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Winslow Homer: *Breezing Up*, 1876

Lake Management Plans for Crooked Lake, Bass Lake, and Gilkey Lake, Oconto County, Wisconsin

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Submitted to:
Crooked Lake Area Lakes Association
Oconto, Wisconsin

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SUMMARY

The Crooked Chain of Lakes, Crooked (143 acres), Bass (11.5 acres) and Gilkey (18 acres) Lakes, are located in Oconto County, Wisconsin.

Goals The goals of this project were:
-to examine existing lake conditions
-to develop a lake management plan that protects, maintains, and enhances the lakes water quality.

Watershed Characteristics

Crooked Lake
-Crooked Lake is a drainage lake that drains 683 acres of land.
-The watershed is dominated by forest.

Bass Lake
-Bass Lake is a drainage lake.
-Bass Lakes watershed is 189 acres.
-The watershed is dominated by forest but residential acreage is important.

Gilkey Lake
-Gilkey Lake is a drainage lake.
-Gilkey Lakes watershed is 244 acres and is dominated by forest.

Water Quality and Quantity Monitoring Methods
-Sampling was conducted in June, July, and August 1994.
-Chemical analysis was conducted by the Wisconsin Laboratory of Hygiene.
The following parameters were analyzed:

Chl a	Temperature
Dissolved Oxygen	Conductivity
Nitrate plus Nitrite	Total Kjeldahl Nitrogen
Total Phosphorus	Secchi Disc
Ammonia	Plant Survey
Underwater Video	

Dissolved Oxygen and Temperature
-Crooked Lake is stratified during the summer.
-Bass Lake weakly stratifies during the summer.
-Gilkey Lake remains well-mixed, and does not stratify.

Nutrients

-Crooked Lake has the lowest nutrient concentrations of the three lakes, followed by Bass and then Gilkey. All three exhibit favorable water quality.

Macrophyte Status

-Crooked Lake survey consisted of fifteen transects. Rooted plants were found in water depths to 12 feet. Plant coverage is about 59% of the bottom of the lake.
-In Bass Lake, four transects were conducted. Plants were found through the lake, but they were sparse in the 10-12 foot depths.
-Gilkey Lake, Approximately 77% bottom coverage was observed.
-Crooked Lake does not have Eurasian watermilfoil at the present time.

Lake Water Quality Trends

-Water chemistry results are comparable to Ecoregion values
-No serious degradation noted at this time
-The data base does not go back far enough to examine trends, however the lakes are in good shape with regard to phosphorus concentrations and transparency.

Lake Modeling

-For modeling purposes, the Wisconsin Model Spreadsheet was used.
-For Crooked Lake, the model predicted a phosphorus concentration range of 10-62 ppb. The actual lake phosphorus level was 11 ppb.
-For Bass Lake, the model predicted a range of 50-157 ppb. The actual lake phosphorus level was 15 ppb.
-For Gilkey Lake, the model predicted a range of 19-70 ppb of phosphorus, and the actual lake phosphorus level was 10 ppb.

Trophic State Index

The Trophic State Index (TSI) rates a lake from 1 to 100, with low numbers being the best. Crooked Lake is currently rated as an oligotrophic-mesotrophic lake. Bass Lake and Gilkey Lake are currently rated as mesotrophic lakes. The current average TSI for Crooked is 39, for Bass is 40, and for Gilkey is 49 (TSI ratings are based on the chlorophyll a level, total phosphorus concentrations, and secchi disk transparency).

Conclusions

All three lakes have phosphorus concentrations and transparencies within ecoregion values.

All three lakes are in a protection and maintenance mode, rather than a restoration mode. Crooked Lake can assimilate more phosphorus than Bass or Gilkey because of its larger volume. However, it is vulnerable to phosphorus loads and also possible phosphorus release from bottom sediments. Watershed protection, which should result in low phosphorus inputs

to Crooked Lake, is paramount. Shoreland best management practices are important for all three lakes, but especially Bass and Gilkey.

No major lake restoration projects are necessary in the near term. The need for alum addition for Crooked Lake is not eminent. However, it would be a good idea to start a lake fund to be used for special projects.

Recommended Lake Management Projects

1. Continue a lake monitoring program.
2. Landscaping for wildlife/buffer systems.
3. On-site system maintenance program.
4. Aquatic plant management program emphasizes small-scale approaches.
5. Spot dredging will only be a short term remedy in near shore areas.
6. Information program promoting balanced lake-use rules. Included are topics addressing responsible use of large-horsepowered boats and jet skis.

--Contents--

1. Introduction and Project Setting

Crooked Lake is a drainage lake and Bass and Gilkey Lakes are drained seepage lakes located in Oconto County, Wisconsin (Figure 1). Crooked Lake is a mesotrophic lake with moderate phosphorus levels (8-12 ug/l) and an excellent secchi disc transparency of 14 feet in summer. Bass Lake is a mesotrophic lake with moderate phosphorus levels (12-18 ug/l) and an outstanding secchi disc transparency (14 feet) in the summer. Gilkey Lake is a mesotrophic lake with phosphorus levels of 8-11 ug/l and a good secchi disc transparency (5+ feet - disc was resting on the pond bottom) in the summer.

A lake contour map of Crooked Lake is shown in Figure 2.

The goals of this project were to examine existing lake conditions and to develop lake management plans to protect, maintain, and enhance lake water quality for the short term and long term.

Past Projects

Several projects have been conducted on Crooked, Bass, and Gilkey Lakes, in addition to fish surveys conducted by the Wisconsin Department of Natural Resources.

Water quality monitoring has been conducted since 1991 by the Lake Association with Dick Firehammer and Harvey Tengler (Lake Association members) monitoring secchi disc transparency and water chemistry (Appendix A).

In July, 1982, Dr. George Metzger conducted a coliform bacteria survey taking twenty duplicate samples (Appendix B).

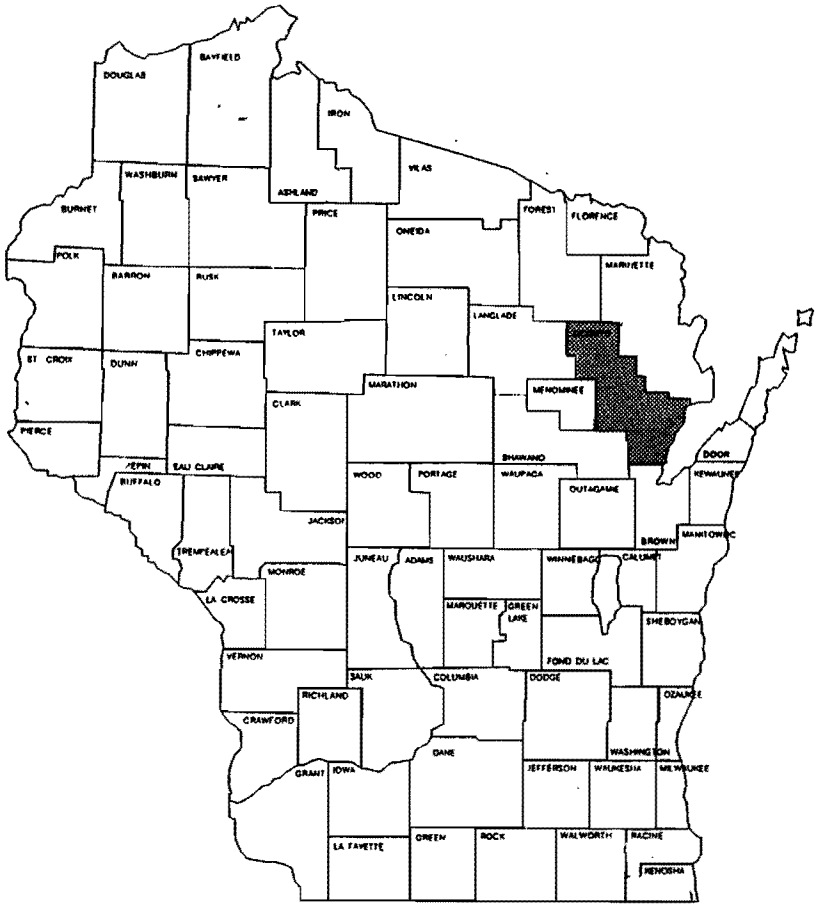


Figure 1. Location of Crooked Lake in Oconto County, Wisconsin.

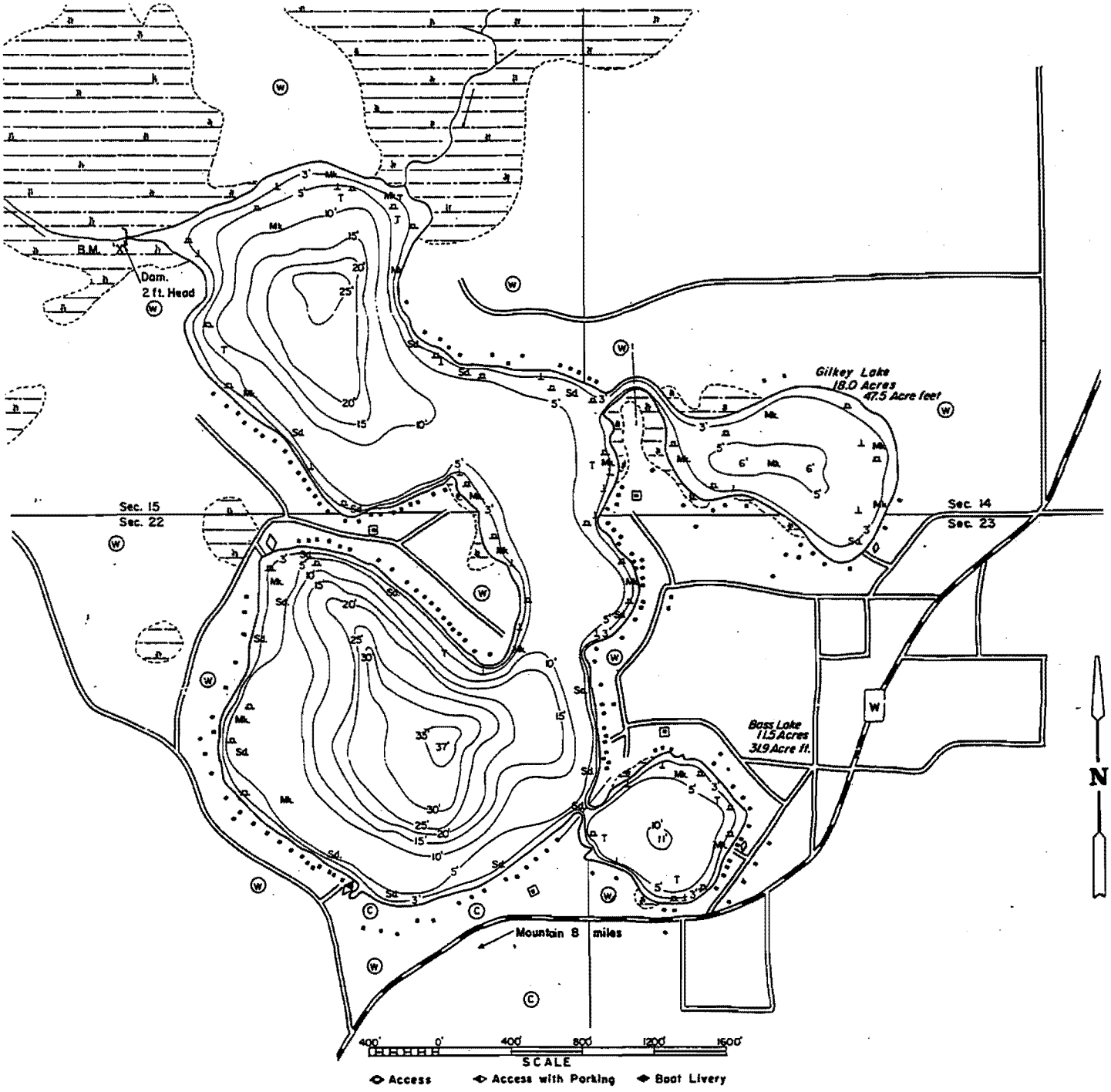


Figure 2. Lake contour map of Crooked Lake.

2. Geologic Setting

It is important to know the context of the land that the lakes reside in, because it has ramifications for water quality.

Crooked, Bass, and Gilkey Lakes were formed from a depression made by an ice block that was left behind when the glaciers retreated from this area about 16,000 years ago. Crooked, Bass, and Gilkey Lakes are located in the Green Bay Lobe of the last glaciation (Figure 3, Map 6) which is in the Northern Highland geographic provence (Figure 3, Map 8). Crooked Lake eventually flows into the Wisconsin River. Crooked, Bass, and Gilkey Lakes are very close to the continental divide (Figure 3, Map 9). Most of the land area now is forested (Figure 3, Map 11).

