Blake Lake Macrophyte Surveys and Management Plan

Prepared for
Blake Lake Protection and Rehabilitation District

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Executive Summary

Macrophyte surveys were completed in Blake Lake (i.e., Big Blake Lake) during June and July of 1997. The surveys evaluated plant coverage, density, and species composition. The results indicate the total area of macrophyte (i.e., aquatic plant) coverage was approximately 122 acres (i.e., 49 percent of lake surface area) during June and 120 acres (i.e., 48 percent of lake surface area) during July. Plant diversity in Blake Lake was relatively high when compared with 47 other Wisconsin lakes (Nichols, 1997). A total of 21 species was found in Blake Lake and approximately 8 or 9 species were found in each sample transect. Although individual species generally occurred in a relatively low density, the concurrent growth of a large number of species at each sample location resulted in an overall plant growth of moderate to high density.

Macrophytes in Blake Lake consisted primarily of native species. Only one exotic species (i.e., not native to this region), *Potamogeton crispus* (curly-leaf pondweed), was found. Exotic or non-native species are undesirable because their natural control mechanisms are not introduced with the species. Consequently, exotic species frequently exhibit rapid unchecked growth patterns, which eliminate native species. The total area containing curly-leaf pondweed was 65 acres during June and 40 acres during July. In general, curly-leaf pondweed occurred concurrently with several native species.

The survey results were used to develop a macrophyte management plan for Blake Lake. The six aquatic plant management goals for Blake lake are:

- Improve navigation within the lake through areas containing dense plant beds
- Remove or limit current exotic plants (i.e., curly-leaf pondweed)
- Preserve native species and prevent introduction of additional exotic species
- Preserve and/or improve fish and wildlife habitat
- Protect and/or improve quality of the resources for all to enjoy (i.e., people, fish, wildlife)
- Minimize disturbance of sensitive areas (i.e., fish and wildlife)

The macrophyte management plan includes four parts:

- Harvesting program to create navigation channels, fish cruising lanes, and increased edge in areas with excessive macrophyte growth (i.e., a total of approximately 5 acres will be harvested to create navigation channels in areas of dense growth);

- Treatment program to minimize the exotic, curly-leaf pondweed, to the greatest extent possible (i.e., A total of 20 acres or approximately one third of the total growth area will be treated with the herbicide Reward during May of each year. Therefore, each of the 3 twenty acre treatment areas will be treated once every three years);

- Education of lake homeowners;

- Prevent the establishment of other exotic species in the lake (e.g., Eurasian water milfoil).

Blake Lake
Macrophyte Surveys and Management Plan

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1.0 Introduction

Blake Lake in Polk County, Wisconsin is valued by riparian owners, area residents, Polk County, and the WDNR for its fisheries and for recreational use (see Figure 1). However, the lake has experienced problems with aquatic plant beds and algal blooms for more than 20 years. Concern for the lake resulted in the formation of a Lake District in 1976, and a subsequent request for WDNR technical and financial assistance.

The WDNR responded to the request by completing a study of Blake Lake and its watershed during November 1978 through October 1979. Macrophytes (i.e., aquatic plants) were found in approximately 10 percent (i.e., 25 acres) of the lake area during the study. However, local residents expressed the opinion that aquatic plant growth was at reduced levels from previous years. Within the macrophyte growth area, a dense growth of *Potamogeton crispus* (Curly-leaf pondweed) was noted during June and a dense growth of *Ceratophyllum demersum* (Coontail) was noted in August. In addition to the two dominant species, the lake noted 6 submergent species, 3 emergent species, and 6 floating-leaf species.

During 1996, representatives from the Blake Lake Protection and Rehabilitation District approached the WDNR to discuss management of the lake's macrophyte growth. The WDNR recommended that the District complete a macrophyte survey and a macrophyte management plan for Blake Lake.

Macrophyte surveys of Blake Lake were completed during 1997. This report presents the macrophyte management plan for Blake Lake. The report discusses:

- Overview of macrophyte growth in lakes
- Compilation and assessment of existing information
- The methodology of the 1997 Blake Lake membership and aquatic plant surveys
- Results and Discussion of the 1997 Blake Lake membership and aquatic plant surveys
- Developing a macrophyte management plan
- Macrophyte management plan for Blake Lake

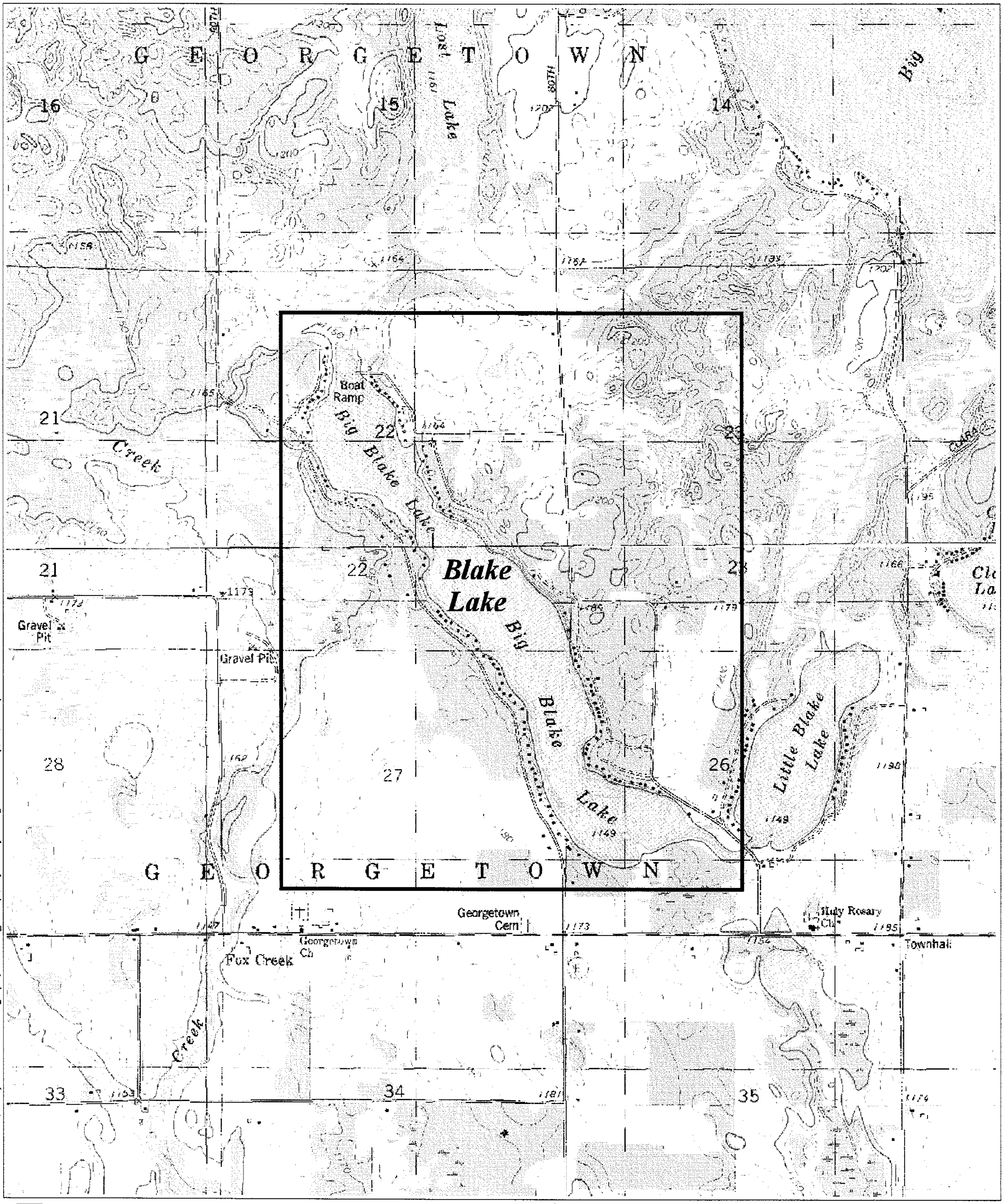

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Figure 1
Site Map
Blake Lake

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2.0 Overview of Macrophyte Growth in Lakes

The basis of the following text on macrophyte growth in lakes is Minnesota Department of Natural Resources (MDNR) *A Guide to Aquatic Plants Identification and Management* (1994).

2.1 Location of Aquatic Plant Growth Within Lakes and Impoundments

Within a lake, pond, or impoundment, aquatic plants grow in the area known as the littoral zone—the shallow transition zone between dry land and the open water area of the lake. The littoral zone extends from the shore to a depth of about 15 feet, depending on water clarity. The littoral zone is highly productive. The shallow water, abundant light, and nutrient-rich sediment provide ideal conditions for plant growth. Aquatic plants, in turn, provide food and habitat for many animals such as fish, frogs, birds, muskrats, turtles, insects, and snails. Protecting the littoral zone is important for the health of a lake's fish and other animal populations.

The width of the littoral zone often varies within a lake and among lakes. In places where the slope of the lake bottom is steep, the littoral area may be narrow, extending several feet from the shoreline. In contrast, if the lake is shallow and the bottom slopes gradually, the littoral area may extend hundreds of feet into the lake or may even cover it entirely. Impoundments frequently note extensive littoral areas in the upper portion due to sedimentation and shallow depths. In contrast, the lower portions of impoundments may have little littoral area.

Cloudy or stained water, which limits light penetration, may restrict plant growth. In lakes where water clarity is low all summer, aquatic plants will not grow throughout the littoral zone, but will be restricted to the shallow areas near shore.

Other physical factors also influence the distribution of plants within a lake or pond. For example, aquatic plants generally thrive in shallow, calm water protected from heavy wind, wave, or ice action. However, if the littoral area is exposed to the frequent pounding of waves, plants may be scarce. In a windy location, the bottom may be sand, gravel, or large boulders--none of which provides a good place for plants to take root. In areas where a stream or river enters a lake, plant growth can be variable. Nutrients carried by the stream may enrich the sediments and promote plant growth; or, suspended sediments may cloud the water and inhibit growth.

2.1.1 Categories of Aquatic Plants

Aquatic plants are grouped into four major categories:

- Algae have no true roots, stems, or leaves and range in size from tiny, one-celled organisms to large, multi-celled plant-like organisms, such as *Chara*. Plankton algae, which consist of free-floating microscopic plants, grow throughout both the littoral zone and the well-lit surface waters of an entire lake. Other forms of algae, including *Chara* and some stringy filamentous types (such as *Cladophora*), are common only in the littoral area.

- Submerged plants have stems and leaves that grow entirely underwater, although some may also have floating leaves. Flowers and seeds on short stems that extend above the water may also be present. Submerged plants grow from near shore to the deepest part of the littoral zone and display a wide range of plant shapes. Depending on the species, they may form a low-growing "meadow" near the lake bottom, grow with lots of open space between plant stems, or form dense stands or surface mats.

- Floating-leaf plants are often rooted in the lake bottom, but their leaves and flowers float on the water surface. Water lilies are a well-known example. Floating leaf plants typically grow in protected areas where there is little wave action.

- Emergent plants are rooted in the lake bottom, but their leaves and stems extend out of the water. Cattails, bulrushes, and other emergent plants typically grow in wetlands and along the shore, where the water is less than 4 feet deep.

2.1.2 Value of Aquatic Plants

Aquatic plants are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. In lakes, life depends—directly or indirectly—on water plants. They are the primary producers in the aquatic food chain, converting the basic chemical nutrients in the water and soil into plant matter, which becomes food for all other aquatic life. Aquatic plants serve many important functions, including:

- ***Provide fish food***—More food for fish is produced in areas of aquatic vegetation than in areas where there are no plants. Insect larvae, snails, and freshwater shrimp thrive in plant beds. Sunfish eat aquatic plants in addition to aquatic insects and crustaceans.

- ***Offer fish shelter***—Plants provide shelter for young fish. Because bass, sunfish, and yellow perch usually nest in areas where vegetation is growing, certain areas of lakes are protected and posted by the DNR as fish spawning areas during spring and early summer. Northern pike use aquatic plants, too, by spawning in marshy and flooded areas in early spring.

- ***Improve water quality***—Certain water plants, such as rushes, can actually absorb and break down polluting chemicals.

- ***Protect shorelines and lake bottoms***—Aquatic plants, especially rushes and cattails, dampen the force of waves and help prevent shoreline erosion. Submerged aquatic plants also weaken wave action and help stabilize bottom sediment.

- ***Provide food and shelter for waterfowl***—Many submerged plants produce seeds and tubers (roots), which are eaten by waterfowl. Bulrushes, sago pondweed, and wild rice are especially important duck foods. Submerged plants also provide habitat to many insect species and other invertebrates that are, in turn, important foods for brooding hens and migrating waterfowl.

- ***Improve aesthetics***—The visual appeal of a lakeshore often includes aquatic plants, which are a natural, critical part of a lake community. Plants such as water lilies, arrowhead, and pickerelweed have flowers or leaves that many people enjoy.

- ***Provide economic value***—As a natural component of lakes, aquatic plants support the economic value of all lake activities. Wisconsin has a huge tourism industry centered on lakes and the recreation they support. Residents and tourists spend large sums of money each year to hunt, fish, camp, and watch wildlife on and around the state's lakes.

3.0 Compilation and Assessment of Existing Information

3.1 Physical Characteristics (Morphometry)

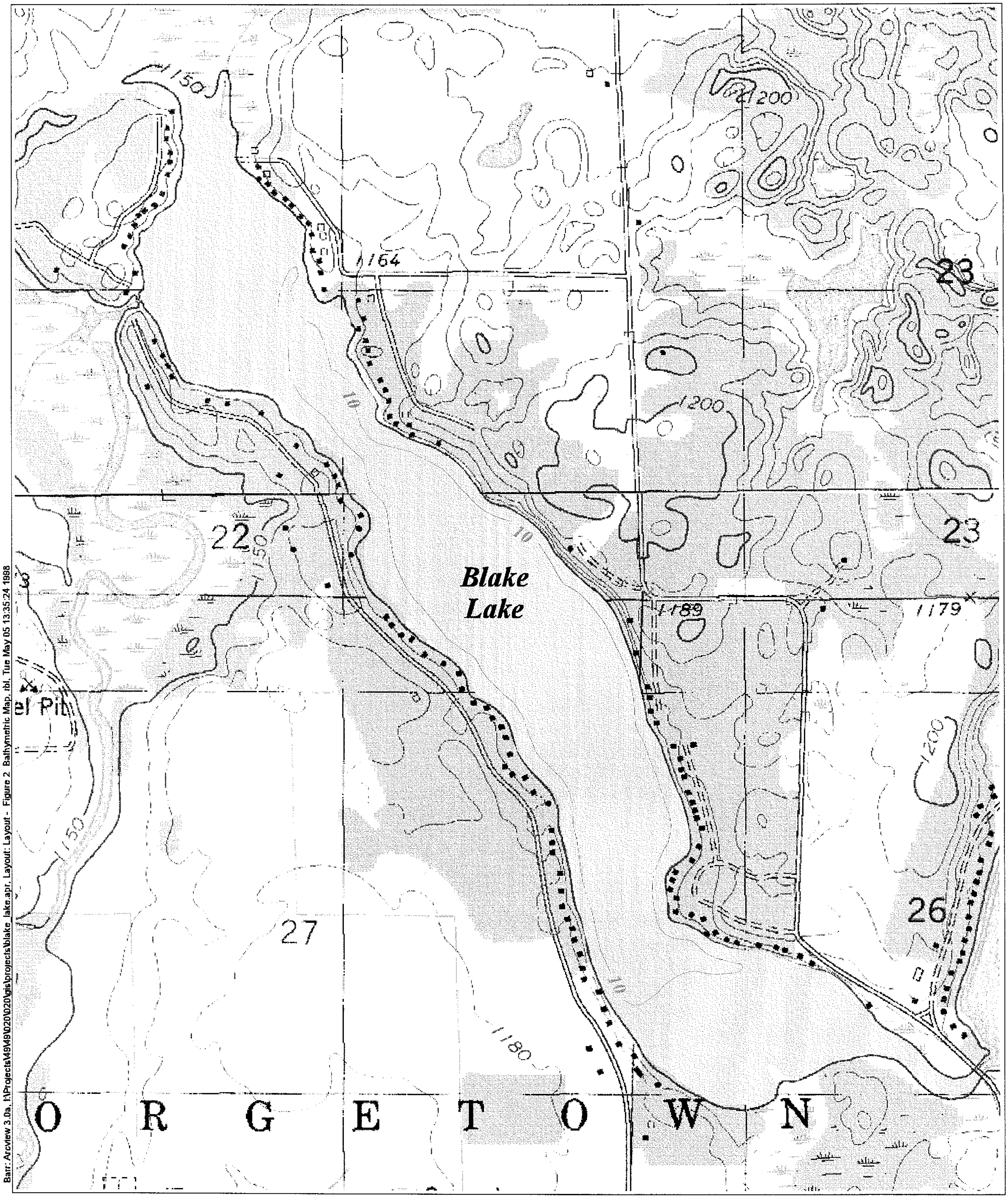
Blake Lake is located in Polk County in northwestern Wisconsin (see Figure 2). The general physical characteristics of the lake is as follows (Wisconsin Department of Natural Resources, 1981):

Parameter	Blake Lake
Surface area (acres)	250.7
Maximum depth (feet)	8.6
Mean depth (feet)	14
Volume (acre-feet)	2,174
Shoreline (miles)	6.65
Watershed Area (acres)	15,369
Ratio of Watershed to Lake	61:1
Hydraulic Retention Time (years)	0.10

3.2 Water Quality

Water quality data were collected by the Wisconsin Department of Natural Resources during November 1978 through October 1979. The study results include the following (WDNR, 1981):

Parameter	Range	Mean
Total Phosphorus (mg/L)	0.026-0.095	0.048
Ammonia Nitrogen (mg/L)	0.00-0.31	0.09
Nitrite + Nitrate Nitrogen	0.00-0.51	0.12
Total Kjeldahl Nitrogen	0.46-0.55	0.51
Alkalinity (as $CaCO_3$) (mg/L)	96-130	108
Conductivity (μmhos/cm)	275-405	336
pH	7.14-8.98	8.10
Total Filterable Residue (mg/L)	64-72	68
Color (platinum units)	62-76	68



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Barr
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0 1000 2000 Feet

10 Depth Contour (feet)

Figure 2
Bathymetric Map
(Depth Map)
Blake Lake

Total phosphorus, chlorophyll, and Secchi disc transparency data collected from Blake Lake were used to determine the trophic state of the lake based upon the Trophic State Index (TSI). The trophic indicators (i.e., total phosphorus, chlorophyll *a*, and Secchi disc) suggest that Blake Lake is a productive eutrophic body of water.

