BLUE MOUNTAIN LAKE
FINAL REPORT

NES

Ecological Services Division of Robert E. Lee & Associates, Inc.

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1.0 INTRODUCTION

Blue Mountain Lake is an approximate ten-acre seepage lake located in Waupaca County, Wisconsin (Figure 1-1). The lake has a maximum depth of nine feet and an average depth of three feet. In 1989, Blue Mountain Lake Limited (BMLL), a non-profit organization, was formed by interested lake residents to "engage in such activities as necessary to protect and improve the water quality of Blue Mountain Lake". Currently, BMLL operates an aeration system during the winter months to oxygenate the lake and prevent fish kills. Anecdotal information from lake residents and users has suggested that aquatic vegetation in some areas of the lake is at nuisance levels, and there is a desire among members of BMLL to develop a comprehensive Lake Management Plan that addresses long-term management goals.

To continue the process of protecting Blue Mountain Lake water quality, BMLL submitted a Lake Management Planning Grant Study application to the Wisconsin Department of Natural Resources (WDNR) in January of 1999. The WDNR awarded the grant to BMLL in April of 1999. The objective of the Blue Mountain Lake Planning Grant Study is to provide a baseline characterization of the lake while identifying lake management issues and needs. To meet this objective, the lake study includes:

1. Description of the physical and chemical characteristics of the lake.
2. Development of a baseline understanding of existing water quality and aquatic vegetation distribution.
3. Definition of the lake's tributary watershed.
4. Identification of existing land uses in the Blue Mountain Lake watershed and examination of the impacts of existing land uses on water quality.
5. Mapping of historic sediment accumulation in the lake, estimation of depositional rates, and definition of potential sources of sediment.
6. Development of comprehensive lake management goals and objectives including alternative lake management strategies.

A description of the study methodologies is provided in Section 2.0, followed by presentation and discussion of the results in Section 3.0. Section 4.0 provides the study conclusions including a summary of the findings and a discussion of future lake management options.

2.0 METHODOLOGY

2.1 Public Education and Involvement Program

Prior to project start-up (i.e., June 5, 1999), NES attended a BMLL meeting to present goals and objectives of the lake planning project and obtain input from BMLL members regarding existing concerns. The primary concerns of the organization members were excessive aquatic vegetation growth and limited recreational opportunities.

On July 15, 2000, NES attended a second BMLL meeting to disseminate information regarding the status of the project and work completed to that point. An update was provided for each of the lake study tasks.

2.2 Watershed Definition and Existing Land Coverages

Panchromatic 1992 digital orthophotography was obtained from the North American Photography Program and incorporated into a Geographic Information System (GIS) database containing the United States Geologic Survey (USGS) 1:24,000 scale topographic quadrangle maps for the Blue Mountain Lake Watershed (i.e., Symco Quadrangle). The orthophotography and topographic maps were used to define the preliminary watershed boundary and land coverages within the watershed. The preliminary data was then verified during a January 18, 2000 field review of the watershed.

2.3 Nonpoint Source Phosphorus and Sediment Loading Analysis

Acreages for each land cover type were input into the phosphorus loading module of Version 2.00 of the Wisconsin Lake Model Spreadsheet (WILMS). WILMS is a lake water quality planning tool developed by the WDNR (Panuska et al. 1994). The output from the WILMS model was used to partition the total phosphorus load for Blue Mountain Lake into the various land cover categories.

To assist in quantifying the rate of sediment accumulation in Blue Mountain Lake, sediment-loading estimates for each land cover type were also calculated and used to determine an annual sediment load resulting from the tributary watershed. Loading coefficients were adapted from loading estimates based upon watershed monitoring conducted in northern Virginia and contained in an unpublished report prepared by the Northern Virginia Planning District Commission (1979).

2.4 Point Source and Septic System Review

An analysis of potential point source discharge sources within the Blue Mountain Lake Watershed was conducted through watershed field reviews and communication with lake residents and users. To examine potential septic system impacts, WILMS was used to model septic system phosphorus contribution to Blue Mountain Lake. WILMS is equipped with a septic system loading module that uses estimates of the number of residences on the lake, average number of individuals per residence, number of seasonal versus permanent residences, and phosphorus retention capability of the soils to calculate the annual phosphorus load from septic systems. A Septic System Questionnaire (Appendix A) was distributed to lake property owners to assist in collecting the information necessary for the septic system modeling.

2.5 Water Quality Monitoring

2.5.1 Water Quality Data

Blue Mountain Lake water samples were collected by NES on June 2, 1999, July 13, 1999, August 18, 1999, January 18, 2000, and April 19, 2000. All water samples were collected three feet below the surface and three feet above bottom at the deepest point in the lake (Figure 2-1). Water quality parameters analyzed included total phosphorus, dissolved phosphorus, chlorophyll *a*, total Kjehldahl nitrogen, nitrate/nitrite, ammonia nitrogen, total alkalinity, suspended solids, and calcium. The specific parameters analyzed for each water sample were based upon the WDNR Long Term Trends Lake Monitoring Methods. Field parameters and Secchi disk depth were also recorded during each water sampling event. Field parameters were measured using a Hydrolab Datasonde 4 Multiprobe and included pH, specific conductivity, and dissolved oxygen/temperature profiles.

2.5.2 Trophic State Index

Lakes are often characterized according to their trophic status. Trophic status is an indicator of the productivity of a waterbody, and is usually characterized as high productivity (eutrophic), medium productivity (mesotrophic), or low productivity (oligotrophic). Productivity is often characterized as energy production and consumption by the living organisms within a natural system. All lakes experience an aging process that progresses towards eutrophication; however, anthropogenic impacts such as excessive nutrient loading can accelerate the process and produce problems like excessive algal growth and poor water quality.

Carlson (1977) developed a Trophic State Index (TSI), wherein the trophic status of a lake can be estimated based on in-lake near surface measurements of chlorophyll *a* (which is an indicator of algal concentration), total phosphorus, or Secchi disk depth. Carlson TSI values were calculated for Blue Mountain Lake using the water quality monitoring data. In addition, the TSI values were compared to a qualitative water quality index developed by Lillie and Mason (1983) for Wisconsin lakes. Lillie and Mason defined ranges of chlorophyll a, total phosphorus, and Secchi disk depth that would correspond to the following water quality descriptors: excellent, very good, good, fair, poor, and very poor.

2.5.3 Phosphorus Sensitivity

Phosphorus sensitivity describes the susceptibility of a waterbody to increased phosphorus loading and considers factors such as lake morphology and existing trophic state. One method of evaluating phosphorus sensitivity is to determine whether phosphorus is the limiting nutrient in the system. The limiting nutrient is defined as the nutrient responsible for limiting primary production (e.g., algal growth). In general, when nitrogen-to-phosphorus ratios are greater than 15:1, phosphorus is considered the limiting nutrient in the lake system (Krenkel and Novotny 1980). When nitrogen-to-phosphorus ratios are less than 15:1, nitrogen is often the limiting nutrient. Lakes in which primary productivity is limited by phosphorus availability are more sensitive to increased phosphorus loading.

A second method of evaluating phosphorus sensitivity has been developed by the WDNR. The WDNR methodology incorporates the lake's morphology, hydrologic characteristics, and TSI values to produce a relative classification of the lake's susceptibility to additional phosphorus inputs. The WDNR analysis first separates the lakes into two major classes. Class I lakes are more sensitive to phosphorus inputs than Class II lakes. Lakes in each general classification are then further subdivided into management groups. The management groups are outlined in Table 2-1.