From these maps, one can see that the lakes are in sandy outwash soils, in predominantly forested areas. For the Crooked Lake group, background soil fertility is low compared to more highly agricultural areas where soil fertility is typically high.

3. Watershed Characteristics

Watershed Delineation

The watershed for Crooked Lake was delineated using U.S.G.S. 7.5 minute quadrangle maps (Figure 4). Subwatershed acres are shown below in Table 1. Drainage to Crooked Lake is complicated. For example, in subwatershed 1 (Figure 4) the drainage is at the extreme end of Crooked Lake near the outlet. A field evaluation hinted that this water inflow would have little impact on the water quality of Crooked Lake, because it probably did not circulate into the main body of the lake. We did not include drainage from this subwatershed as part of the Crooked Lake watershed (Figure 5 shows this inlet area).

The outlet for Crooked Lake is controlled by a low head, fixed crest dam (Figure 6).

Table 1. Watershed areas for Crooked Lake.

Crooked Lake	683 acres
Bass Lake	189 acres
Gilkey Lake	224 acres
subtotal	1,096 acres

Land Use

General land use in the watershed was determined from U.S.G.S maps showing wetlands, Oconto County Soil Survey showing forested areas,, and watershed travels to view first hand. No agricultural acreage was found. Wetland and forest acreage dominate. Bass Lake has a large percentage of its land use in residential acreage. Land use break downs for each lake is shown in Table 2. The Crooked, Bass, and Gilkey Lake watersheds encompass approximately 1,096 acres. The direct drainage for Crooked Lake is 683 acres, for Gilky Lake, 224 acres and for Bass Lake 189 acres. Of that 1,096 acres, forested lands dominate with 649 acres followed by 257 acres of wetlands area and then 190 acres of residential lands (Table 2).

Table 2. Land use in the Crooked, Bass, and Gilkey Lake watersheds. Areas presented are in acres. Numbers shown in parentheses are the percent of land use.

	Land use of each Lake			
	Forest	**Wetlands***	**Urban**	**Total**
Crooked Lake	356	249	78	683
Bass Lake	104	0	85	189
Gilkey Lake	189	8	27	224
	649	257	190	1,096

*areas shown do not include the lakes of Crooked, Bass, and Gilkey.

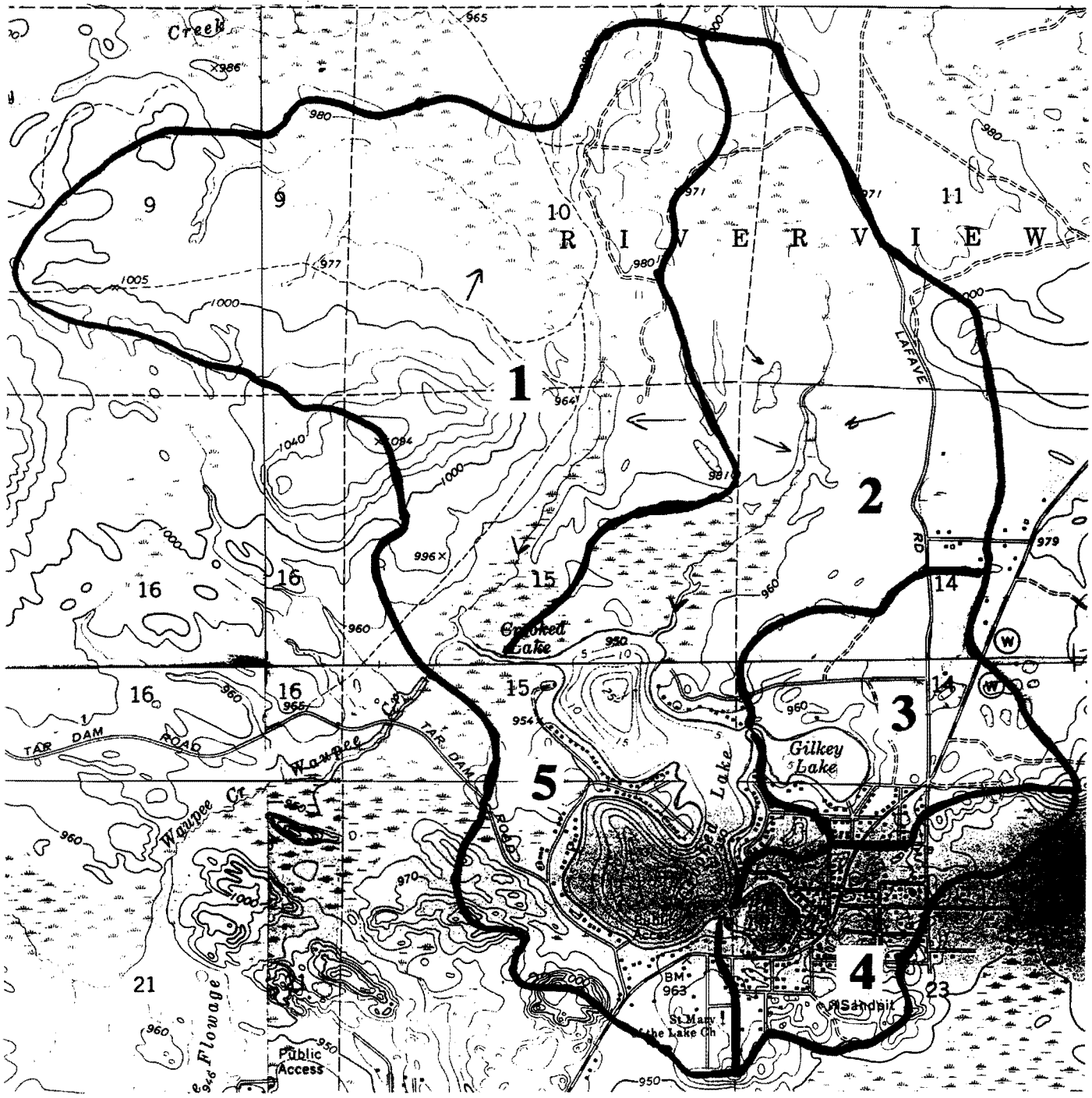


Figure 4. Crooked Lake watershed.

Figure 5. Both pictures show the outlet area of North Crooked Lake, before the dam. We tried to find the incoming stream for subwatershed 1, and the bottom picture shows it. This water input does not seem to impact Crooked Lake, it heads right to the dam.

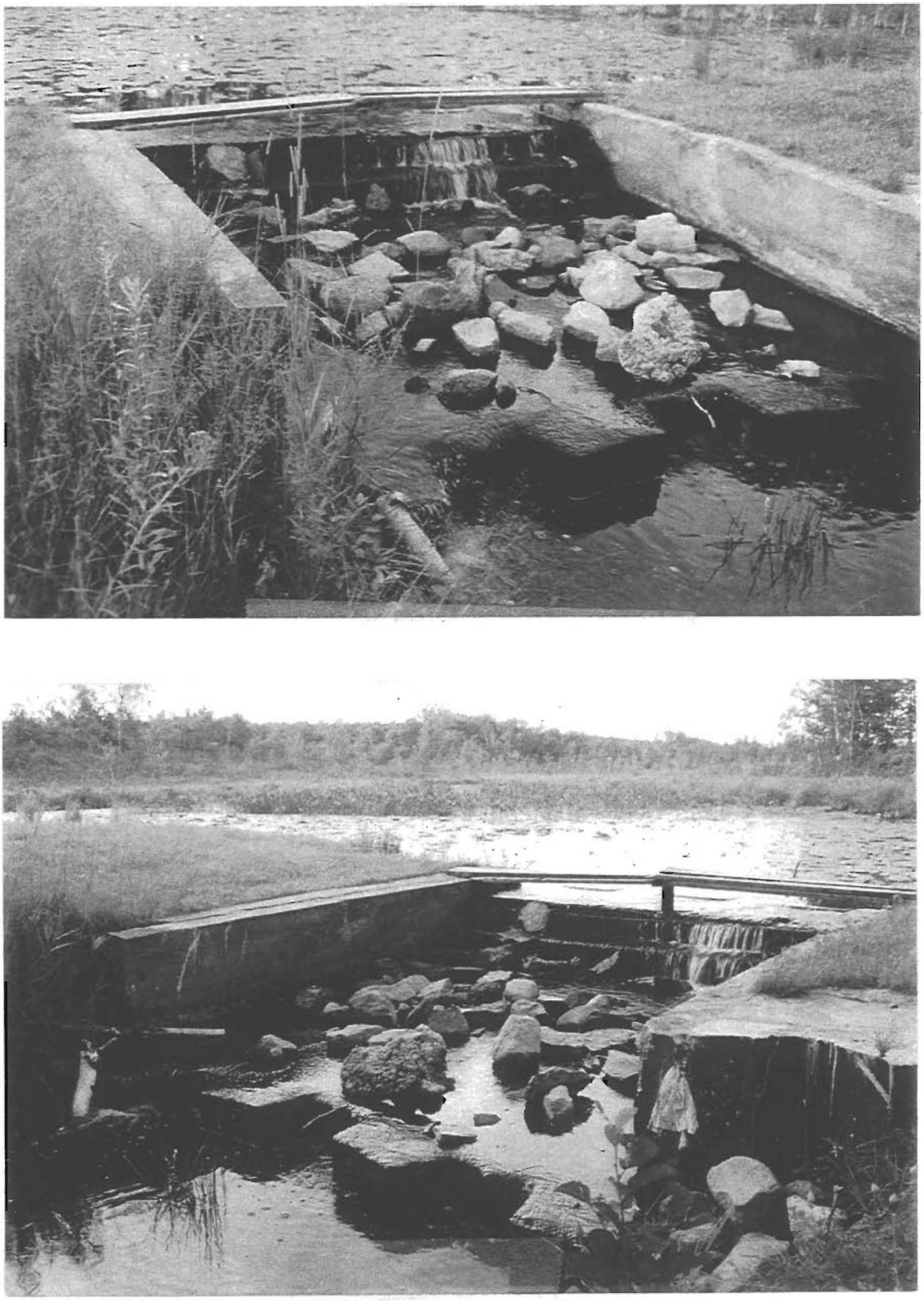


Figure 6. The Crooked Lake Dam. Accessible from Tar Dam Road.

Soils

Soils in the watershed are dominated by sandy soils (Figure 7 and Table 3). Some of the soils have limitations for septic tank/soil absorption systems. Of the soils with limitations, the main problem is the soils are a poor filter, meaning septic tank effluent drains through the sand relatively quickly and thus there may not be adequate nutrient or bacterial removal. Information addressing problems with septic tank/soil absorption systems is found in the management section (last section).

Table 3. Soils legend.

Co	Cormant loamy fine sand, 0 to 1 percent slopes
Lx	Loxley mucky peat, 0 to 1 percent slopes
MnB	Menahga sand, 0 to 6 percent slopes
MnC	Menahga sand, 6 to 15 percent slopes
Sb	Saprists and Aquents, ponded
Sd	Seelyeville and Markey mucks, 0 to 1 percent slopes
Sfc	Shawano fine sand, 6 to 12 percent slopes
WaA	Wainola loamy fine sand, 0 to 3 percent slopes