The University of St. Thomas completed limited water quality studies of Blake Lake during 1983 and 1993 (Grills, D., 1997). The results of the studies are:

Parameter	7/5/83	7/26/83	Early June '93	Mid July '93	8/16/93	Late August '93
Depth of Lake at Sampling Site	3.2 meters	3.25 meters	Not Recorded	Not Recorded	2.79 meters	Not Recorded
Transparency (Secchi Disc)	1.63 meters	0.81 meters	2.2 meters	1.3 meters	0.35 meters	0.75 meters
Surface Water Temperature	23.5° C	27° C	24° C	24° C	25° C	25° C
8' Depth Water Temperature	23.5 ° C	26° C	Not Recorded	Not Recorded	25° C	Not Recorded
Dissolved Oxygen at Surface	9 mg/L	8 mg/L	9 mg/L	7 mg/L	8 mg/L	8 mg/L
Dissolved Oxygen at 8'	6 mg/L	7.5 mg/L	Not Recorded	Not Recorded	3 mg/L	Not Recorded
Surface Ortho Phosphorus	2 μg/L	5 μg/L	0 μg/L	0 μg/L	8 μg/L	0 μg/L
Biological Oxygen Demand (Surface)	3 mg/L	3 mg/L	7 mg/L	4 mg/L	7 mg/L	7 mg/L
Surface Nitrate Nitrogen	0 mg/L	0.02 mg/L	0 mg/L	0 mg/L	0 mg/L	0 mg/L
Surface Nitrite Nitrogen	0 mg/L	0 mg/L	0 mg/L	0 mg/L	0 mg/L	1.5 mg/L
Surface Ammonia Nitrogen	0.4 mg/L	0.4 mg/L	0 mg/L	0 mg/L	0.5 mg/L	0.3 mg/L
Surface pH	8.5	9.5	9.4	9.2	9.5	9.2

Volunteers have collected Secchi disc (i.e., a measure of water transparency) data from Blake Lake. Average summer Secchi disc transparency measurements during the period 1991 through 1992 were 1.7 and 1.3 meters, respectively (WDNR, 1992). The data indicate the lake has been eutrophic (rich in nutrients and very productive). The determination was based upon a Trophic State Index (TSI) that relates Secchi disc transparency to water quality and the trophic state of a given lake (Heiskary, 1990). Transparency data collected during 1983 and 1993 (i.e., summer average of 1.22 and 1.15 meters during 1983 and 1993, respectively, based upon College of St. Thomas data) also indicate Blake Lake was eutrophic (Grills, D., 1997).

Secchi disc data collected during 1983 and during 1991 through 1993 indicate recreational-use impairment ranged from moderate to severe and was, on average, moderate. The determination is based upon the results of a survey completed by the Metropolitan Council (Osgood 1989) correlating the perceptions and expectations of people using a lake with its water quality. Survey results revealed the following relationship between a lake's recreational-use impairment and Secchi disc transparencies:

- No impairment occurs at Secchi disc transparencies greater than 4 meters;
- Minimal impairment occurs at Secchi disc transparencies of 2 to 4 meters;
- Moderate impairment occurs at Secchi disc transparencies of 1 to 2 meters;
- Moderate to severe use-impairment occurs at Secchi disc transparencies less than 1 meter (3.3 feet).

3.3 Watershed Characteristics

The watershed that drains to Blake Lake is approximately 15,369 acres. The major tributary to Blake Lake is the Straight River. The river flows into Big Round Lake, moves through Little Blake Lake and then enters Blake Lake. The lake then empties into the Fox Creek at the northwest end (WDNR, 1981).

3.4 Hydrologic Budget

An annual hydrologic budget of Blake Lake was constructed from data collected during November 1978 through October 1979. During the study period, surface runoff comprised 87 percent of the inflow to Blake Lake, which was primarily outflow from Big Round Lake via the Straight River. The estimated hydrologic budget for Blake Lake was (WDNR, 1981):

Calculated Water Budget	
Source	**Blake Lake**
Inputs:	
Precipitation	0.8 cfs
Surface Runoff	25.4 cfs
Groundwater	3.1 cfs
Total Inputs	29.3 cfs
Outputs:	
Outlet	28.6 cfs
Evaporation	0.7 cfs
Total Outputs	29.3 cfs
Hydraulic Retention Time	0.10 year

3.5 Phosphorus Loading

An annual phosphorus budget was estimated from data collected during the November 1978 through October 1979. The following data sources, extrapolations and assumptions were used in the process of constructing the phosphorus budget to Blake Lake.

- The amount of phosphorus contributed by surface runoff was determined from data collected from the inflow to Blake Lake (i.e., Straight River) and extrapolated to the remaining watershed.
- The groundwater flow into Blake Lake was estimated from base flow during winter months. An average total soluble phosphorus concentration of 0.027 mg/L (from an earlier report on Big Round Lake) was multiplied by the groundwater volume entering the lake.
- The septic system contribution was estimated using the assumption that there are 40 permanent residences and 80 percent was used for the soils. An average number of people occupying each home was four with each person contributing 2.2 g P/day for permanent occupancy and 1.8 g P/day for seasonal occupancy. The length of occupancy for permanent residences was 365 days with 100 days used for seasonal residences.
- The atmospheric loading was calculated using a literature value of 0.3 kg/hectare/year.

The estimated annual phosphorus budget during the study year was (WDNR, 1981):

Estimated Annual Phosphorus Budget		
Source	**Blake Lake**	
	kg./yr.	**Percent**
Surface Runoff	1,190	90
Groundwater	72	5
Septic System Leachate	38	3
Atmospheric	30	2
Total	1,330	100

Approximately 90 percent of the external phosphorus load to Blake Lake is estimated to result from surface runoff. Approximately 70 percent of this loading originated in the Straight River watershed, with a significant contribution from Big Round Lake. An earlier report on Big Round Lake concluded that internal phosphorus loading from the sediments was a major source of phosphorus to that lake. Therefore, internal phosphorus loading to Big Round Lake contributes greatly to the Blake Lake annual phosphorus load (WDNR, 1981).

3.6 Macrophytes

Macrophyte surveys completed during 1979 indicated macrophytes were found in approximately 10 percent (25 acres) of the lake area. The following species were found in Blake Lake:

Common Name	**Scientific Name**
Submergents	
Curly-Leaf Pondweed	*Potamogeton crispus*
Bushy Pondweed, Slender Naiad	*Najas flexilis*
Flat-stem Pondweed	*Potamogeton zosteriformis*
Coontail, Hornwort	*Ceratophyllum demersum*
Water Milfoil	*Myriophyllum sp.*
Pondweed (Unidentified)	*Potamogeton sp.*
Wild Celery, Eel-Grass, Tape-Grass	*Vallisneria americana*
Water Stargrass	*Zosterella dubia (formerly Heteranthera dubia)*

Common Name	Scientific Name
Floating-leaf	
Yellow Water Lily	*Nuphar sp.*
White Water Lily	*Nymphaea sp.*
Lesser Duckweed	*Lemna minor*
Star Duckweed	*Lemna trisulca*
Watermeal	*Wolffia sp.*
Big Duckweed	*Spirodella polyrhiza*
Emergents	
Cattail	*Typha sp.*
Wild Rice	*Zizania aquatic*
Bulrush	*Scirpus spp.*

Macrophyte densities were light to moderate from ice-out through June, except for a dense growth of *Potamogeton crispus* in the extreme northwest end of the lake. By August, elevated macrophyte densities were found in many areas and the growth of *Potamogeton crispus* was replaced by *Ceratophyllum demersum* (WDNR, 1981).

3.7 Fishery

A 1978 fish survey report for Blake Lake stated, "The bass fishery is very good, and along with panfish create a desirable, if not diversified, fishery." Based on fisheries surveys of Blake Lake, the following generalizations can be made (WDNR, 1981):

- Largemouth bass are by far the dominant gamefish
- Small numbers of muskellunge and walleye are present. Both species probably enter Blake Lake from Big Round Lake via the Straight River, although small resident populations may exist.
- An abundant bluegill population is present.

3.8 Sediments

During a study of Blake Lake during 1978 through 1979, the WDNR determined that the lake appeared to be over one-half full of sediment. Although the lake's maximum water depth was 14 feet, the sediment thickness reached a maximum of 25 feet. The sediments were 48 percent organic and 52 percent inorganic on a dry weight basis, with the inorganic portion primarily consisting of silt and clay (WDNR 1981).

4.0 Methods

4.1 Membership Surveys

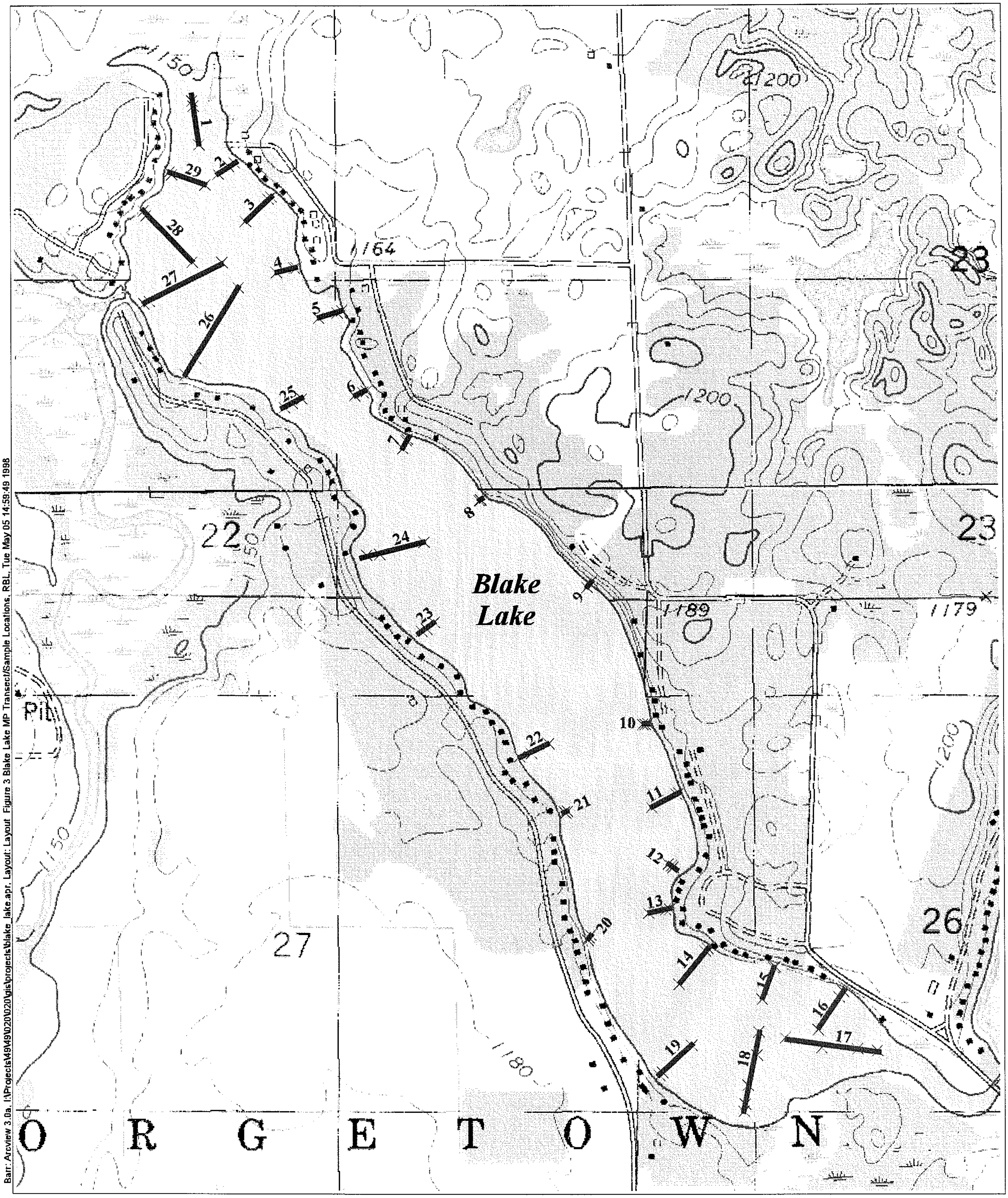
Members of the Blake Lake Protection and Rehabilitation District were surveyed during 1997 to determine lake uses, lake use impairment, and opinions regarding macrophyte management options. The survey is presented in Appendix A.

4.2 Aquatic Plant Surveys

Aquatic plant (macrophyte) surveys of Blake Lake were completed during June 12 through 13 and during July 24 through 25 of 1997. The surveys were completed by Barr Engineering Co. with assistance from volunteers.

The methodology used was based upon Jessen and Lound (1962). The surveys were completed according to methods outlined in *Wisconsin's Department of Natural Resources Long-Term Trend Lake Monitoring Methods*, (Bureau of Water Resources Management, July 1987) as modified by Deppe and Lathrop (1992). This methodology enables the plant specialist an opportunity to determine the presence, frequency, and density of different plant species. The following outlines the methodology followed in the study.

- Transects were chosen at approximately 500-foot intervals of shoreline. The locations of the 29 transects selected for the study of Blake Lake are shown on Figure 3. Transects extended from shore to the maximum depth of plant growth.
- Compass readings were taken at each transect location for future reference.
- Transects were broken down into the following depth categories:
  0 to 1.5 feet
  1.5 to 5.0 feet
  5 to 10 feet (or to the maximum rooting depth)
- Four rake samples were taken at each depth zone to determine the presence and abundance of species. The sample point at each depth zone consisted of a 6-foot diameter circle divided into four quadrants. A tethered garden rake with an extended handle (16 feet) was used to collect a sample from each quadrant.



Barr
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0 500 1000 1500 2000 Feet

Sample Point
4 Transect
Transect Number

Figure 3
Macrophyte Transect
and Sample Locations
Blake Lake

- Collection of samples, identification of species, and determination of density ratings for each species occurred at all sampling points. The rake coverage technique was used to assign density ratings (Deppe and Lathrop 1992) in accordance with the following criteria:

Rake Coverage (% of Rake Head) Covered by a Species	**Density Rating**
81-100	5
61-80	4
41-60	3
21-40	2
1-20	1
0	0

- A Global Positioning System (GPS) unit was used in the field to note latitude and longitude readings of each sampling point for future reference.

- Sediment type was determined at each sampling point.

- Maximum rooting depths were observed at all transects.

5.0 Results and Discussion

5.1 Membership Survey Results

Members of the Blake Lake Protection and Rehabilitation District were surveyed to determine their:

- understanding of the functions and values of aquatic plants,
- uses of the lake,
- perceived impairment of lake uses by aquatic plants, and
- aquatic plant management preferences.

A total of 225 surveys were mailed and 77 responses were received (i.e., 31 percent return rate). Survey results are presented in Figures 4 through 6 and are summarized in Appendix A. The survey results indicated:

- Most respondents (i.e., 88 percent) recognized that aquatic plants have value.
- Respondents indicated aquatic plants have a high level of importance for fish shelter.
- Respondents indicated aquatic plants have a high to medium level of importance for fish food.
- Respondents indicated the primary use of Blake Lake is fishing (94 percent). Other major uses include viewing (82 percent), swimming (70 percent), powerboating (47 percent), and canoeing (43 percent).
- Respondents indicated the primary use impairment caused by aquatic plants is swimming (62 percent) and the second highest use impairment is fishing (60 percent).
- A total of 56 percent of respondents indicated they have removed or attempted to remove aquatic plants around their dock or along their shoreline.
- A total of 39 percent of respondents indicated they are opposed to the use of chemicals to remove aquatic plants from the lake.
- Only 23 percent of respondents indicated they are opposed to mechanical harvesting of aquatic plants in the lake.
- A total of 57 percent of respondents indicated the lake district should not own and operate a weed harvestor.

