Wisconsin Lake Planning Grants LPL-260 and LPL-289 Final Report

Big Butternut Lake
Polk County, Wisconsin

Prepared for the
Big Butternut Lake Protection
and Rehabilitation District

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Executive Summary

This Executive Summary briefly presents the results of two Wisconsin Department of Natural Resources (DNR) Lake Planning Grant studies (WDNR project numbers LPL-260 and LPL-289) which were carried out on Big Butternut Lake, Polk County, Wisconsin during 1995 through 1996. Lakeshore residents, members of the Big Butternut Lake Protection and Rehabilitation District (BBLPRD), and other interested parties will receive a copy of this summary. The complete technical report is available for review at the Village of Luck Hall, or from BBLPRD board members.

The grants for this study were obtained by the Big Butternut Lake Protection and Rehabilitation District (BBLPRD); Barr Engineering Company, Minneapolis, Minnesota prepared the original work scope and grant applications, carried out the actual studies, and prepared the final report. Volunteers from the BBLPRD and staff from the Polk County Land Conservation Department collected lake water samples throughout the summer of 1995. Staff from the Village of Luck collected lake level data and flow data from Butternut Creek from May through October, 1995. Volunteers from the BBLPRD also helped to mark treatment plots at the northeast end of the lake for the application of herbicide to curlyleaf pondweed.

Members of the lake association identified three areas of concern during the preparation of the study work plan: infestation of the aquatic macrophyte (lake weed) curlyleaf pondweed in the northeast end of the lake; water quality degradation in the lake, including annual occurrence of late summer nuisance algae blooms; and lakeshore erosion caused by intermittent high water levels. Each of these were addressed in the Lake Planning Grant studies. A brief summary of the results and recommendations for each is presented below.

Water Quality

Results of the analyses performed during 1995 showed that the water quality in Big Butternut Lake was quite good during May; the transparency of the water was high, and few algae were present. However, the water quality degraded throughout the summer. The water transparency decreased dramatically, and blue-green nuisance algae were abundant. The data indicate that phosphorus is the nutrient responsible for the algae blooms and the general water quality degradation. Phosphorus is transported to the lake from several sources. It is contained in stormwater runoff from the lake's watershed (the land area surrounding Big Butternut Lake which drains to the lake); sources for stormwater phosphorus include lawn fertilizer, leaves and yard waste, eroded soil, and agricultural runoff. Phosphorus is also delivered to the lake from the bottom sediments within the lake. This "internal load" of phosphorus occurs when the water layer near the sediments (the hypolimnion) is devoid of oxygen. Since Big Butternut Lake is relatively shallow, the internal load of phosphorus is readily transported to the lake surface during periods of windy weather. Some phosphorus is also delivered to the lake when the lake weeds, particularly the curlyleaf pondweed, die and decompose.

Some recommendations for improving the water quality in Big Butternut Lake include:

- **Determine the amount and sources of phosphorus from the lake's watershed, and perform a modeling study to evaluate the feasibility of management options.** This recommendation would be completed through a Lake Planning Grant Study during 1997. The results of this study will identify specific management options for improving the water quality in Big Butternut Lake. Management options to be evaluated will include application of alum (alum sulfate) to the lake sediments to decrease the internal phosphorus load, installation of a hypolimnetic aerator, and construction of stormwater detention ponds. This study would also identify any unusual or problematic phosphorus sources within the watershed, as well as any areas in the watershed that provide water quality benefits to the lake, such as wetland areas or ponds. This recommendations would be funded through a Wisconsin DNR Lake Planning Grant; $10,000 would be provided by the DNR, while the BBLPRD would provide $3,333 for a total budget of $13,333.

- **Continue management of curlyleaf pondweed.** Curlyleaf pondweed is an exotic (non-native) lake weed present in abundance in Big Butternut Lake. When the weed dies and decomposes in early-July, it removes oxygen from the water column of the lake, and releases phosphorus as well. The management of curlyleaf pondweed will be discussed further in the next section.

- **Continue participating in the WDNR volunteer monitoring program.** BBLPRD volunteers collected water samples during 1996 as part of the WDNR volunteer monitoring program. Continued participation in the program will provide annual water quality data so that profound changes in the water quality of the lake can be detected. There is no cost to the BBLPRD for this program.