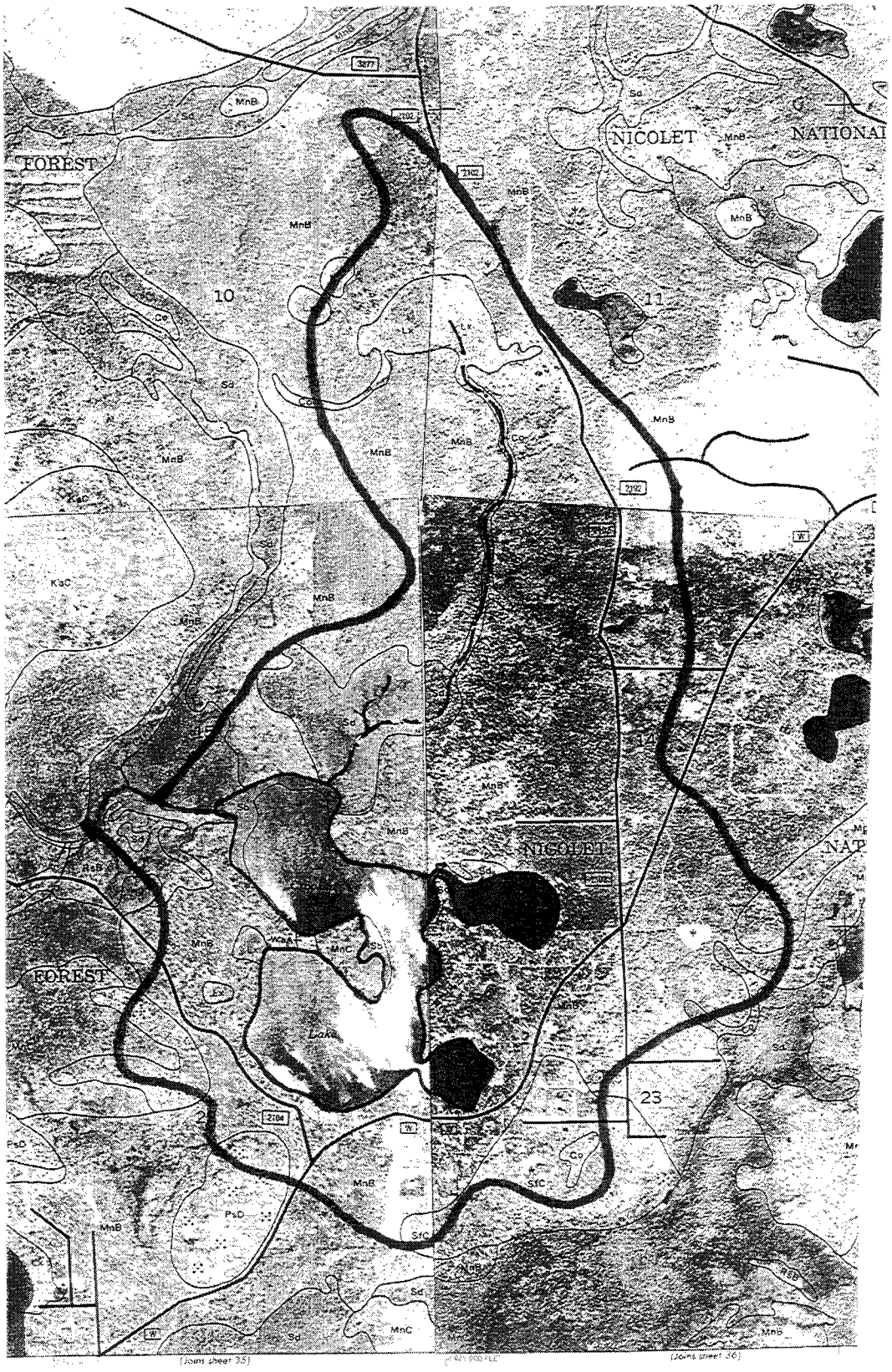


Figure 7. Soils map for the Crooked Lake watershed.

Streams

Of the three lakes only Crooked Lake has a defined stream inflow (shown in subwatershed 2 of Figure 4). This is a sluggish stream that drains a large wetland area. It was sampled two times in 1994. Phosphorus concentrations are reasonable even during a rain event. Suspended solids are higher compared to base flow (Table 4).

Table 4. Phosphorus and total suspended solids concentrations for a stream in subwatershed 2 (in Figure 4) that flows into Crooked Lake. The residential runoff sample was collected by Harvey Tengler from a buried bottle in his yard that collected runoff during a storm.

	Date	TP (µg/l)	Total Solids (mg/l)
Crooked Lake Inlet with rain	7.17	46	116
Crooked Lake inlet	8.16	7	<2
Residential runoff	7.17	1,011	--

Flow measurements of this stream were attempted but not successfully gathered. The stream in subwatershed 2 moves very slowly, and a stream bank width could not be determined because there is no solid bank, its nearly all wetland with floating vegetation.

One residential runoff sample was collected in 1994 (Table 3). Although one sample does not necessarily give a lot of confidence for estimating yearly values, the high phosphorus concentration (1,011 ppb) indicates that residential runoff could be a nutrient loading factor to the Crooked Lakes.

4. Lake Characteristics

Physical/Chemical Data

Summary of lake characteristics for the Crooked Lakes is shown in Table 5.

Table 5. Crooked, Bass, Gilkey Lakes physical characteristics (Source: WDNR lake maps and planimetering by Blue Water Science using USGA maps).

	Crooked	Bass	Gilkey	Crooked Lakes
Area (Lake)(acres):	143.3	12	18	173
Mean depth (feet):	11	7	5	10
Maximum depth (feet):	37	11	6	37
Volume (acre-feet):	1,576	84	90	1,730
Fetch (feet):	3,200	900	1,250	
Watershed area (acres):	683	189	224	1,096
Watershed: Lake surface ratio:	5:1	16:1	12:1	6:1
Estimated average water residence time (years):				
Public accesses (#):	2	1	1	4

Summer water chemistry data collected during 1994 included secchi disc, total phosphorus (TP), chlorophyll a (Chl a), total kjeldahl nitrogen (TKN), nitrate (NO_3), and conductivity (Cond) (Table 6). Samples were collected at the Crooked Lake inlet and at the surface and two feet off the bottom in the deepest area of Crooked 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. Phosphorus was low in the Crooked Lake Inlet.

Table 6. Crooked, Bass, and Gilkey Lakes secchi disc transparency and water chemistry for the summer of 1994 (collected by S. McComas and H. Tengler).

	Date	Secchi Disc (Feet)	TP	TKN	Chl a	NO_3	TP:TN	Cond
N. Crooked								
- top	6.14	9.5	13	400	7.5	--	31:1	132
- top	7.12	9.5	12	500	4.2	--	42:1	152
- top	8.16	13.2	8	450	2.1	<7	56:1	140
- bottom	8.16	--	32	--	--	<7	--	--
S. Crooked								
- top	7.12	10.0	--	--	--	--	--	150
- top	8.16	12.5	--	--	--	--	--	142
Bass								
- top	6.14	8.5	18	500	7.0	8	28:1	140
- top	7.12	10.0	16	500	3.4	10	31:1	152
- top	8.16	10 (b)	12	570	1.0	<7	48:1	132
- bottom	8.16	--	11	--	--	<7	--	--
Gilkey								
- top	6.14	5 (b)	10	500	2.7	9	40:1	170
- top	7.12	6 (b)	11	400	2.4	--	36:1	200
- top	8.16	5 (b)	8	460	--	<7	58:1	190
- bottom	8.16	--	10	--	--	<7	--	--

Individual Lake Statistics

Crooked Lake

Crooked Lake is 143 acres in size, with a watershed of 683 acres. The average depth of Crooked Lake is 3.4 meters (11 feet) with a maximum depth of 11.3 meters (37 feet) (Table 3). A lake contour map is shown in Figure 2.

The secchi disc transparency had an average summer depth of 3.2 meters (10.5 feet) in 1994.

The summer dissolved oxygen (DO) and temperature profiles are shown in Figure 8.

A concern for Crooked Lake is the decrease in oxygen in the hypolimnion.

Views of Crooked Lake are shown in Figure 9.

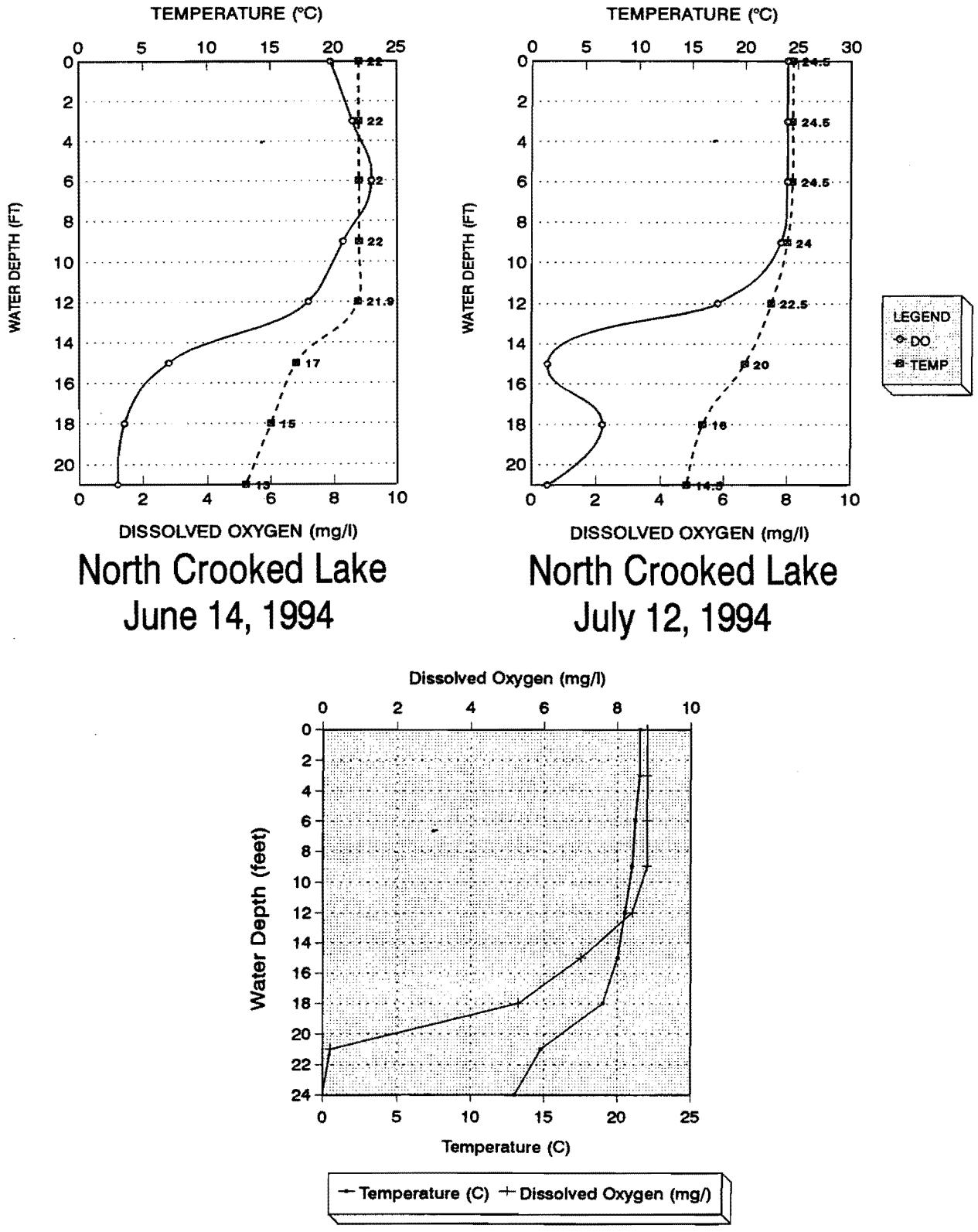
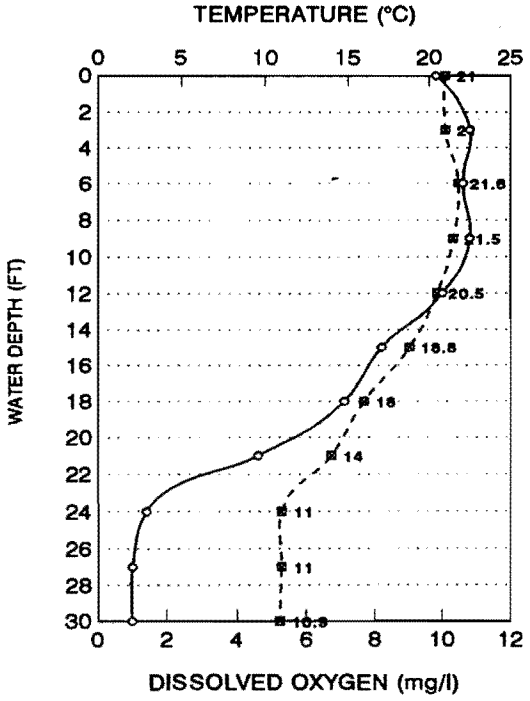
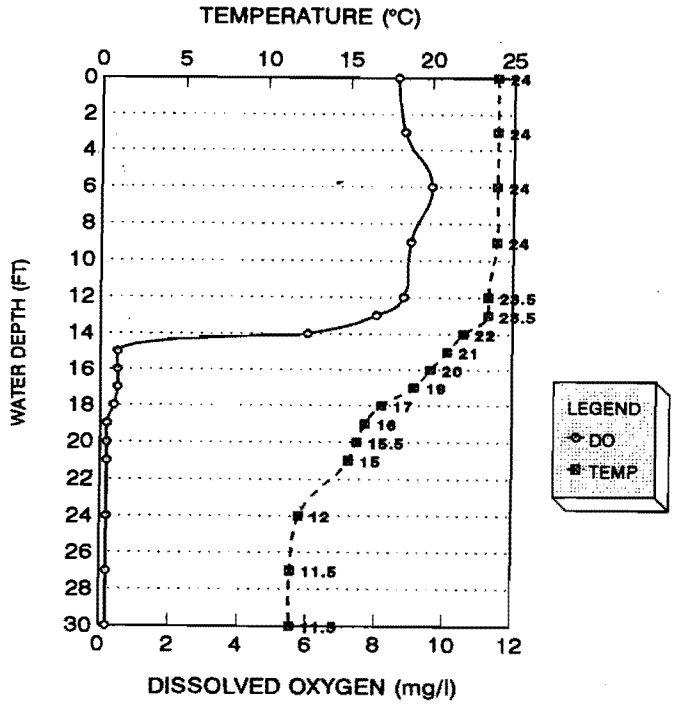