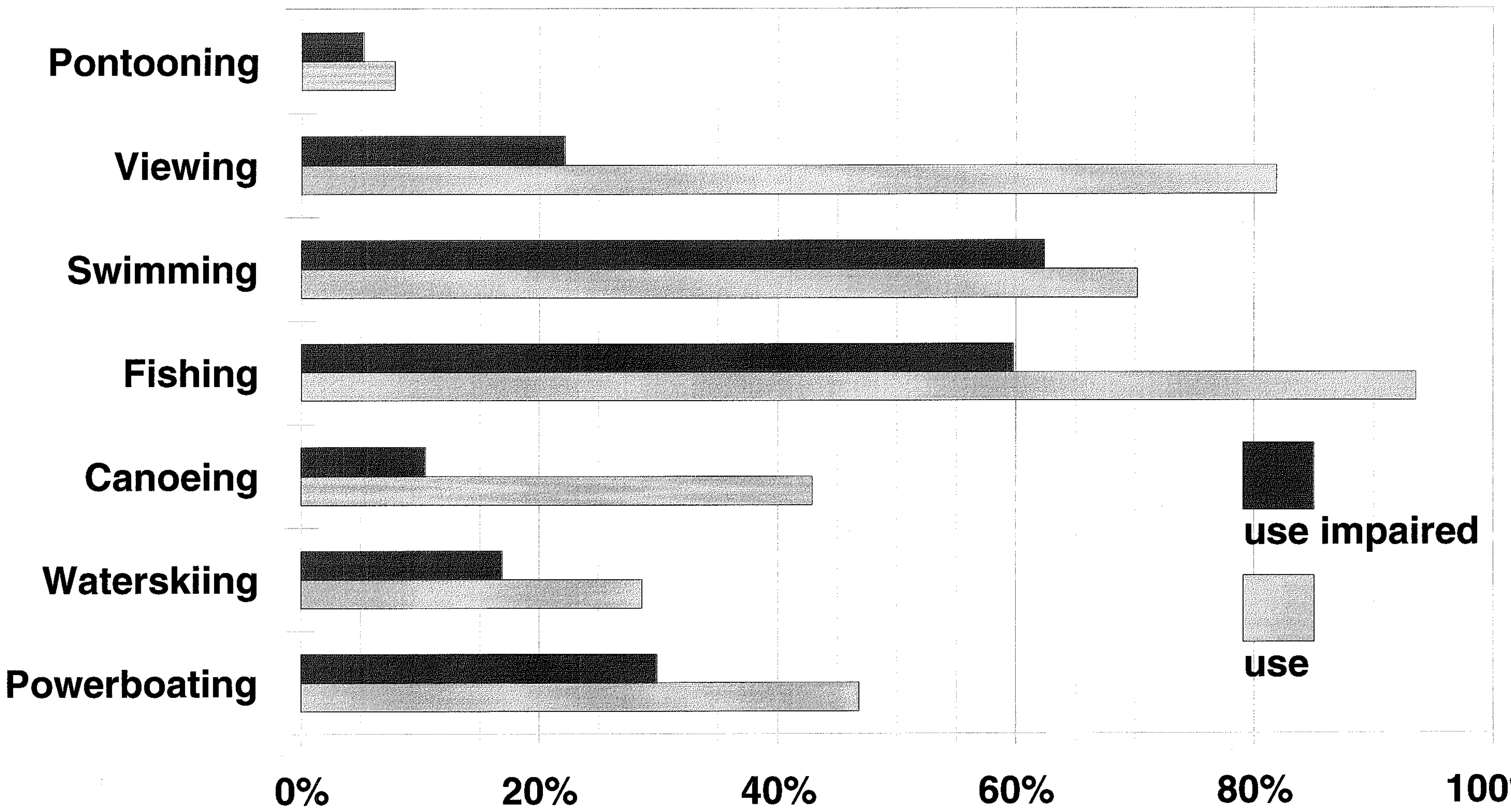

Figure 4. Recreation Use and Impairment Percent of Total Responses

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Figure 5. Aquatic Plant Functions

Rated Level of Importance

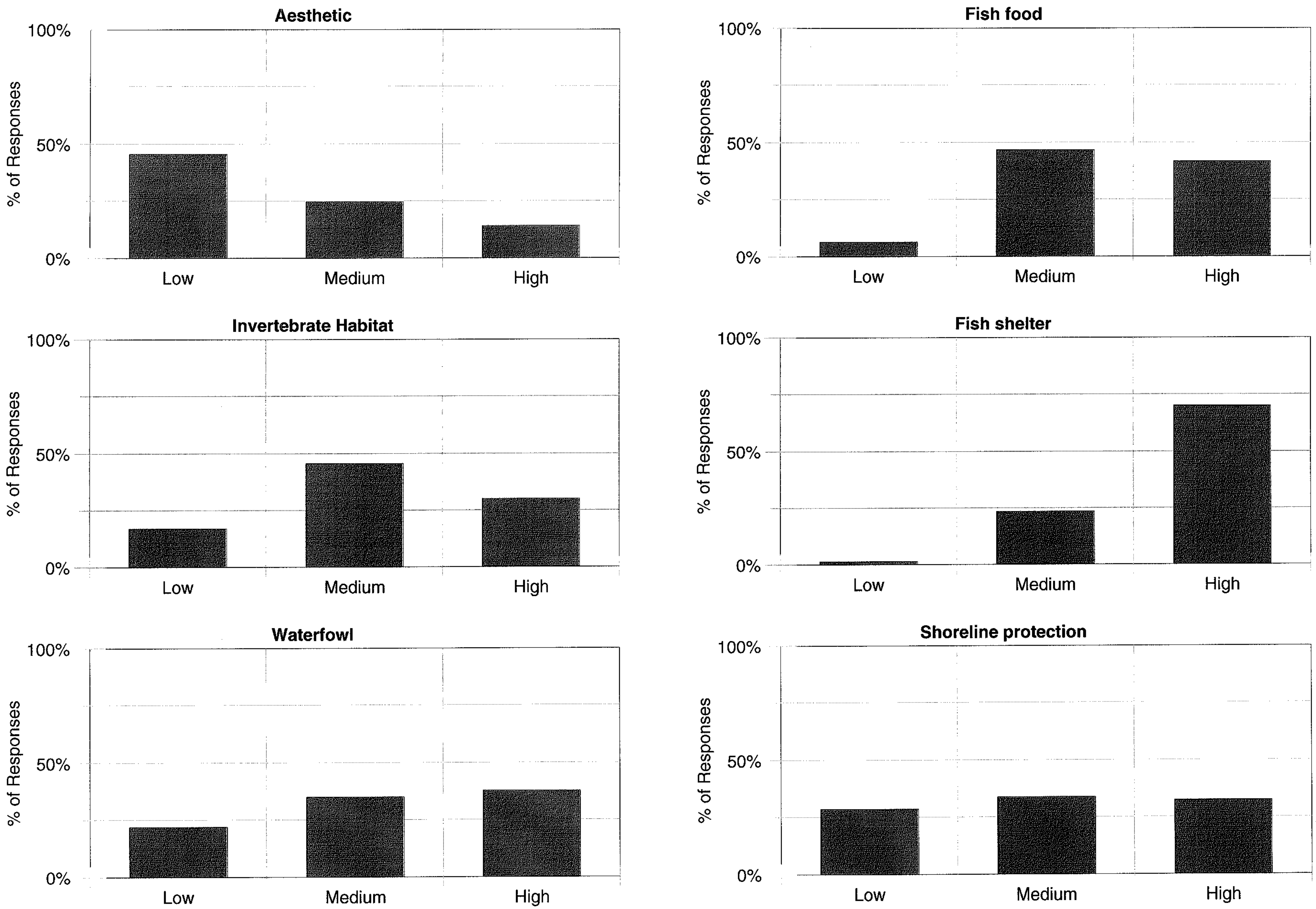

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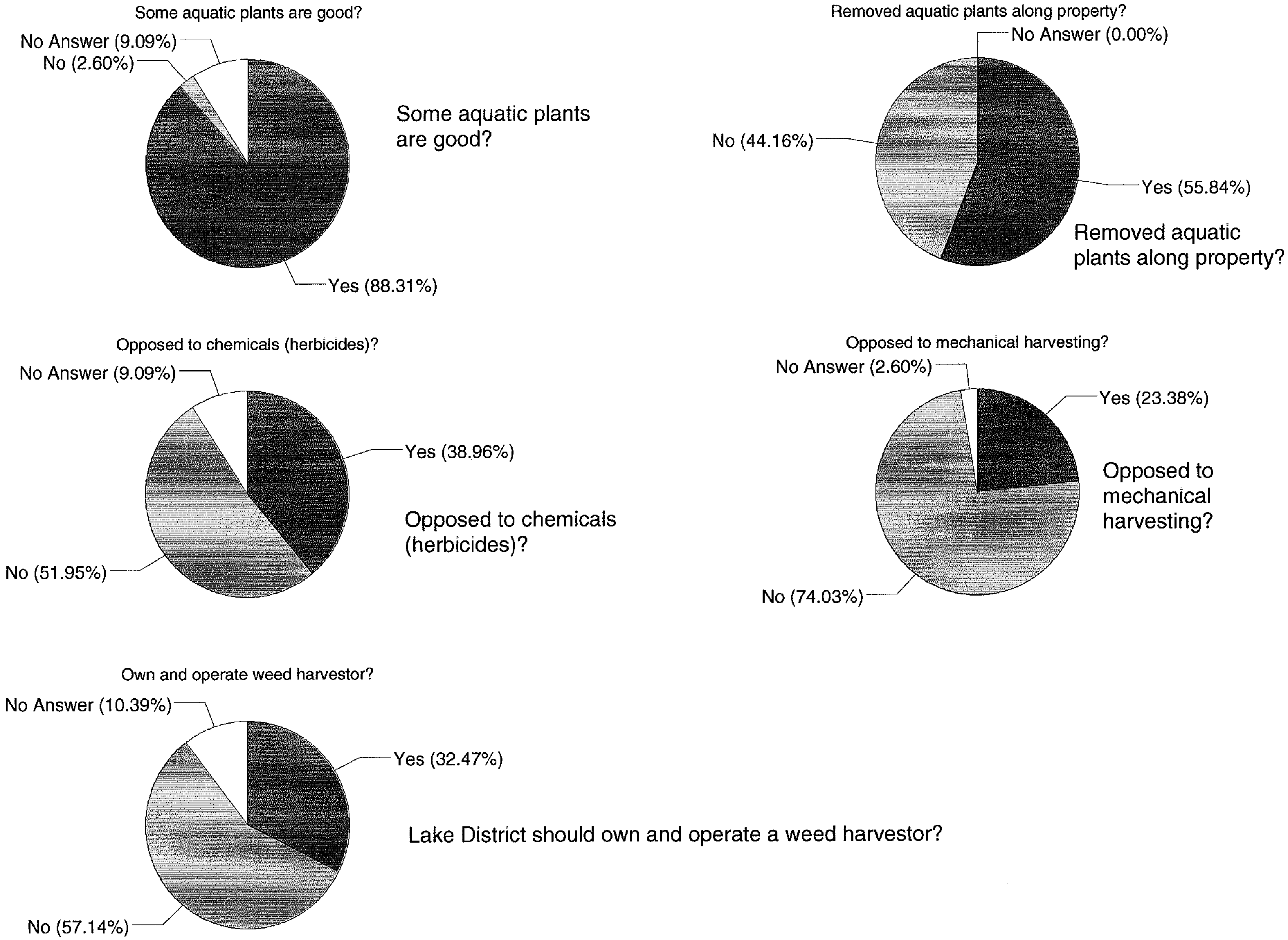
Figure 6
Responses for Managing Aquatic Plants



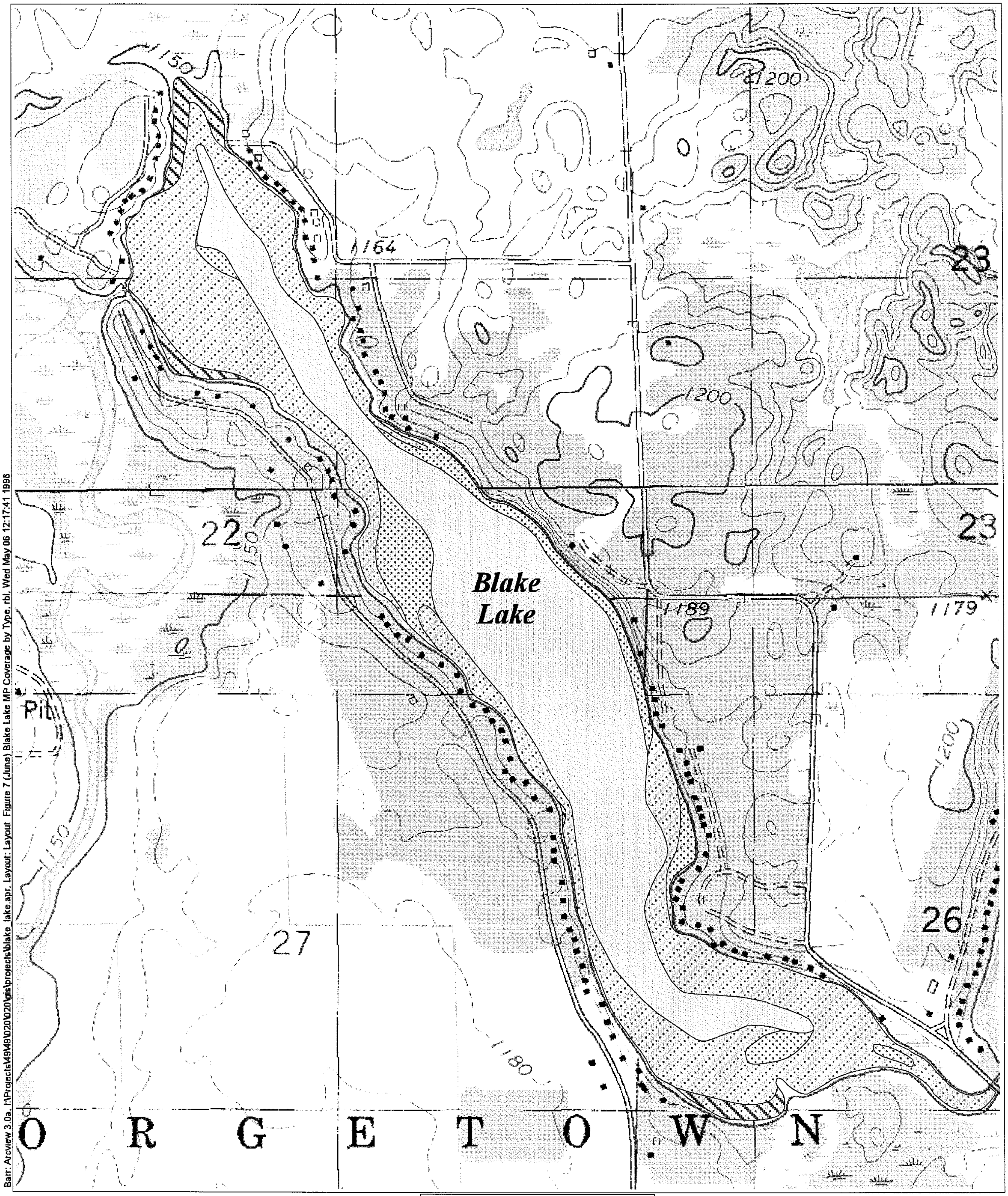
5.2 Macrophyte Survey Results

Results of the Blake Lake 1997 macrophyte surveys indicate the lake contained a diverse assemblage of macrophyte (aquatic plant) species representing the four macrophyte types—submersed plants, floating-leaf plants, emergent plants and the alga *Chara*. Of the four types, submersed plants dominated the macrophyte community. Survey results indicated (See Figures 7 through 8 and Appendix B):

- Submersed plants were found in all sample transects of Blake Lake.
- Floating-leaf plants were found in 90 percent of sample transects during June and in 55 percent of sample transects during July.
- Emergent plants were found in 17 percent of sample transects during June and in 14 percent of sample transects during July.
- The alga *Chara* was not found during June but was found in 41 percent of the sample transects during July.

