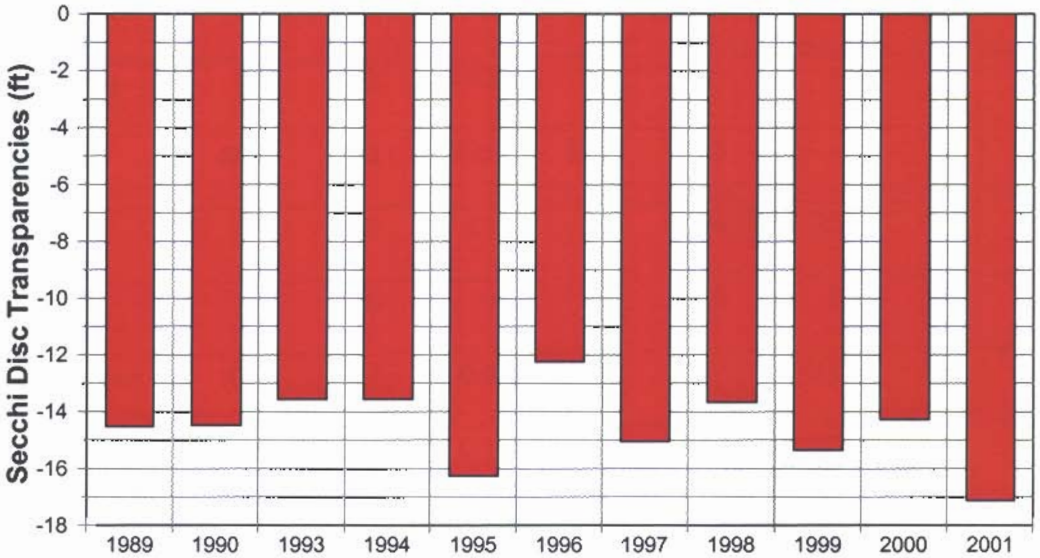


Figure 10. The good news is water clarity in Plum Lake is good and does not appear to be declining. The above graph shows water clarity going back to 1989. Clarity was good in 2001 and hopefully this trend will continue. Secchi reading over the last five years have been taken by Plum Lake Association volunteers. This work is very useful in tracking Plum Lake water clarity.

4.3. Phosphorus and Nitrogen, and Water Clarity

Summer water chemistry data collected during 1996 included secchi disc, total phosphorus (TP), chlorophyll a (Chl a), total kjeldahl nitrogen (TKN), nitrate (NO_3), and conductivity (Cond) (Table 10). Samples were collected at the surface and two feet off the bottom in the deepest area of Plum Lake. Total phosphorus was higher in the bottom water than the top water indicating some phosphorus release from the bottom material (sediments or plants) may be occurring, but it is minor. Nitrogen levels are also low, which is normal for a lake like Plum Lake.

Table 10. Summer monitoring results for Plum Lake.

	June 5, 1996	July 25, 1996	Aug 19, 1996	1996 Summer Average	June 27, 2001	July 24, 2001	Aug 25, 2001	2001 Summer Average
Secchi disc (ft)	10.0	16.5	12.5	13.0	15.0	14.0	17.0	15.3
Total phosphorus - top (ppb)	13	11	8	11	20*	28	12**	20
Total phosphorus - bottom (ppb)	15	15	22	17	--	43	163***	103
Chlorophyll a (ppb)	5	4	3	4	1	3	1	2
Nitrate-Nitrogen - top (ppb)	<10	<10	<10	<10	<20	--	--	<20
Nitrate-Nitrogen - bottom (ppb)	83	15	<10	36	--	--	--	--
Total Kjeldahl Nitrogen (ppb)	300	600	200	366	<500	--	--	<500
Temperature - top	17	20	23	20	22.4	23	23	22.8
Temperature - bottom	8	9	9	9	9	8	9	8.7
Dissolved oxygen (ppm) - top	10.4	8.7	9.0	9.4	9.4	10.8	8.5	9.6
Dissolved oxygen (ppm) - 36'-40' bottom	3.6	0.1	0.1	1.3	0.4	0.2	0.2	0.3
Conductivity	68	75	75	73	84	88	82	85

* on June 27, 2001, East Plum = 20; West Plum = 17.
** iron = 73 ppb
*** iron = 8,800 ppb

Water chemistry data from earlier studies is sparse, but it can be inferred that Plum Lake has been a relatively infertile lake for some time. Some water quality data are shown in Table 11. Plum Lake has a neutral to slightly basic pH, low dissolved solids, and moderate alkalinity. There is little danger of Plum Lake becoming an acid lake.

Table 11 . Water chemistry results from earlier studies.

	August 11, 1969	October 30, 1989
Secchi disc (ft)	20	11
Total phosphorus (ppb)	--	<10
Dissolved phosphorus (ppb)	--	4
Ammonia (ppb)	--	30
Alkalinity (ppm)	49.5	--
pH	7.2	7.7
Conductivity	90	97
Chloride (mg/l)	--	1.6
Hardness (mg/l)	--	45
Calcium (mg/l)	--	12
Magnesium (mg/l)	--	4
Potassium (mg/l)	--	1
Silica (mg/l)	--	12

Gravel and cobble are typical shallow sediment conditions in Plum Lake. These are relatively infertile habitats.

4.4. Algae and Zooplankton

Algae are small green plants, often consisting of single cells or grouped together in filaments (strings of cells). Zooplankton are small crustacean-like animals that can feed on algae. Examples of algae and zooplankton from Plum Lake are shown in Figure 11. Algae are dominated by "good" algae, generally non-bloom forming species. The zooplankton community is typical for lakes in Northern Wisconsin. In the photos below, images are magnified 150 times.

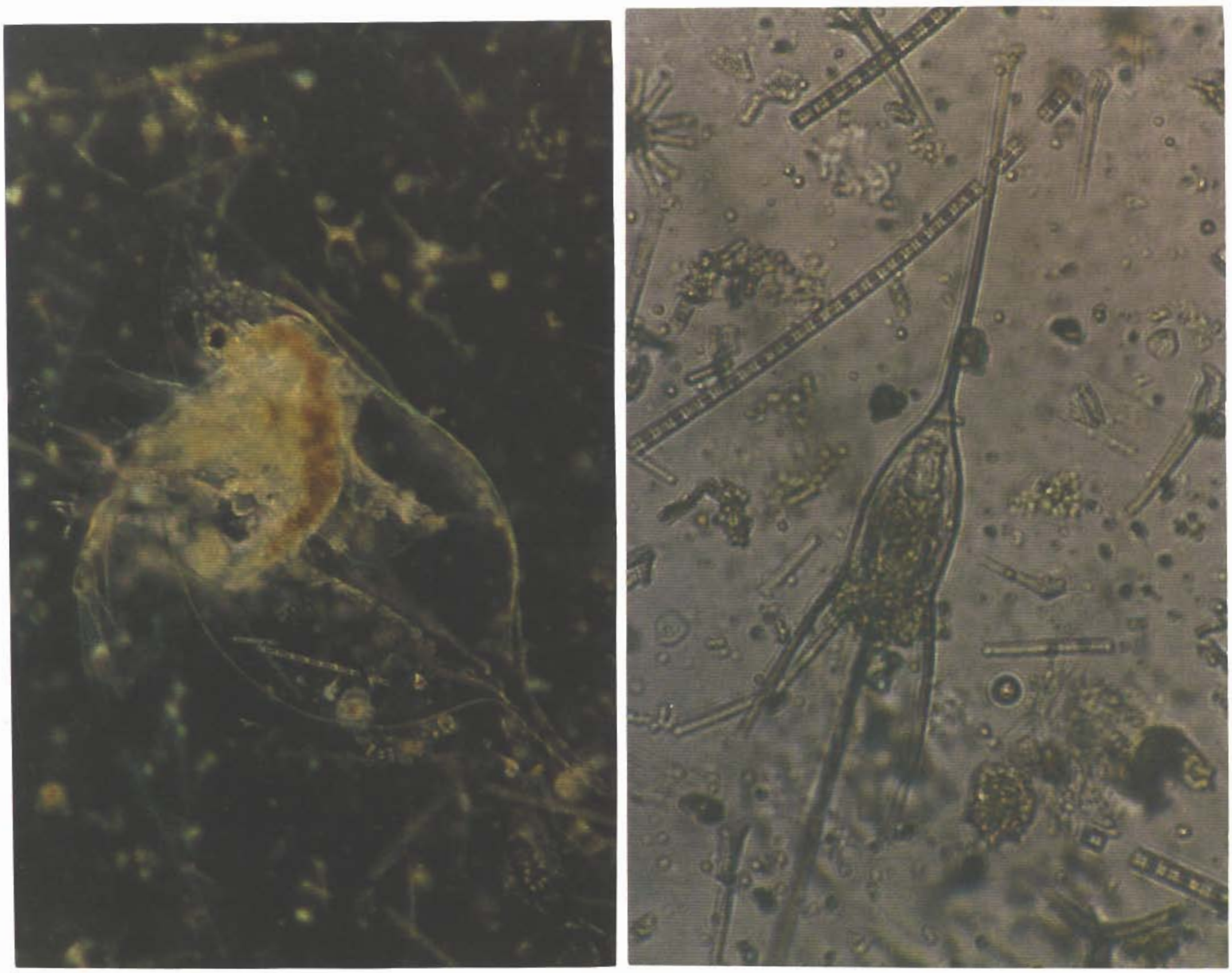


Figure 11. Two examples of zooplankton species from Plum Lake in 1996. The animal on the left is *Daphnia galeata mendotae*, a relatively large zooplankton (1-2 mm in length) that feeds on algae. The animal on the left is a rotifer, *Kelicottia*. Rotifers are quite small (<1mm in length) and feed primarily on small algae and bacteria.