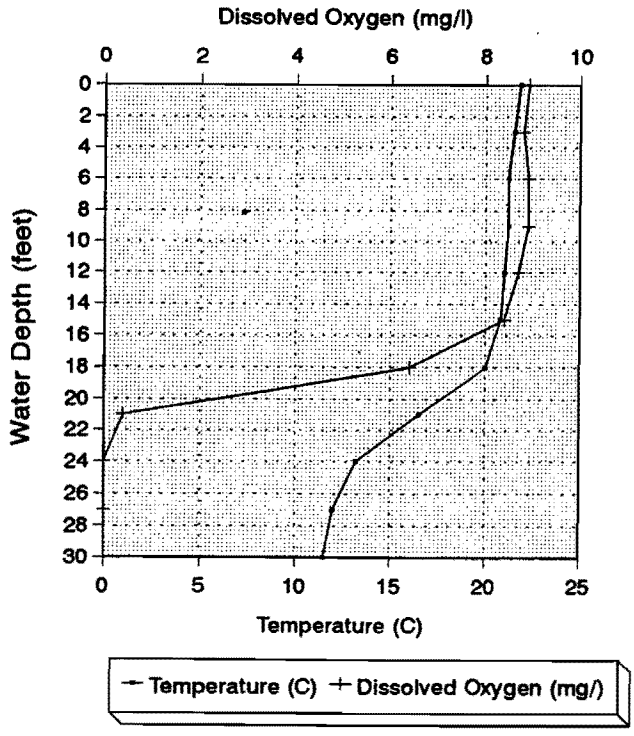
Figure 8. DO/Temperature profiles for Crooked Lake.



South Crooked Lake
June 14, 1994



South Crooked Lake
July 12, 1994



South Crooked Lake
August 16, 1994

Figure 8. Concluded.

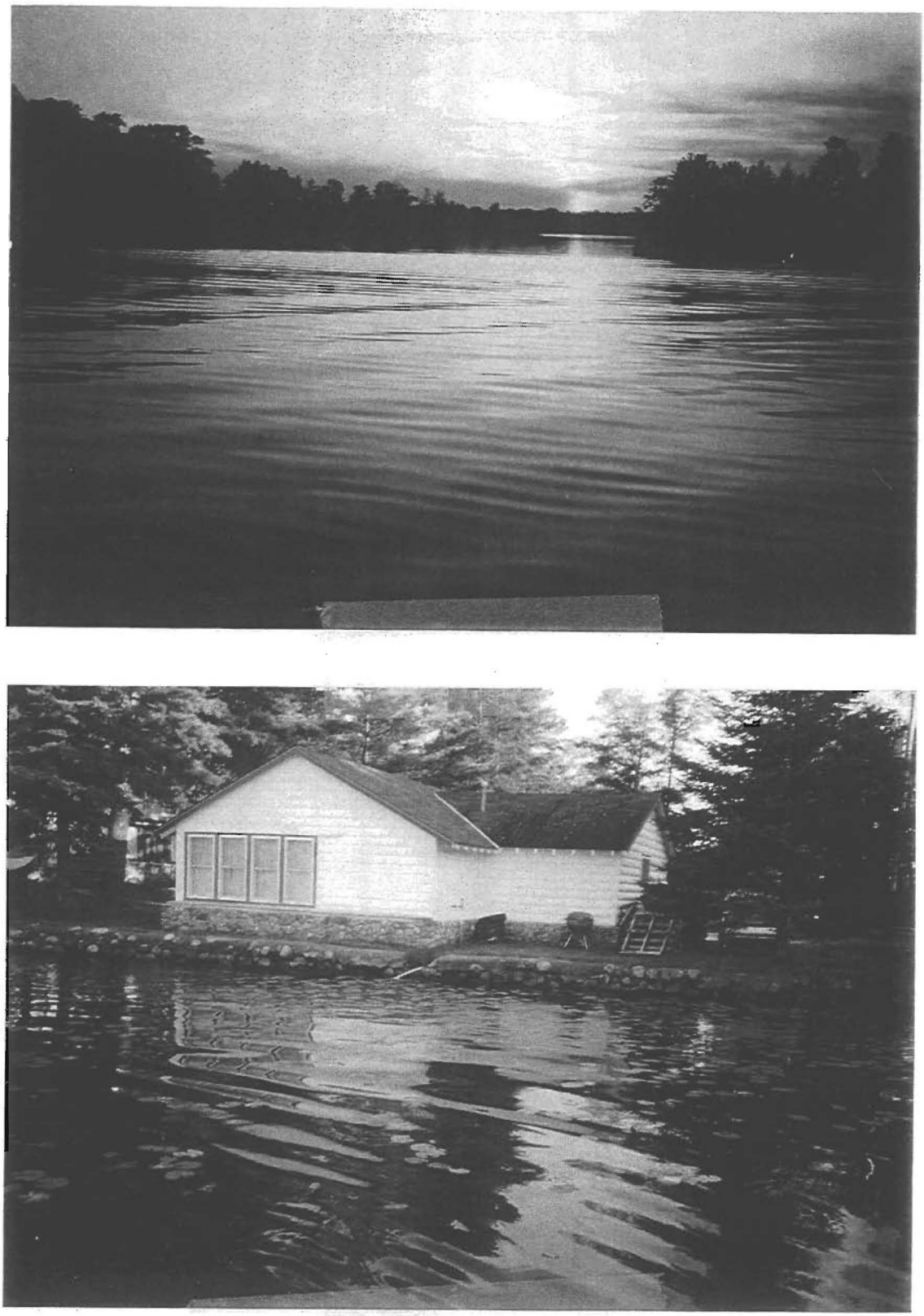


Figure 9. View of Crooked Lake, Oconto County, Wisconsin.

Bass Lake

Bass Lake is 11.5 acres in size, with a watershed of 189 acres. The average depth of Bass Lake is 2.1 meters (7 feet) with a maximum depth of 3.4 meters (11 feet)(Table 5).

The summer dissolved oxygen (DO) and temperature profiles (Figure 10) indicate that in the deeper waters the DO is in good supply. The temperature throughout the water column is relatively constant changing only a few degrees indicating the lake is polymictic and probably mixes occasionally through the summer.

The secchi disc transparency had an average summer depth of 2.9 meters (9.5 feet) in 1994.

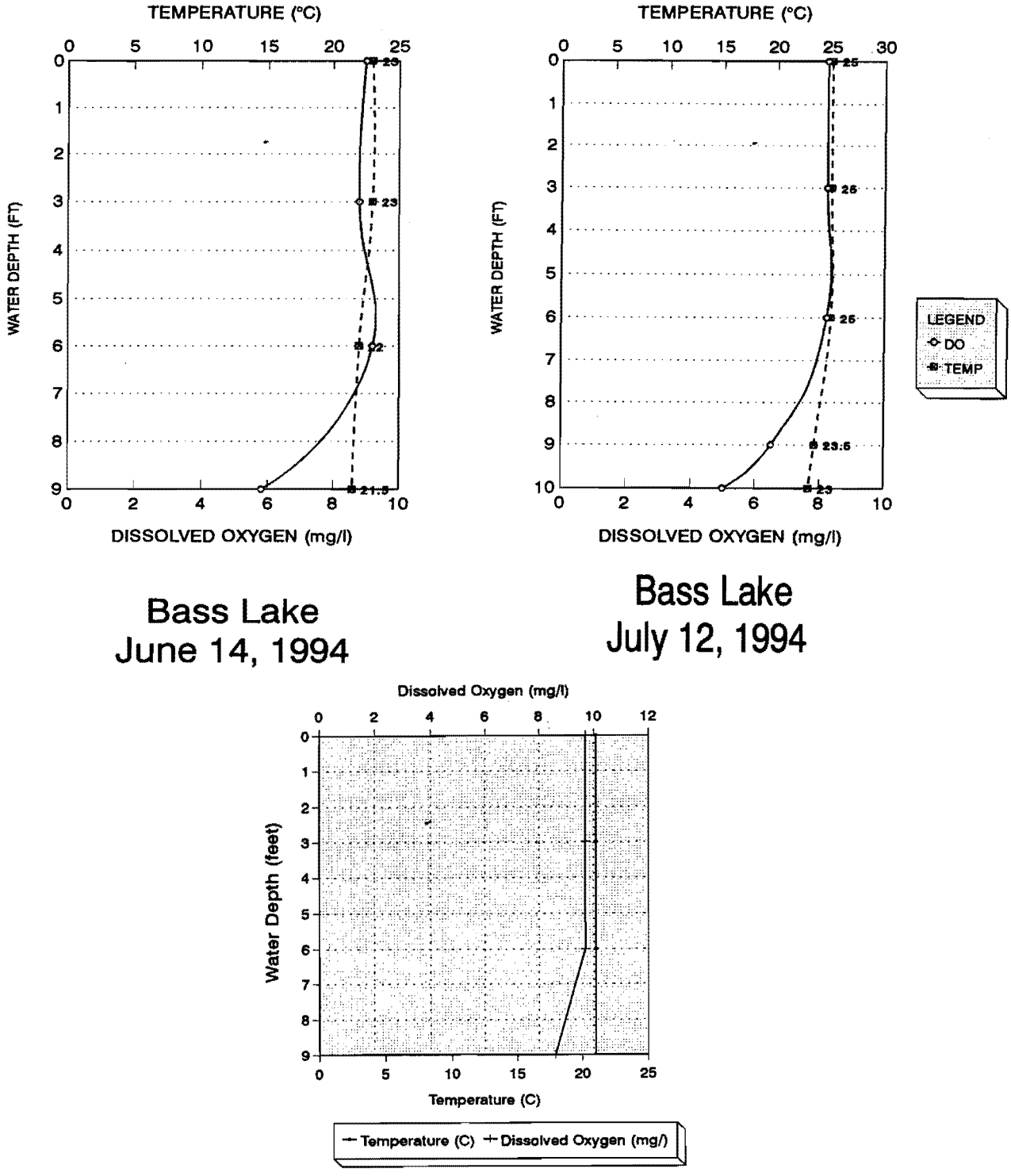


Figure 10. Bass Lake DO/Temperature curves.

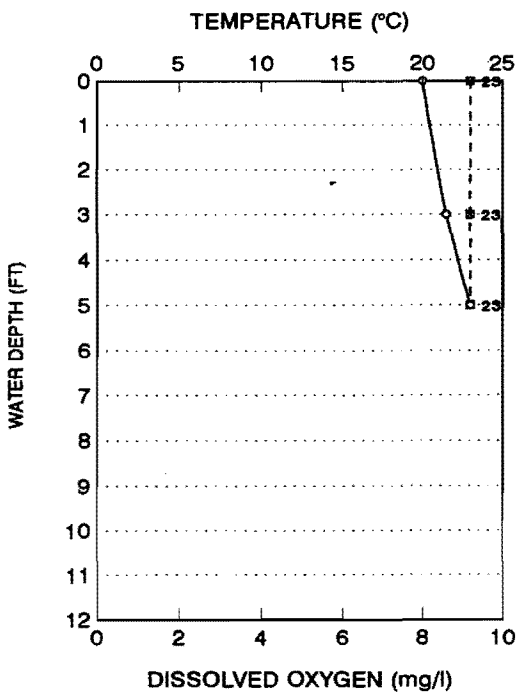
Gilkey Lake

Gilkey Lake is 18 acres in size, with a watershed of 224 acres. The average depth of Gilkey Lake is 1.2 meters (4 feet) with a maximum depth of 1.8 meters (6 feet)(Table 6).