The large number of species noted in Blake lake during 1997 (i.e., 21 species) is indicative of a stable and healthy macrophyte community. Further evidence of a diverse plant community was indicated by the large number of species found in each transect. The average number of species occurring in each transect was 8 and 9 during June and July, respectively. The large number of species in each transect:

- provides a diverse habitat for fish and invertebrates (i.e., food for fish) and encourages a more diverse fish and invertebrate community;
- protects fisheries habitat from destruction by a disease as a species-specific disease would have little impact upon the diverse community;
- affords protection from invasion by exotic species (i.e., exotic species generally invade areas lacking vegetation);



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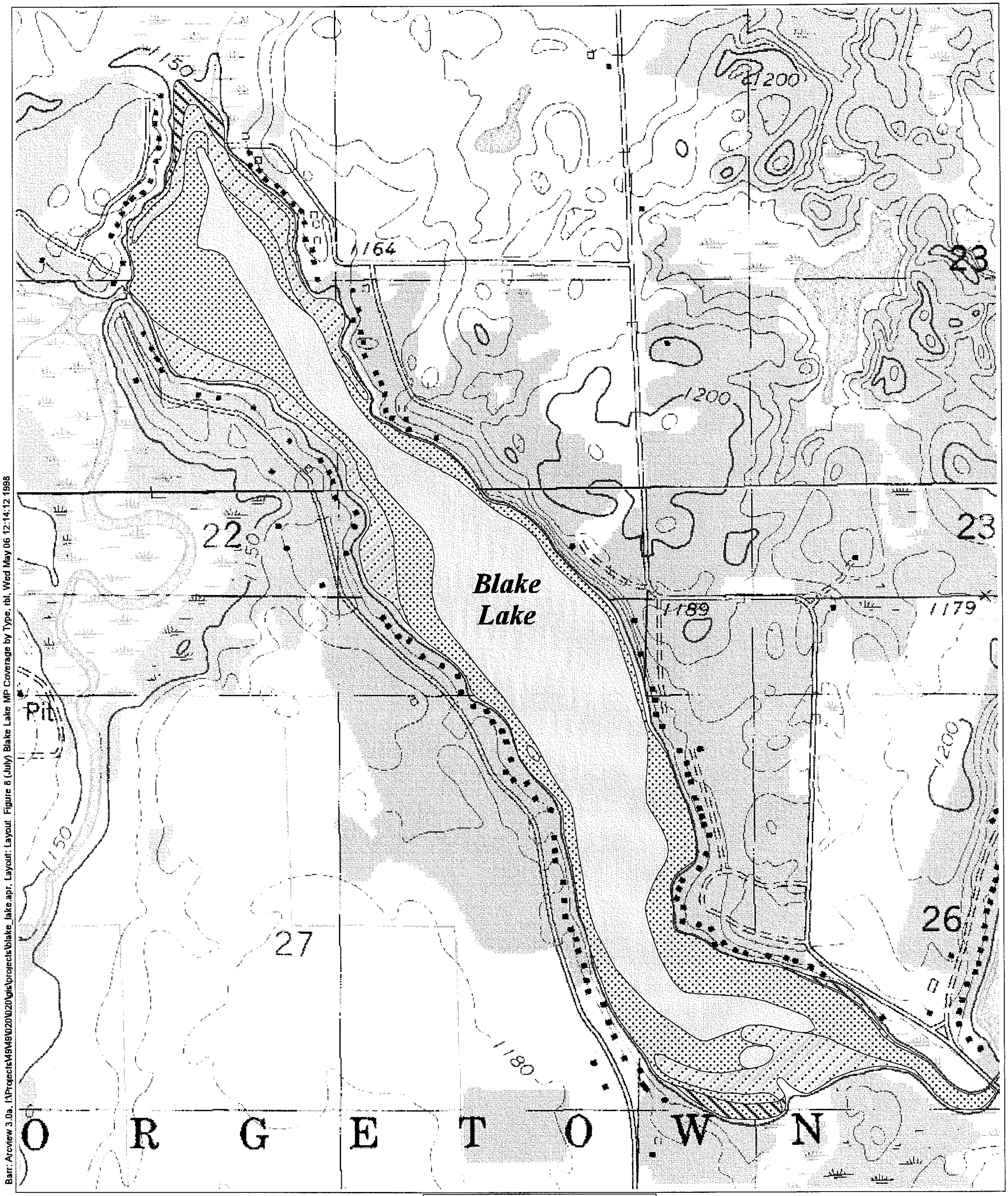
0 500 1000 1500 2000 Feet

Macrophyte Type
- Emergent
- Floating-leaf
- Submerged

Figure 7
Macrophyte Coverage
by Type (June)
Blake Lake



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0 500 1000 1500 2000 Feet

Macrophyte Type

- Emergent
- Floating-leaf
- Submerged

Figure 8
Macrophyte Coverage by Type (July)
Blake Lake

A few species were abundant in both lakes during 1997, but diversity characterized the macrophyte community. The four predominant species during June were *Ceratophyllum demersum* (Coontail/Hornwort), *Lemna trisulca* (Star Duckweed), *Potamogeton pusillus* (Small Pondweed) and *Potamogeton zosteriformis* (Flat-stem Pondweed). Each species occurred in 60 percent to 69 percent of the sample locations (See Figure 8). The four predominant species during July were *Ceratophyllum demersum* (Coontail/Hornwort), *Myriophyllum sibericum* (formerly *Myriophyllum exalbescens*, Northern Water Milfoil), *Potamogeton pusillus* (Small Pondweed), and *Potamogeton zosteriformis* (Flat-stem Pondweed). Each species occurred in 48 percent to 75 percent of the sample locations (See Figure 9).

Macrophyte diversity was calculated for Blake Lake using a modification of Simpson's Index (1949):

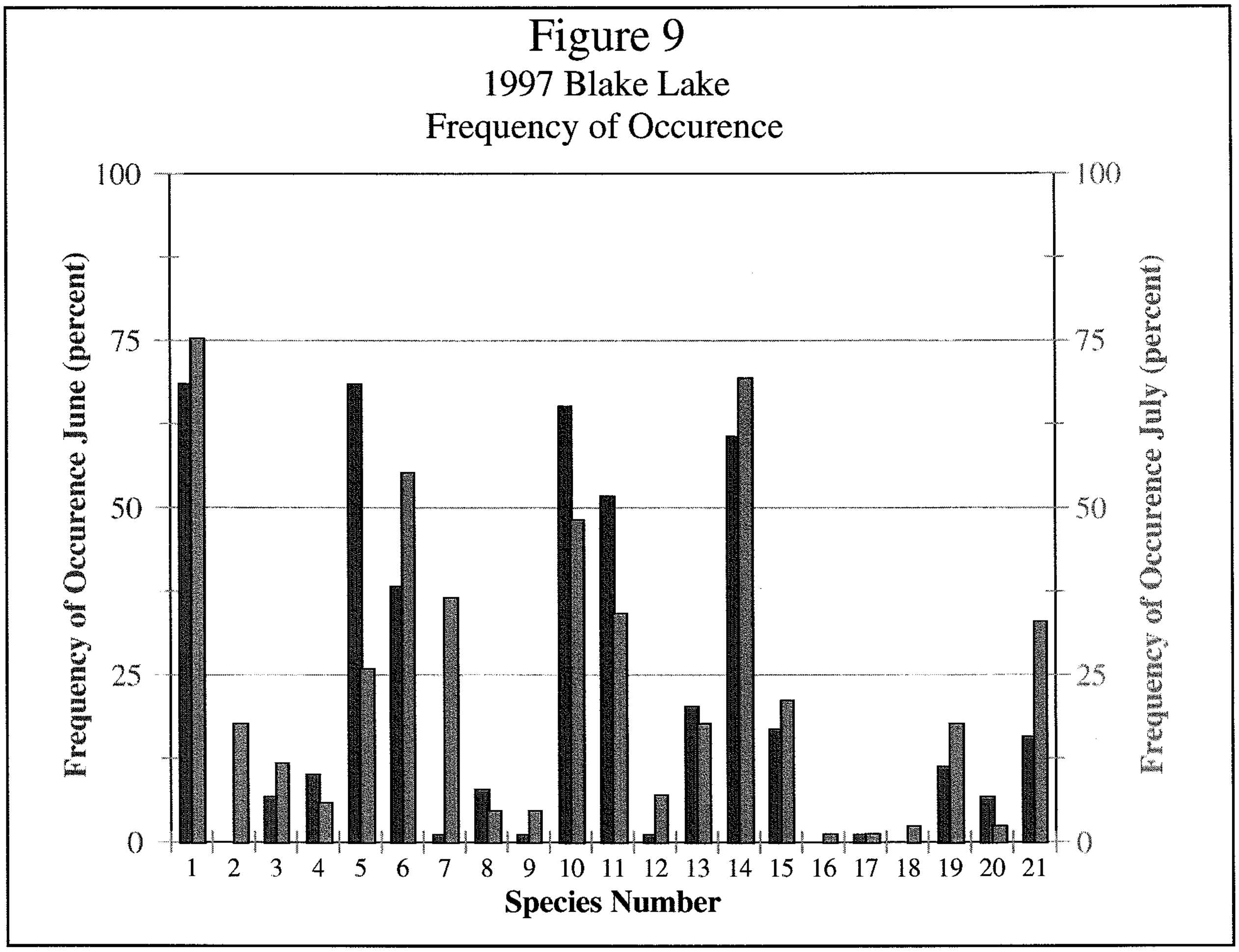
$$1-\sum (rf/100)^2$$

Where:

rf = the relative frequency of each species. Frequencies were calculated as the number of sampling points where a species occurred divided by the total number of sampling points at depths less than or equal to the maximum depth of plant growth. Frequencies were relativized to 100 percent to describe community structure (i.e., rf). Frequencies are shown in Figure 9. Relative frequencies are presented in Appendix C.

The data indicate the lake's plant community was highly diverse. On a scale of 0 to 1, with 0 indicating no plant diversity and 1 indicating the highest plant diversity, Blake Lake noted a diversity of 0.89 during June and July of 1997. During 1979 and 1997, diversities during the late summer were similar (i.e., 0.89 and 0.91, respectively). Early summer diversities differed somewhat between 1979 and 1997 (i.e., 0.78 during 1979 and 0.89 during 1997) and a greater diversity was observed during 1997. The diversities measured in 1997 are near the high end of the range of diversities noted for 47 Wisconsin lakes sampled by the Wisconsin Department of Natural Resources, Office of Inland Lake Renewal (See Table 1).

The cumulative effect of the large number of species in the lakes was assessed from the proportion of open area in the littoral zone (i.e., Percent Open Area). The percent open area was estimated from the number of sampling points containing no vegetation divided by the total number of sampling points at a depth less than or equal to the maximum depth of plant growth. Maximum depth of plant growth is the water depth at the deepest sampling point where plant growth was found. The maximum depth of plant growth in Blake Lake was, on average, 10 feet during June and 9 feet during July. Blake Lake noted a 10 percent open area during June and a 6 percent open area during July. Consequently the cumulative effect of the large number of species was the growth of plants throughout much of the littoral area of the lake.



Species Number	Species Name	Common Name	Frequency of Occurrence (%) June	July
1	*Ceratophyllum demersum*	Coontail/Hornwort	68.5	75.3
2	*Chara spp.*	Musk Grass	--	17.6
3	*Elodea canadensis*	Canada Waterweed	6.7	11.8
4	*Eriocaulon spp.*	Pipewort	10.1	5.9
5	*Lemna trisulca*	Star Duckweed	68.5	25.9
6	*Myriophyllum exalbescens*	Northern Watermilfoil	38.2	55.3
7	*Najas flexilis*	Bushy Pondweed	1.1	36.5
8	*Nuphar variegatum*	Yellow Waterlily	7.9	4.7
9	*Nymphaea tuberosa*	White Waterlily	1.1	4.7
10	*Potamogetan pusillus*	Small Pondweed	65.2	48.2
11	*Potamogeton crispus*	Curlyleaf Pondweed	51.7	34.1
12	*Potamogeton pectinatus*	Sago Pondweed	1.1	7.1
13	*Potamogeton richardsonii*	Claspingleaf Pondweed	20.2	17.6
14	*Potamogeton zosteriformis*	Flat-stem Pondweed	60.7	69.4
15	*Ranunculus spp.*	Buttercup	16.9	21.2
16	*Sagittaria spp.*	Arrowhead	--	1.2
17	*Scirpus spp.*	Bulrush	1.1	1.2
18	*Sparganium eurycarpum*	Giant Bur-reed	--	2.4
19	*Vallisneria americana*	Wild Celery	11.2	17.6
20	*Zizania aquatica*	Wild Rice	6.7	2.4
21	*Zosterella dubia*	Water Star Grass	15.7	32.9

Table 1 Diversities of Some Wisconsin Plant Communities (from Nichols 1997)

Lake Name	Diversity (Late Summer)	Lake Name	Diversity (Late Summer)
Amnicon Lake	0.95	Leota Lake	0.78
Apple River Flowage	0.91	Little Arbor Vitae Lake	0.78
Ashippun Lake	0.91	Little Elkhart Lake	0.91
Balsam Lake	0.90	Long Lake T32N	0.81
Bear Lake	0.85	McCann Lake	0.80
Big Blake Lake (Blake)	**0.91***	Mid Lake (Nawaii)	0.78
Big Butternut Lake	0.84	Morris Lake (Mt. Morris)	0.91
Big Hills Lake (Hills)	0.88	Mud Hen Lake	0.90
Big Round Lake	0.89	Muskellunge Lake	0.92
Cary Pond	0.79	Oconomowoc Lake, Upper	0.70
Cedar Lake	0.91	Okauchee Lake	0.86
Chain Lake	0.74	Pearl Lake	0.86
Church Pine Lake	0.93	Pigeon Lake	0.89
Chute Pond	0.86	Pike Lake	0.90
Clear Lake	0.74	Pine Lake	0.91
Como Lake	0.88	Post Lake	0.91
Decorah Lake	0.93	Rib Lake	0.71
Dowling Lake	0.87	Round (Wind) Lake	0.92
Enterprise Lake	0.86	Silver Lake (Anderson)	0.69
George Lake	0.58	Tichigan Lake	0.69
Half Moon Lake	0.93	Twin Lake, North	0.73
Half Moon Lake T47N	0.77	Twin Lake, South	0.81
Helen Lake	0.80	White Ash Lake	0.91
Island Lake	0.78	White Ash Lake, North	0.86

*Diversities during 1979 and during 1997 were similar, 0.89 and 0.91, respectively.

Macrophyte coverage in Blake Lake has increased nearly five-fold during the past 20 years. During 1997, the total coverage by macrophytes was 122 acres (i.e., 49 percent of lake surface area) during June and 120 acres (i.e., 48 percent of lake surface area) during July (See Figures 7 and 8). During 1979, the total coverage by macrophytes was 25 acres (i.e., 10 percent of lake surface area) (WDNR, 1981).

Although individual species in Blake Lake generally occurred in a relatively low density during 1997, the concurrent growth of a large number of species at each sample location resulted in an overall plant growth of moderate to high density. The density of individual species per sample location ranged from 1.0 to 5.0 during June and July. However, the average density of individual species ranged from 1.0 to 2.0 during June and from 1.0 to 1.6 during July (i.e., on a scale of 0 to 5, as discussed in the methods section, 0 indicated the lowest density and 5 indicated the highest density) (See Figure 10). The concurrent occurrence of approximately 8 or 9 individual species per sample transect (i.e., average number of species per transect during June and July, respectively) resulted in an overall plant growth of moderate to abundant density (see Figures 11 and 12). Locations with a high macrophyte density posed navigation problems to area residents.