Zooplankton were sampled in 2000 and 2001 and results were not much different compared to 1996 (Table 12 and Figure 12).

Table 12. Zooplankton counts for 1996, 2000, and 2001.

	June 5, 1996	June 5, 1996 DUP	July 26, 1996	Aug 19, 1996	July 17, 2000	July 27, 2001
Cladocerans	2	1	12	7	8	5
Big	2	1	6	1	2	2
Little	0	0	6	6	4	0
Ceriodaphnia	0	0	0	0	0	0
Bosmina	0	0	0	0	1	3
Chydorus	0	0	0	0	1	0
Copepods	92	49	10	12	10	27
Calonoids	7	0	3	11	4	4
Cyclophoids	59	42	7	1	4	18
Nauplii	26	7	0	0	2	5
Rotifers	0	0	0	0	2	31
TOTAL	94	50	22	19	20	63

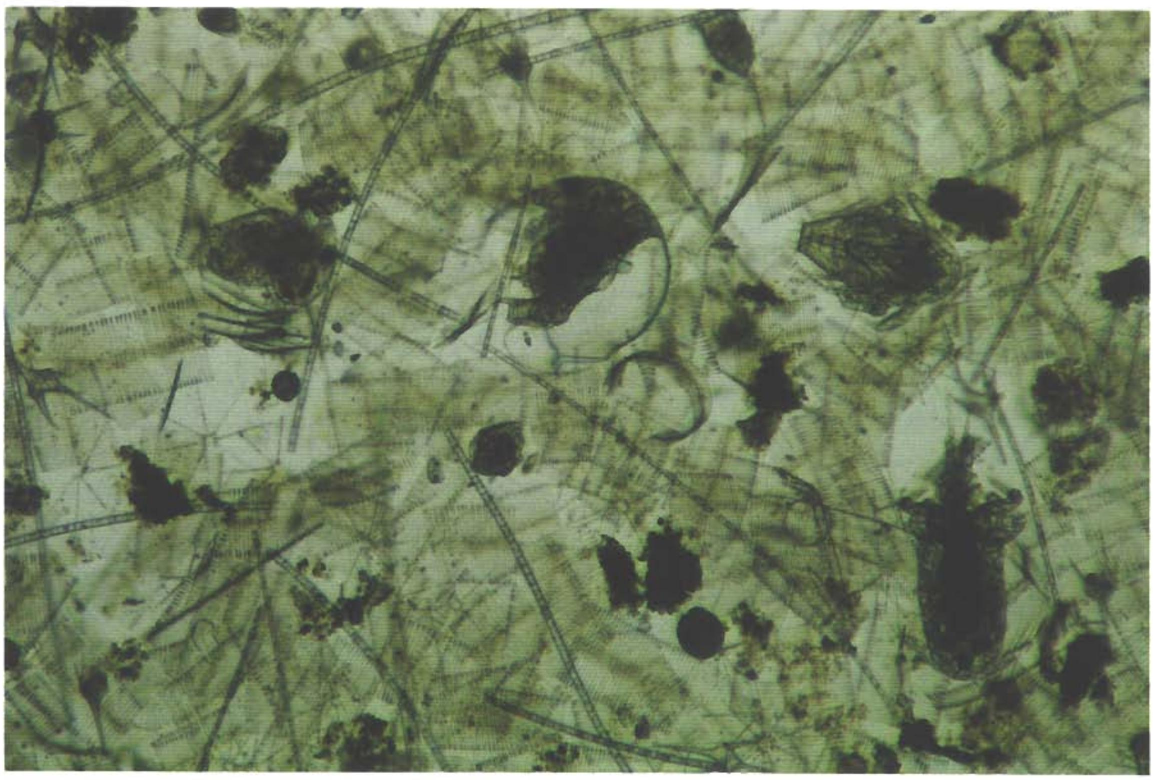


Figure 12. The zooplankton and algal conditions in Plum Lake on July 27, 2001 consisted of bosmina (shown above) and a lot of diatoms (also shown above).

4.5. Aquatic Plants

Two aquatic plant surveys have been conducted since 1996. One was on July 26, 1996 and the most recent was on August 25, 2001. The objectives were to characterize the distribution and species diversity of plants in Plum Lake.

In both 1996 and 2001, 44 transects were run with sampling occurring in 0 to 8 feet of water. Rooted plants were found in water to a depth of 8 feet. Plant coverage is shown in Figure 13. Plant coverage on the bottom is roughly 10% of the bottom area. The list of aquatic plants found in Plum Lake in 1996 and 2001 is shown in Table 13. Additional information is shown in the Appendix.

Table 13. Species list of the aquatic plants found in Plum Lake.

Common Name	Scientific Name	1996	2001
Submersed Plants			
Northern watermilfoil	*Myriophyllum sibiricum*	X	X
Water celery	*Vallisneria americana*	X	X
Naiad	*Najas flexilis*	X	X
Coontail	*Ceratophyllum demersum*	X	
Flatstem pondweed	*Potamogeton zosteriformis*	X	X
Illinois pondweed	*P. illinoensis*		
Sago pondweed	*P. pectinatus*		
Cabbage	*P. amplifolius*	X	X
Claspingleaf	*P. richardsonii*	X	X
Variable pondweed	*P. gramineus*		X
Robbins pondweed	*P. robbinsii*	X	
Whitestem pondweed	*P. praelongus*	X	
Muskgrass	*Chara sp.*		X
Elodea	*Elodea canadensis*	X	X
Rosette			X
Needle spike rush			X
Emergent Plants			
Pickeral plant	*Pontederia cordata*	X	X
Wild rice	*Zizania aquatica*		X
Arrowhead	*Sagittaria sp.*	X	
Bulrushes	*Typha sp.*	X	X
Spatterdock	*Nuphar variegatum*	X	X
White waterlily	*Nymphaea tuberosa*	X	X
Watershield		X	
Catttails	*Typha sp*	X	X