Table 2-1. WDNR phosphorus sensitivity classifications

Primary Classification	*Secondary Classification*	*Parameters*
Class I		*Stratified Lake and Flushing Rate <6*
	A	Existing Water Quality Fair to Excellent (TSI≤54)
	B	Existing Water Quality Poor to Very Poor (TSI>54)
	Ins	Data Insufficient to Assess Trophic Condition
	D	Stained, Dystrophic, or Aquatic Plant-Dominated Lake
Class II		Mixed Lake or Flushing Rate>6
	A	Existing Water Quality Fair to Excellent (TSI≤54)
	B	Existing Water Quality Poor to Very Poor (TSI>54)
	Ins	Data Insufficient to Assess Trophic Condition
	D	Stained, Dystrophic, or Aquatic Plant-Dominated Lake

2.6 Aquatic Vegetation Analysis

2.6.1 Transect Survey

A quantitative aquatic vegetation survey was conducted by sampling two transects located in the northern and southern lobes of Blue Mountain Lake on June 25, 1999 (Figure 2-2). On each transect, a ten-foot diameter circle was sampled within each of the four different depth ranges (Table 2-2). The maximum depth of sampling was determined through field observation of the approximate maximum depth of aquatic vegetation growth. At each sampling location, substrate type and species composition were recorded.

Table 2-2. Depth ranges for transect sampling of aquatic vegetation

Depth Code	**Depth Range (feet)**
1	0.0-1.5
2	1.5-3.0
3	3.0-5.0
4	5.0-10.0

A visual estimate of percent foliage cover for each species was also recorded at the sampling locations. Coverage is determined as the perpendicular projection to the ground from the outline of the aerial parts of the plant species and is typically reported as the percent of total area (e.g., substrate or water surface)


Indicates Depth Contour
Indicates Depth Measured
200
0
200
400 Feet

covered (Brower et al. 1990). For emergent and floating leaved vegetation, the percent of water surface covered was used in the visual estimate, and for submergent vegetation the percent of substrate covered was used. After the collection of field data, the Daubenmire Classification Scheme (Mueller-Dumbois and Ellenberg 1994) was used to rank each species observed according to estimated foliage cover (Table 2-3). By providing a range of percent foliage cover for each rank, the Daubenmire Classification Scheme helps to minimize errors due to observer bias, visual estimation, etc.

Table 2-3. Daubenmire classification scheme for ranking based upon estimated foliage cover

Percent Foliage Cover	Rank
0-5	1
5-25	2
25-50	3
50-75	4
75-95	5
95-100	6

The collected transect data was used to estimate *frequency of occurrence* and *relative frequency of occurrence* for each species observed. The *frequency of occurrence* is defined as the number of times a given species occurred on the eight observed transects. The *relative frequency of occurrence* is the frequency of that species divided by the sum of the frequencies of all species in the community (Brower et al. 1990).

2.6.2 Floristic Quality Assessment

A Florist Quality Assessment (FQA) was applied to the aquatic vegetation species list generated for Blue Mountain Lake using the methodology of Nichols (1999). FQA is a rapid assessment metric used to assist in determining the floristic and natural significance of a given area. The assessment system is not intended to be a stand-alone tool, but is valuable as a complementary and corroborative method of evaluating the natural quality of a site.

The primary concept in FQA is species conservatism. Each aquatic vegetation species for Blue Mountain Lake was assigned a coefficient of conservatism (*C*) ranging from 0 to 10. The coefficient of conservatism estimates the probability that a plant is likely to occur in a landscape relatively unaltered from what is believed to be pre-settlement condition. A *C* of 0 indicates little fidelity to a natural community, and a *C* of 10 is indicative of restriction to high quality natural areas. The FQA was applied sample location, a slotted soil recovery probe with a five-foot extension (9.5 feet total length) was used to examine the lake substrate. The substrate profile was sampled for texture, structure, and thickness.

3.0 RESULTS AND DISCUSSION

3.1 Watershed Definition

The Blue Mountain Lake Watershed is shown in Figure 3-1. A summary of the morphometric (i.e., lake shape) and hydrologic characteristics of Blue Mountain Lake are shown in Table 3-1. A small open water area north of the lake (Figure 3-1) was privately excavated approximately 15 years ago (Funk 2000, pers. comm.). Likely, the excavated open water area has limited surface water connection to the lake, with the only connection coming during spring flooding. Because of the lack of an obvious surface water connection between the lake and the excavated area, the land contributing surface water to the excavated pond was not considered part of the Blue Mountain Lake Watershed in the following analyses.

Table 3-1. Morphometric and hydrologic characteristics of Blue Mountain Lake

Parameter	Value
Lake Surface Area	9.8 acres
Lake Volume	29.4 acre-feet
Tributary Drainage Area	34.8 acres
Annual Watershed Runoff Volume	30.5 acre-feet
Annual Direct Precipitation Volume	3.1 acre-feet
Hydraulic Loading	33.6 acre-feet/year
Areal Water Load	3.42 feet/year
Drainage Basin to Lake Surface Area Ratio	3.6:1
Hydraulic Retention Time	0.88 years

The tributary drainage area for the Blue Mountain Lake Watershed is 34.8 acres, resulting in a drainage basin to lake surface area ratio (DB:LA) of 3.6:1 (Table 3-1). For comparison purposes, the mean DB:LA ratio for mixed seepage lakes in Wisconsin is 7.0:1 (Lillie and Mason 1983). Blue Mountain Lake, therefore, has a smaller than average drainage basin given its surface area.

A lake's retention time is the length of time required for the lake to undergo a complete exchange of water. Because Blue Mountain Lake is shallow, it has a relatively short retention time despite its small drainage basin size. The Blue Mountain Lake retention time is estimated at 0.88 years (Table 3-1), and according to Lillie and Mason (1983), the mean retention time for mixed seepage lakes in Wisconsin is 1.24 years. Blue Mountain Lake, therefore, has a shorter than average retention time.

3.2 Existing Land Coverage and Nonpoint Source Loading Analysis

Planted conifers and rural residential development cover the greatest acreage (i.e., ~89% of the total acreage) in the Blue Mountain Lake Watershed (Figure 3-2, Table 3-2). The planted conifer areas consist of approximately twenty-five year-old red pine (*Pinus resinosa*), white pine (*Pinus strobus*), and white spruce (*Picea glauca*). Overall, the watershed is relatively undisturbed; however, there has been increasing residential development pressure. Surface runoff from rural residential land use comprises an estimated 45.7% of the total phosphorus load and 91.7% of the total sediment load to Blue Mountain Lake. The next highest phosphorus and sediment contributions came from the areas of planted conifers and comprised 4.6% and 6.0% of the total loads, respectively (Table 3-2). Interpretation of the results shown in Table 3-2, however, should be done with caution for two primary reasons. First, loading coefficients for a given land coverage can vary within different geographic regions due to factors such as soil types, topography, etc. The loading coefficients used in this study are generalized estimates and locally derived loading coefficients obtained by methods such as watershed monitoring data would yield more accurate results. Second, the phosphorus and sediment loading coefficients do not represent the nutrient or sediment load delivered to the receiving water, rather they represent the "raw" load from the associated land use type. For example, a phosphorus loading coefficient for agricultural land is based upon estimates of nutrient export directly from this land use type, and does not account for any mitigative processes (e.g., distance from receiving body, natural vegetative buffers, installed best management practices, etc.) that may occur within the watershed.

Table 3-2. Land coverages and associated phosphorus and sediment loading within the Blue Mountain Lake Watershed

Land Coverage	Acreage	Annual P Load (pounds/year)	% of Total P Load	Annual Sed. Load (pounds/year)	% of Total Sed. Load
Rural Residential (1.0 du/acre)	20.2	9.0	45.7%	3232	91.7%
Planted Conifers	10.6	0.9	4.6%	212	6.0%
Wetlands	2.5	0.2	1.0%	50	1.4%
Dry-mesic Forest	1.5	0.1	0.5%	30	0.9%
TOTAL	34.8	10.2	51.8%	3524	100%

As shown in Table 3-2, the total nonpoint source phosphorus load from watershed surface runoff is estimated as 51.8% of the total phosphorus load to the lake. The remaining external phosphorus load to Blue Mountain Lake results from direct precipitation to the lake and septic system leachate. Direct precipitation is estimated to comprise 13.2% of the total Blue Mountain Lake phosphorus load. The estimated load from septic system leachate will be discussed in Section 3.3.