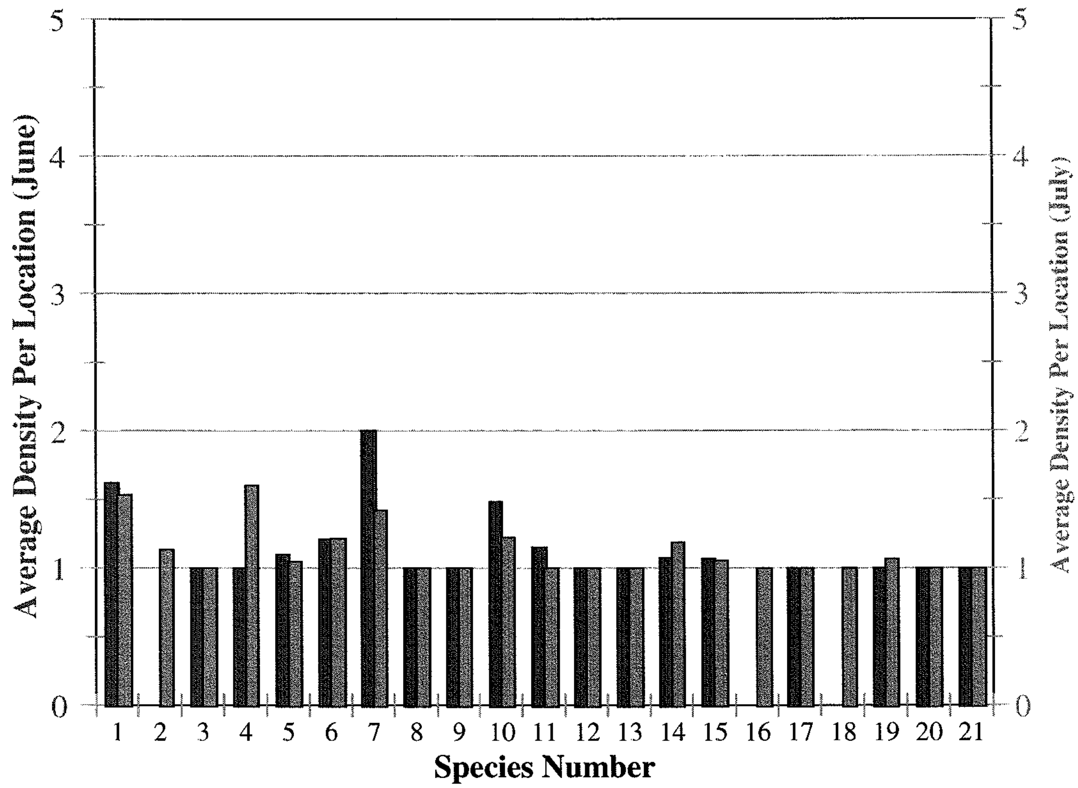
The Blake Lake macrophyte communities perform a number of valuable functions. These include:

- Habitat for fish, insects, and small aquatic invertebrates
- Food for waterfowl, fish, and wildlife
- Oxygen producers
- Provide spawning areas for fish, in early spring
- Helps stabilize marshy borders of the lake; helps protect shorelines from wave erosion
- Provides nesting sites for waterfowl and marsh birds

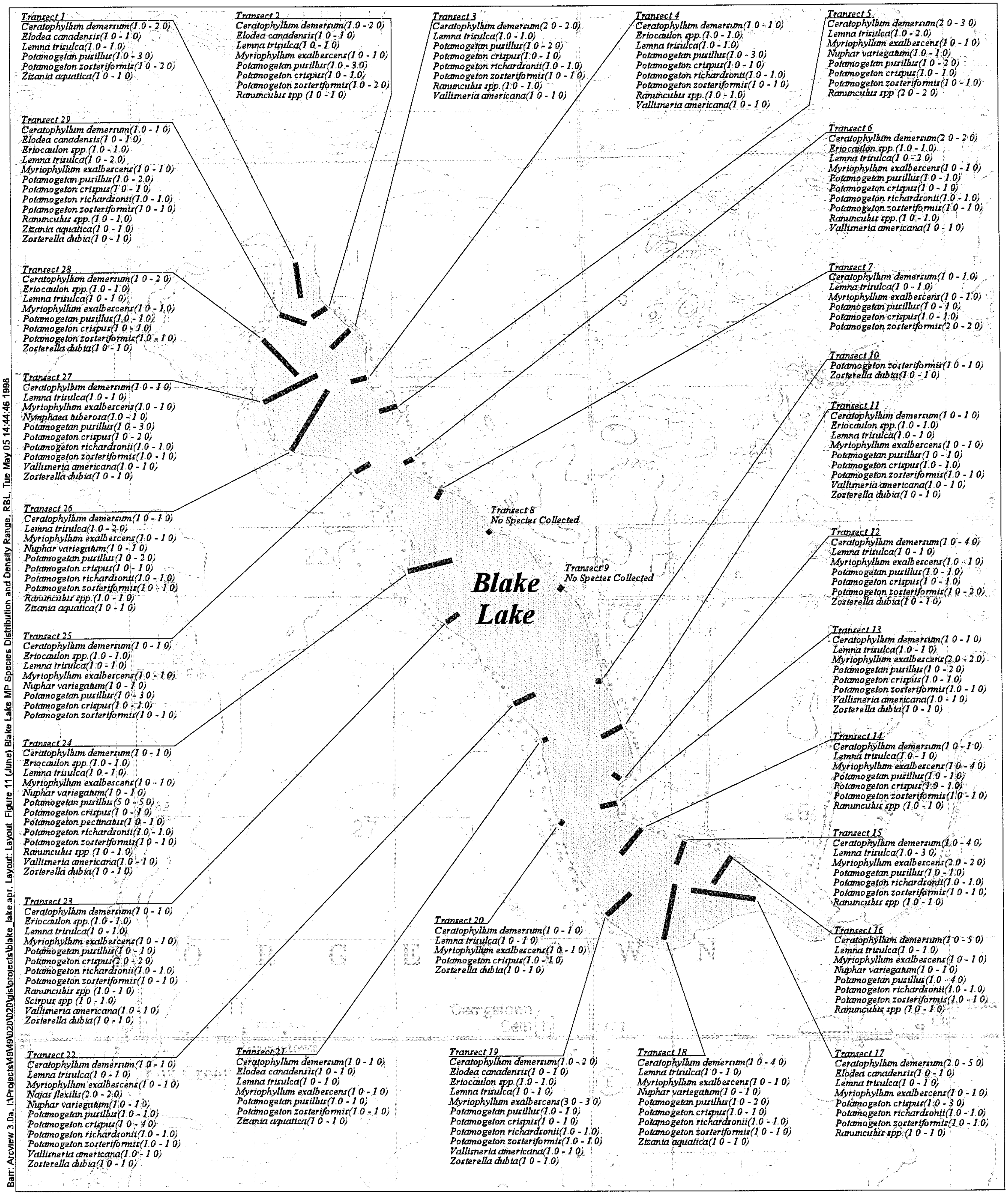
Table 2 summarizes the functions performed by several individual species noted in the lake.

Macrophytes in Blake Lake consisted primarily of native species (i.e., species historically present in this region). Only one exotic (i.e., not native) species, *Potamogeton crispus* (curly-leaf pondweed), was noted. Curly-leaf pondweed is an exotic perennial, rooted, submersed aquatic vascular plant which was first noted in Minnesota about 1910 (Moyle and Hotchkiss 1945). Native to Eurasia, Africa, and Australia, this species has been found in most of the United States since 1950, and is currently found in most parts of the world (Catling and Dobson, 1985). Exotic or non-native species are undesirable because their natural control mechanisms are not introduced with the species. Consequently, exotic species frequently exhibit rapid unchecked growth patterns.

Figure 10
1997 Blake Lake
Average Macrophyte Density



Species Number	Species Name	Common Name	Average Density June	Average Density July
1	*Ceratophyllum demersum*	Coontail/Hornwort	1.6	1.5
2	*Chara spp.*	Musk Grass		1.1
3	*Elodea canadensis*	Canada Waterweed	1.0	1.0
4	*Eriocaulon spp.*	Pipewort	1.0	1.6
5	*Lemna trisulca*	Star Duckweed	1.1	1.0
6	*Myriophyllum exalbescens*	Northern Watermilfoil	1.2	1.2
7	*Najas flexilis*	Bushy Pondweed	2.0	1.4
8	*Nuphar variegatum*	Yellow Waterlily	1.0	1.0
9	*Nymphaea tuberosa*	White Waterlily	1.0	1.0
10	*Potamogetan pusillus*	Small Pondweed	1.5	1.2
11	*Potamogeton crispus*	Curlyleaf Pondweed	1.2	1.0
12	*Potamogeton pectinatus*	Sago Pondweed	1.0	1.0
13	*Potamogeton richardsonii*	Claspingleaf Pondweed	1.0	1.0
14	*Potamogeton zosteriformis*	Flat-stem Pondweed	1.1	1.2
15	*Ranunculus spp.*	Buttercup	1.1	1.1
16	*Sagittaria spp.*	Arrowhead		1.0
17	*Scirpus spp.*	Bulrush	1.0	1.0
18	*Sparganium eurycarpum*	Giant Bur-reed		1.0
19	*Vallisneria americana*	Wild Celery	1.0	1.1
20	*Zizania aquatica*	Wild Rice	1.0	1.0



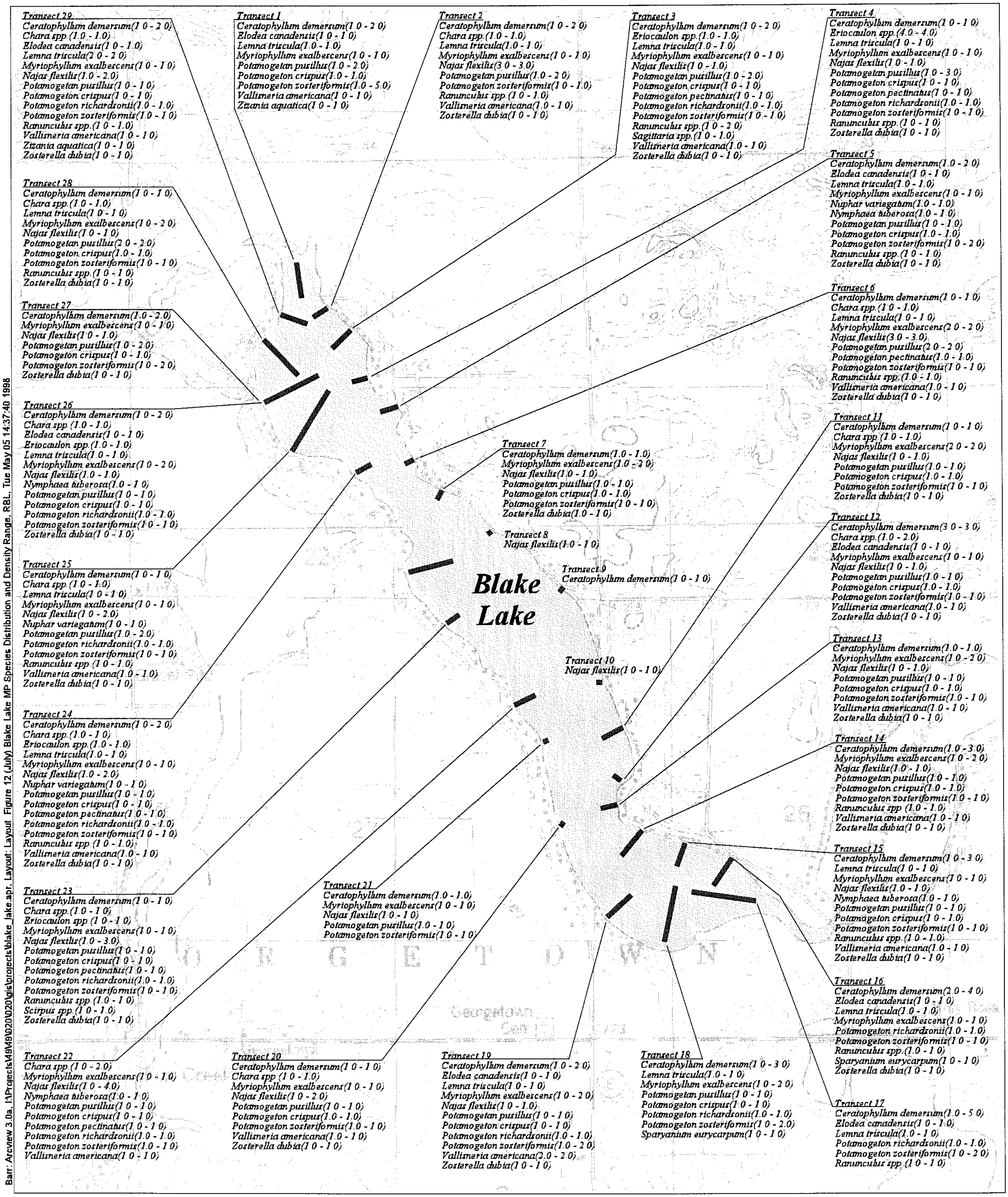
Barr: Arcview 3.0a, I:\Projects\49\49\020\020\gis\projects\blake_lake.apr, Layout: Layout Figure 11 (June) Blake Lake MP Species Distribution and Density Range, RBL, Tue May 05 14:44:46 1998

Barr Engineering Company

Transect

0 500 1000 1500 2000 2500 3000 Feet

Figure 11
Macrophyte Species Distribution and Density Range (June)
Blake Lake



Barr: Arcview 3.0a, I:\Projects\49\49\020\020\gis\projects\blake_lake.apr, Layout: Layout Figure 12 (July) Blake Lake MP Species Distribution and Density Range, RBL, Tue May 05 14:37:40 1998

Barr Engineering Company

0 500 1000 1500 2000 2500 3000 Feet

Transect

Figure 12
Macrophyte Species Distribution
and Density Range (July)
Blake Lake

Table 2 Functions of Aquatic Plant Species Found in Blake Lake

Scientific Name (Common Name)	Plant Type	Plant Functions
Ceratophyllum demersum (Coontail)	Submersed	Many waterfowl species eat the shoots; it provides cover for young bluegills, perch, largemouth bass, and northern pike; supports insects that fish and ducklings eat.
Chara spp. (Muskgrass)	Submersed	Muskgrass is a favorite waterfowl food. Algae and invertebrates found on muskgrass provide additional grazing. It is also considered valuable fish habitat. Beds of muskgrass offer cover and are excellent producers of food, especially for largemouth bass and smallmouth bass.
Elodea canadensis (Canada Waterweed)	Submersed	Provides habitat for many small aquatic animals, which fish and wildlife eat.
Eriocaulon aquaticum (Pipewort)	Submersed	Beds of pipewort create shallow water structure for young fish, amphibians and invertebrates. The leaves are sometimes grazed by ducks including black duck and American wigeon.
Lemna trisulca (Star Duckweed)	Floating-leaf	Star duckweed is a good food source for waterfowl. Tangled masses of fronds also provide cover for fish and invertebrates.
Myriophyllum sibericum (formerly exalbescens) (Northern Milfoil)	Submersed	Provides cover for fish and invertebrates; supports insects and other small animals eaten by fish; waterfowl occasionally eat the fruit and foliage.
Najas flexilis. (Spiny Naiad, Bushy Pondweed)	Submerged	Bushy pondweed is one of the most important plants for waterfowl. Stems, leaves and seeds are all consumed by a wide variety of ducks including black duck, bufflehead, canvasback, gadwall, mallard, pintail, redhead, ringnecked duck, scaup, shoveler, blue-winged teal, green-winged teal,wigeon and wood duck. It is also important to a variety of marsh birds as well as muskrats. Slender naiad is a good producer of food and shelter for fish.
Nuphar variegatum (Yellow Water Lily)	Floating-leaf	Yellow water lily anchors the shallow water community and provides food for many residents. It provides seeds for waterfowl including mallard, pintail, ringneck and scaup. The leaves, stems and flowers are grazed by deer. Muskrat, beaver and even porcupine have been reported to eat the rhizomes. The leaves offer shade and shelter for fish as well as habitat for invertebrates.
Nymphaea tuberosa (White Water Lily)	Floating-leaf	White water lily provides seeds for waterfowl. Rhizomes are eaten by deer, muskrat, veaver, moose and porcupine. The leaves offer shade and shelter for fish.
Potamogeton crispus (Curly-leaf Pondweed)	Submersed	Provides some cover for fish, several waterfowl species feed on the seeds; diving ducks often eat the winter buds.

Table 2 Functions of Aquatic Plant Species Found in Blake Lake (cont.)

Scientific Name (Common Name)	Plant Type	Plant Functions
Potamogeton pusillus (Small Pondweed)	Submersed	Small pondweed can be a locally important food for a variety of ducks and geese including gadwall, mallard, northern pintail, ring-necked duck, white-winged scoter, blue-winged teal, green-winged teal and American wigeon. The plant may also be grazed by muskrat, deer, beaver and moose. Small pondweed provides a food source and cover for fish.
Potamogeton Richardsonii (Clasping-leaf Pondweed)	Submerged	Broad-leaf pondweeds provide excellent habitat for panfish, largemouth bass, muskellunge, and northern pike; bluegills nest near these plants and eat insects and other small animals found on the leaves; walleyes use these pondweeds for cover.
Potamogeton zosteriformis (Flat-stem Pondweed), *Potamogeton pusillus* (Narrow-leaf Pondweed)	Submersed	Provides some cover for bluegills, perch, northern pike, and muskellunge, though these fish prefer broadleaf pondweeds; good cover for walleye; provide food for waterfowl; support aquatic insects and many small animals that fish and ducklings eat.
Ranunculus spp. (Water Crowfoot or Buttercup)	Submersed	As flowers give way to fruit, the water crowfoot bed becomes a choice spot for dabbling ducks. Both fruit and foliage of water crowfoot are consumed by a variety of waterfowl. When it is growing in shallow zones, it is sometimes consumed by upland game birds including ruffed grouse. Stems and leaves of water crowfoot provide valuable invertebrate habitat.
Sagittaria spp. (Arrowhead)	Emergent	Tubers, nutlets and other parts are eaten by waterfowl. Stems, roots and tubers are eaten by muskrats, porcupine and beaver. It also provides shade and shelter for young fish.
Sparganium eurycarpum (Giant Bur-reed)	Emergent	Colonies of bur-reed help anchor sediment and provide nesting sites for waterfowl and shorebirds. The fruit is eaten by a variety of waterfowl including mallards and tundra swans. The whole plant is grazed by muskrat and deer.
Vallisneria americana (Wild Celery)	Submersed	Provides shade and shelter for bluegills, young perch, and largemouth bass; choice food of waterfowl, particularly diving ducks; attracts muskrats, marsh birds, and shore birds.
Zizania aquatica (Wild Rice)	Emergent	Wild rice has a higher protein content than most cereal grains, making it a good food for wildlife and humans. Wild rice attracts many wild birds, especially waterfowl and red-winged blackbirds, and it also provides nesting cover for waterfowl.
Zosterella dubia (Water Star Grass)	Submersed	Water star grass can be a locally important source of food for geese and ducks including northern pintail, blue-winged teal and wood duck. It also offers good cover and foraging opportunities for fish.

Curly-leaf pondweed is detrimental to lakes for three reasons:

1. It tends to crowd out native aquatic macrophyte (i.e., lake weed) species.

2. Dense colonies of the weed may interfere with recreational activities on the lake.

3. After curly-leaf pondweed dies out in early July, it may sink to the lake bottom and decay, causing oxygen depletion and exacerbating internal release of phosphorus.