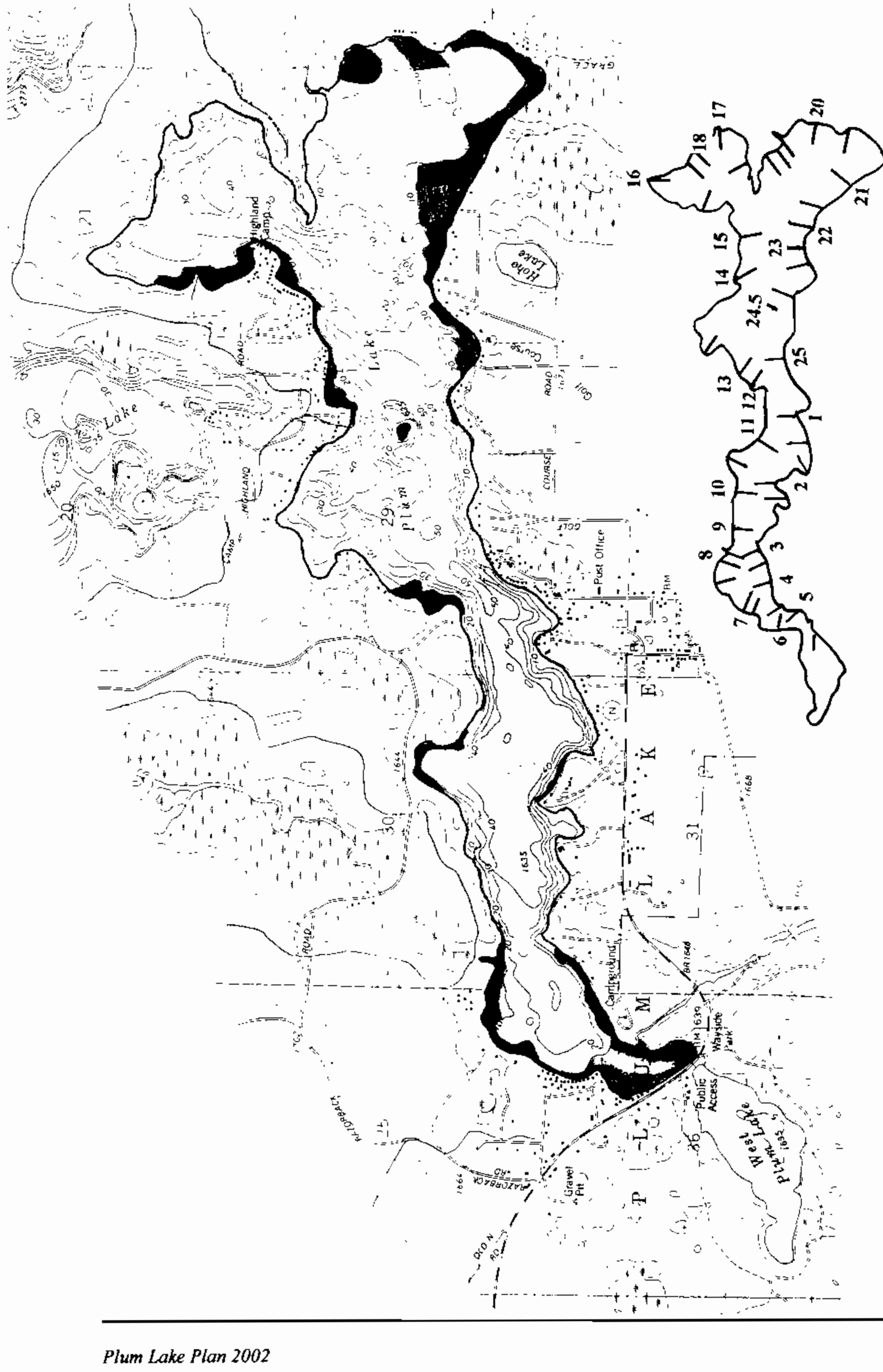


Figure 13. Aquatic plant map.

Figure 16. [top] It's a small boulder field on Transect 20 located in the east end of Plum Lake. This is the location of a steep drop off. The picture was taken on August 26, 2001.
[bottom] In about 25 feet of water on Transect 20, the rocks are buried in soft sediments. No plant growth was found this deep, although there was enough light to support growth. Crayfish were observed down here also.

Overall aquatic plant abundance in 1996 was sparse. The most common submerged plant was cabbage followed by flatstem pondweed (Table 14). Wild rice was common in the west end of Plum Lake. Examples of aquatic plant growth from 1996 are shown in Figures 14 and 15.

Table 14. Plum Lake aquatic plant occurrence for July 26, 1996 based on 44 transects and one depth of 0-8 feet. Density ratings are 1-5 with 1 being low and 5 being the most dense.

	Depth 0-8 feet (n=44)		
	Occur	% Occur	Density
Cabbage (*Potamogeton amplifolius*)	11	25	1.5
Claspingleaf pondweed (*P. richardsonii*)	2	5	1.0
Coontail (*Ceratophyllum demersum*)	5	11	1.6
Elodea (*Elodea canadensis*)	3	7	1.7
Flatstem pondweed (*P. zosteriformis*)	6	14	1.0
Naiads (*Najas sp*)	1	2	1.0
Northern watermilfoil (*Myriophyllum sibiricum*)	5	11	1.0
Robbins pondweed (*P. robbinsii*)	2	5	1.0
Water celery (*Vallisneria americana*)	3	7	1.0
Whitestem pondweed (*P. praelongus*)	1	2	1.0
Arrowhead (*Sagittaria sp*)	2	5	1.0
Bulrush (*Scirpus sp*)	3	7	1.0
Cattails (*Typha sp*)	1	2	1.0
Pickerel plant (*Pontederia conrdata*)	5	11	1.0
Spatterdock (*Nuphar variegatum*)	4	9	1.0
White waterlily (*Nymphaea tuberosa*)	2	5	1.0
Watershield (*Brasenia Schreberi*)	1	2	1.0
Wild rice (Zizania aquatica	2	5	4.0

Figure 14. Examples of emergent plants in Plum Lake are shown above.
[top] Wild rice beds are found at the west end of Plum Lake.
[bottom] Occasional beds of arrowhead are found in Plum as well. Emergent plants offer good fish habitat. More emergent plant beds would be good for Plum Lake.

Figure 15. [top] Variable pondweed (*Potamogeton gramineus*) grows in shallow water, but in limited amounts.
[bottom] "Cabbage" (*Potamogeton amplifolius*) is a good aquatic plant to have in a lake. It is found in Plum Lake but is scarce. It seems to be a popular food for rusty crayfish.

Plant Survey from August 25, 2001

The same 44 transects sampled in 1996 were sampled again in 2001. The percent occurrence of individual plant species is shown in Table 15. In 2001, the most common plant was water celery followed by cabbage (Table 15). Aquatic plant habitat conditions (Figure 16) and aquatic plant characteristics are shown in Figures 17 and 18.

Table 15. Plum Lake aquatic plant occurrences and densities for the August 25, 2001 survey based on 44 transects and 1 depth of 0-8 feet. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-8 feet (n=44)		
	Occur	% Occur	Density
Cabbage (*Potamogeton amplifolius*)	9	20	1.2
Chara (*Chara sp.*)	2	5	1.0
Claspingleaf pondweed (*P. richardsonii*)	1	2	1.0
Dwarf milfoil (*Myriophyllum tenellum*)	1	2	1.0
Elodea (*Elodea canadensis*)	1	2	1.0
Flatstem pondweed (*P. zosteriformis*)	2	5	1.0
Naiads (*Najas sp*)	2	5	1.5
Northern watermilfoil (*Myriophyllum sibiricum*)	3	7	1.0
Needle spike rush (*Eleocharis acicularis*)	3	7	1.0
Slender arrowhead (*Sagittaria graminea*)	1	2	1.0
Variable pondweed (*P. gramineus*)	2	5	1.3
Water celery (*Vallisneria americana*)	11	25	1.6
Bulrush (*Scirpus sp*)	3	7	1.7
Cattails (*Typha sp*)	1	2	1.0
Pickerel plant (*Pontederia conrdata*)	1	2	1.0
Spatterdock (*Nuphar variegatum*)	2	5	2.0
White waterlily (*Nymphaea tuberosa*)	1	2	1.0
Wild rice (*Zizania aquatica*)	2	5	2.5

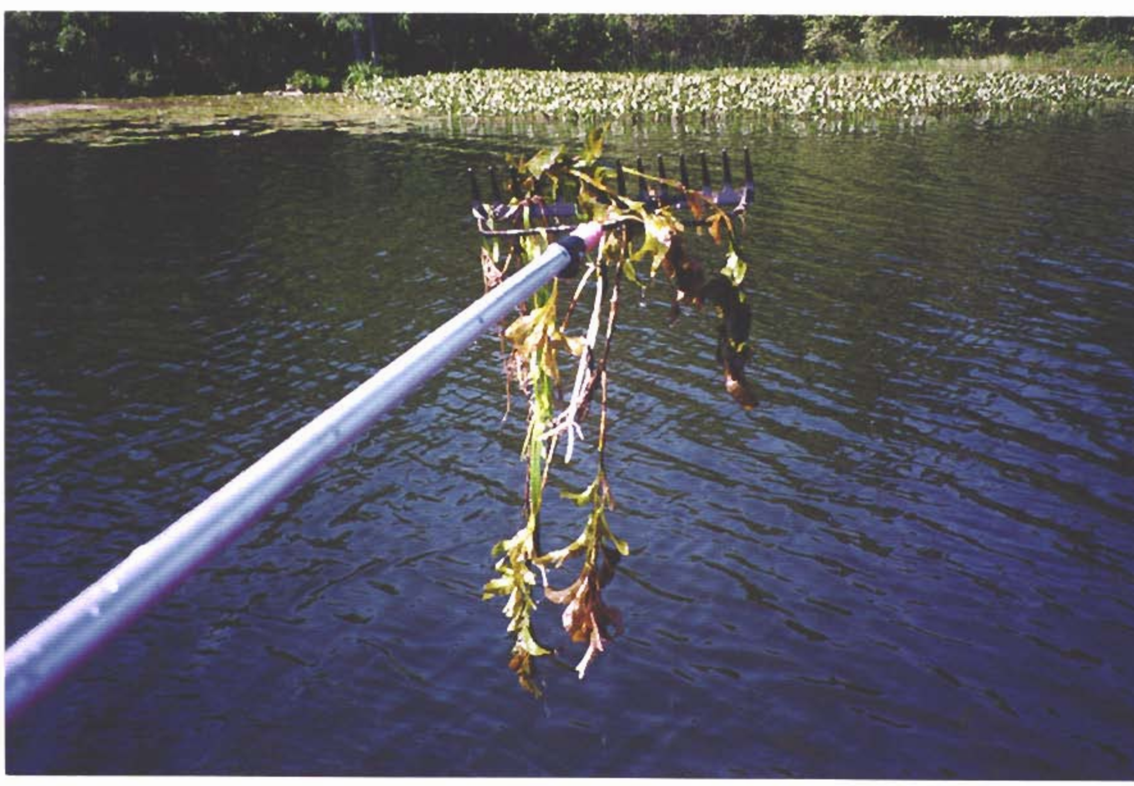


Figure 17. [top] Wild rice beds are still found in the west end of Plum Lake. There does not appear to be any significant changes from 1996.
[bottom] Cabbage was found on nine transects around Plum Lake. Here is cabbage sampled with a rake on Transect 21. Note the emergent pickerel plant in the background.