3.3 Point Source and Septic System Discharge Inventory

Watershed field reviews, communication with lake residents and users, and review of the *Wolf River Basin Water Quality Management Plan* (Bougie et al. 1996) revealed no documented point source discharges to Blue Mountain Lake. The potential phosphorus load from sanitary sewer systems around the lake was modeled using WILMS. Information necessary for the modeling effort was gathered through distribution of a questionnaire to lake residents (Appendix A).

Of the sixteen households that exist along the shoreline of Blue Mountain Lake, eleven provided responses to the questionnaire distributed by Mike Funk. Slightly less than half of the households (45%) that responded indicated that they have recently (i.e., since 1990) installed a new septic system and all but one of the systems is a Conventional System (i.e., tank and leachate field)(Table 3-3). Table 3-3 also provides information on the number of individuals that typically occupy each household and the length of time in which they reside at the household. According to the responses received, most of the households (82%) are seasonal. These data were utilized in estimating potential phosphorus loads due to septic system leachate.

Table 3-3. Household responses to questions 1-4 in the septic system questionnaire (Appendix A)

Year of Septic System Installation	Type of Septic System	Residency Period (months)	Number of Individuals Occupying Household
1998	Conventional	3	3
1997	Conventional	12	2
1996	Conventional	2	4
1992	Conventional	12	2
1990	Conventional	6	2
Between 1976-1978	Conventional	7	5
Between 1970-1972	Conventional	7	5
1960	Conventional	3	4
Unknown	Conventional	2	5
Unknown	Conventional	1	2
None	Outhouse	3	3

WILMS estimated that 35.0% of the lake's total phosphorus load could be due to septic system leachate. The *Soil Survey of Waupaca County, Wisconsin* (USDA 1981) identifies the upland shoreline soils as Plainfield loamy sand. The publication also describes the Plainfield map unit as severely limited for sanitary systems due to the sandy soils providing poor leachate filtering, and states that while the soils drain satisfactorily they could potentially contaminate groundwater due to the lack of adequate filtering. Given that Blue Mountain Lake represents a low point in the surrounding landscape, has steep shorelines, and has a small tributary watershed, the hydrologic budget of the lake likely has a substantial groundwater component. As a result, contamination of groundwater by shoreline septic systems would probably also mean contamination of the lake.

3.4 Water Quality Monitoring

3.4.1 Water Quality Data

A summary of the water quality monitoring data can be found in Appendix C. Table 3-4 summarizes the Blue Mountain Lake water quality data relative to regional lake water quality data. Total phosphorus and chlorophyll *a* concentrations in Blue Mountain Lake were lower than regional averages. Both phosphorus and chlorophyll *a* values can be used as an indicator of algal concentrations in a waterbody. High values of phosphorus and chlorophyll *a* indicate high concentrations of algae and, typically, poor water clarity. Conversely, low chlorophyll *a* values often coincide with relatively high Secchi disk depths. Blue Mountain Lake, however, had lower than average phosphorus and chlorophyll *a*, and lower than average Secchi disk depths. The explanation for the poor water clarity in Blue Mountain Lake is probably related to factors other than algae that can influence water clarity.

Table 3-4. Comparison of mean Blue Mountain Lake and regional water quality parameters

	Blue Mountain Lake	Regional Average[a]	Percent Greater or Less than Regional Average
Area (acres)	9.8	84	-98%
Mean Depth (ft)	3.0	13.1	-77%
Secchi Disk (ft)	6.6	7.9	-16%
Chlorophyll *a* (ug/l)	3.8	7.5	-49%
Total Alkalinity (mg/l)	61	122	-50%
pH	7.3	7.9	-8%
Total Nitrogen (mg/l)	0.89	0.72	+24%
Total Phosphorus (mg/l)	0.015	0.020	-25%

a. From Lillie and Mason, 1983

3.4.2 Trophic State Index

Table 3-5 summarizes the Carlson (1979) TSI and Lillie and Mason (1983) Water Quality Index (WQI) values for Blue Mountain Lake. In general, lakes with a TSI less than or equal to 39 are considered oligotrophic, those from 40 to 49 are considered mesotrophic, and those with a TSI greater than or equal to 50 are considered eutrophic. Blue Mountain Lake exhibited primarily mesotrophic conditions throughout the sample period. The WQI values indicate that, overall, Blue Mountain Lake experiences good water quality. In summary, neither water clarity nor water quality appears to be a problem in Blue Mountain Lake.

Table 3-5. **Summary of Blue Mountain Lake trophic state and water quality indices for each sample date**

	June 2, 1999		July 13, 1999		August 18, 1999		January 18, 2000		April 19, 2000	
	TSI	WQI	TSI	WQI	TSI	WQI	TSI	WQI	TSI	WQI
Chlorophyll *a* (ug/l)	41	Very Good	39	Very Good	48	Good	----	----	47	Good
Total Phosphorus (mg/l)	51	Good	49	Good	48	Good	50	Good	47	Good
Secchi Disk (ft)	48	Good	47	Good	51	Fair	54	Fair	50	Fair

3.4.3 Phosphorus Sensitivity

For the Blue Mountain Lake surface water, the nitrogen-to-phosphorus ratio was 74.5:1. In general, when nitrogen-to-phosphorus ratios are greater than 15:1, phosphorus is likely the limiting nutrient in the lake system (Krenkel and Novotny 1980). The nitrogen-to-phosphorus ratio for Blue Mountain Lake is very high, indicating that the probable nutrient of concern relative to water quality is phosphorus.

The WDNR classification methodology for phosphorus sensitivity classifies Blue Mountain Lake as a Class IIA lake. In general, Class II lakes are less sensitive to phosphorus inputs than Class I lakes; nevertheless, within the Class II management group Blue Mountain Lake has the maximum phosphorus sensitivity ranking.

3.4.4 Dissolved Oxygen/Temperature Profiles

Temperature and dissolved oxygen data is used to help determine the zone of biological activity for a lake. Lakes in this region of the country typically stratify, which means that a clear separation develops whereby warm, oxygen-rich surface water rests upon a layer of colder, oxygen-poor water called the *hypolimnion.* In winter, lakes typically have low levels of dissolved oxygen and cold temperatures throughout their depths, but can still stratify. After the ice melts, warmer air temperatures heat the upper layer, and wind begins to mix oxygen from the atmosphere into the upper layer, creating the oxygen-rich, warm water layer called the *epilimnion.*

The dissolved oxygen/temperature profiles for Blue Mountain Lake suggest that the lake is primarily mixed during the growing season (Figures 3-3 through 3-6). However, on August 18, 1999, the lake appears to be showing evidence of thermal stratification. The lake may experience periods of mixing and stratification that are dependent upon weather phenomenon. For example, the lake may become stratified over a period of stagnant (i.e., low wind) conditions, and then become mixed after strong wind events.