Curlyleaf Pondweed Management

Curlyleaf pondweed is an exotic (non-native) weed species present in Big Butternut Lake. Two lake-wide macrophyte (aquatic weed) surveys were conducted on Big Butternut Lake during 1995. The surveys show that curlyleaf pondweed grows in several large areas of the lake. Curlyleaf pondweed is unusual in that it grows during fall, remains under the ice during winter, then grows rapidly in the spring before native weed species appear. It then dies-out by early-July, forming floating mats of dead vegetation which either sink to the lake bottom, or wash up on the lakeshore. To aid in developing a curlyleaf pondweed management strategy for Big Butternut Lake, three treatment plots were marked with buoys at the northeast end of the lake. An early-spring herbicide application was performed on two of the plots, the third plot was used for comparison. Unfortunately, thick ice and snowcover and harsh winter conditions during 1995 - 1996 resulted in a natural decline in curlyleaf pondweed density during 1996; therefore the effects of the herbicide application to the test plots could not be quantified. The Wisconsin DNR has stated that in order to allow large-scale treatment of the curlyleaf pondweed in the lake, they must be provided with evidence that curlyleaf pondweed is effecting the water quality of the lake, and that the early season application of herbicide is effective at controlling the curlyleaf pondweed growth. The DNR would also like to have the BBLPRD define specific goals for the management of the weed growth in the lake.

Some recommendations for the management of curlyleaf pondweed developed during this study include:

- **Develop lake-wide goals for the management of curlyleaf pondweed and other aquatic weeds in Big Butternut Lake.** The Wisconsin DNR may be more flexible in allowing management of the aquatic weeds in the lake if the BBLPRD developed a set of specific management goals. Examples of macrophyte management goals include: to reduce the growth of curlyleaf pondweed in the lake to promote the re-establishment and regrowth of native weed species; to reduce the growth of curlyleaf pondweed in the lake to improve water quality in the lake; to educate lakeshore owners about the importance of native weed species to the health of Big Butternut Lake and its fishery. It is important that lakeshore property owners be willing to accept and support the macrophyte management goals.

- **Repeat the mid-May application of herbicide to a treatment plot at the northeast end of the lake.** The BBLPRD will mark two plots with buoys; one will be treated with herbicide during May 1997, the other will be left for comparison. A Barr Engineering biologist will then survey the plots to compare the weed growth in each. Cost for this recommendation would be approximately $2,500.

- **Educate lakeshore property owners about macrophyte (weed) management.** Haphazard and unnecessary removal of native weed species by individual property owners may cause the spread of curlyleaf pondweed. Property owners should be encouraged to limit weed removal to what is absolutely necessary for use of their lakeshore. Educational materials could be distributed by newsletter, by radio, through the schools, or through the local newspaper.

Lake Water Level Investigation

Occasional high water levels in Big Butternut Lake have resulted in shoreline erosion and property damage around the lake. In order to determine what physical structures control the outflow of the lake, Barr Engineering Company surveyed all road crossings and culverts along Butternut Creek. From the survey information and water flow and precipitation data collected by the Village of Luck, Barr Engineering determined that under most conditions, the outflow from the lake is controlled by the twin culverts under Chippewa Trail (Minnie's Road). During some conditions, the lake outflow may be controlled by the channel between the lake and Chippewa Trail. A separate analysis performed by the Wisconsin DNR gave similar results. One option for decreasing high water levels in the lake would be in installation of an overflow culvert at Chippewa Trail. However, the DNR would not allow such an installation until a hydraulic modeling analysis is performed showing the effects of the culvert on the water levels in both Big Butternut Lake and the next lake downstream on Butternut Creek, Little Butternut Lake.

Some recommendations developed during this portion of the study include:

- **Continue monitoring the water levels in the lake.** A water level gauge was installed in the lake near the boat landing during 1995, and the Village of Luck collected daily readings. It is recommended that the gauge be reinstalled, and weekly gauge readings collected. There is minimal cost for this option due to continued support from the Village of Luck.