Figure 18. [top] Transect 21 had the biggest plant patch on Plum Lake. This is what water celery looks like underwater.
[middle] Cabbage and northern watermilfoil were also found on Transect 21.
[bottom] Close-up of a northern watermilfoil stem.

When comparing results of the 1996 and 2001 plant surveys, there are several changes. Coontail and flatstem pondweed were less abundant in 2001 and water celery was more abundant (Table 16).

Table 16. Comparison of the percent occurrence of plants from 1996 and 2001.

	1996 % Occurrence	2001 % Occurrence
Cabbage (*Potamogeton amplifolius*)	25	20
Chara (*Chara sp.*)	--	5
Claspingleaf pondweed (*P. richardsonii*)	5	2
Coontail (*Ceratophyllum demersum*)	11	--
Dwarf milfoil (*Myriophyllum tenellum*)	--	2
Elodea (*Elodea canadensis*)	7	2
Flatstem pondweed (*P. zosteriformis*)	14	5
Naiads (*Najas sp*)	2	5
Northern watermilfoil (*Myriophyllum sibiricum*)	11	7
Needle spike rush (*Eleocharis acicularis*)	--	7
Robbins pondweed (*P. robbinsii*)	5	--
Slender arrowhead (*Sagittaria graminea*)	--	2
Variable pondweed (*P. gramineus*)	--	5
Water celery (*Vallisneria americana*)	7	25
Whitestem pondweed (*P. praelongus*)	2	--
Arrowhead (*Sagittaria sp*)	5	--
Bulrush (*Scirpus sp*)	7	7
Cattails (*Typha sp*)	2	2
Pickerel plant (*Pontederia conrdata*)	11	2
Spatterdock (*Nuphar variegatum*)	9	5
Watershield (*Brasenia Schreberi*)	2	--
White waterlily (*Nymphaea tuberosa*)	5	2
Wild rice (*Zizania aquatica*)	5	5

4.6. Crayfish

The rusty crayfish has been a resident in Plum Lake since at least the 1990s. This voracious non-native crayfish is notorious for decimating aquatic plant beds.

Initially this might sound like a good deal for some lake users (i.e. fewer weeds easier boating, better swimming). However, the importance of a healthy aquatic plant community far outweighs any inconveniences the plants may cause.

For example, aquatic plant beds stabilize bottom sediments, retard wave action that can cause shoreline erosion, and take up nutrients that may otherwise fuel algae blooms. Additionally, they provide habitat for invertebrates, shelter for young gamefish and panfish, and spawning grounds for gamefish such as northern pike. So, while the feeding habits of the rusty crayfish may appear to reduce the aquatic plant coverage in the lake, there are additional ramifications for other parts of the Plum Lake ecosystem.

Presently there are no sure-fire methods for controlling rusty crayfish populations, but some possibilities have been proposed. There are chemicals that selectively kill crayfish, but none are known that selectively kill *rusty* crayfish and not other native species. Therefore, chemical control is not a prudent option. Intensive harvesting is not likely to eradicate the rusty crayfish population, but may reduce the population's size and the ecological impacts that they have.

Another option is to let nature take its course. This species is relatively new to Plum Lake, and the resident fish species may simply need time to adapt to this foreign visitor. Perhaps if some of the fish that inhabit near shore areas (e.g. bass, sunfish, and yellow perch) develop the ability to eat them, natural control may be realized.

Plum Lake rusty crayfish are shown in Figure 19. Plant beds they apparently have been feeding on are shown in Figures 20 and 21.

Figure 19. Rusty crayfish are an unwelcome guest in Plum Lake at this time. However, in the future, their number should decline as their food source declines and as fish learn how to eat them.

Figure 20. [top] A few aquatic plant beds seem to be unaffected from grazing by rusty crayfish in Plum Lake. This is the underwater scene of plants from Transect 20.
[bottom] It's a different scene in a cabbage patch on Transect 13. This cabbage patch seems to be heavily grazed down.

4.7. Fish

Plum Lake has a good fish community, with northern pike and walleyes being the top predator. The forage fish population has remained steady based on the two creel surveys conducted on Plum Lake in the 1990s (Table 16). Walleye and perch populations appear to have increased from 1990-91 to 1995-96.

Catch rates of the common fish species in Plum Lake are shown in Table 16 and a Plum Lake northern pike is pictured in Figure 22.

Table 16. Specific catch rates for two creel surveys conducted on Plum Lake from May of 1990 to March of 1991, and again from May of 1995 to March of 1996.

	5/90 to 3/91	5/95 to 3/96
Northern pike	0.20/hr	0.26/hr
Smallmouth bass	0.09/hr	0.07/hr
Bluegill	2.68/hr	2.08/hr
Walleye	0.12/hr	0.27/hr
Perch	0.33/hr	0.70/hr

* source: DNR North Central District; Woodruff, WI

Figure 22. We found this dead northern pike floating in the west end of Plum Lake in 1996. Northern pike and walleye are the dominant fish predators in Plum Lake.

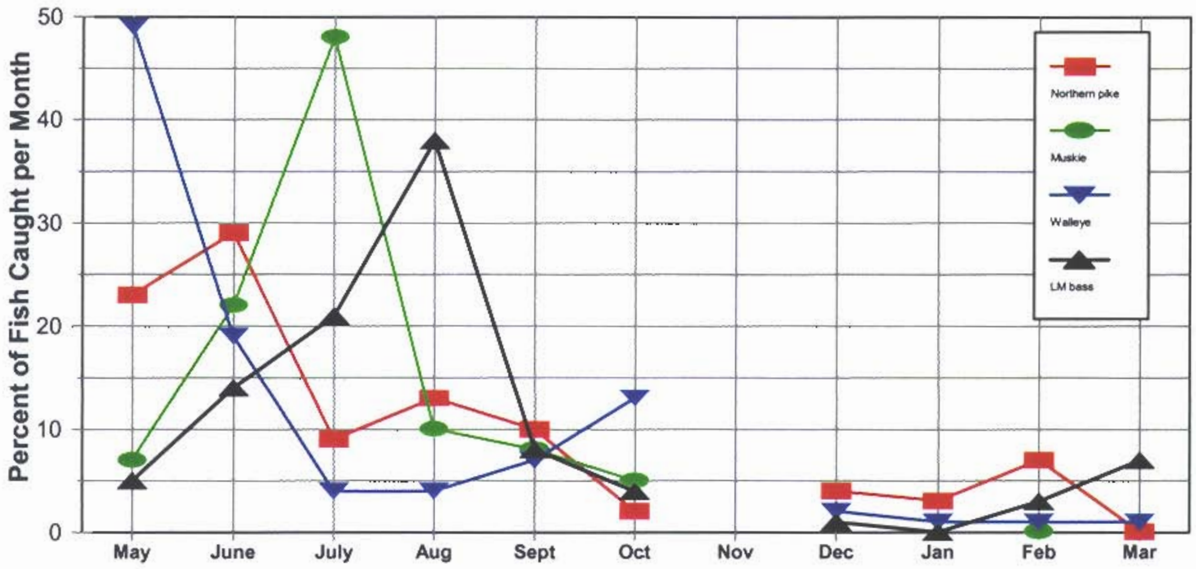
The Wisconsin DNR conducted a comprehensive creel survey from May 1, 1995 to March 31, 1996. In a creel survey, a fisheries biologist interviews fishermen on the lake about what they are catching and how long they have been fishing that day on the lake. A summary of results is shown in Table 17. The most commonly caught fish in Plum Lake were bluegill followed by yellow perch. Nearly an equal number of walleyes and northern pike were caught (Table 17).