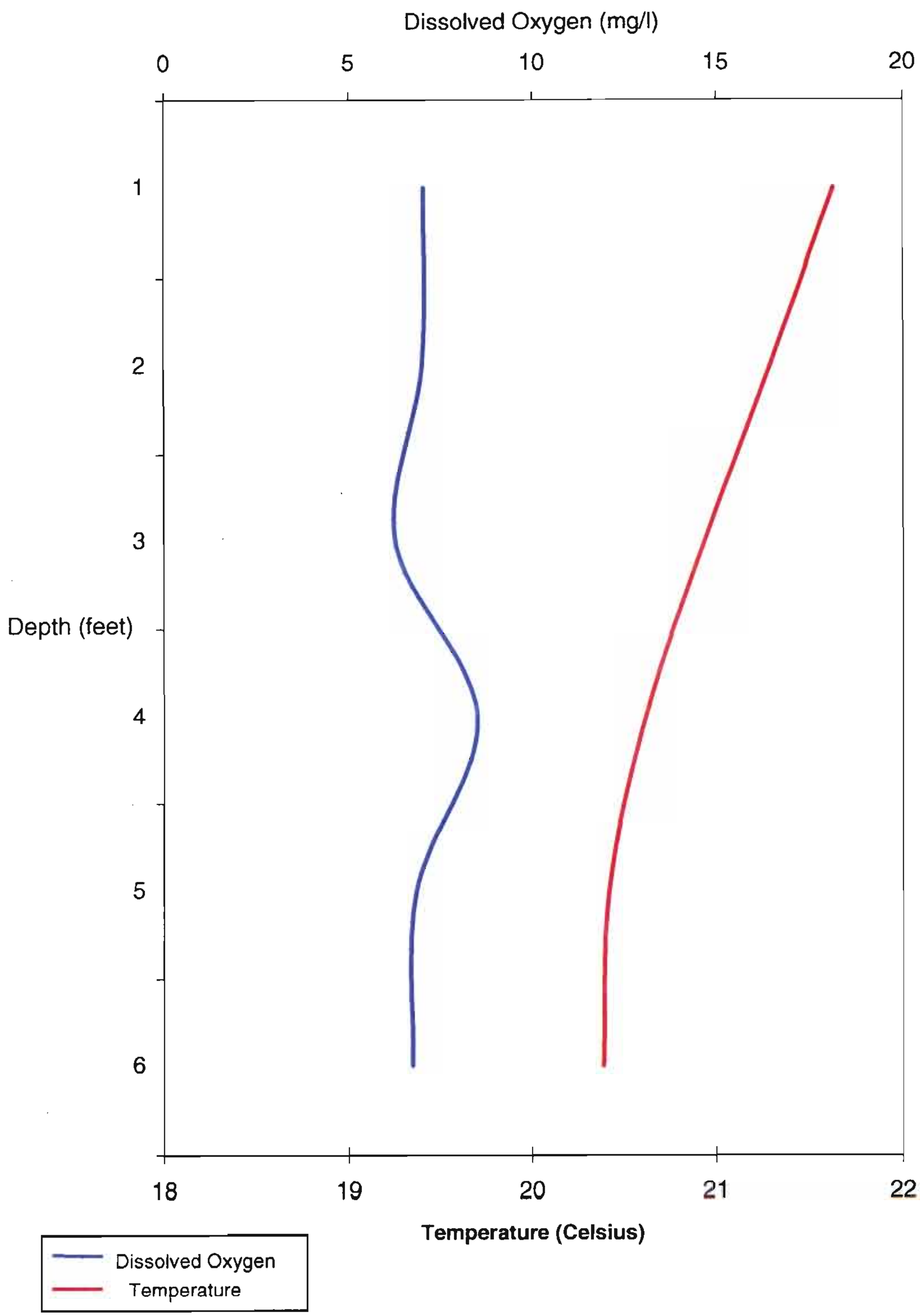

Figure 3-3. Dissolved Oxygen/Temperature Profiles for June 2, 1999

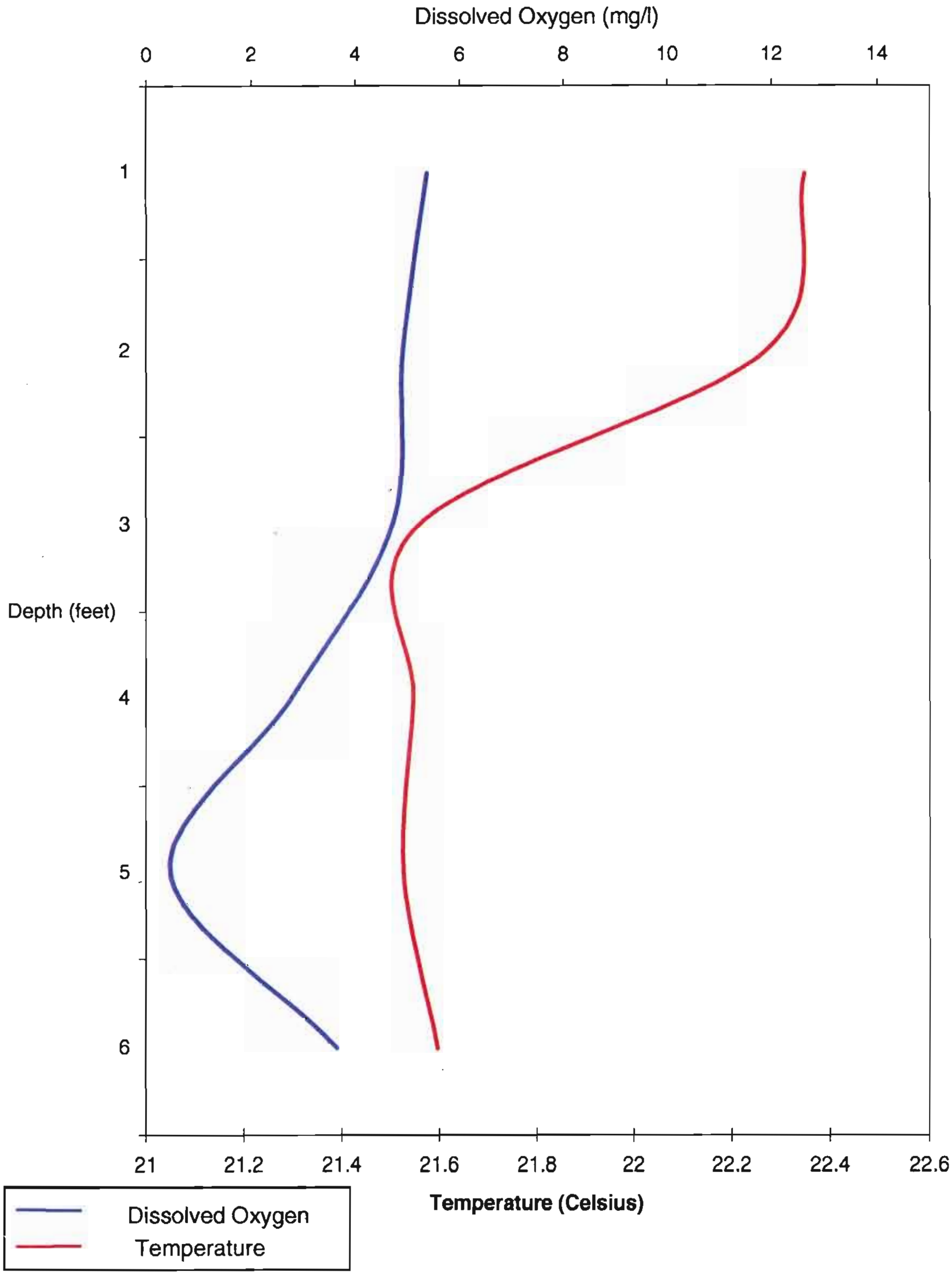

Figure 3-4. Dissolved Oxygen/Temperature Profiles for August 18, 1999

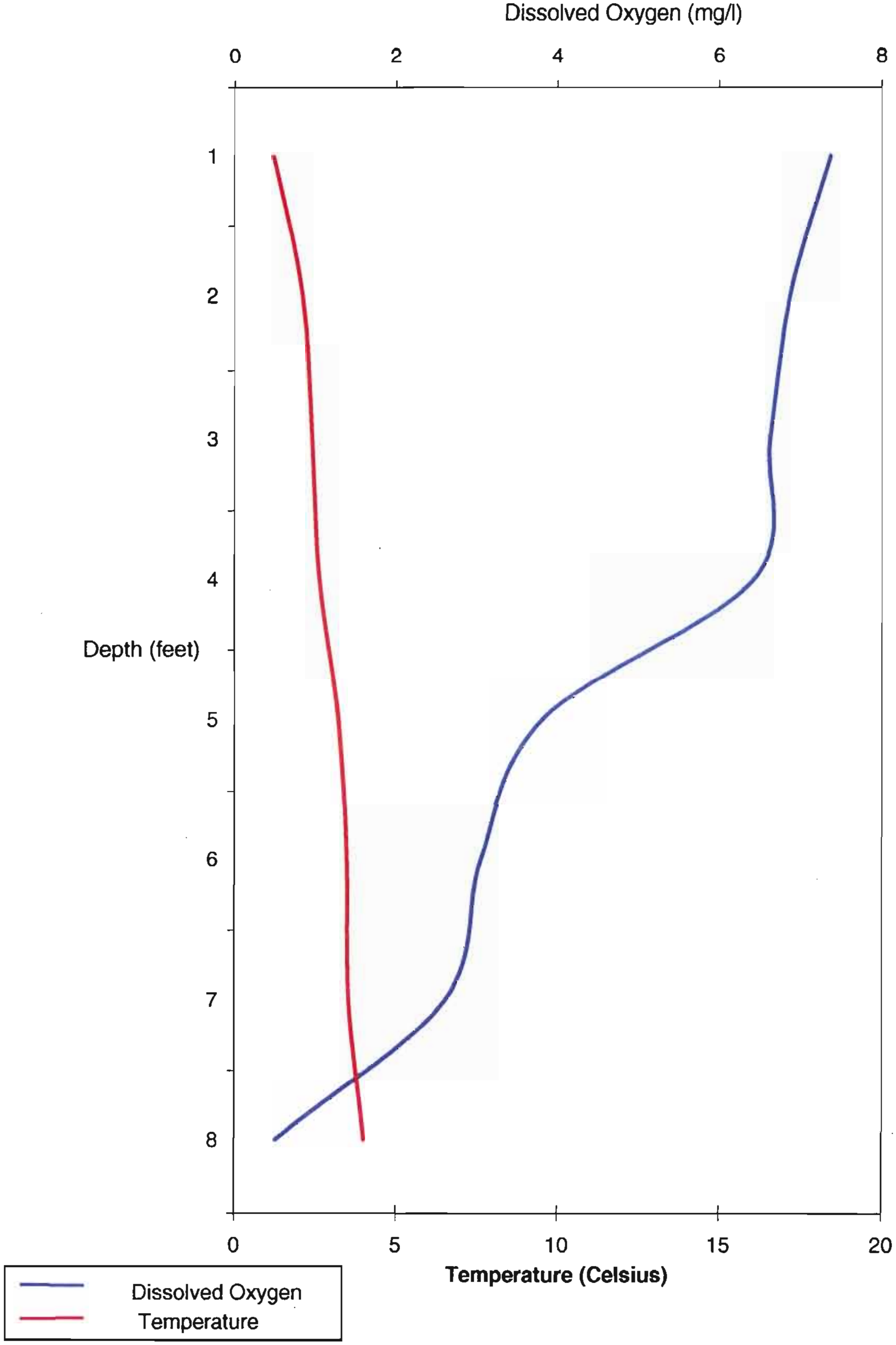

Figure 3-5. Dissolved Oxygen/Temperature Profiles for January 18, 2000

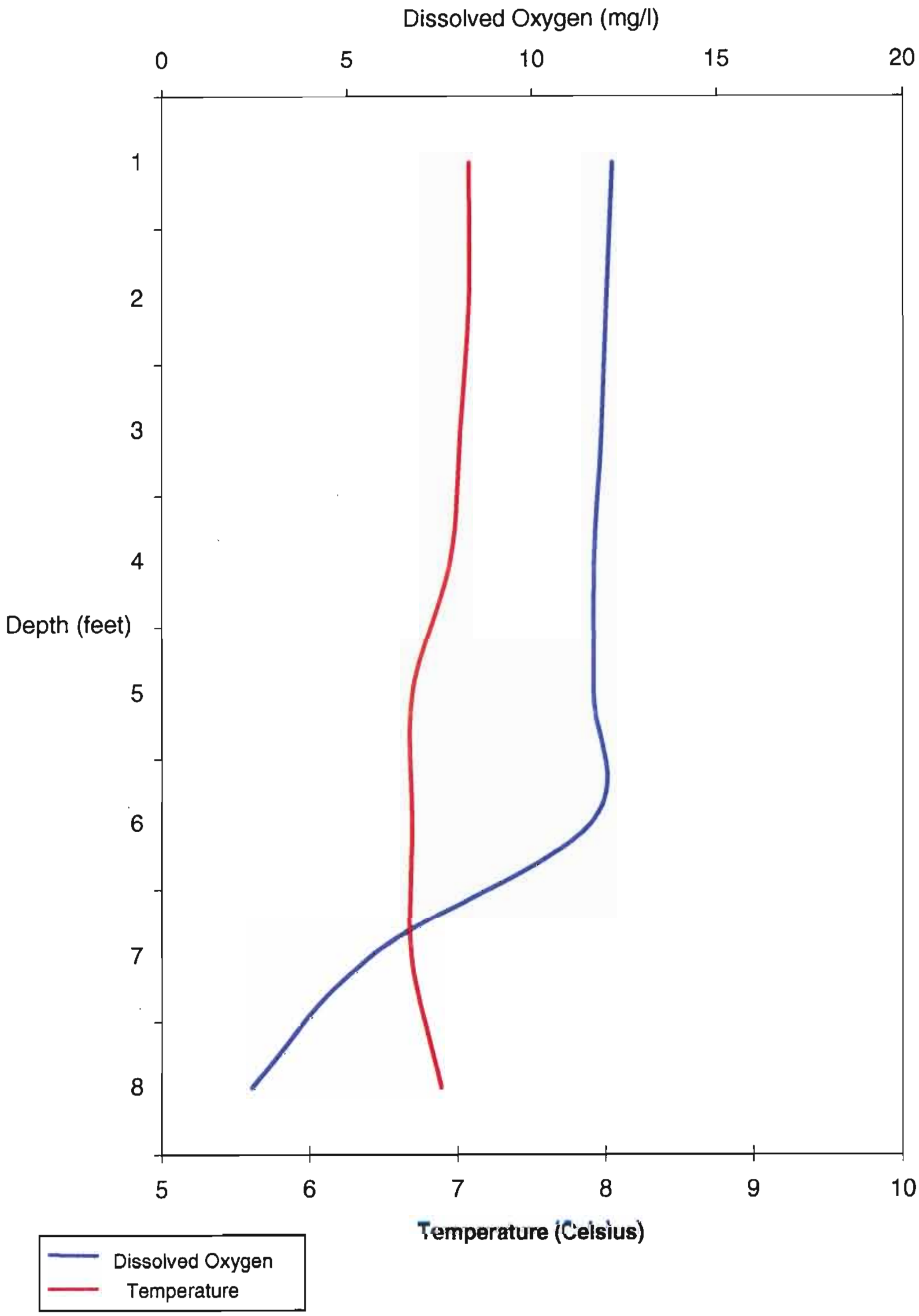

Figure 3-6. Dissolved Oxygen/Temperature Profiles for April 19, 2000

Examination of the winter profile (Figure 3-5) indicates that during the time of sampling (i.e., January 18, 2000) winter dissolved oxygen levels in the lake were good and did not indicate any reason for concern. These levels are probably elevated with the aid of the aeration system that is currently in place on the lake. During the winter months, the aerator prevents total icing of the lake allowing some open water contact and mixture with the oxygen-rich atmosphere.