Curly-leaf pondweed was found in approximately 52 percent of the sample transects during June and approximately 48 percent of the sample transects during July (see Figures 13 and 14). It generally occurred in low density (i.e., density of 1 on a scale of 0 to 5, with 0 being the lowest density and 5 being the highest density), but occasionally occurred in higher densities (i.e., ranging from 2 to 5). Curly-leaf pondweed occurred concurrently with several native species. The data indicate that native species are relatively successful in competing with curly-leaf pondweed in Blake Lake, thus minimizing its impact upon the native plant community.

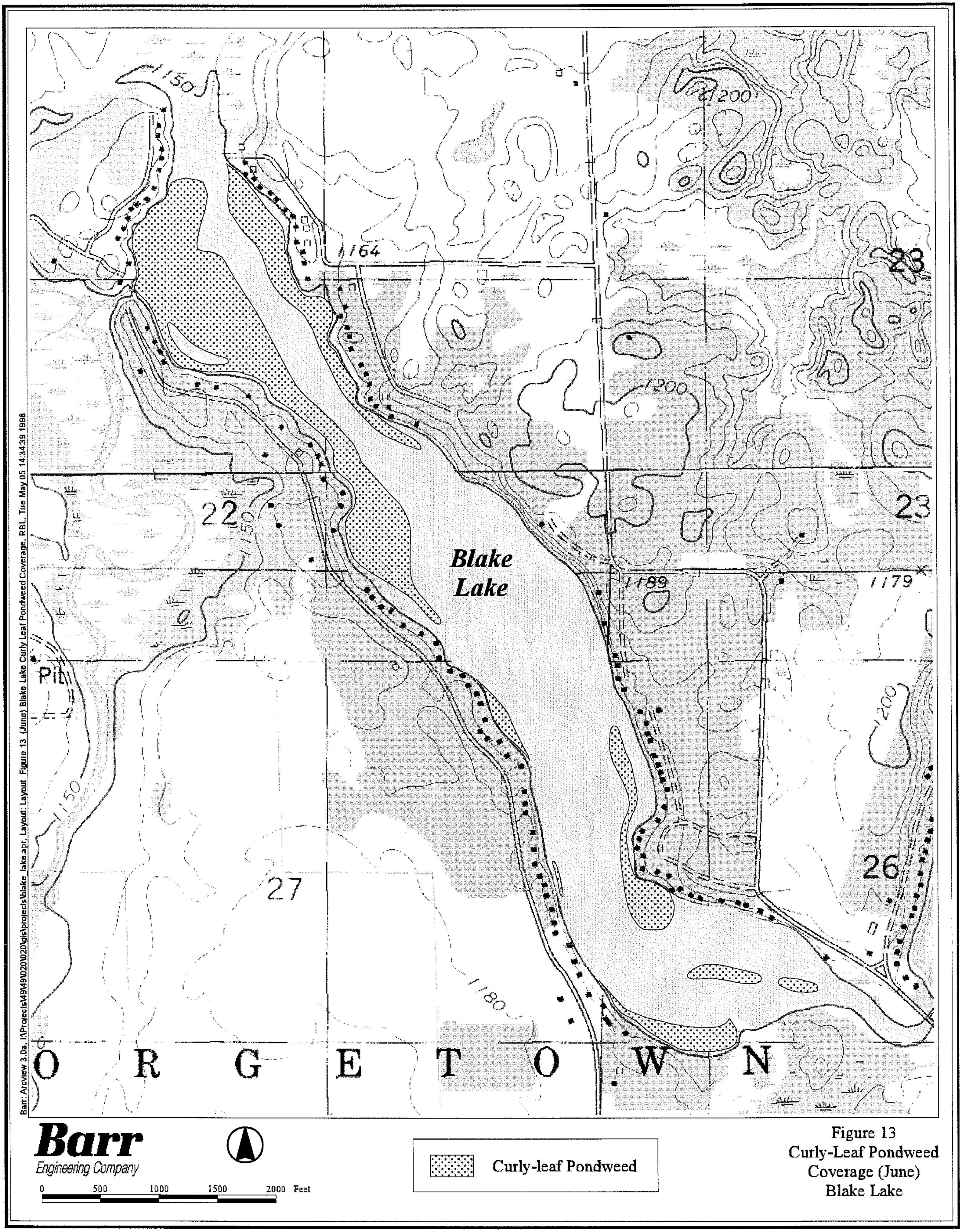
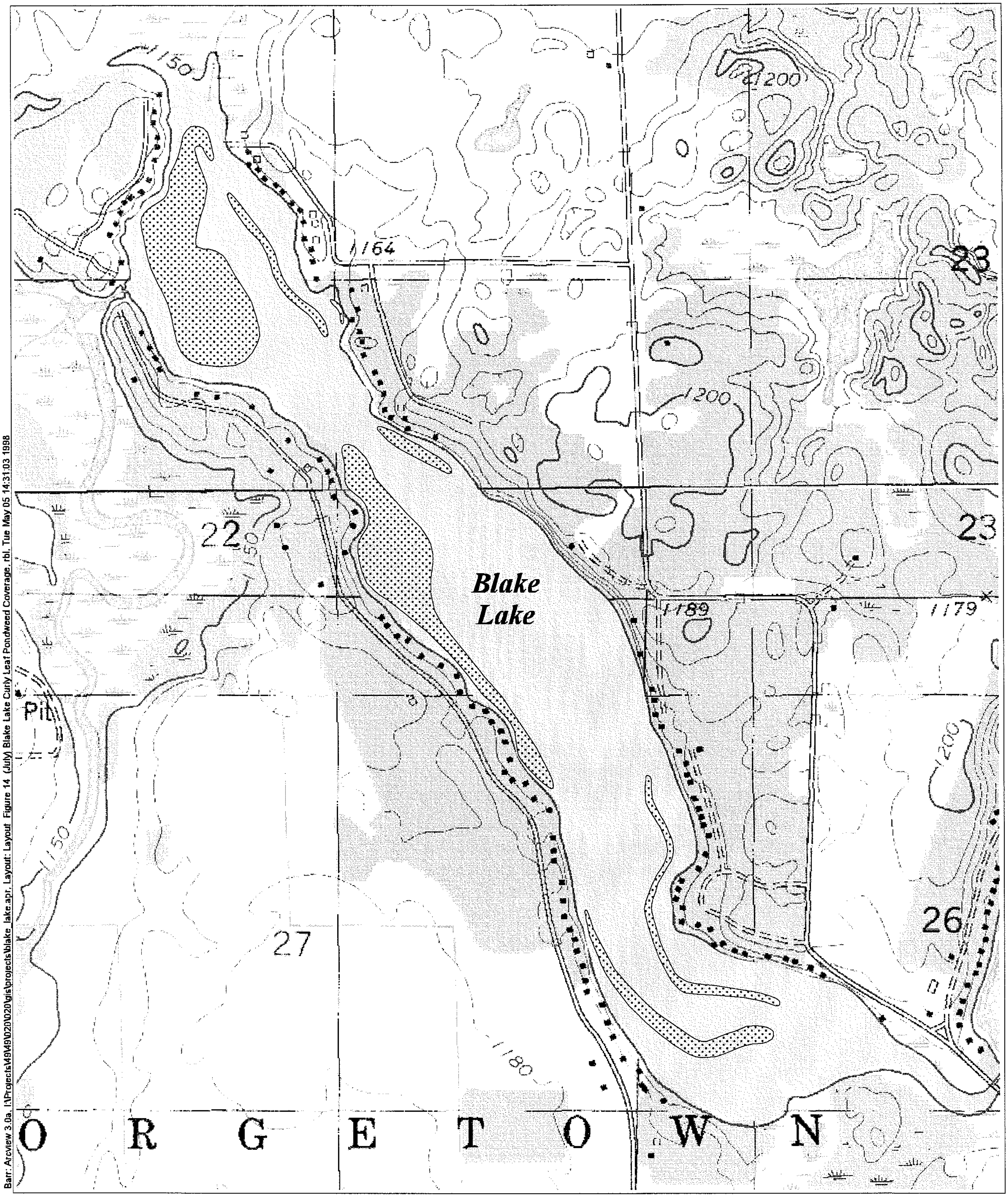


Figure 13
Curly-Leaf Pondweed
Coverage (June)
Blake Lake



Barr: Arcview 3.0a, I:\Projects\49\49\020\020\gis\projects\blake_lake.apr, Layout: Layout Figure 14 (July) Blake Lake Curly Leaf Pondweed Coverage, rbl, Tue May 05 14:31:03 1998

Barr Engineering Company

0 500 1000 1500 2000 Feet

Curly-leaf Pondweed

Figure 14
Curly-Leaf Pondweed
Coverage (July)
Blake Lake

6.0 Developing a Macrophyte Management Plan

A macrophyte management plan is an orderly approach to plant management. It helps define the problem, set priorities, develop management strategies, and evaluate progress. As an educational tool, it can describe the what, how, why, and where of management techniques. As a team effort, a plan can focus community involvement. A successful macrophyte management plan is built on five principles:

- Define the problem
- Establish goals
- Understand plant ecology
- Consider all the techniques
- Monitor the results

These five principles were used to develop a macrophyte management plan for Blake Lake.

6.1 Define the Problem

The combined effects of lake morphology and a relatively high nutrient input from the lake's watershed have resulted in a healthy and diverse macrophyte community in the lake. Several dense plant growths were observed, although much of the lake noted a moderate growth. The dense plant growths cause navigational problems for riparian owners and make it difficult for them to gain access to the lake. Therefore, navigation channels are needed in the dense plant growth areas to provide lake access to riparian residents.

The moderate plant growth noted in much of the lake provides optimum habitat conditions for the lake's fishery. Submersed aquatic plants influence both fish distribution and abundance by creating structurally complex habitats (Crowder and Cooper, 1979) that affect predator-prey relationships (Barnett and Schneider, 1974; Moxley and Langford, 1982). Total fish abundance can be substantially higher in areas with aquatic plants than in areas without plants (Laughlin and Werner, 1980; Holland and Huston, 1984).

However, foraging success of predators generally declines as plant density increases (Reynolds and Babb, 1978; Savino and Stein, 1982; Durocher, Provine, and Kraai, 1984; Wiley, et al., 1984). Extensive forage cover reduces hunting success of predator species, limiting growth rates and decreasing length/weight condition values. This can lead to an increase in numbers of forage species, which increases competition for food by the foraging species and ultimately leads to an over-crowded condition. Vegetation also serves as cover for macroinvertebrates, and forage species ability to find food may be decreased, intensifying intraspecific and interspecific competition for food. Abundant cover may also allow forage species to harass nesting predators, reducing spawning successes necessary to offset predator mortality rates (Madsen, et al., 1994). Additionally, water quality influenced by dense macrophyte or algae stands often affects fish growth and reproductive success, especially where photosynthesis causes pH shifts above 10. Largemouth bass, for example, become lethargic at high pH, and will not feed or spawn (Buck and Thoits, 1970). The data underscore the importance of preserving the current overall moderate plant density within the lakes to provide optimum conditions for the lakes' fisheries. Density increases within the plant communities would likely result in negative impacts to the lakes' fisheries.

The presence of curly-leaf pondweed in Blake Lake is of concern because curly-leaf pondweed is an exotic species (i.e., not native to this region) and frequently causes problems by outcompeting native plants and developing objectionable dense growths. Although curly-leaf pondweed is not currently considered a problem in most areas of growth (i.e., low density and occurring concurrently with several native species), some areas of growth are very dense (i.e., densities of 3 to 5 on a scale of 0 to 5, with 0 representing no growth and 5 representing maximum density). Therefore, present curly-leaf growth areas may require management to reduce growth in areas of objectionable density and prevent the occurrence of additional objectionable curly-leaf growth areas.

6.2 Establish Goals

The Blake Lake Protection and Rehabilitation District has established six aquatic plant management goals for Blake Lake:

- Improve navigation within the lake through areas containing dense plant beds
- Remove or limit current exotic plants (i.e., curly-leaf pondweed)
- Preserve native species and prevent introduction of additional exotic species
- Preserve and/or improve fish and wildlife habitat
- Improve quality of resource for all to enjoy (i.e., people, fish, wildlife)
- Minimize disturbance of sensitive areas (i.e., fish)

The goals are consistent with Wisconsin Wetland Water Quality Standards stated in Chapter NR 103.03:

"To protect, preserve, restore and enhance the quality of waters in wetlands and other waters of the state influenced by wetlands, the following water quality related functional values or uses of wetlands, within the range of natural variation of the affected wetland, shall be protected: ...
(e) Habitat for aquatic organisms in the food web including, but not limited to fish, crustaceans, mollusks, insects, annelids, planktonic organisms and the plants and animals upon which these organisms feed and depend upon for their needs in all life stages; (f) Habitat for resident and transient wildlife species, including mammals, birds, reptiles and amphibians for breeding, resting, nesting, escape cover, travel corridors and food: and (g) Recreational, cultural, educational, scientific and natural aesthetic values and uses."

6.3 Understand Plant Ecology

Macrophyte management alternatives are based upon an understanding of plant ecology. Understanding the biology of aquatic plants and their habitat requirements is necessary to effectively manage plants. Effective management is necessary to maintain the delicate balance of preservation of fish and wildlife habitat and concurrently provide reasonable lake-use opportunities to area residents. The following discussion considers aquatic plant ecology and its relationship to macrophyte management alternatives.

The biology of aquatic plants and their habitat requirements are inseparably interrelated. The habitat requirements of plants are divided into two general groups, the living group (biotic) and the nonliving group (abiotic). The following discussion of plant habitat requirements is based upon Nichols (1988).

The biotic group contains the predators, parasites, and other organisms which depend upon or compete with an organism for their livelihood. These interrelationships form the basis for biological plant management methods.

The abiotic factors form the basis of plant control techniques involving habitat manipulation, and include those physical and chemical attributes which are necessary for plant growth and development: light, bottom type, water, temperature, wind, dissolved gases and nutrients. Light, water, temperature, dissolved gases and nutrients relate to the plant's ability to carry out the vital processes of photosynthesis and respiration. Bottom type and wind relate to specific physical locations where a plant can grow. The following discussion will show the relationship between critical habitat requirements and possibilities for management.

Both the quantity and quality of light influence plant growth. Light in the red and blue spectral bands is used for photosynthesis; low and high light intensities inhibit photosynthesis.

Management activities that make use of shade and dyes, for example, are based on limiting light intensity or changing the spectral qualities of the light. Deepening the lake through dredging or damming is another method of altering the light available to a plant, as light is naturally attenuated in water and the spectral qualities changed.

In the aquatic environment, water is available in abundance and is, therefore, often overlooked as being critical for aquatic plants. Yet, aquatic plants are adapted to growing in an environment with an abundant water supply and are, therefore, sensitive to water stress. Macrophytes might be controlled by removing their water supply, resulting in the desiccation of the plant.

Plants are generally tolerant of a wide range of temperatures, and temperature fluctuations in the aquatic environment are smaller than in the surrounding aerial environment. Therefore, plant management schemes involving temperature effects depend on artificially exposing aquatic plants to the harsher aerial environment, where not only temperature but desiccation and other factors aid in controlling plant growth.

The two gases of primary importance in the aquatic system are carbon dioxide and oxygen, which are used for photosynthesis and respiration, respectively. The availability of carbon in the form of free CO_2 or bicarbonate appears to influence the distribution of some plant species (Hutchinson, 1970). Although oxygen is many times limiting in the aquatic system, most plants are adapted to living in low oxygen conditions. Because the carbon dioxide reaction is so well buffered by an equilibrium with CO_2 in the air and because the plants are tolerant to low oxygen supplies, the success of any scheme to manage plants by altering the dissolved gases in water seems doubtful.

Aquatic plant problems are caused by nutrient enrichment of the sediment. Nitrogen and phosphorus are the two nutrients of prime concern (Vollenweider, 1968; Sawyer, 1947; Stewart and Rohlich, 1967). Gerloff and Krombholz (1966) and Gerloff (1969) point out that the concentration of nutrients in the habitat may not be related to the concentration in the plant, depending on the availability of the nutrient. Plants remove nutrients in excess of their needs and store excess nutrients (i.e., luxury consumption, Gerloff 1969). These excess nutrient supplies could be used at times when the plant undergoes nutrient stress. These factors inherent in the biology of the plant will have to be overcome when developing practical, in-lake methods of nutrient limitation for macrophyte control.