Table 17. Creel survey analysis from May 1, 1995 to March 31, 1996.

Species	Total Catch	Total Harvest	Percent Released	Fish Caught per Acre
Cisco	11	0	100%	0
Redhorse	32	0	100%	0
Muskellunge	352	20	94%	0.3
Smallmouth bass	417	56	87%	0.4
Walleye	6,684	943	86%	6.0
Northern pike	6,714	1,219	82%	6.1
Largemouth bass	474	122	74%	0.4
Pumpkinseed	2,171	636	71%	2.0
Yellow perch	8,609	3,009	65%	7.8
Rock bass	798	292	63%	0.7
Bluegill	33,929	14,157	58%	30.1
Black crappie	533	319	40%	0.5
Bullhead	24	24	0%	0

The catch rate based on the creel survey of gamefish and panfish broken down by month is shown in Figure 22. If you were fishing on the lake, the dominant gamefish species changes by the month. For example, most walleyes are caught in May, northern pike in June, Muskies in July, and largemouth bass in August (Figure 22).

Creel Survey 1996 Gamefish



Creel Survey 1996 Preyfish

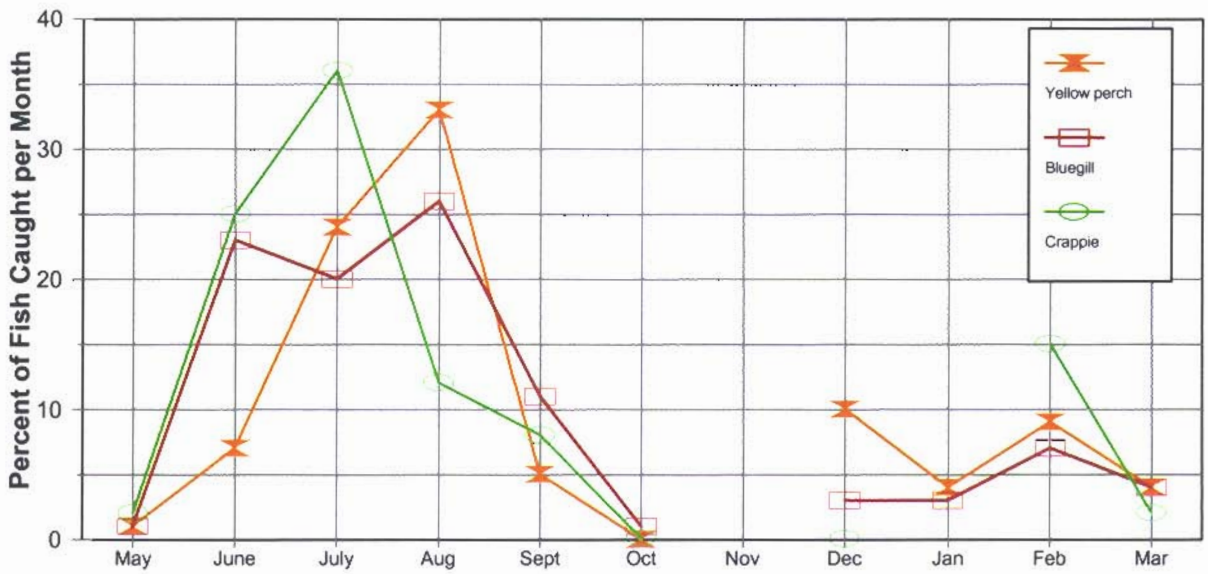
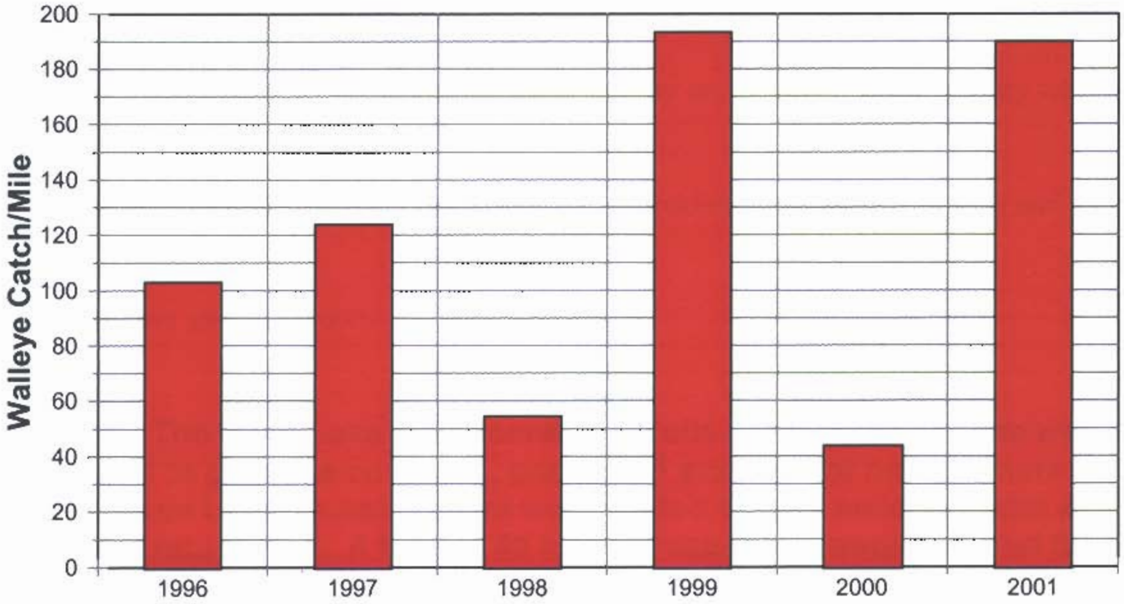


Figure 22. Percent of fish caught by month during the creel survey. Top graph represents four gamefish species and the bottom graph represents three panfish species.

Walleyes have been sampled annually since 1996 by electrofishing. Results show varied catch rates from year to year, although their sizes have remained somewhat constant (Figure 23).



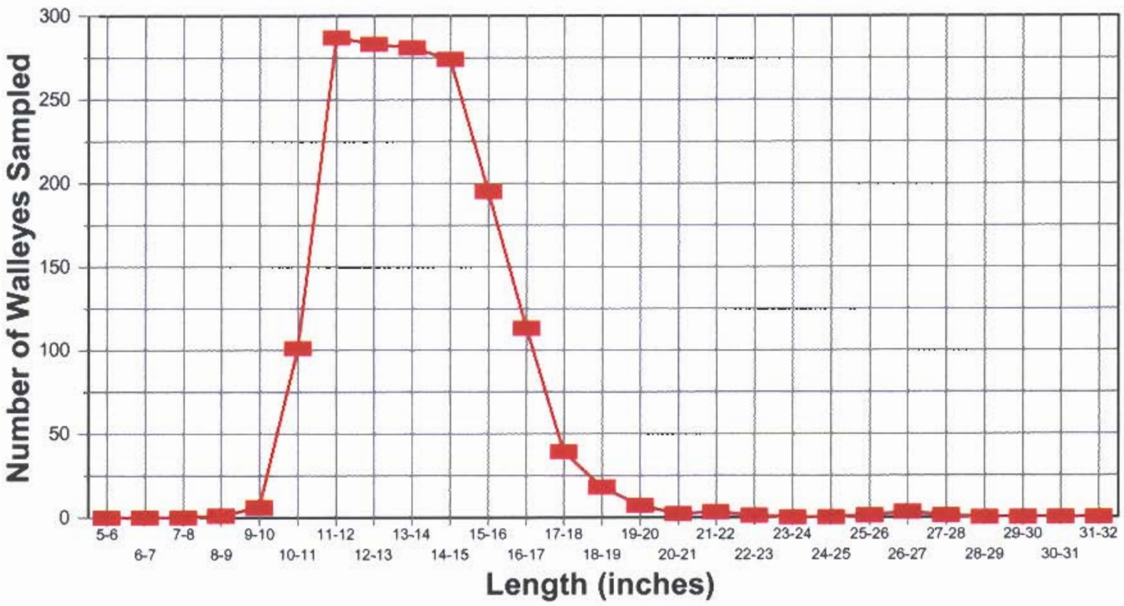


Figure 23. [top] Electrofishing results for walleyes from 1996 through 2001. Catch rates vary from year to year.
[bottom] Most of the walleyes sampled in Plum Lake measured from 11 to 15 inches.

5. Lake and Watershed Assessment

5.1. Lake Questionnaire Results

A lake use survey was mailed to 140 member households and 50 surveys were returned. Responses are shown in the next few pages (Table 18).