3.5 Aquatic Vegetation Analysis

3.5.1 Species Abundance and Distribution

A total of 18 species of aquatic vegetation were observed in Blue Mountain Lake. The median species number for lakes in this region is 14 (Nichols 1999); therefore, Blue Mountain Lake has a slightly higher than average number of species when compared to other lakes within the same ecoregion.

The relative abundance of each species of aquatic vegetation in Blue Mountain Lake was qualitatively estimated as rare, infrequent, common, or abundant (Table 3-6). For comparison purposes, the relative abundance of each species in Wisconsin (Nichols and Vennie 1991) is also shown in Table 3-6. Three species, water bulrush, flat-leaved bladderwort, and small bladderwort, are of particular interest. Water bulrush is categorized as infrequent in Wisconsin while both bladderworts are categorized as rare. All three of these species, while relatively infrequent or rare statewide, are common to abundant in Blue Mountain Lake.

Table 3-6. Aquatic vegetation observed in blue mountain lake and relative abundance at the lake and state level

Common Name	Scientific Name	Nativity	Relative Abundance in Lake	Relative Abundance in Wisconsin
Emergent Vegetation				
Water bulrush	*Scirpus subterminalis*	Native	Abundant	Infrequent
Spike-rush	*Eleocharis smallii*	Native	Common	Common
Purple loosestrife	*Lythrum salicaria*	Exotic	Infrequent	------------
Common arrowhead	*Sagittaria latifolia*	Native	Infrequent	Abundant
Softstem bulrush	**Scirpus validus**	Native	Infrequent	Common
Bur-reed	*Sparganium sp.*	Native	Infrequent	------------
Broad-leaved cattail	*Typha latifolia*	Native	Infrequent	Common
Floating-leaved Vegetation				
Water shield	**Brasenia schreberi**	Native	Abundant	Common
White water lily	**Nymphaea tuberosa**	Native	Common	Abundant
Yellow pond-lily	**Nuphar variegata**	Native	Common	Abundant
Water smartweed	**Polygonum amphibium**	Native	Infrequent	Infrequent
Submergent Vegetation				
Variable-leaf pondweed	*Potamogeton gramineus*	Native	Abundant	Common
Large-leaved pondweed	*Potamogeton amplifolius*	Native	Common	Abundant
Floating-leaf pondweed	*Potamogeton natans*	Native	Common	Abundant
Flat-stemmed pondweed	*Potamogeton zosteriformis*	Native	Common	Abundant
Flat-leaved bladderwort	*Utricularia intermedia*	Native	Common	Rare
Small bladderwort	*Utricularia minor*	Native	Common	Rare
Slender naiad	*Najas fexilis*	Native	Infrequent	Abundant

To assist in quantifying the abundance of the aquatic vegetation in Blue Mountain Lake, the percent foliage cover of each species observed along the sampled transects was also recorded. Table 3-7 shows the maximum observed rooting depth and mean Daubenmire classification ranking for each aquatic species observed in Blue Mountain Lake. The species with the highest mean Daubenmire classification rankings (i.e., percent foliage cover) are water shield, water bulrush, and variable-leaf pondweed. In general, the maximum rooting depth is approximately 4.0 feet for emergent vegetation, 6.0 feet for floating-leaved vegetation, and 8.0 feet for submergent vegetation. The maximum depth of Blue Mountain Lake is only nine feet; therefore, the entire lake is vegetated (Figure 3-7).

Table 3-7. Maximum observed rooting depth and mean daubenmire classification ranking for each species of aquatic vegetation

Common Name	Scientific Name	Maximum Observed Rooting Depth (feet)	Mean Daubenmire Classification Ranking[1]
Water shield	*Brasenia schreberi*	6.0	4.1
Spike-rush	*Eleocharis smallii*	2.5	1.7
Slender naiad	*Najas flexilis*	0.5	1.0
Yellow pond-lily	*Nuphar variegata*	6.0	2.0
White water lily	*Nymphaea tuberosa*	3.0	2.3
Water Smartweed	*Polygonum amphibium*	0.5	1.0
Large-leaved pondweed	*Potamogeton amplifolius*	8.0	1.0
Variable-leaf pondweed	*Potamogeton gramineus*	2.5	2.7
Floating-leaf pondweed	*Potamogeton natans*	8.0	1.4
Flat-stemmed pondweed	*Potamogeton zosteriformis*	8.0	1.0
Common arrowhead	*Sagittaria latifolia*	0.5	1.0
Water bulrush	*Scirpus subterminalis*	4.0	3.0
Softstem bulrush	*Scirpus validus*	0.5	1.0
Bur-reed	*Sparganium sp.*	0.5	1.0
Broad-leaved cattail	*Typha latifolia*	0.5	2.0
Flat-leaved bladderwort	*Utricularia intermedia*	4.0	1.6
Small bladderwort	*Utricularia minor*	8.0	1.2

1. Mean is for only those sample plots where a particular species was found.

3.5.2 Floristic Quality Assessment

The FQA completed for the Blue Mountain Lake aquatic vegetation indicated a mean native species coefficient of conservatism of 6.06. (Table 3-8) Nichols (1999) found that the median *C* for lakes in the region is 5.6. Blue Mountain Lake, therefore, appears to have a relatively high mean coefficient of conservatism.

Table 3-8. Coefficients of conservatism for blue mountain lake aquatic vegetation

Common Name	Scientific Name	Coefficient of Conservatism
Water shield	*Brasenia schreberi*	7
Spike-rush	*Eleocharis smallii*	6
Slender naiad	*Najas flexilis*	6
Yellow pond-lily	*Nuphar variegata*	6
White water lily	*Nymphaea tuberosa*	6
Water Smartweed	*Polygonum amphibium*	5
Large-leaved pondweed	*Potamogeton amplifolius*	7
Variable-leaf pondweed	*Potamogeton gramineus*	7
Floating-leaf pondweed	*Potamogeton natans*	5
Flat-stemmed pondweed	*Potamogeton zosteriformis*	6
Water bulrush	*Scirpus subterminalis*	9
Softstem bulrush	*Scirpus validus*	4
Broad-leaved cattail	*Typha latifolia*	1
Flat-leaved bladderwort	*Utricularia intermedia*	9
Softstem bulrush	*Scirpus validus*	10
Purple loosestrife	*Lythrum salicaria*	Non-native species
Mean *C*		6.06

The native floristic quality index for Blue Mountain Lake is 24.25. The median floristic quality index value for lakes in this region is 20.8 (Nichols 1999), indicating that Blue Mountain Lake is above the regional average. Overall, the floristic quality assessment suggests that the aquatic vegetation of Blue Mountain Lake is indicative of undisturbed conditions and relatively high floristic quality.

Only one exotic species, purple loosestrife, was observed on Blue Mountain Lake, and this plant was only found at one location along the northwest shoreline (Figure 2-2). The observed population of purple loosestrife was small and, therefore, management of the plant through manual harvesting or herbicide application may be a viable method of eradication. Given that this plant is a prolific seeder, management options for purple loosestrife should be enabled as soon as possible. If management is not undertaken, purple loosestrife could begin to dominate the lake shoreline, thereby displacing native vegetation and degrading the associated aquatic habitat.

3.6 Recreational Opportunities

To better understand how Blue Mountain Lake is currently being utilized for recreation and to find out what individual perceptions of future recreational opportunities are for the lake, a questionnaire was designed by NES and distributed to households around the lake. Eleven responses were received from various households around Blue Mountain Lake. According to lake residents, there are four main activities that they are currently enjoying on the lake: fishing, boating/canoeing, viewing, and swimming. These same residents further indicated that they want Blue Mountain Lake to continue providing these activities into the future (Table 3-9).