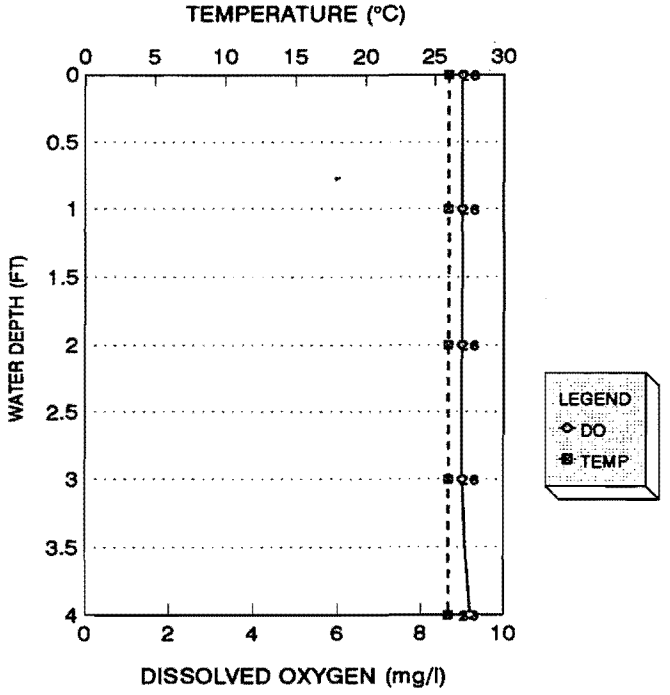
The secchi disc transparency had an average summer depth of 1.6 meters (5.3 feet) in 1994.

Gilkey Lake DO/Temperature curves are shown in Figure 11.

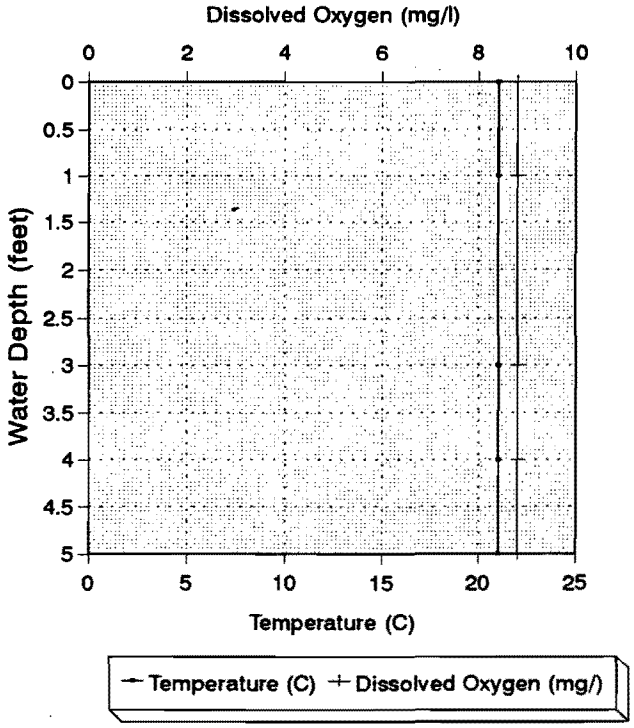
The channel between Crooked Lake and Gilkey Lake is shown in Figure 12.



Gilkey Lake
June 14, 1994



Gilkey Lake
July 12, 1994



Gilkey Lake
August 16, 1994

Figure 11. DO/Temperature curves for Gilkey Lake.

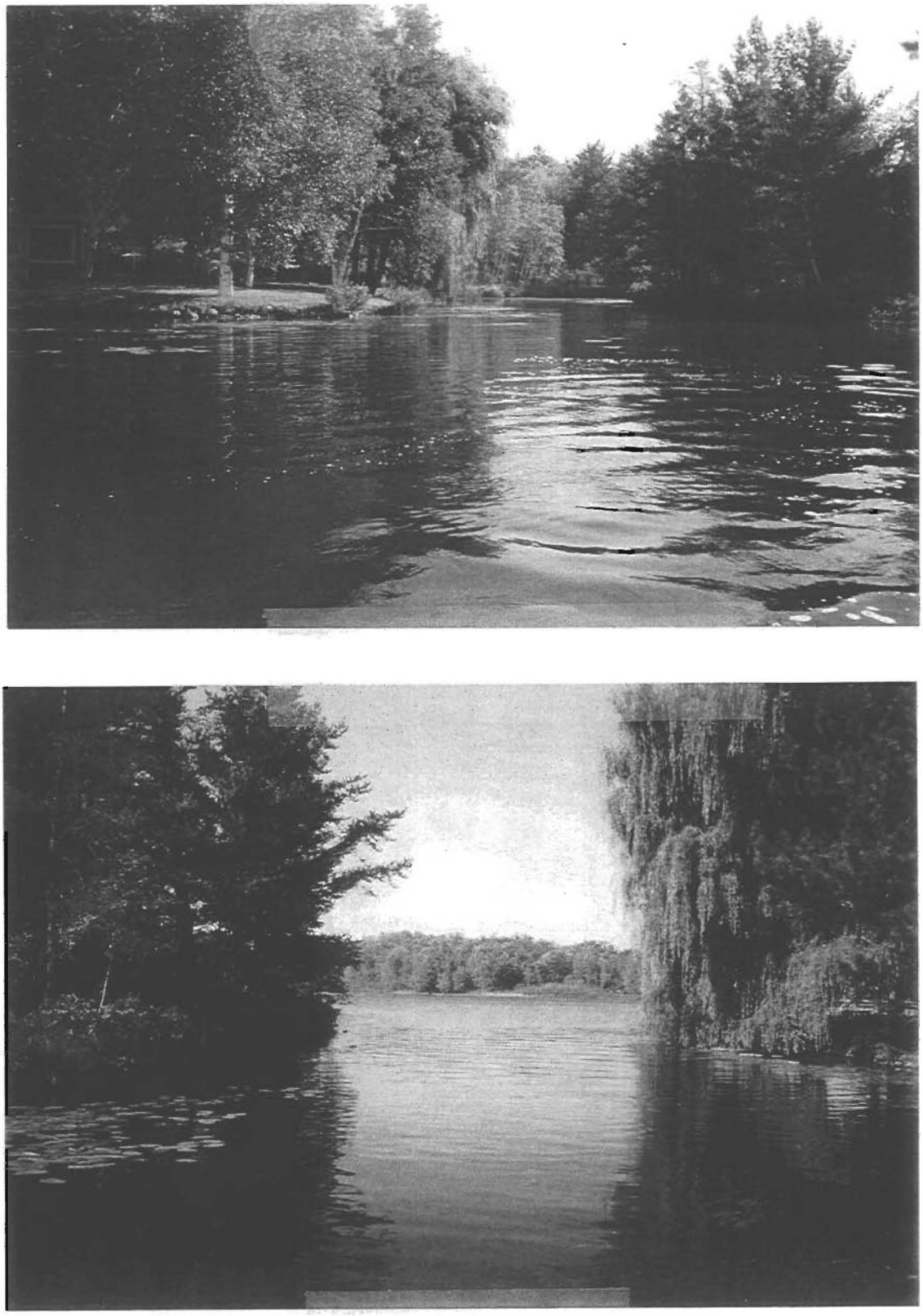


Figure 12. Channel between Crooked Lake and Gilkey Lake.

Algae and Zooplankton

Algae: Algae samples were collected two times during the sampling year of 1994. Algae, also called phytoplankton, are microscopic plants that are indicators of the amount of nutrients, mostly phosphorus, in a water system.

The dominant algae species was different for each sampling date. Chlorococcales were the dominant species during the June sample date and Microcystis was the dominant specie during the August sample date (Table 7).

Zooplankton: Zooplankton samples were collected two times during the 1994 sampling summer. Copepods were the dominant zooplankton for the first sample date (6.14.94) and Daphnids were dominant for the second sample date (8.16.94). Results of both sampling dates are shown in Table 8.

Table 7. Algae counts for Crooked Lake.

Date	Lake	Species	Number/ml
6.14.94	Crooked	Chlorococcales	276
	Bass	Chlorococcales	340
		Microcystis	17
	Gilkey	Chlorococcales	52
8.16.94	Crooked	Microcystis	435
	Bass	Microcystis	522
	Gilkey	Microcystis	1,131

Table 8. Zooplankton counts for Crooked Lake.

		Daphnids						Copepods				Rotifers
Lake	Date	Big	Little	Ceriodaphnia	Bosmina	Chydorus	Total	Calanoids	Cyclopoids	Nauplii	Total	
Crooked	6.14.94	3	10	0	0	1	14	5	23	35	63	0
Gilkey	6.14.94	3	10	0	0	0	13	5	8	15	28	7
Bass	6.14.94	3	39	0	1	8	51	5	35	14	54	0
Crooked	8.16.94	7	6	0	0	0	13	4	13	1	18	3
Gilkey	8.16.94	4	17	0	4	0	25	6	17	3	26	12
Bass	8.16.94	0	15	2	27	0	42	2	24	9	35	16

Macrophytes

An aquatic plant survey was conducted on Crooked, Bass, and Gilkey Lakes in 1994 and results are shown on the next couple of pages. Overall. plant coverage for all three lakes was 59% of the bottom area (Table 9). This is good. As a rule of thumb, if coverage is over 40%, you generally find clear water conditions.

Table 9. Percent of plant coverage on Crooked, Gilkey and Bass Lakes

	Crooked	Gilkey	Bass	Crooked + Gilkey +Bass
Plant coverage	59%	77%	100%	59%

A map of transects used to evaluate the plant community is shown in Figure 13. Based on data from these transects, plant maps were prepared and are shown in Figures 14 and 15. A list of plant species found in shown in Table 10.

A plant occurrence and densities for individual lakes are shown in the next section.

Table 10. Species list of the aquatic plants found in Crooked Lake.

Common Name	Scientific Name
Native watermilfoil	*Myriophyllum exalbescens*
Fern pondweed	*Potamogeton robbinsii*
Cabbage	*P. amplifolius*
Floatingleaf pondweed	*P. natans*
Stringy pondweed	*Potamogeton sp*
Naiad	*Najas sp*
Chara	*Chara sp*
Elodea	*Elodea canadensis*
Coontail	*Ceratophyllum demersum*
Bladderwort	*Utricularia sp*
Spatterdock	*Nuphar sp*
White waterlily	*Nymphaea tuberosa*
Watershield	*Brasenia schreberi*
Pickerelweed	*Pontederia cordata*
Bulrush	*Scirpus sp*
Filamentous algae	

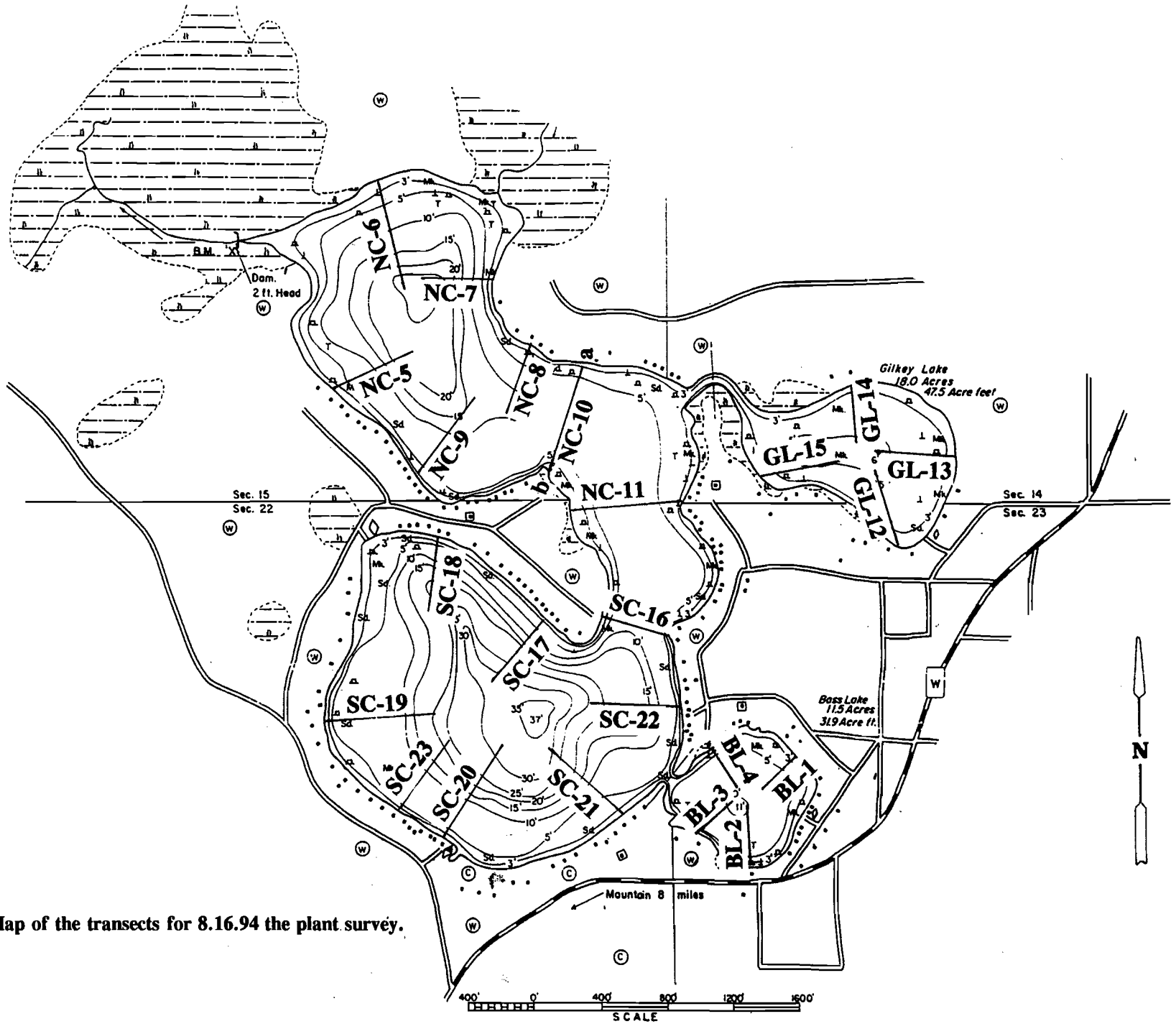


Figure 13. Map of the transects for 8.16.94 the plant survey.