Lake aesthetics ranked as the most enjoyable activity on the lake. Water quality was rated as good to excellent for Plum Lake.

The most serious lake problems mentioned by respondents were rusty crayfish and water quality.

Responses are shown below:

Table 18. The Plum Lake questionnaire results. The questionnaire was developed to gage the concerns, goals, and attitudes of homeowners living around Plum Lake. Questionnaire were mailed to lake residents with a stamp for return mail. A total of 50 mailed responses were received for a grand total of 140 responses.

1. What do you enjoy most about Plum Lake? Please rank 1 through 8 with 1 being the highest rank.

1	Aesthetics (viewing) (2.2)*
2	Swimming (3.2)
3	Wildlife (3.3)
4	Fishing (3.8)
5	Motorized boating (waterskiing, jet skies, etc) (3.9)
6	Non-motorized boating (canoeing, kayaking, sailing, etc) (4.4)
7	Ice fishing (6.3)

* *represents average value based on number of responses.*

2. How would you rate the current water quality of Plum Lake? (Water quality indicators are things such as water clarity, algae, weeds or plants, swimming conditions, or fishing conditions.)

16	Excellent
29	Good
3	Fair
0	Poor

3. Since you have lived on or near Plum Lake, the quality has:

4	Improved	3	Degraded considerably
20	Remained the same	2	No opinion/can't tell
20	Degraded slightly	0	Other:

The average length of residency on Plum Lake was 30 years.

4. What do you see as the critical issues regarding the lake?
Please use a "1" for important, "2" for somewhat important, and a "3" for not important. Numbers can be used more than once.

1	Rusty crayfish (1.28)*	2	Water quality (1.41)
3	Wildlife (1.56)	4	Development (1.58)
5	Water craft (1.63)	6	Lake crowding (1.65)
7	Poor fishing (1.67)	8	Weeds (1.68)
9	Lake water levels (2.15)	10	Excessive algae (2.30)

* *represents average value based on number of responses.*

5. Who do you think is responsible for protecting and improving the lake. Enter the three most important groups or agencies by putting their letter in the spaces provided.

1st	2nd	3rd		
1	2	--	A.	Federal government
12	4	8	B.	State government
7	**11**	6	C.	County government (Vilas County)
8	9	9	D.	Local government (Plum Lake Township)
4	9	**10**	E.	Plum Lake Riparian Homeowners Association
11	6	6	F.	Individual lake residents
2	5	3	G	The general public who use the lake
4	1	2	H.	All equally
--	--	1	I.	Other

6a. Are you familiar with the latest boating and shoreline regulations?
29 Yes 12 No 13 I would like more information

6b. Is stricter enforcement of boating and shoreline activities needed?
22 Yes 25 No 1 Maybe

7. What should be done to improve or protect the quality of the lake? (Examples of projects are watershed practices, buffer strips, wetland restoration, fish stocking, educational materials, etc).

A variety of answers were given.

8. You have variety of options for managing land practices on your lot. How is your yard maintained? (Please check all that apply)

- 30 No fertilizer applied
- 11 Fertilizer is applied: 7 One; 4 Two; 0 Three times per year
- 1 Use a commercial fertilizer service
- 38 Maintain natural landscaped area
- 27 Maintain a vegetative buffer between lake and mowed lawn

9. Where is your septic system located in relationship to the lake?

A. Low risk	B. Medium risk	C. High risk	ANSWER:
Drainfield is at least 200 feet from the lake.	Drainfield is at least 100 feet from the lake.	Drainfield is less than 100 feet from the lake.	A = 23 B = 19 C = 3

10. What is the age and capacity of your septic system?

A. Low risk	B. Medium risk	C. High risk	ANSWER:
System is five years old or less	System is between six and twenty years old	System is more than twenty years old	A = 12 B = 28 C = 7

11. Has your septic tank been pumped recently?

A. Low risk	B. Medium risk	C. High risk	ANSWER:
The septic tank is pumped on a regular basis as determined by annual inspection or about every 1-2 years.	The septic tank is pumped, but not regularly.	The septic tank is not pumped.	A = 38 B = 5 C = 3

12. Is your system exhibiting any signs of problems?

A. Low risk	B. Medium risk	C. High risk	ANSWER:
Household drains flow freely. There are no sewage odors inside or outside. Soil over drainfield is firm and dry.	Household drains run slowly. Soil over drainfield is sometimes wet.	Household drains back up. Sewage odors can be noticed in the house or yard. Soil is wet or spongy in the drainfield area.	A = 45 B = 1 C = 0

13. Are you interested in participating in a Lake Management Program on a personal level? _34_ Yes; _15_ No; _1_ Maybe

Are you willing to do any of the following:

- _8_ Use soil test recommendations for fertilizer application?
- _18_ Plant native wildflowers, grasses, etc to attract wildlife?
- _20_ Leave as is or restore natural shoreland vegetation?
- _26_ Help trap rusty crayfish using small traps designed by University of Wisconsin-Trout Lake Station?
- _12_ Take water clarity readings using a secchi disc and send information to WDNR-Rhinelander?
- _4_ Other ideas ____________________

14. Where do you get your information on how lakes work?

- _18_ Lake Association newsletters
- _25_ Wisconsin DNR
- _24_ Newspapers
- _11_ Television
- _10_ Other ____________________

5.2. Plum Lake Status

The status of Plum Lake is good and probably could be graded as a high "B". Values for phosphorus, chlorophyll and secchi depth are within ecoregion values, which if turned into grades would be above average.

A lake model was run for Plum Lake using ecoregion values for phosphorus inputs from the watershed. An ecoregion is a geographic region in the State that has similar geology, soils, and land use. Plum Lake is in the Northern Lakes and Forests ecoregion. Lakes in this ecoregion have the best water quality values in the State. The results of the lake model indicate the water quality in Plum Lake is what would be expected for relatively unimpacted lakes in this ecoregion (Table 19).

Table 19. Observed and predicted values for three water quality parameters in Plum Lake.

Parameter	Observed in Plum Lake		Predicted by Ecoregion Model (LEAP)
	1996	2001	
Total phosphorus (ppb)	11	20	12
Secchi disc (ft)	13	15.3	14.9
Chlorophyll a (ppb)	4	2	3

A map showing the ecoregion areas and the Plum Lake location is displayed in Figure 24. A range of ecoregion values for lakes in the "Northern Lakes and Forests" ecoregion along with actual Plum Lake data are shown in Table 20.

These comparisons indicate that Plum Lake is in a protection status in terms of water quality, meaning no drastic lake or watershed restoration projects are needed. At this point in time, the challenge is to keep the lake in good shape.

An important component to watch and control is nutrient inputs -- both phosphorus and nitrogen. If phosphorus concentrations increase to around 40 ppb or above, nuisance algae blooms could develop, and this could cause a cascade of problems.

Likewise, construction and lake resident activities can have significant impacts on phosphorus inputs. Studies in Maine show that clearing the trees off your property, even a partial clearing can increase phosphorus inputs to the lake from the runoff. Shoreland projects to reduce nutrient inputs are important.

Table 20. Summer average quality characteristics for lakes in the Northern Lakes and Forest ecoregion, as noted in Description Characteristics of the Seven Ecoregions in Minnesota, by G. Fandrei, S. McCollar. 1988. Minnesota Pollution Control Agency.

Parameter	Northern Lakes & Forests	Plum Lake (1996)	Plum Lake (2001)
Total phosphorus (ug/l)			
Epilimnion	14-27	11	20
Hypolimnion	--	17	103
Chlorophyll (ug/l)	<10	4	2
Chlorophyll - max (ug/l)	<15	5	3
Secchi disc (ft)	8-15	13	15.3
Total kjeldahl nitrogen (mg/l)	<0.75	0.37	<500
Nitrite + Nitrate N (mg/l)	<0.01	0.04	--
Conductivity (umhos/cm)	50-250	73	85
TN:TP ratio	25:1-35:1	33:1	
Plant coverage	--		

Figure 24. Ecoregion map for Wisconsin.

5.3. What Will Plum Lake Look Like in the Future

If no substantial increases in phosphorous occur in Plum Lake, in the future the lake should look much like it does now. Lake modeling is a tool that aids in predicting what phosphorus concentrations should be in a lake based on the amount of nutrients that come into a lake on an annual basis. A lake model can also be used to predict what future conditions could be if changes occur in the watershed that bring in more phosphorus.

The phosphorus model used in this study was the Wisconsin Lake Model Spreadsheet. The spreadsheet is a compilation of ten different models. Before the models could be run, nutrient and water budgets for Plum Lake were needed. To estimate the nutrient budget, phosphorus concentrations were assigned for various land use delineations and then assuming a certain amount of runoff per year we estimated phosphorus inputs from various land uses. Results of these calculations are summarized in Table 21, and show that forest land is the major phosphorus contributor to Plum Lake followed by wetlands and then followed by the golf course area and lastly the residential area. Our estimate is that septic tanks inputs are relatively low.