Table 3-9. Responses to questions 1 and 2 on the blue mountain lake use questionnaire (Appendix B)

	Fishing	Boating/Canoeing	Viewing	Swimming
Primary Use of Blue Mountain Lake	10	6	11	10
Future Uses of Blue Mountain Lake	9	8	7	9

*Note: There are greater than ten responses for each as each household indicated participation in more than one activity.

Three of the main activities indicated require some open water areas to allow enjoyable participation. However, Blue Mountain Lake is a shallow lake and has relatively good clarity which allows aquatic vegetation to grow over the entire lake by the middle of the summer. BMLL members indicated this often times dense vegetative growth is an impediment for some recreational activities. To better understand the views of the lake residents on the issue, the third question on the Lake Use Questionnaire asked whether or not vegetative growth was indeed a problem and if so, what they thought should be done to manage the vegetation. Every response received except one indicated a problem with the amount of vegetation present within the lake. Individuals cited septic system updates, phosphorus reductions (i.e., ban lawn fertilizers), chemical and/or mechanical treatment and dredging as potential solutions to the reduction of aquatic vegetation within their lake. All the responses made it clear that reduction of aquatic vegetation is a prerequisite to enjoyable recreation.

One additional question was put forth on the Lake Use Questionnaire to obtain feedback from lake residents. Residents were asked if there were any other issues or concerns that they would like to see addressed. Not all of the households responded to this question, but most of those that did thought the amount of organic sediments on the bottom of the lake were also a problem. Once again, dredging was put forth as a solution to create both a deeper and larger lake in which to enjoy. Other concerns put forward included the use of motorized vehicles, including motorboats, on the lake, phosphorus loading into the lake, no toilets present at public area, lack of environmentally conscious uses of the lake and development around the lake.

Although some of these concerns are more difficult to address than others, NES tried to touch on each in Section 4.2 – Management Options. However, most of the attention was given to the issues of sediment and aquatic vegetation reduction.

3.7 Lake Morphology and Bottom Sediments

A comparison of the 1964 and 1999 bathymetry maps was difficult. For unknown reasons, the WDNR lake map presents Blue Mountain Lake as being smaller and of a different shape than what was identified by NES. A 1992 digital orthophotograph incorporated into a GIS database system and GPS technology were utilized to obtain the lake size and shape by NES and Robert E. Lee & Associates, Inc.. Therefore, data collected should be more accurate than the methods used by the WDNR in 1964. Under this premise, NES utilized data produced within the GIS system to characterize the morphometric and hydrologic characteristics of Blue Mountain Lake.

Due to the differing lake shapes and sizes, contours from the 1964 bathymetry map could not be overlayed on the 1999 map, making it difficult to determine sediment accumulation in the lake over the past 35 years. Even though the contours could not be overlayed, a review and comparison of the two maps indicated some similarities in the contour shapes and water depths. Similarities in the contours and water depths are compelling enough to indicate very little or no sediment accumulation has probably occurred within the past 35 years.

In general, the areas from the shoreline of Blue Mountain Lake to approximately a depth of 1.5 feet consist of a thin layer of organic matter over coarse sand (Table 3-10). However, the depths over 1.5 feet were drastically different with over eight feet of flocculent (i.e., loose) partially decomposed organic matter. The maximum depth of the flocculent matter could not be determined with the sampling equipment available, but based upon field observations it likely extends to ten feet or greater.

Table 3-10. Summary of substrate characteristics along the three sample transects

Water Depth	**0.0-1.5 feet**	**1.5-3.0 feet**	**3.0-5.0 feet**	**5.0-10.0 feet**
		Transect 1		
Texture (Thickness)	Loose, fibrous organic (0-2") Coarse sand (2-12+")	Loose, fibrous organic (0-8+')	Loose, fibrous organic (0-8+')	Loose, fibrous organic (0-8+')
		Transect 2		
Texture (Thickness)	Coarse sand (0-1')	Loose, fibrous organic (0-8+')	Loose, fibrous organic (0-8+')	Loose, fibrous organic (0-8+')
		Transect 3		
Texture (Thickness)	Coarse sand (0-1')	*Loose, fibrous organic (0-8+')*	Loose, fibrous organic (0-8+')	Loose, fibrous organic (0-8+')

Blue Mountain Lake is surrounded by steep, sandy shorelines. A fair portion of the shoreline and watershed are vegetated by coniferous trees, and overall vegetative growth is average to sparse in most areas. In general, the watershed probably contributes a small organic load (e.g., dead vegetation, falling leaves, etc.) to the lake. Within the lake, however, there is an abundant vegetative community that produces large volumes of biomass each year. The organic matter accumulating at the bottom of the lake is probably primarily from autochthonous sources (i.e. generated within the lake).

4.0 CONCLUSIONS

4.1 Summary of Findings

The results of this Lake Planning Grant study are summarized below and provide a brief overview of the issues associated with Blue Mountain Lake.

- Blue Mountain Lake is a mixed seepage lake that is 90% larger and 77% shallower than the average lake in the region.
- Blue Mountain Lake is a mesotrophic, phosphorus-limited lake.
- Blue Mountain Lake is moderately sensitive to increased phosphorus loading.
- Water Quality Index values show that the lake exhibits good water quality and clarity.

- The watershed is approximately 35.0 acres in size and primarily consists of rural residential development and conifer plantations.
- The largest nonpoint source of phosphorus and sediment is rural residential development.
- The lake shoreline soils are described by the Soil Survey of Waupaca County as severely limited for sanitary systems. This is due to the sandy soils providing poor leachate filtering, which could potentially contaminate groundwater.
- Results from the Septic System Questionnaire indicate all but one of the systems are conventional systems with many of them greater than twenty years in age.
- The Wisconsin Lake Model Spreadsheet (WILMS) predicts that as much as 35% of the phosphorus loading into the lake could be due to failing septic systems.
- The Lake Use Questionnaire responses indicate there are four main recreational activities that occur on the lake: boating/canoeing, swimming, fishing, and viewing.
- The Lake Use Questionnaire results also indicate that aquatic vegetation and sediment accumulation are major issues that need to be addressed.
- The floristic quality assessment suggests that the aquatic vegetation is indicative of undisturbed conditions and relatively high floristic quality.
- One small population of purple loosestrife, an exotic species, was observed on the lake shoreline.
- Existing bottom contours and depth were compared to 1964 contours and found to be similar.
- Areas of the lake were found to have 8+ feet of loose, partially decomposed organic matter.
- The primary source of in-filling is likely decomposing aquatic vegetation, however, the depth of the lake does not appear to have changed appreciably over the last 35 years.
- Decomposing aquatic vegetation can cause oxygen depletion in lakes, especially in winter. The abundant aquatic vegetation and shallow water depths are the primary reasons for historic Blue Mountain Lake winter fish kills.
- Winter dissolved oxygen readings were high indicating the aeration system is working which should eliminate winter fish kills.

4.2 Management Options

4.2.1 Mechanical Harvesting

Mechanical harvesting, the actual physical removal of aquatic plants from a waterbody has been utilized for many years to assist in managing aquatic vegetation. By physically removing the vegetation, an immediate reduction would occur allowing more recreational activity. The BMLL, however, would need to either rent or purchase a harvester to maintain an active vegetation management program which includes harvesting several times each year. Harvesting could become costly and it will not resolve issues related to the amount of vegetation present within Blue Mountain Lake. Because harvesting is intrusive, the WDNR will not always permit the removal of aquatic vegetation, especially in a healthy system, and the WDNR will not provide grant money to conduct such activities.