- **Perform a hydraulic modeling feasibility study to assess the effects of an overflow culvert at Chippewa Trail.** This analysis would ensure that an overflow culvert at Chippewa Trail would provide benefits for water level control in Big Butternut Lake, and would ensure that no detrimental effects would occur downstream in Little Butternut Lake. The WDNR requires the completion of this study before any permits would be issued. Approximate cost for Barr Engineering Company to complete this study would range from $5,000–$10,000.

1.0 Introduction

1.1 Study Description and Goals

This report details the results of two Wisconsin Department of Natural Resources (DNR) Lake Planning Grant studies (WDNR project numbers LPL-260 and LPL-289) which were carried out on Big Butternut Lake, Polk County, Wisconsin during 1995 through 1996. The grants were obtained by the Big Butternut Lake Protection and Rehabilitation District (BBLPRD); Barr Engineering Company, Minneapolis, Minnesota prepared the original work scope and grant applications, and carried out the actual studies.

Members of the lake association identified three areas of concern during the preparation of the study work plan: infestation of the aquatic macrophyte (lake weed) curlyleaf pondweed in the northeast end of the lake; annual occurrence of late summer nuisance algae blooms; and lakeshore erosion caused by intermittent high water levels. Study goals were developed for each of these, and included:

Water Quality

- Determine the current water quality of Big Butternut Lake by measuring physical, chemical, and biological parameters typical of detailed water quality assessments.
- Analyze data to determine phosphorus and algae dynamics in lake. Estimate current trophic status, effects of internal phosphorus load, and effects of zooplankton population fluctuations on algal abundance.
- Compare water quality of lake during 1983 with that measured during the course of this study.

Aquatic Macrophytes/Curlyleaf Pondweed

- Identify speciation and location of submerged macrophytes in Big Butternut Lake. Perform a controlled experimental treatment of curlyleaf pondweed beds to assess potential long-term management strategies.

Lake Level/Shoreline Erosion

- Determine what physical structures control the water level in Big Butternut Lake. Gather information to set water level goals for the lake.

This report is divided into four sections. Section 1.0 provides introductory information on the lake and watershed. Section 2.0 details the results of the water quality survey, and as well as recommendations. Section 3.0 lists the results of the aquatic macrophyte (weed) surveys and the experimental curlyleaf pondweed treatments, as well as recommendations for future aquatic macrophyte management. Section 4.0 details the results of the lake level survey, as well as the survey of Butternut Creek, and provides recommendations for future lake level management.

1.2 Lake and Watershed Description

Big Butternut Lake is located adjacent to the Village of Luck, Polk County, Wisconsin (Figure 1). The lake is an important regional asset, and is popular for swimming, fishing, and aesthetic and wildlife viewing. A public boat ramp and fishing pier is located at the southwest end of the lake, and a public beach is located at the northwest end. Major hydrologic tributaries to the lake include two creeks which enter the lake on the northeast and southeast shores of the lake, and several storm sewers which drain runoff from the Village of Luck and enter the lake along the west shore. The lake outlet, Butternut Creek, is located on the southwest shore.

Table 1 details the morphometry of Big Butternut Lake. The lake is shallow for its size, with a maximum depth of only 19 feet, and a mean depth of only 13 feet. As will be discussed in Section 2.0, due to the lake's shallow depth, late-summer internal phosphorus load most likely causes the severe algal blooms observed in the lake during July and August.

The lake's watershed is approximately 2,450 acres (as delineated by the WDNR). The watershed is relatively small in comparison with the surface area of the lake; the watershed area to lake surface area ratio is 6.5 to 1. Current land use was not determined during this study. However, the general land use patterns include single family residences and seasonal cabins along the lakeshore; single family residences, commercial property, and school property within the Village of Luck; intermittent single-family rural residences scattered throughout the rest of the watershed. While numerous dairy and crop farms may have once operated within the watershed, currently there is minimal farming activity. Septic systems located around the lake were recently inspected by the County and the BBLPRD. Systems not in compliance were required to be replaced with holding tanks. All outhouses (i.e., pit-privies) along the lakeshore were filled and taken out of service.