To produce nuisance algae blooms in Plum Lake, we estimate that an additional 2000 kg of phosphorous would be needed. A problem that is difficult to address is how to estimate the amount of new phosphorus that could lead to phosphorus release from lake sediments. Considerably less than 2,000 kg could cause higher lake productivity and possibly stronger anoxic conditions which could result in increased phosphorus release from bottom lake sediments.

Table 21. Phosphorous inputs to Plum Lake from land use in the watershed.

Land Use	Acres	Hectares	Loading per Hectare (kg/ha-yr)	Yearly Loading (kg/yr)	Loading Percent
Forest	10,112	4,092	0.10	409	42.8
Wetlands	4,374	1,770	0.10	177	18.5
Precipitation	1,108	448	0.30	134	14.1
Golf course	600	243	0.50	122	12.7
Urban	224	91	1.0	91	9.5
Onsite	--	--	--	24	2.5

- **Model prediction: Reckow Model for Natural Lakes - 12 mg/m^3**
- **An additional 2,000 kg (68% increase) to obtain 40 mg/m^3, could produce nuisance conditions.**
- **Total loadings: under normal conditions: 2,110 lbs (957 kg)**
  under nuisance conditions: 6,520 lbs (2,960 kg)

6. Lake Projects

A list of projects has been prepared that are intended to protect the water quality of the Plum Lake. Projects are listed below:

1. Landscaping Ideas
2. Onsite System Maintenance
3. Golf Course Nutrient Management
4. Rusty Crayfish Projects
5. Future Directions: Monitoring is important

6.1. Landscaping Ideas

In the Water

For long term success of a lake improvement project, it's essential that Plum Lake maintain a diverse aquatic plant community. Often, a seed bank is already present in a lake, and disturbed areas will be recolonized by plants naturally. When this does not occur, transplanting desirable submerged aquatic plants may be the solution. This process is called aquascaping. The species being considered are northern watermilfoil and various *Potamogeton* pondweeds that are native to the area.

At this time, I would not recommend transplanting submerged aquatic plants. Because rusty crayfish are still a factor, they would probably eat the new sprouts. Also, survivorship of transplanted plants is low.

Rather, I would wait until rusty crayfish numbers go down and see if submerged plants can come back on their own. The seedbank is there.

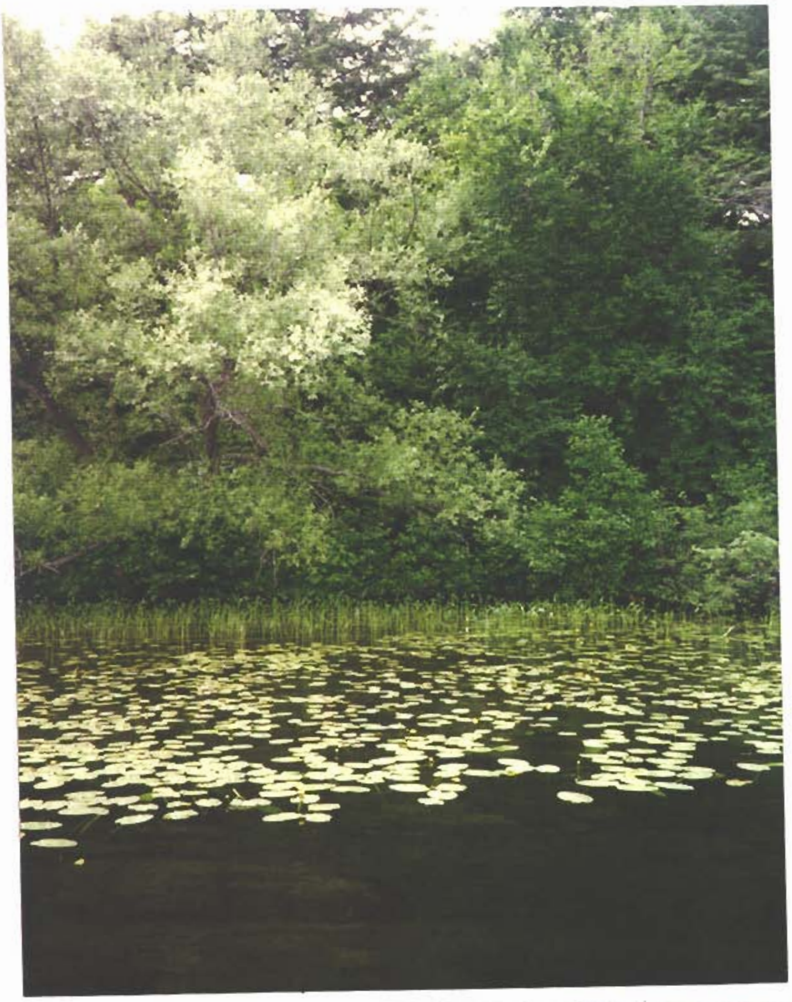


Figure 25. Shown above are existing weed patches in Plum Lake. As rusty crayfish populations decline, aquatic plant communities should increase.

Landscaping Ideas On Land

Activities associated with lakeshore development can impact a lake in many ways. As cabin or home construction increases around a lake, lawns are installed and fertilized. Wetlands may have been filled in the past thus removing some natural filtering action. Rooftops, driveways, sidewalks, and roads increase impervious surfaces. Impervious surfaces are surfaces that prevent runoff from infiltrating into the soil. When runoff doesn't infiltrate the amount of runoff increases, and this water picks up extra nutrients and sediments and delivers them to the lake. Another factor is when the runoff doesn't infiltrate into the soil, it is not very well filtered in the surface runoff.
So development around a lake can increase nutrient and sediment inputs to a lake compared to undeveloped conditions. However, cabin owners can implement some projects to minimize adverse impacts on their lake. That is what this alternative is about; the little things that can be done; and although they may seem trivial, everything is cumulative. For example, if each cabin owner could reduce phosphorous inputs to the lake by 1 pound/year, that may not sound like much. But look at it from the perspective of 30 or 40 cabin owners over 10 years. That represents 400 pounds of phosphorous that has not reached the lake.

The careful planting of selected land plants and aquatic plants can improve water quality by reducing nutrients that run into the lake (land plants) and by taking up nutrients and by stabilizing bottom sediments (aquatic plants). Examples of typical plants are shown in the fact sheets that will be available to lake association members. Another benefit is planned landscaping can enhance wildlife by creating refuges and food sources for water fowl and aquatic animals. The combination of landscaping and aquascaping is appropriate for wetlands, streams, and lakes. For this project we are encouraging the use of vegetative buffers to help reduce erosion and nutrient inputs to the lakes.

Some benefits of this approach are:

- Erosion can be a problem nearly anywhere in the watershed. It is especially critical adjacent to a water body because sediment delivery rates are so high. Landscaping upland areas may not only reduce soil erosion, but may reduce the use of fertilizer as well. Aquascaping is a form of erosion control in the nearshore areas of lakes, and can be used on stream banks as well. Aquatic vegetation can stabilize nearshore areas.

- A natural buffer can be installed between your shoreline and the upland area of your lot. Let a strip about 15 feet wide go natural and see what grows. This strip is a buffer strip and will help remove sediments and nutrients from going into the lake.

- Transplanting native terrestrial and aquatic plants also aids in reestablishing native plants that have disappeared from the area. One of the objectives of this project is to see if homeowners can reestablish native vegetation in their nearshore areas.

Figure 26. Looking for landscaping ideas? Drive around the lake and look at what is growing in a natural state. Make note of the species and then model your lot after what you find.

6.2. On-site System Maintenance Program

The septic tank/soil absorption field has been one of the most popular forms of on-site wastewater treatment for years. When soil conditions are proper and the system is well maintained, this is a very good system for wastewater treatment. The on-site system is the dominant type of wastewater treatment found around Plum Lake today.

However, problems can develop if the on-site system has not been designed properly or well-maintained. Around Plum Lake there are on-site systems that need maintenance and upgrades. At the same time, it is good practice to ensure that systems that are functioning adequately now will continue to do so in the future.

This project calls for an organized program to be developed that makes homeowners aware of all they can do to maintain their on-site systems.

A description of activities associated with the on-site maintenance program are described below:

- WORKSHOP
  A workshop should be scheduled for Plum Lake Watershed residents to demonstrate the installation of a conforming septic system and the proper care and maintenance of a septic tank and septic system.