4.2.2 Chemical Treatment

Several companies currently market and sell products registered with the Environmental Protection Agency that effectively poison and reduce the amount of aquatic vegetation within a waterbody. Chemically treating the aquatic vegetation within Blue Mountain Lake, however, would essentially eliminate one concern and add to another. When vegetation is poisoned, it eventually perishes, begins to breakdown and then accumulates on the lake bottom. The added accumulation would increase the organic sediment deposition which was a concern of lakeshore residents. Permits would also be required by the WDNR before any kind of treatment was undertaken.

When discussing the removal of aquatic vegetation either through harvesting or chemical treatment, it must be understood that there is a relationship between water clarity and the vegetation growing within a lake. The relationship is referred to as inverse. As aquatic vegetation increases within a system, the amount of suspended solids within the water column declines creating better water clarity. "The information on the inverse relationship between aquatic plants and water clarity needs to be discussed when planning any aquatic plant management because the control of abundant aquatic plants to alleviate a defined problem may cause another perceived problem. Most people consider clear water as a good attribute in lakes and when it decreases from 15 feet to 3 feet after controlling aquatic plants, people may decide that the aquatic plant problem was not as bad as the reduced water clarity" (U.S. EPA 1997).

4.2.3 Dredging

Many of the Blue Mountain Lake residents have expressed an interest in pursing dredging for the lake. Dredging in navigable lakes is regulated by Wisconsin Statutes, Chapter 30.20. To undertake a dredging project in a navigable lake, the project proponent must obtain a contract from the State of Wisconsin. The contract functions like a permit, but provides the state with an opportunity to charge the permittee for extracted materials because the state owns the lakebed (Kent 1994).

In order to obtain a contract from the state, certain criteria would need to be met and followed before the contract would be awarded. If a contract is secured, the individuals around the lake would then have to consider spending between $2-15 per cubic yard to remove the material which could add up to hundreds of thousands of dollars to complete the process. Based upon contour and depth similarities, it appears there is very little or no sedimentation accumulation occurring within the lake.

Dredging would reduce the amount of sediment on the bottom of the lake making the lake deeper thus reducing aquatic vegetation growth, but dredging does nothing for fish habitat, water quality or algae production within the lake. Given the cost for conducting dredging operations and the fact that accumulation does not appear to be significant over the past 35 years, Blue Mountain Lake Limited may want to consider a more viable and less costly option.

4.2.4 Anaerobic Bacteria

Clean-Flo International (Brooklyn Park, Minnesota) has discovered and applied an effective method for reducing organic sediments on the bottom of ponds and lakes. The first step in the process involves using an Inversion/Oxygenation System. The system introduces oxygen into the bottom of the lake so it can be cycled throughout the entire waterbody to provide full aeration within the lake. This step is necessary to provide the appropriate habitat in which organic sediment-eating microorganisms can thrive; without healthy oxygen levels throughout the entire lake, the organisms would perish. The microorganisms would be seeded into the lake where they would feed on the bottom organic material, converting it into carbon dioxide and water. Studies have shown these beneficial microorganisms can reduce sediment depths by 2-6 feet within a 3-5 year time period. However, they **have not** had success in reducing more than 6 feet of sediment. The sediment reducing microorganisms are not harmful to the environment as these organisms are found naturally on decomposing logs and litter accumulation within forests. In fact, they become a part of the food chain as insects within the water feed upon the organisms creating more insect life resulting in more food for the fish population (Laing 1999).

In order to run the inversion/oxygenation system, an electrical source would be necessary, however, Blue Mountain Lake currently runs an aerator during the winter months to prevent winter fish kills so the system should be easily operated. According to representatives from Clean-Flo, the system is easy to install and the costs are minimal compared to dredging. It is estimated that it would cost between $13,500 and $14,000 to get the inversion/oxygenation system installed and operational and to seed the microorganisms into Blue Mountain Lake. This cost also includes a years worth of maintenance materials.

It appears the microorganisms would be feasible, but permits would be required by the WDNR before any actions are taken. Obtaining a permit from the WDNR, however, may not be easy as they are reluctant about the total lake aeration and microorganism seeding. One concern is that if a lake becomes completely aerated for a long period of time, the water chemistry within the lake can change which impacts the organisms living within the lake. Another concern is the change in vegetation types that would occur as the lake bottom changed. The aquatic vegetation on Blue Mountain Lake is currently very healthy with a diverse number of species. Loss of these species and a change in water chemistry may make it difficult to obtain permits.

4.2.5 Phosphorus Loading

According to the water sampling conducted on Blue Mountain Lake, the phosphorus levels present on the lake are below the regional average and the water quality is good. Blue Mountain Lake is a phosphorus limited lake which means that additional phosphorus added to the lake through anthropogenic activities will increase production (i.e, algae blooms) within the lake. Because a high percentage of phosphorus loading was predicted to be coming from the residential developments and the septic systems around the lake, lake residents and the BMLL may want to pursue future management of phosphorus loading to prevent a decline in water quality. Although it is unlikely phosphorus reduction will decrease the amount of vegetation currently within the lake, reduction will assist in maintaining a healthy lake ecosystem in the future.

4.2.6 Exotic Species Management

One area of purple loosestrife was identified along the northwest shoreline of Blue Mountain Lake. Purple loosestrife is an aggressive plant that without control would likely continue to spread along the lake shoreline. Given the current extent of colonization, a focused management effort may be able to reduce the population and control the spread of loosestrife. Options for management could include manual removal, herbicide application, or a combination of the two. Blue Mountain Lake Limited should consider the development of a lakewide purple loosestrife management plan. If initiated soon, the potential exists to prevent further colonization or possibly reduce the extent of existing colonization.

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Appendix C. Water quality monitoring results for Blue Mountain Lake, June 2, 1999 – April 19, 2000

Parameter	Sample	Date				
		6/02/99	7/13/99	8/18/99	1/18/00	4/19/00
Secchi (feet)		7.7	8.0	6.0	4.9	6.5
Cloud Cover (percent)		50	30	100	20	100
Temperature	S	NR	NR	22.4	4.0	7.1
(degrees Celsius)	B	NR	NR	21.50	2.1	4.4
pH	S	NR	NR	7.2	6.9	8.3
(surface units)	B	NR	NR	6.5	7.1	7.9
Dissolved Oxygen	S	NR	NR	5.4	.5	12.2
(mg/l)	B	NR	NR	2.8	6.9	11.7
Conductivity	S	NR	NR	0.1312	NR	125
(umhos/cm)	B	NR	NR	0.259	NR	123
Total Alkalinity	S	NR	NR	NR	NR	61
(mg/l)	B	NR	NR	NR	NR	59
Total Kjehldahl Nitrogen	S	NR	NR	NR	NR	0.88
(mg/l)	B	NR	NR	NR	NR	0.87
Ammonia Nitrogen	S	NR	NR	NR	NR	ND
(mg/l)	B	NR	NR	NR	NR	0.058
$NO_2 + NO_3$ Nitrogen	S	NR	NR	NR	NR	0.014
(mg/l)	B	NR	NR	NR	NR	0.020
Total Nitrogen	S	NR	NR	NR	NR	0.89
(mg/l)	B	NR	NR	NR	NR	0.89
Total Phosphorus	S	0.018	0.015	0.013	0.016	0.012
(mg/l)	B	0.021	0.026	0.038	0.017	0.011
Dissolved Phosphorus	S	NR	NR	NR	ND	ND
(mg/l)	B	NR	NR	NR	ND	ND
Nitrogen/Phosphorus Ratio	S	NR	NR	---	---	74.2
	B	NR	NR	---	---	80.1
Chlorophyll *a*	S	2.43	1.65	6.0	NR	5.02
(ug/l)	B	10.1	NR	11.0	NR	5.36
Total Suspended Solids	S	NR	NR	NR	NR	<5
(mg/l)	B	NR	NR	NR	NR	<5
Calcium	S	NR	NR	NR	NR	13
(mg/l)	B	NR	NR	NR	NR	13

S = Surface, B= Bottom, NR = Not Recorded