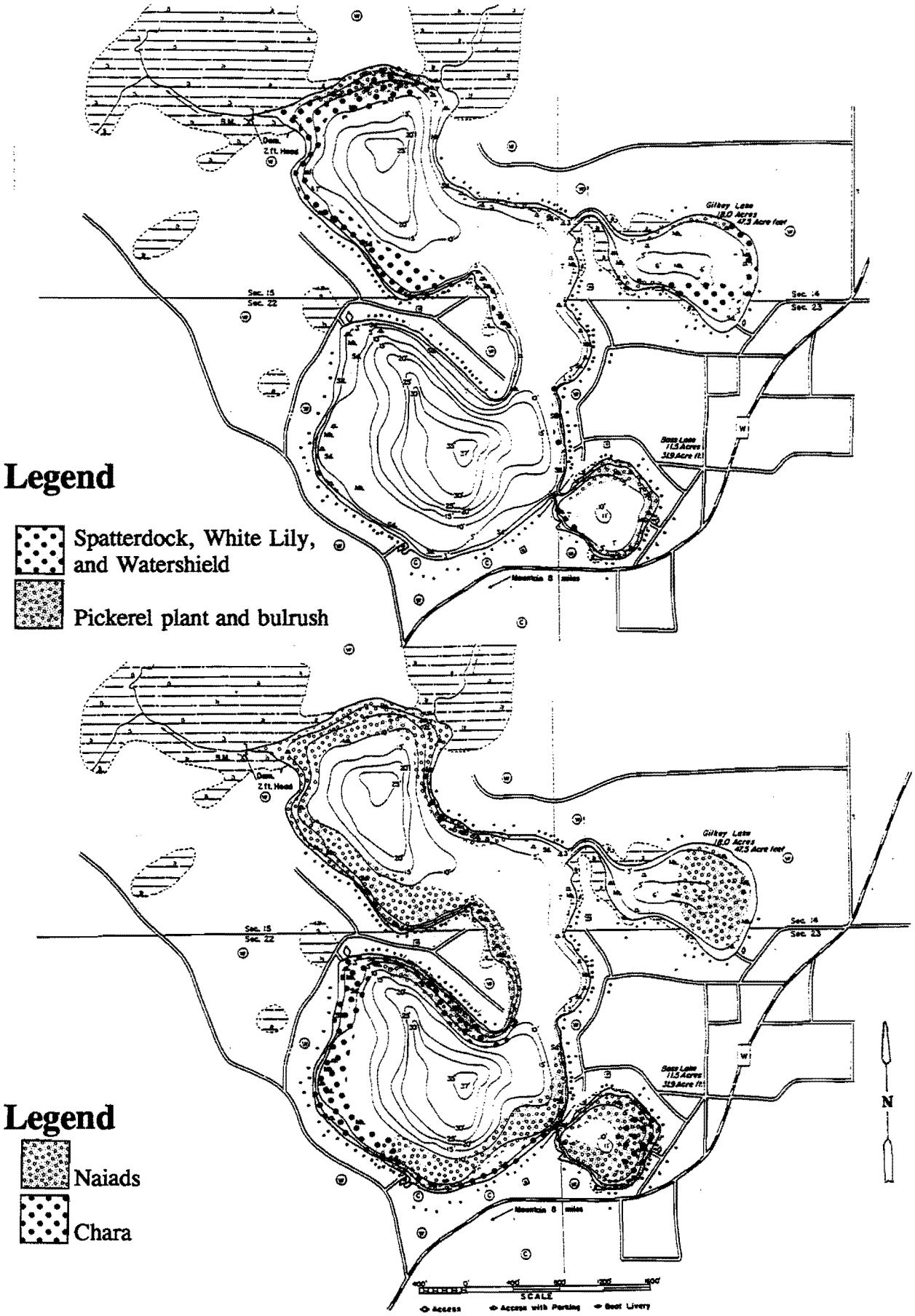


Figure 14. Aquatic plant distribution of major plant groups for the Crooked Lakes [Based on the August 16, 1994 plant survey].

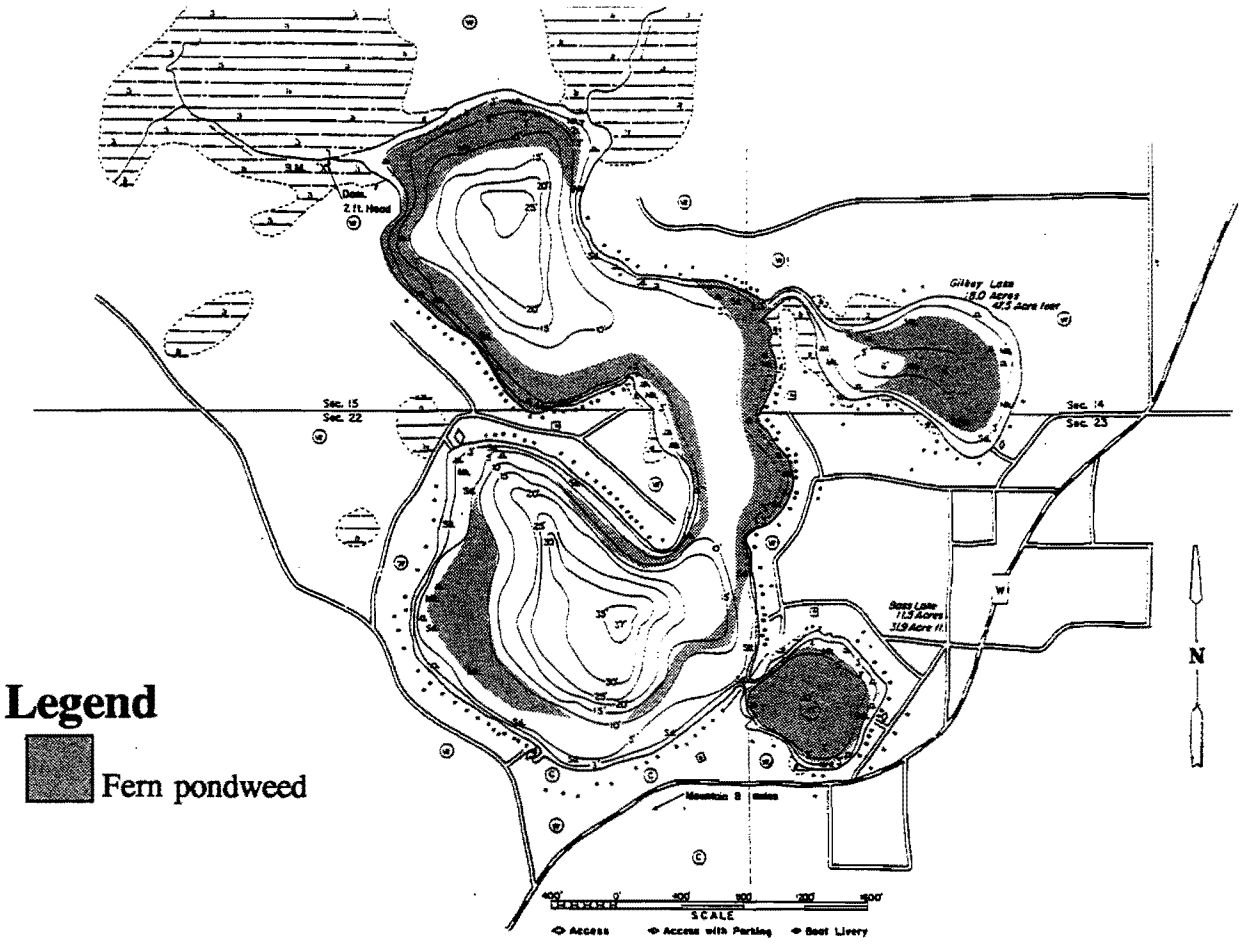


Figure 15. Aquatic plant distribution of the fern pondweed based on the August 16, 1994 plant survey.

Individual Lake Plant Statistics

Crooked Lake

Fifteen transects were run with sample points at 0-3 feet, 4-6 feet, 7-10 feet, and 11-12 feet. Rooted plants were found in water to a depth of 12 feet. Plant coverage is shown in Figure 13. Plant coverage on the bottom is roughly 59% of the bottom area. Five plant groups are represented, with the fern pondweed group dominating. Species percentage occurrance and density are shown in Table 11.

Bass Lake

Four transects were run with sample points at 0-3 feet, 4-6 feet, 7-10 feet, and 11-12 feet. Plant species and percent occurrence is shown in Table 12. Rooted plants were found in water to a depth of 10 feet. Plant coverage is shown in Figure 15. Plant coverage on the bottom is approaching 100 % of the bottom area. Five plant groups are represented, with no group dominating.

Gilkey Lake

Four transects were run with sample points at 0-3 feet, 4-6 feet, 7-10 feet, and 11-12 feet. Plant species and percent occurrence is shown in Table 13. Rooted plants were found in water to a depth of 6 feet. Plant coverage is shown in Figure 16. Plant coverage on the bottom is roughly 77 % of the bottom area. Five plant groups are represented, with no group dominating.

Table 11. Plant percentage and density at each transect depth in Crooked Lake.

NORTH CROOKED	Depth 0-3			Depth 4-6			Depth 7-10			Depth 11-12			TOTALS				
														All Stations		Where plants are	
Plant Species	Occur	%Occur	Density	Occur	%Occur	Density	Occur	%Occur	Density	Occur	%Occur	Density	Occur	%Occur	Density	%Occur	Density
Naiads	3	38	4.3	6	75	4.2	4	50	3.9	3	38	2.3	16	50	1.9	76	3.8
Fern pondweed	2	25	2	6	75	2.3	2	25	2.3	0	0	0	10	31	0.7	48	2.6
Cabbage	2	25	2	3	38	2	2	25	1.8	0	0	0	7	22	0.42	33	19
Spatterdock	4	50	2.25	2	25	2.5	1	13	1	0	0	0	7	22	0.47	33	2.1
White waterlily	2	25	2	1	13	1	1	13	2	0	0	0	4	13	0.22	19	1.8
Stringy pondweed	1	13	2	1	13	2	0	0	0	1	13	2	3	9	0.19	14	2
Watershield	1	13	1	1	13	1	1	13	2	0	0	0	3	9	0.13	14	1.3
Pickeral plant	1	13	1	1	13	2	0	0	0	0	0	0	2	6	0.09	10	1.5
Chara	1	13	3	1	13	5	0	0	0	0	0	0	2	6	0.25	10	4
Bladderwort	0	0	0	0	0	0	1	13	1	0	0	0	1	3	0.03	5	1
Floatingleaf pondwee	0	0	0	0	0	0	1	13	2	0	0	0	1	3	0.06	5	2
Bulrush	1	13	1	0	0	0	0	0	0	0	0	0	1	3	0.03	5	1
Northern milfoil	1	13	1	0	0	0	0	0	0	0	0	0	1	3	0.03	5	1
Filamentous algae	0	0	0	0	0	0	1	13	3	0	0	0	1	3	0.09	5	3

SOUTH CROOKED	Depth 0-3			Depth 4-6			Depth 7-10			Depth 11-12			TOTALS				
														All Stations		Where plants are	
Plant Species	Occur	%Occur	Density	Occur	%Occur	Density	Occur	%Occur	Density	Occur	%Occur	Density	Occur	%Occur	Density	%Occur	Density
Naiads	1	13	4	5	63	4	4	50	4.3	3	38	4.7	13	41	1.7	42	4.3
Chara	6	73	1	2	2.5	2	0	0	0	0	0	0	8	25	0.31	26	1.3
Fern pondweed	1	13	2	0	0	0	2	25	3	2	25	1.5	5	16	0.34	16	2.2
Cabbage	0	0	0	1	13	3	2	25	1	0	0	0	3	9	0.16	10	1.7
Unknown	0	0	0	2	25	2.5	1	13	1	0	0	0	3	9	0.19	10	2
White waterlily	2	25	2	0	0	0	0	0	0	0	0	0	2	6	0.13	6	2
Spatterdock	1	13	2	0	0	0	0	0	0	0	0	0	1	3	0.06	3	2
Coontail	0	0	0	0	0	0	1	13	2	0	0	0	1	3	0.06	3	2
Turf	1	13	4	0	0	0	0	0	0	0	0	0	1	3	0.13	3	4
Elodea	0	0	0	0	0	0	0	0	0	1	13	1	1	3	0.03	3	1

Table 12. Species density and percent occurrance for Bass Lake.