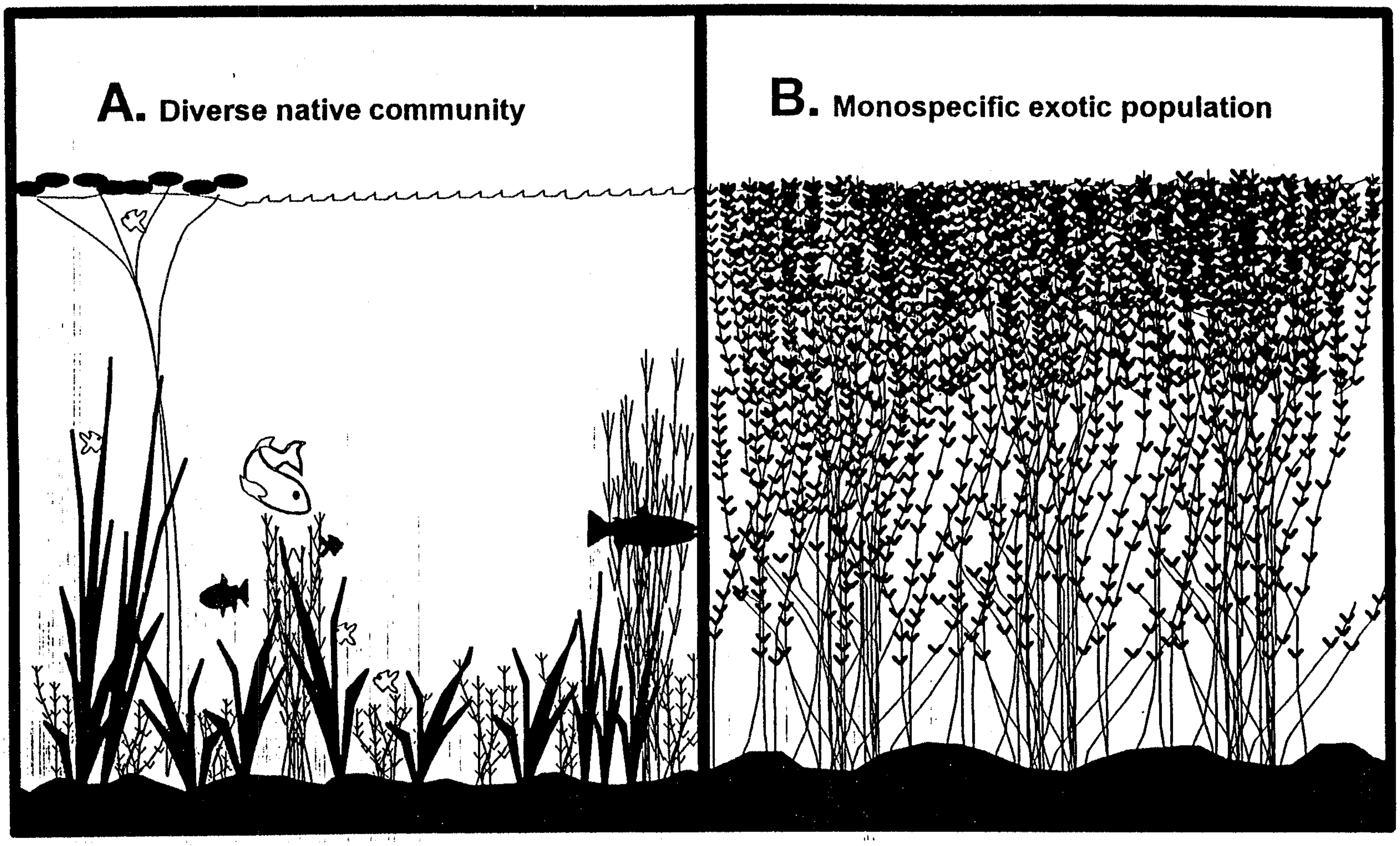
Wind and bottom type are physical conditions that may limit plant growth. Heavy winds tear and uproot the plant, and soil types that are too coarse or are not consolidated enough make rooting very difficult. Some bottom types are rich in nutrients essential for plant growth. Substrates may be altered by removing, covering, or nutrient inactivation.

By manipulating the plant's environment, management tries to induce these limiting conditions and thus restrict the growth of the plants.

Differences in growth patterns between exotic plants (i.e., not native to this area) and native plants indicate a possible need for management of exotic species to protect native communities. Native plant communities are typically dominated by growth forms that concentrate biomass below the surface of the water (See Figure 15A), contain a high diversity of species, and have low to moderate levels of biomass. Exotic plants typically follow a voracious growth pattern. Exotic species generally produce a dense canopy of vegetation at the air:water interface and develop high levels of biomass (See Figure 15B). Such a growth pattern interferes with use of the water resource by recreational-users and may eliminate the beneficial native plant community through shading (Smart, et al., 1996). Management to control the growth of exotic species is necessary to protect the native plant community and provide a reasonable use of the lake to recreational-users.

The exotic species of concern in Blake Lake is curly-leaf pondweed. Curly-leaf pondweed has unique life cycle adaptations which give it competitive advantages over many native aquatic plants. Unlike most native plants, curly-leaf pondweed may be in a photosynthetically active state even under thick ice and snow cover (Wehrmeister, 1978). Therefore, it is often the first plant to appear after ice-out. Tenacious growth results in the formation of dense mats by late spring which may crowd out native species and interfere with recreation. (Catling and Dobson, 1985). Curly-leaf usually senesces by early July, but it first forms small reproductive pods called turions (resembles a small pine cone) during late June. These turions disperse by water movement throughout a water body. Turions lay dormant during the summer when native plants are growing, and germinate in the fall when most native vegetation has senesced. Thus curly-leaf pondweed is able to use turions to invade new areas of a water body. The density of curly-leaf pondweed growth in a given year is influenced by winter conditions; winter months with heavy snow cover and thick ice conditions are often followed by less dense plant growth.

Large populations of curly-leaf pondweed can alter the nutrient dynamics of water bodies. As curly-leaf plants senesce in the summer, large amounts of vegetation fall to the lake bottom and decompose. This decomposition can increase internal nutrient loading in a water body, which in turn may cause an increase in algal growth.



Source: Smart et al., 1996

Figure 15

Submersed Aquatic Plant Communities

Native species appear to compete well with curly-leaf pondweed, restricting its growth within Blake Lake. However some areas within Blake Lake contain very dense, objectionable growth areas of curly-leaf pondweed.

6.4 Consider All Techniques

Following a consideration of all possible management alternatives, feasible options may be identified for Blake Lake. The following discussion focuses on four types of aquatic plant management techniques currently used for macrophyte control. They include:

1. Physical
2. Mechanical
3. Chemical
4. Biological

6.4.1 Physical

Physical tactics typically used to manage aquatic plants are light manipulation and habitat manipulation. Habitat manipulation includes such techniques as overwinter lake drawdown, dredging, sand blanketing, the use of dyes, and nutrient limitation and inactivation (Barr, 1997).

Although light manipulation has been used in lakes with some success, its greatest utility has been found in managing dense vegetation in streams through streamside shading. Shading by use of different densities of shading cloth has resulted in decreased plant biomass. Natural shade from streamside vegetation has also reduced plant biomass along the stream course (Barr, 1997).

Lake level drawdown, particularly over winter, is commonly used to control nuisance aquatic plants in northern North America. Biomass studies before and after drawdown have demonstrated that drawdown was effective in controlling plants down to the depth of drawdown, but had no effect at greater depths. While drawdown is an extremely effective technique for some species, it may actually stimulate the growth of other species. (Madsen and Bloomfield, 1992). A study of Trego Flowage (Washburn County, Wisconsin) indicated the benefits of drawdown were temporary, and the same species of plants returned in about their former abundance within a few years (Barr, 1994).

Another commonly-used group of physical control techniques uses benthic barriers, weed rollers, or sediment alteration to inhibit the growth of aquatic plants at the sediment surface. Benthic barriers are generally applied to small areas (Barr, 1997). These materials are anchored to or sink to the lake bottom and smother plants to prevent their growth. Negatively buoyant (i.e., sink in water) screens are available in rolls 7 feet wide and 100 feet long. The screens can be laid on the lake bottom in the spring and removed in the fall. These screens can be reused for about 10 years. Bottom barriers would be appropriate for controlling aquatic plant nuisances for small applications such as adjacent to a boat dock or from small swimming areas. The barriers are safe, effective, non-chemical control using a simple technology. The cost is reasonable (i.e., approximately $270 per bolt, 7' x 100') and the barriers are reusable for about 10 years (Osgood, 1997).

Weed rollers or 'Automated Unintended Aquatic Plant Control Devices' are motor-drive rollers (round bars) placed on the lake bottom and roll over and uproot plants. The rollers are 25-to-30 feet long and are centered on the end post of a dock. The rollers roll in a circular pattern, normally covering 270^0 or using a 25-foot roller over a full circular area. Weed rollers would be appropriate for controlling aquatic plant nuisances in small areas such as adjacent to a boat dock or for small swimming areas. The rollers are safe, effective non-chemical control using a simple technology. The cost is reasonable (approximately $2,000 to $2,500, and the device can be shared by several people) (Osgood, 1997).

Sediment inactivation has included the application of phosphorus binding substances to sediments (i.e., such as lime slurry). The growth of aquatic plants is inhibited by the reduced availability of phosphorus in sediments (Barr, 1997)

6.4.2 Mechanical

Mechanical control involves macrophyte removal via harvesting. Small scale harvesting may involve the use of the hand or hand-operated equipment such as rakes, cutting blades, or motorized trimmers. Individual residents frequently clear swimming areas via small scale harvesting. Large-scale mechanical control often uses floating, motorized harvesting machines that cut the plants and remove them from the water onto land, where they can be disposed. All plants that are mechanically controlled should be removed from the lake (Barr, 1997)

6.4.3 Chemical

Chemical aquatic vegetation management programs are widespread, being the preferred method of control in many areas. Chemical control involves the use of a herbicide (i.e., a plant-killing chemical) that is applied in liquid, granular, or pellet form. The aquatic plants (sometimes only stems and leaves) die and decompose in the lake. To reduce human exposure to the chemicals, temporary water-use restrictions are imposed in treatment areas whenever herbicides are used. Only herbicides for aquatic use are allowed, and any use of an herbicide requires a WDNR permit (Barr, 1997).

6.4.4 Biological

Biological control involves the use of a biological control agent to control macrophyte growth. Biological controls include predation by herbivorous fish, mammals, waterfowl, insects and other invertebrates, diseases caused by microorganisms and competition from other aquatic plants (Little, 1968). The most widely used biological control agent is herbivorous fish, particularly grass carp. Weevils have been used experimentally to control Eurasian Watermilfoil (Creed, et al., 1995; Newman, et al., 1995).

A summary of aquatic macrophyte control techniques available in Wisconsin are summarized in Table 3.

6.5 Monitor the Results

A monitoring program to evaluate results will provide information to determine whether the management program results in goal achievement. Monitoring will determine changes, both desirable and undesirable, and detect problems before they become unmanageable.

Table 3 Control Techniques for Aquatic Plants: Procedure, Cost, Advantages and Disadvantages (Modified from a Summary Prepared by the Vermont DNR)

Control Technique	Procedure	Cost	Advantages	Disadvantages
Mechanical and Physical Removal			+Immediate plant removal and creation of open water +No interference with water supplies or water-use	– Creates plant fragments – Usually disturbs sediments, affecting biota and causing short-term turbidity – Plant disposal necessary
Harvesting	Plant stems and leaves cut up to 8 ft below water surface, collected and removed from lake	Cut from 1 to 2 ac/day @ $1,200/day New machine: $80,000-100,000+	+Relatively low operational cost	– Can get regrowth within 4 weeks – Removes small fish, turtles, etc.
Hydro-raking	Mechanical rake removes plants up to 14 ft below water surface and deposits them on shore	Rake up to 1 ac/day @ $1,500–$2,000/ac	+Longer lasting control than harvesting because of root removal	– Regrowth by end of growing season
Rotovating	Sediment is "tilled" to a depth of 4"-6" to dislodge plant roots and stems Can work in depths up to 17 ft	Can do up to 2-3 ac/day @$700–$1,200/ac Cost of new machine is $100,000+	+Immediate 85 percent – 95 percent decrease in stem density +Up to 2 years control +Frequently done in fall when plant fragments not viable	
Hydraulic Dredging	Steel cutter blade dislodges sediment and plants; removed by a suction pump	$2,500/ac and up Cost of new machine is $100,000+	+90 percent effective at root removal, with plant regrowth probable within 1 year	– Expensive

Table 3 Control Techniques for Aquatic Plants: Procedure, Cost, Advantages and Disadvantages (Modified from a Summary Prepared by the Vermont DNR) -- (cont.)

Control Technique	Procedure	Cost	Advantages	Disadvantages
Diver-operated Suction Harvesting	Scuba divers use 4" suction hose to selectively remove plants from lake bottom Plants disposed of on shore	Cost is $800–$10,000/ac depending on cost of divers, type of sediments, travel time, etc. Cost of new machine $20,000+	+Up to 97 percent effective at removing plant roots and stems +1–2 years of control +Can work in areas with underwater obstruction	– Effectiveness varies greatly with type of sediment – Slow and labor intensive – Expensive – Potentially hazardous because of scuba
Handpulling	Plants and roots are removed by hand using snorkeling and wading Plants disposed of on shore	Variable, depending on volunteers; divers cost $15-$60/hr	+Most effective on newly established populations that are scattered in density +Volunteers can keep cost down +Long term control if roots removed	– Too slow and labor intensive to use on large scale – Short-term turbidity makes it difficult to see remaining plants
Chemical Treatment			+ Doesn't interfere with underwater obstructions	– Affects water-use; can be toxic to biota – Plants remain in lake and decompose, which can cause oxygen depletion late in the season
2,4-D (Aquakleen, Aquacide)	Systemic herbicide available in liquid and pellet form that kills plants by interfering with cell growth and division Can be applied at surface or subsurface in early spring as soon as plants start to grow, or later in the season	$350–$700/ac depending on plant density and water depth; cost does not include collection or analysis of water samples, which may be required	+Under favorable conditions can see up to 100 percent decrease +Kills roots and root crowns +Fairly selective for EWM +Control for up to 2 years possible	– Toxic to fish – Potential risk to human health remains controversial – Plants decompose over 2-3 weeks

Table 3 Control Techniques for Aquatic Plants: Procedure, Cost, Advantages and Disadvantages (Modified from a Summary Prepared by the Vermont DNR) -- (cont.)

Control Technique	Procedure	Cost	Advantages	Disadvantages
Tripclopyr (Garlon 3A)	Liquid systemic herbicide that kills plants by interfering with hormones that regulate normal plant growth	$75/gal or $1200-$1700/ac, depending on water depth, concentration of chemical, etc. Sample collection cost not included	+Effectively removes up to 99 percent of EWM biomass 4 weeks after treatment +Control may last up to 2 years +Fast-acting herbicide +Kills roots and root crowns +Fairly selective for EWM	– No domestic-use of water within 1 mile of treated area for 21 days after treatment – No fishing in treated area for 30 days after treatment – Expensive – Experimental
Fluridone (Sonar)	Systemic herbicide available in liquid and pellet form that inhibits a susceptible plant's ability to make food Can be applied to surface or subsurface in early spring as soon as plants start to grow	$500-$1500/ac depending on water depth and formulation Sample collection cost not included	+Can be applied near water intakes if concentration is less than 20 ppb +Under favorable conditions susceptible species may decrease 100 percent after 6-10 weeks +Control lasts 1-2 years depending supplemental hand removal +Because slow-acting, low oxygen generally not a problem	– Long contact time required; may take up to 3 months to work – Potential risk to human health remains controversial – Not selective for milfoil – Spot treatments generally not effective
Endothall (Aquathol and Aquathol K)	Granular (Aquathol) and liquid (Aquathol K) kills plants on contact by interfering with protein synthesis Can be applied to surface or subsurface when water temperature is at least 65°F	$300-$700/ac depending on treatment area and use of adjuvants Sample collection cost not included	+Under favorable conditions can see up to 100 percent decrease +Fast-acting herbicide	– Regrowth within 30 days – Not selective for milfoil – Does not kill roots; only leaves and stems that it contacts – No swimming for 24 h, no fishing for 3 days

Table 3 Control Techniques for Aquatic Plants: Procedure, Cost, Advantages and Disadvantages (Modified from a Summary Prepared by the Vermont DNR) -- (cont.)

Control Technique	Procedure	Cost	Advantages	Disadvantages
Diquat (Reward)	Liquid kills plants on contact by interfering with photosynthesis Can be applied to surface or subsurface when water temperature is at least 65°F	\$200-\$500/ac Sample collection cost not included	+Fast-acting herbicide +Relatively cheap per acre	– Retreatment within same season may be necessary – Not selective for milfoil – Does not kill roots; only leaves and stems that it contacts – No swimming for 24 h, no drinking for 14 days – Toxic to wildlife

7.0 Macrophyte Management Plan for Blake Lake

The management plan for Blake Lake is based upon the need to: (1) provide a reasonable access to the lake by users living adjacent to very dense plant growths, (2) control curly-leaf pondweed growth in the lake, (3) preserve current macrophyte community (i.e., native species and moderate plant density), and (4) prevent the introduction of additional exotic species to the lake. Details of the management plan follow.

7.1 Harvesting Plan

A harvesting plan is recommended for Blake Lake to provide navigation channels to lake-users living adjacent to very dense plant growths. The harvested navigation channels will concurrently provide benefits to the lakes' fisheries. Benefits include cruising lanes for fish (e.g., bass) and increased invertebrate populations. The increased numbers of invertebrates will result from an increase in the edge area within the dense plant beds. Studies have shown that larger quantities of invertebrates live at the edge of dense macrophyte beds than in the middle. Consequently, cutting channels through dense plant beds will increase the edge area, thus increasing invertebrate numbers. Increased invertebrate numbers result in increased quantities of food for the fish (Pellet 1998). Cutting channels through plant beds also makes it easier for fish to move through the plant bed and capture their prey (Marshall 1990).