- SEPTIC TANK PUMPING CAMPAIGN
  Vilas County could work with the Plum Lake Association in a coordinated campaign effort to get every septic tank associated with a permanent residence pumped 2-3 years and seasonal systems pumped 4-6 years in the shoreland area to help reduce phosphorous loading to the septic system drainfield.

- ORDINANCE IMPLEMENTATION
  Work to implement and then get enforcement of a county ordinance, where septic systems must be "evaluated" at the time a property is transferred. The seller would obtain a septic system evaluation from Vilas County at the time of property transfer. The evaluation would determine if the septic system was "failing", "non-conforming", or "conforming". A "failing" septic system includes septic systems that discharge onto the ground surface, discharges into tiles and surface waters, and systems found to be contaminating a well. The county would require a "failing" system to be brought into compliance with the Vilas County ordinance within 90 days of property transfer. A dry well, leaching pit, cesspool, or a septic system drainfield with less than 3-foot vertical separation instance from the bottom of the drainfield to the seasonal high water table or saturated soil conditions would be "non-conforming", but not required to be upgraded at property transfer under the Vilas County Ordinance.

Through these county property transfer requirements a percentage of the septic systems that are not failing but are "non-conforming" would be upgraded to "conforming" if a prospective buyer was applying for a mortgage. This is because the potential buyer's lending institution in some cases will not approve the buyer's loan request because the property to be purchased does not have a conforming septic system. The county's evaluation report would state whether or not the evaluated septic system is "conforming" or "non-conforming".

6.3. Golf Course Nutrient Management

The vast majority of the Plum Lake watershed is undeveloped forest and wetland (81% combined). The golf course land only accounts for 4% of the total watershed area, but it has the potential to contribute an inordinate amount of nutrients to the lake if too much fertilizer is being applied to the course. Plum Lake is currently in excellent condition and has very good water clarity. So, protection is the key to ensuring that it stays that way. A periodic review of herbicide and fertilizer use would be a good idea. This study did not find problems with the golf course (based on the conductivity survey and on the lack of runoff from the course to the lake) (Figure 27). The golf course has been here since the early 1900s. If it was a major nutrient contributor to Plum Lake, the impacts would have been noticed by now.

Monitoring runoff that drains the golf course land and flows into Plum Lake would provide valuable information about whether the golf course is exporting unusually high levels of nutrients and/or sediments to the lake.

Figure 27. [top] Several wetland areas are being enhanced around the golf course. Nutrient management programs apply only the minimum amount of fertilizer needed.
[bottom] Not much surface runoff enters Plum Lake. Low spots collect and infiltrate water.

6.4. Rusty Crayfish Projects

The rusty crayfish situation has been evaluated from a number of angles. The most cost-effective management approach is to "let nature take its course." A variety of control measures have been tried over the last 15 years. None have produced satisfactory control. What seems to happen over time are two naturally occurring controls become important. First, the crayfish actually eat themselves out of house and home. With a decline of weed beds, their food source is diminished, and this will limit their population. Secondly, fish learn how to attack and eat the feisty crayfish. Once the fish community learns how to overcome the threatening posture and slightly oversized pinchers, they will be dining on crayfish.

You can tell when fish are starting to have an impact, because small crayfish will be eaten first, leaving only larger crayfish in the population. Plum Lake is not at this stage yet.

Rusty crayfish could be a problem for another 5 to 10 years in Plum Lake with the possibility their population would decline after that. Then their population probably would resemble a native crayfish population . . . they would be around but not much of a problem.

There are two crayfish projects the Plum Lake Riparian Association could consider. The first is to use fish to control the smaller crayfish. Yellow perch can be good crayfish predators. Catch and release tactics would be helpful. Signs and information materials could be distributed to lake residents and at public landings to encourage catch and release fishing. The idea is to maximize the impact of fish predation on crayfish.

The second project area is to set traps and remove crayfish. An example of a trap is shown in Figure 28. It would take a substantial effort for several years to have a significant impact.

Big Bearskin Lake (Oneida Co) has been harvesting crayfish for a number of years. They should be contacted for harvesting techniques and ideas (Roger Soletski is the president)(Figure 29).

For Plum Lake, at least 200 traps should probably be set for 5 to 6 years. This may be a project area that Lake Association volunteers could participate in.

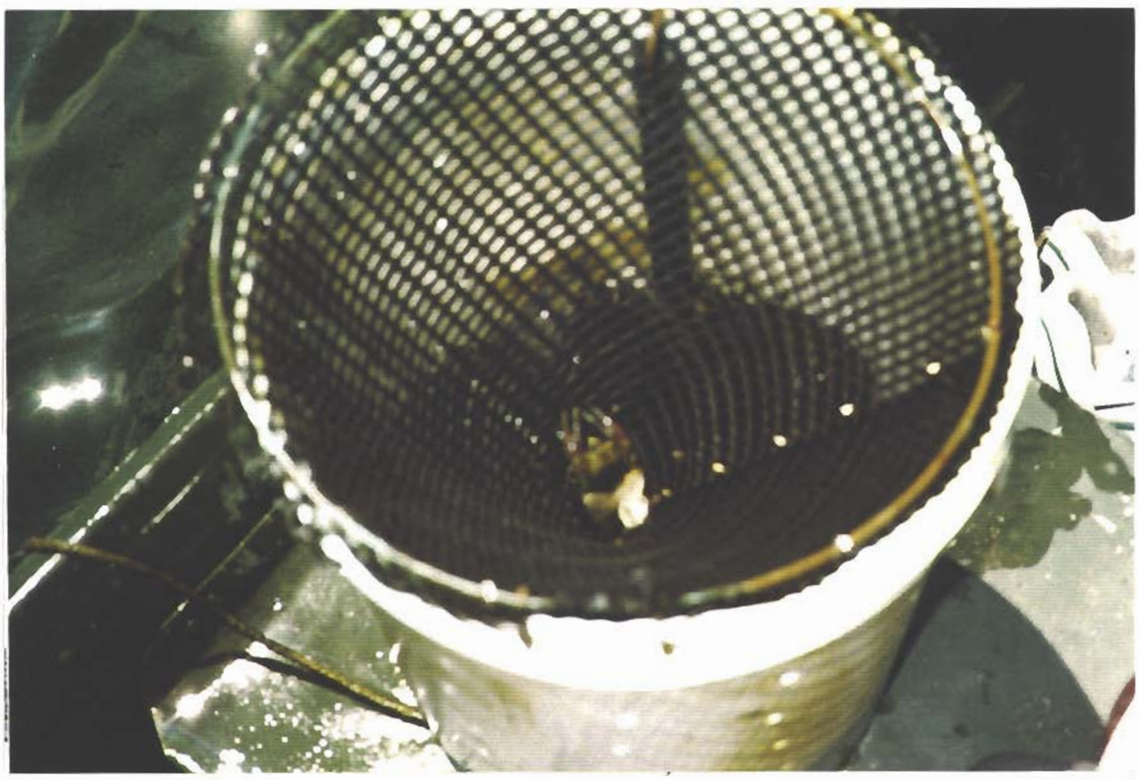


Figure 28. [top] Managing the Plum Lake crayfish situation is a high priority for lake residents based on questionnaire returns.
[bottom] A funnel-shaped moth fitted over a bucket with bait is an effective crayfish trapping device and could be used in Plum Lake.

Figure 29. [top] Big Bearskin crayfish traps are ready to go into the lake. Plum Lake volunteers could make and install traps as well. [bottom] Roger Soletski, Big Bearskin Lake, checks the crayfish holding cage at Big Bearskin. The larger crayfish can be sold.

6.5. Future Directions

To evaluate Plum Lake, a water quality monitoring program and fish sampling program should be ongoing. This program will address the issues of:

- Changes in lake quality as measured by total phosphorus, secchi disc, algae and macrophyte distribution.
- Significant changes in the fish community.

Lake Monitoring Details

Secchi Disc transparencies should be taken monthly, through the summer by volunteers.

If volunteers and the budget are available, surface water samples should be collected and analyzed for the total phosphorus, total nitrogen, and chlorophyll a. University of Wisconsin-Stevens Point has a very good lake testing program. Lakes are sampled in the spring and the fall and costs are about $300 per year. Citizen volunteers can take the water samples.

Every couple of years, an aquatic plant survey should be conducted to check the coverage and the types of aquatic plants in Plum Lake. This could be done by a consultant or possibly through the WDNR-Rhinelander.

Fish surveys are conducted by the WDNR every five to ten years and reports should be inserted into the Plum Lake Riparian Association water quality files.

At the present time, boat houses are in pretty good shape around the lake. They pose little adverse impact on Plum Lake water quality and in fact have benefit as providing structure for fish habitat.

Spreading the News

At the annual meeting, a lake status report could be delivered that summarizes activities over the past year as well as what was happening on the lake.