BASS LAKE	Depth 0-3			Depth 4-6			Depth 7-10			TOTALS				
											All Stations		Where plants are	
Plant Species	Occur	%Occur	Density	Occur	%Occur	Density	Occur	%Occur	Density	Occur	%Occur	Density	%Occur	Density
Nalads	2	50	4	3	75	2.8	3	75	2.4	8	67	2	67	3
Cabbage	1	25	2	3	75	1.7	3	75	1.3	7	58	0.92	58	1.3
Fern pondweed	1	25	2	2	50	1.5	3	75	2	6	50	0.92	50	1.8
White waterlily	2	50	1.5	1	25	2	0	0	0	3	25	0.42	25	1.7
Pickeral plant	3	75	1.7	0	0	0	0	0	0	3	25	0.42	25	1.7
Watershield	1	25	1	1	25	1	0	0	0	2	17	0.17	17	1
Spatterdock	2	50	1.5	0	0	0	0	0	0	2	17	0.25	17	1.5
Chara	0	0	0	0	0	0	1	25	2	1	8	0.17	8	2
Cattails	1	25	1	0	0	0	0	0	0	1	8	0.08	8	1
Elodea	0	0	0	0	0	0	1	25	1	1	8	0.08	8	1

Table 13. Species density and percent occurrance for Gilkey Lake.

GILKEY LAKE	Depth 0-3			Depth 4-6			TOTALS				
								All Stations		Where plants are	
Plant Species	Occur	%Occur	Density	Occur	%Occur	Density	Occur	%Occur	Density	%Occur	Density
Cabbage	0	0	0	3	75	1.8	3	38	0.88	50	1.8
Naiads	0	0	0	2	50	4.5	2	25	1.1	33	4.5
Fern pondweed	0	0	0	2	50	2	2	25	0.5	33	2
White waterlily	1	25	3	1	25	2	2	25	0.63	33	2
Spatterdock	2	50	1.5	0	0	0	2	25	0.38	33	1.5
Floatingleaf pondwe	1	25	1	1	25	1	2	25	0.25	33	1
Bulrush	1	25	2	1	25	1	2	25	0.38	33	1.5
Pickeral plant	1	25	1	0	0	0	1	13	0.13	17	1
Watershield	1	25	2	0	0	0	1	13	0.25	17	2
Elodea	0	0	0	1	25	1	1	13	0.13	17	1
Isoletes	0	0	0	1	25	3	1	13	0.25	17	2

Fish

The last two fish surveys (1985 and 1993) conducted on Crooked Lake were done with electrofishing equipment (Table 14). The surveys indicated that there was natural recruitment of largemouth bass, northern pike, walleyes, and other species. This means that fish are successfully spawning in Crooked Lake. At the present time no stocking is required to keep the fishery strong.

The last species of fish to be stocked by the Department of Natural Resources was northern pike in 1968. There has been more recent stocking of walleye conducted by the Crooked Lake Sportsman's Club.

Table 14. Results of fish surveys conducted on Crooked Lakes, 1985 and 1993. Results are shown in inches.

1985-electrofishing

Species	Number catch	Mean length	Size range	catch/unit
Largemouth bass	31	9.5	<3.0 - 20.4	16.32
Northern pike	9	16.7	12.5 - 22.9	4.74
Bluegill	141	5.2	2.2 - 7.7	74.21
Yellow perch	19	4.5	2.1 - 6.7	10.00
Black crappie	5	8.0	6.8 - 9.6	2.63
Pumpkinseed	3	4.9	4.2 - 5.7	1.58
Rock bass	3	6.6	5.7 - 7.2	1.58
Brown bullhead	14	8.5	5.9 - 10.7	7.37

1993-electrofishing

Species	Number catch	Mean length	Size range	catch/unit
Walleye	30	8.2	5.2 - 19.7	15.8
Largemouth bass	24	11.9	2.0 - 19.0	12.6
Northern pike	7	17.3	13.5 - 20.4	3.7
Bluegill	90	4.7	2.9 - 8.6	180
Bullhead	16	7.4	6.1 - 9.0	32
Yellow perch	6	5.9	5.0 - 7.5	12
Pumpkinseed	7	5.6	4.3 - 6.1	14

Septic Leachate Survey and Coliform Bacteria Study

A conductivity survey was performed on Crooked, Gilkey and Bass Lakes during the sampling year of 1994. A conductivity survey uses a Yellow Springs Inc. specific conductance meter with the probe secured to the end of a pole. A boat moves slowly around the shoreline and the meter is watched to spot changes in specific conductance. The survey setup is shown in Figure 16. The objective of the conductivity survey is to find possible groundwater inflows (springs) or faulty on-site wastewater treatment systems. A conductivity less than the background conductivity of the open lake indicates areas of groundwater inflow, whereas a higher conductivity, could indicate a faulty septic system.

There are a few locations around Crooked and Bass Lake that need to be looked at more closely in regard to potential failing on-site systems or a point source of pollution to the lake (Figure 17). Conductivity that is different than open lake background (Crooked Lake: 150 umhos/cm^2; Gilkey Lake: 202 umhos/cm^2; Bass Lake 152 umhos/cm^2) by about 10% should be looked at more closely. There appears to be one location around Crooked Lake, one location around Gilkey Lake and one location around Bass Lake that could be groundwater inflows.

The highest conductivity in Gilkey Lake compared to Bass and Crooked is interpreted to indicate that Gilkey may have significant groundwater inputs.

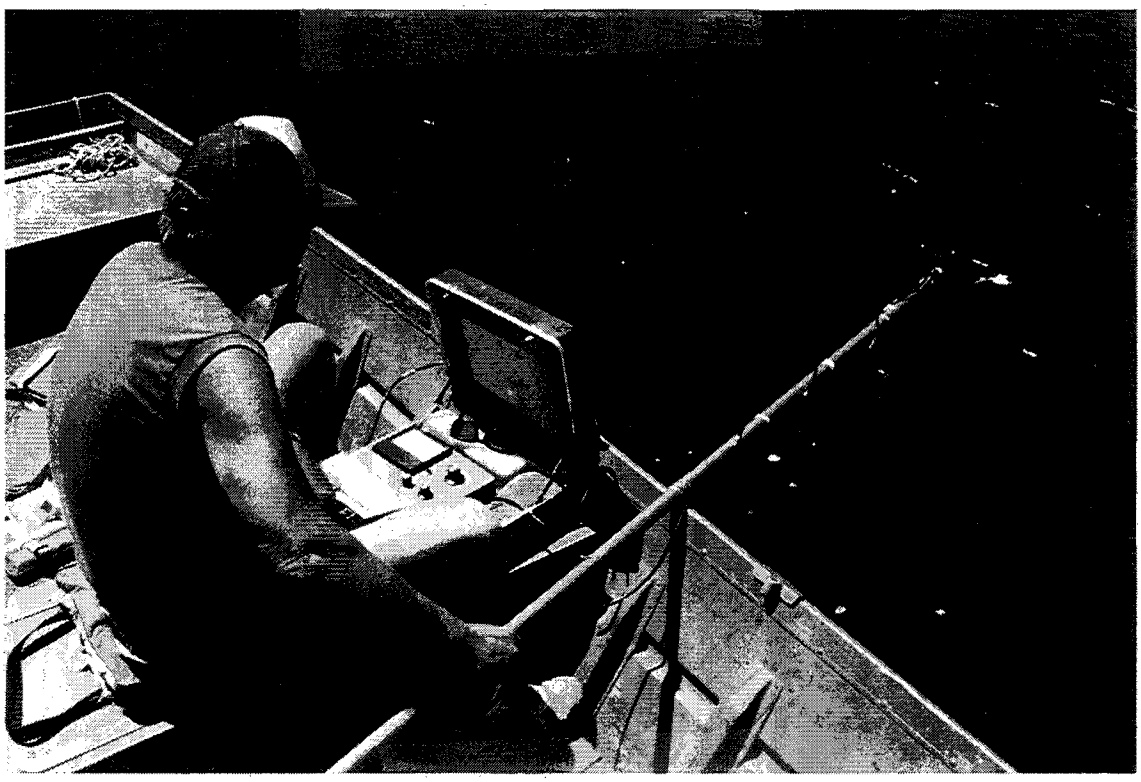


Figure 16. The major components of a septic leachate survey are displayed. Harvey Tengler held the probe and read the meter for the Crooked Lake survey.

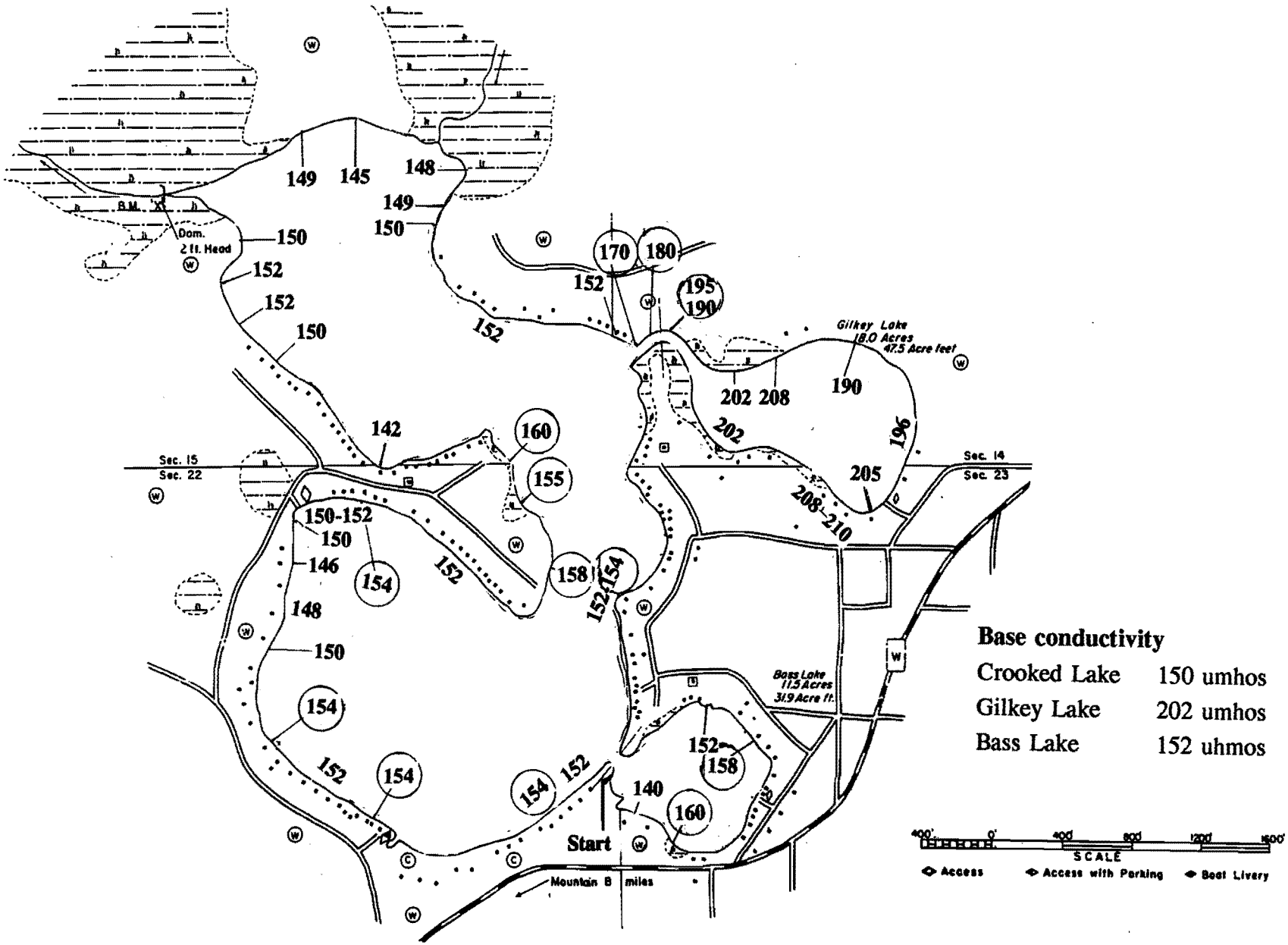


Figure 17. Results of the septic leachate survey conducted in July 1994. Numbers represent specific conductance. Circled numbers indicate a departure from the baseline and a potential spring or septic plume.