The harvesting plan for Blake Lake is presented in Figure 16. The harvested channel width will be restricted to 20 feet because most harvested areas include areas that are designated as fish sensitive areas by the area fisheries manager (See Figure 17). The restriction will minimize disturbance to the fishery and while providing navigation channels for riparian residents. Chemical treatment is not allowed in fish sensitive areas.

The harvested area totals approximately 5 acres and is expected to cost approximately $5,000 per harvesting event. The cost estimate is based upon the assumption that harvesting will be completed by a commercial company, harvesting will occur at a rate of approximately 0.1 acres per hour and at a cost of approximately $100 per hour. Harvesting frequency will depend upon need (i.e., frequency needed to keep navigational channels open) and available resources (i.e., monies available for harvesting).

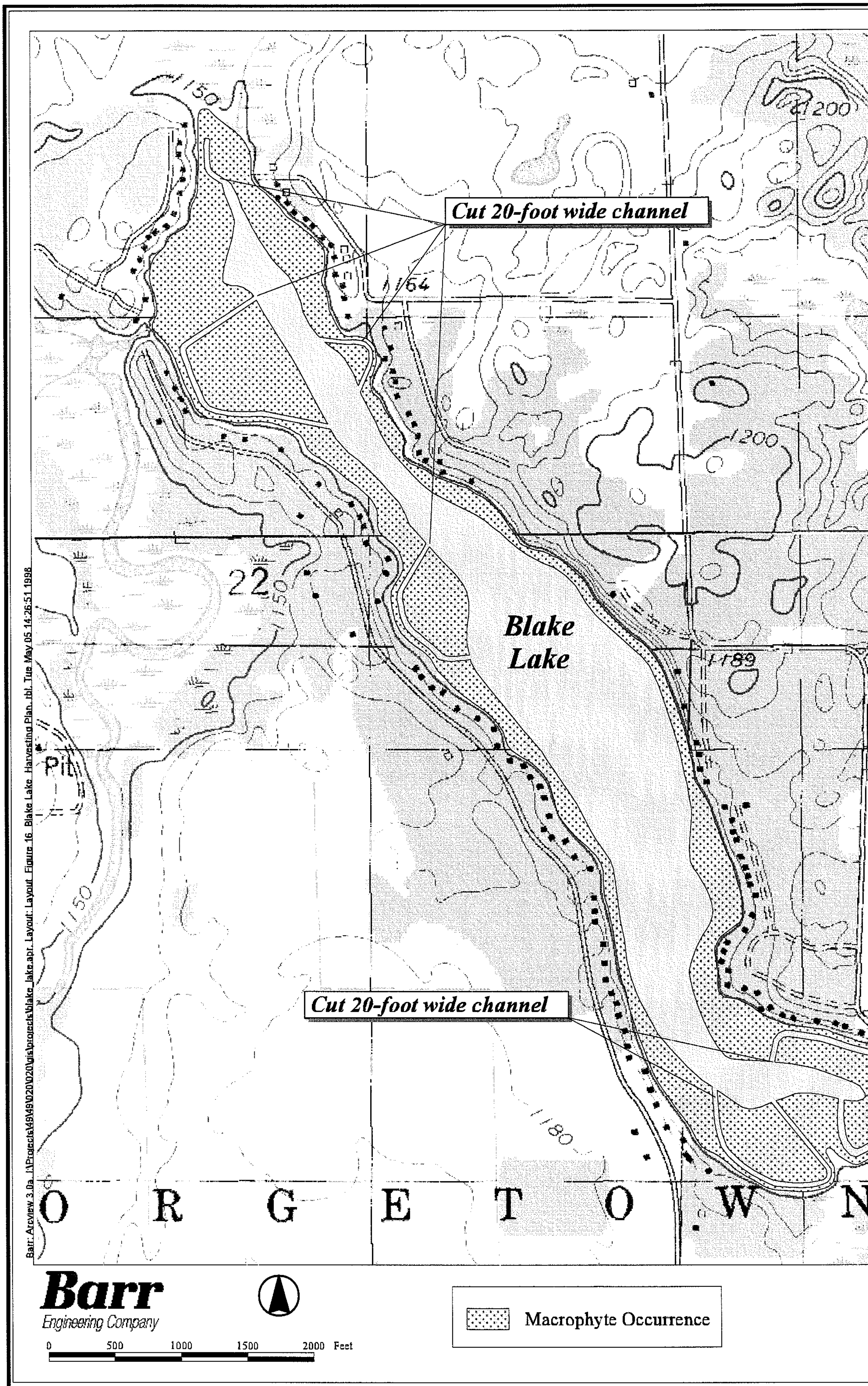
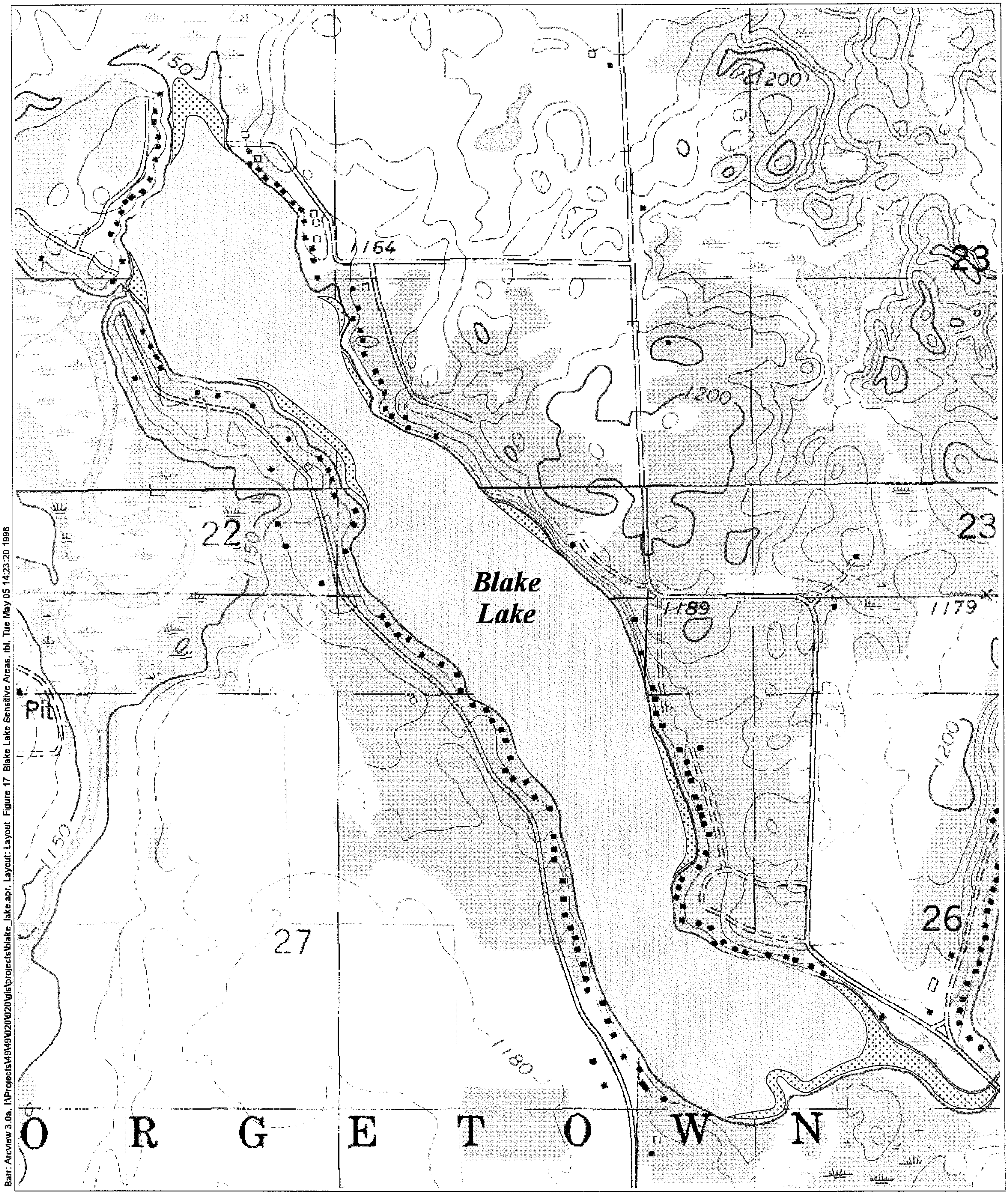


Figure 16
Harvesting Plan
Blake Lake



Barr
Engineering Company

0 500 1000 1500 2000 Feet

Sensitive Areas

Figure 17
Sensitive Areas
Blake Lake

7.2 Curly-leaf Pondweed Control

A treatment plan is recommended to minimize curly-leaf pondweed growth in Blake Lake (See Figure 18). The treatment program will protect native species and preserve current native communities. Treatment will consist of an early spring herbicide treatment (i.e., Reward, active ingredient = Diquat) of curly-leaf pondweed growth areas (See Figures 13 and 14) that are not located in fisheries sensitive areas (See Figure 17). Approximately 60 acres containing curly-leaf pondweed is recommended for treatment. The 60 acre curly-leaf pondweed treatment area has been subdivided into three 20-acre treatment areas, A, B, and C (See Figure 18). Each twenty acre treatment area will be treated once every three years (e.g., area A will be treated during 1999, area B during 2000, and area C during 2001). Treatment will occur during May when the curly-leaf pondweed is actively growing and the lake water temperature is at least 15 degrees Celsius. The estimated annual cost of treatment is $7,800. The cost estimate is based upon the assumption that a commercial applicator will complete the treatment at an estimated cost of $390 per acre and an estimated area of 20 acres will be treated.

7.3 Education of Lake Homeowners

An education program will be completed to help area residents achieve an understanding of:

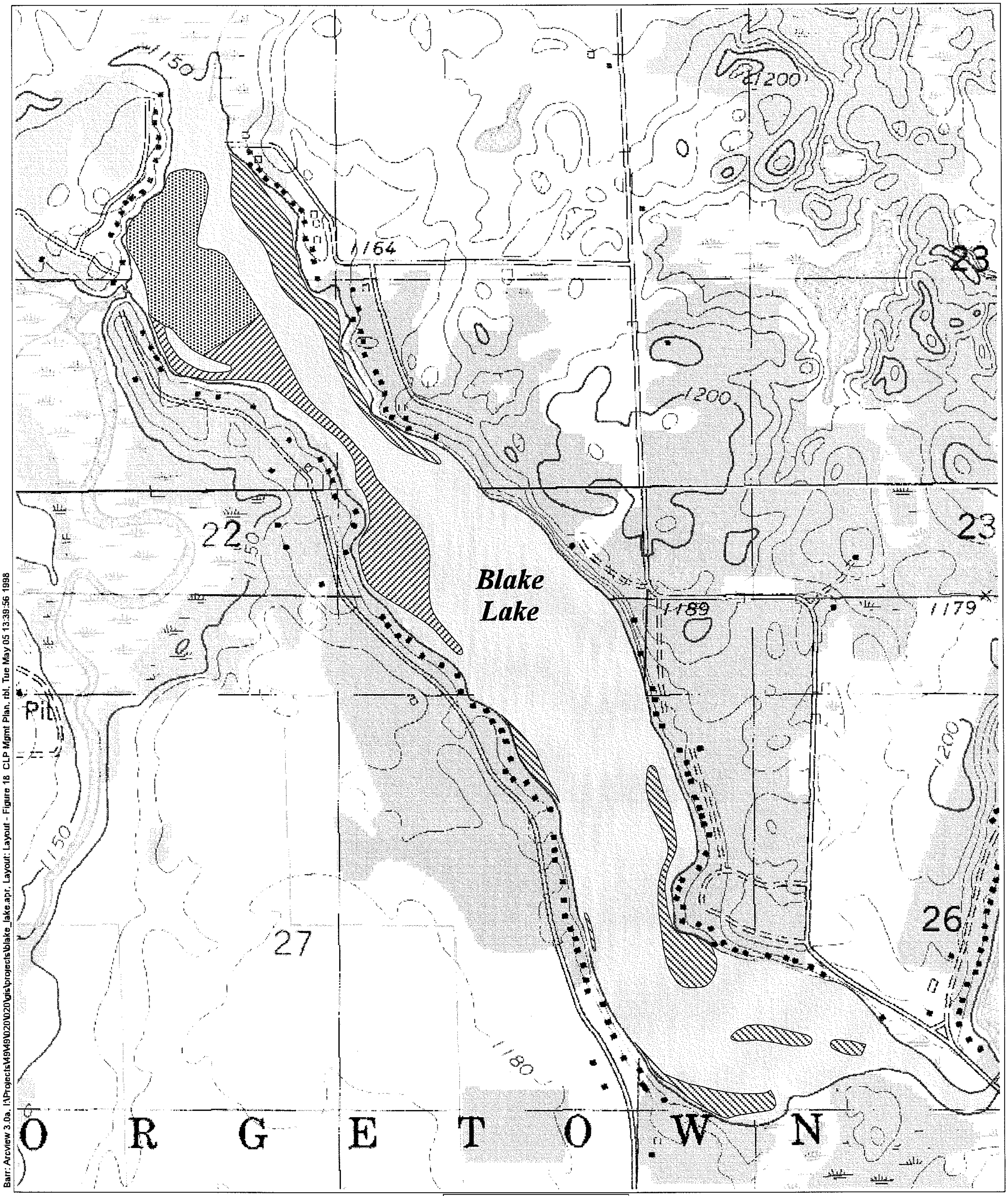
- The functions and roles of native species/native communities within Blake Lake.
- The exotic species, curly-leaf pondweed, and its threat to the native plant community within Blake Lake.

The education program will be completed by the Blake Lake Protection and Rehabilitation District with assistance from the WDNR and the Polk County Land Conservation Department.

7.4 Control Introduction of Exotic Species to the Lake

A plan to control the introduction of exotic species was developed to protect the native species communities within the lakes. The plan involves education of lake-users and constant vigilance by lake residents. The education component involves:

- Posting signs at boat launches reminding lake-users to remove aquatic plants from boat trailers before entering and before leaving the lakes to prevent the introduction of unwanted species.



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Barr
Engineering Company

0 500 1000 1500 2000 Feet

Treatment Period

No. 1
No. 2
No. 3

Figure 18
Curly-leaf Pondweed
Management Plan
Blake Lake

- Volunteers from the Blake Lake Protection and Rehabilitation District could be present at the boat launches during busy weekends in June through August to inspect boats and trailers, distribute educational flyers, and advise boat owners to always remove vegetation from boats and trailers before entering or leaving the lakes.

- Information concerning exotic species and a reminder to remove plants from boat trailers could be displayed on bulletin boards at the boat launches. The bulletin board could be used to encourage boaters to pick up a free brochure describing exotic species, the potential dangers of exotic species, and the importance of vegetation removal to prevent exotic species introduction. The brochure could be placed in a dispenser located near the boat launch.

- Professionals such as WDNR staff, Polk County staff, or a consultant could hold informational meetings. The meetings could provide information about exotic species, methods of exotic species introduction, problems caused by introduction of exotic species, and prevention of exotic species introduction. Training to identify exotic species such as curly-leaf pondweed and Eurasian watermilfoil could be provided by a professional.

Creation of a Shoreline Weed Attack Team (SWAT) to inspect the littoral areas of the lakes for possible invasion by exotic species is recommended. A combination of planning and teamwork by lake residents will protect the lakes from exotic species invasion. The two most likely points for exotic species introduction are the public boat launch and the water inlet to the lake (Straight River). The lake inlet and boat launch area should be inspected regularly throughout the summer for possible pioneer Eurasian Watermilfoil or curly-leaf pondweed or other exotic vegetation establishing in that area. An inspection schedule could be established for SWAT volunteers to insure that regular inspection occurs.

Lastly, constant vigilance by lake residents and/or SWAT volunteers will be needed to identify changes in curly-leaf pondweed growth within the lake and/or the establishment of Eurasian watermilfoil or other exotic species in the lake. The Blake Lake Protection and Rehabilitation District could form SWAT teams to conduct annual surveys of the entire littoral area of each lake. The team could establish an inspection schedule and plan a cookout/social gathering to follow completion of the inspection. Individual exotic plants identified by the survey should be removed by covering with a fine mesh bag[1] and the root crown of the plant should be removed whenever possible. This is likely to require snorkeling equipment. The plants that are dug up should be removed from the lake and disposed of where they have no chance of being washed into the lake. The areas with beds of exotic plants (e.g. curly-leaf pondweed, Eurasian watermilfoil) should be marked clearly on a map and could also be supplemented with markers along the shoreline. A treatment approach for the beds should be identified and a WDNR permit for treatment obtained.

7.5 Evaluation Program

An evaluation program is recommended to monitor the effectiveness of the lake management plan. A macrophyte survey of each lake should be completed once every five years. The methodology used for the 1997 survey of the lakes should be used for each survey. Survey results should be compared with results of previous surveys to determine changes in the macrophyte community. The survey results will indicate the effectiveness of macrophyte management plan implementation and will identify any needed modifications of the plan.

[1]Nitex - a nylon mesh used for plankton nets can be purchased from aquatic suppliers, such as WILDCO and mesh bags could be sewn from the material. A 300 micron mesh would be adequate for capturing plants, including plant fragments.

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