Bacteria Survey

Based on results from the septic leachate survey, several locations around the lake appeared to have potential septic system inflows. In September, we collected a water sampled from these areas. (Figure 18) and analyzed the water for coliform bacteria. Results are shown in Table 15. We did not find any substantial bacteria numbers.

Table 15. Results of water samples analyzed for Fecal streptococcus and E. coli. Sample were collected on 9.6.94 and results are shown in number per milliliter.

Sample Number		Fecal Streptococcus	E. coli
3	Bass Lake near public landing	10	10
4	Bass Lake near tavern	<10	<10
5	Crooked Lake near point	<10	<10
1	Upper Crooked Lake, by yellow house	<10	<10
2	Gilkey Lake, near homes in corner	<10	<10
6	Lower Crooked Lake, low lying homes	<10	10

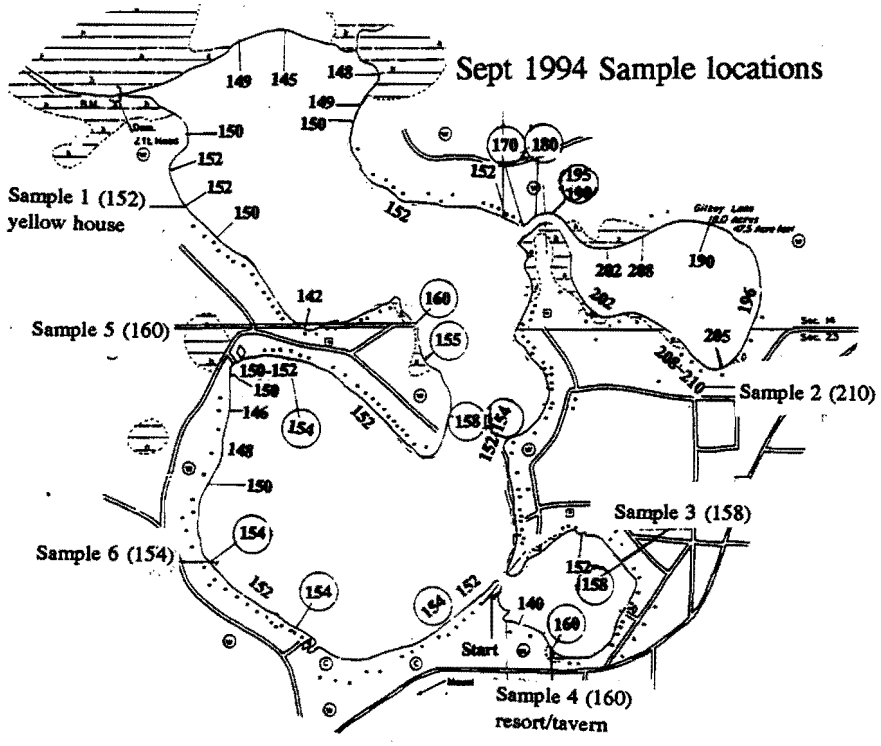


Figure 18. Location of water samples collected for fecal coliform analysis in Sept, 1994.

Table 16. Fecal coliform (as E. coli) from 1982. T.N.T.C. refers to Too Numerous to Count.

Col site	Colonies/100 ml (avg)
1	5.5
2	22
3	61.5
4	T.N.T.C.
5	12
6	11.5
7	2
8	5
9	6
10	9
11	22
12	135
13	14
14	57
15	45
16	8
17	5
18	2
19	4.5
20	19

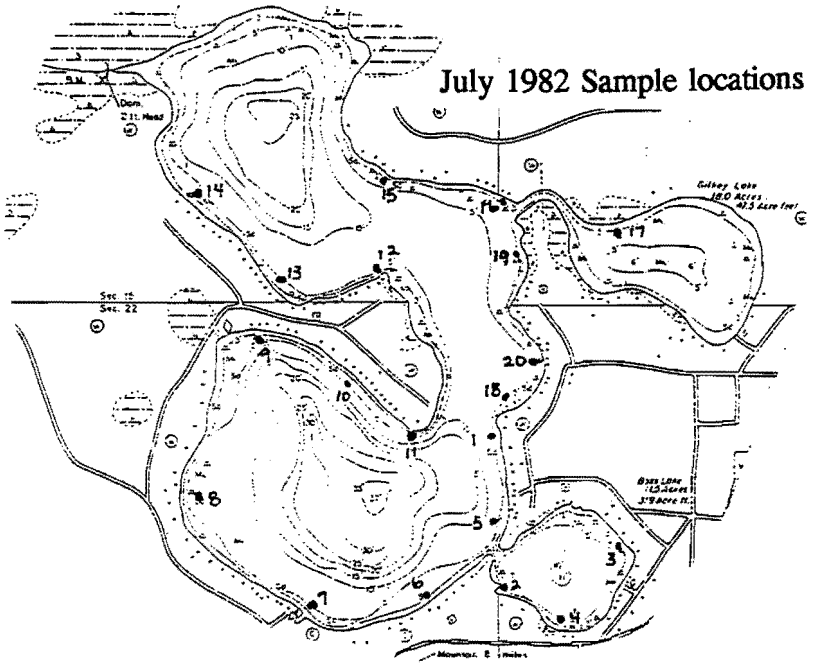


Figure 19. Locations of water samples collected for fecal coliform analyses in July, 1982.

Comparing bacteria numbers between 1982 and 1994, it would appear conditions are not any worse in 1994 and may be even better. However ongoing onsite system wastewater treatment maintenance is still important for long-term lake protection.

5. Crooked Lake, Bass Lake, and Gilkey Lake Phosphorus Model

Lake modeling is a tool that aids in predicting what phosphorus concentrations should be in a lake based on the amount of nutrients that comes 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 a compilation of ten models organized in the Wisconsin Lake Model Spreadsheet (WLMS). A typical lake model format is shown in Table 17. Before the models could be run, nutrient and water budgets for Crooked, Bass, and Gilkey Lakes 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. A summary of phosphorus export coefficients for each land use and then the total estimated phosphorus input to Crooked, Bass, and Gilkey Lakes are shown in Appendix D. At the present time runoff from the lake lots (residential) is the major nutrient contributor to Crooked, Bass, and Gilkey Lakes. The variables with high uncertainty are groundwater inputs as well as septic tank inputs. Our estimates are that septic tanks inputs are relatively low.

The phosphorus model predictions and the actual observed phosphorus load are shown in Table 18.

Table 17. Phosphorus models used for Crooked, Bass, and Gilkey Lakes.

Canfield and Bachmann Phosphorus Model (1981)

$$TP = \frac{L}{z(0.162\ (L/z)^{0.458} + p)}$$

where:

TP (mg/m^3) = concentration of total phosphorus in the lake water

L ($mg/m^2/yr$) = annual phosphorus loading per unit of lake surface area

z (m) = mean depth of the lake

p (yr^{-1}) = hydraulic flushing rate

Table 18. Total phosphorus predictions in the Crooked Lakes based on lake models. Details of lake model runs are in Appendix D.

	Crooked	Gilkey	Bass	Crooked + Gilkey + Bass
Actual Observed P conc. in summer of 1994	11	10	15	11
1. Walker 1987, Reservoir model	38	48	75	44
2. Canfield-Bachmann 1981 Natural lake model	37	49	98	46
3. Canfield-Bachmann 1981 Artificial Lake model	32	39	68	37
4. Reckhow 1979, Natural Lake model	10	19	50	15
5. Reckhow 1977 Anoxic Lake model	62	70	157	77
6. Reckhow 1977 Oxic Lakes, qs <50m/yr	34	62	128	46
7. Reckhow 1977 Oxic Lakes, qs >50 m/yr	13	38	80	20
8. Walker 1977 General Lake model	41	55	123	52
9. Vollenweider 1975 Lake model	12	22	59	17
10. Dillon-Rigler-Kirchner 1975 Lake model R=0.85	14	24	62	20

6. Lake Status

The status of Crooked, Bass, and Gilkey Lakes is good. Values for phosphorus, chlorophyll and secchi depth are within ecoregion values (Table 19). An ecoregion is a unit of the State that has relatively homogenous geology and soils and also is expected to have lake water quality within a range of values. These value vary depending on the ecoregion.

Table 19. Summer average water quality characteristics for lakes in the Northern Lakes and Forest ecoregion, as noted in Descriptive Characteristics of the Seven Ecoregions in Minnesota, by G. Fandrei, S. Heiskary, and S. McCollar. 1988. Minnesota Pollution Control Agency.

Parameter	Northern Lakes & Forests	North Central Hardwood Forests	Crooked Lake	Bass Lake	Gilkey Lake
Total phosphorus (μg/l)	14-27	23-50	11	15	10
Chlorophyll a					
mean	<10	5-22	4.6	3.8	2.6
maximum	<15	7-37	7.5	7.0	2.7
Secchi disc (feet)	8-15	4.9-10.5	10.5	9.5	5.3
(meters)	2.4-4.6	1.5-3.2	3.2	2.9	1.6
Total Kjeldahl Nitrogen (mg/l)	<0.75	<0.60-1.2	0.45	0.52	0.45
Nitrite & Nitrate N (mg/l)	<0.75	<0.01	<0.007	0.008	0.008
Alkalinity (mg/l)	40-140	75-150			
Color (Pt-Co units)	10-35	10-20			
pH (SU) 7.2-8.3	8.6-8.8	8.2-9.0			
Chloride (mg/l)	<2	4-10			
Total Suspended Solids (mg/l)	<1-2	2-6			
Total Suspended Inorganic Solids (mg/l)	<1-2	1-2			
Turbidity (NTU)	<2	1-2			
Conductivity (umhos/cm)	50-250	300-400	141	141	187
TN:TP Ratio	25:1-35:1	25:1-35:1	43:1	36:1	45:1

A map showing the ecoregion area and the Crooked Lakes location is displayed in Figure 20. Phosphorus concentrations were generally less than 20 ppb for Crooked, Bass and Gilkey Lakes.

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

Omernik, J.M. and A.L. Gallant. 1988. Ecoregions of The Upper Midwest States. U.S. EPA 600/3-88/037, Corvallis, OR.

Legend

- Northern Lakes and Forests
- North Central Hardwood Forests
- Driftless Area
- Southeastern Wisconsin Till Plains
- Central Corn Belt Plains

Figure 20. Wisconsin ecoregions.

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

Although Crooked Lake can assimilate more phosphorus than the other two lakes, it is still very vulnerable. A doubling or tripling of phosphorus concentrations in Crooked Creek could spell trouble for Crooked Lake. This could easily occur if proper watershed management is not implemented.

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. Bass and Gilkey Lakes are vulnerable to an increase in phosphorus inputs, and therefore shoreland nutrient inputs could be significant and contribute to water quality degradation. Shoreland projects to reduce nutrient inputs are important.

Trophic State Index

The Trophic State Index (TSI) was calculated for water chemistry results and is shown in Table 20. Results indicate Crooked Lake, Bass Lake, and Gilkey Lake are mesotrophic lakes. Crooked Lake had the best TSI of the three lakes, followed by Bass and Gilkey. Although there was some variability within a lake for phosphorus, chlorophyll, and transparency values, they are fairly close.

Table 20. Summary of Trophic State Index Values for Crooked, Bass, and Gilkey Lakes

	Crooked Lake	Bass Lake	Gilkey Lake
TSIP (TP)	41	46	39
TSIC (Chl a)	47	45	43
TSIS (Secchi disc)	43	39	53
TSI (mean)	44	43	45

TSI = Trophic State Index

TSI(Chl a)(ppb or ug/L) = $36.25 + 15.5 \log_{10}$ [Chl a]
TSI(TP)(ppb or ug/L) = $60 - 33.2 \log_{10} (40.5/TP)$
TSI(Secchi)(meters) = $60-(SD \log_{10} \times 33.2)$

7. Conclusions

All three lakes have phosphorus concentrations and transparencies within ecoregion values.

All three lakes are in a protection and maintenance mode, rather than a restoration mode. Crooked Lake can assimilate more phosphorus than Bass or Gilkey because of its larger volume. However, it is vulnerable to phosphorus loads and also possible phosphorus release from bottom sediments. Watershed protection, which should result in low phosphorus inputs to Crooked Lake, is paramount. Shoreland best management practices are important for all three lakes, but especially Bass and Gilkey.

No major lake restoration projects are necessary in the near term. The need for alum addition for Crooked Lake is not eminent. However, it would be a good idea to start a lake fund to be used for special projects.