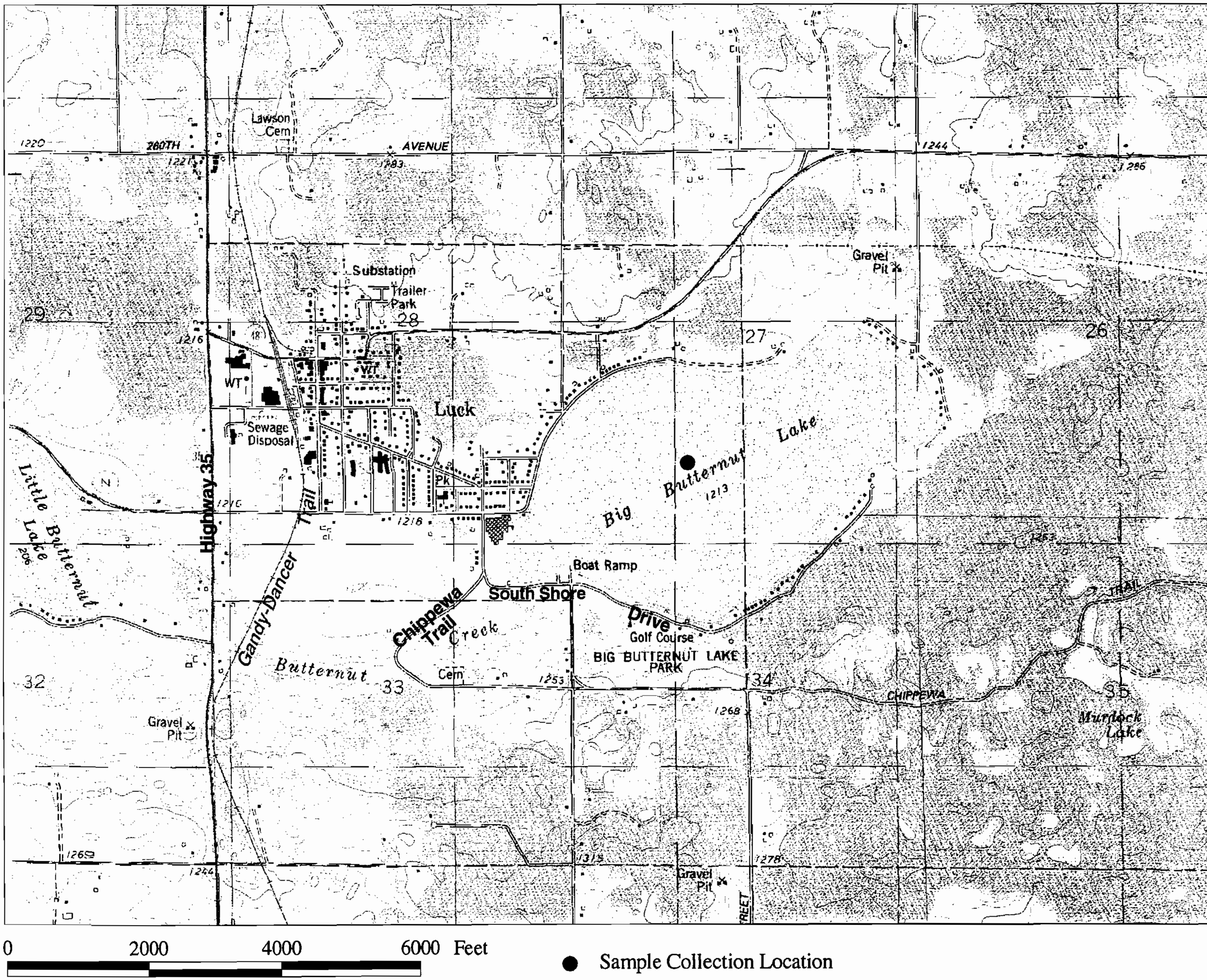


Figure 1

LOCATION MAP
Big Butternut Lake

Table 1 Big Butternut Lake Watershed and Lake Morphometry[1]

Lake Surface Area	378 acres 153 hectares
Maximum Depth	19 feet 5.8 meters
Mean Depth	13 feet 4.0 meters
Lake Volume	4,877 acre-feet 6.02×10^6 cubic meters
Watershed Area	2,450 acres 992 hectares
Watershed:Lake Ratio	6.5:1

[1] Values in this Table were taken from the report Big Butternut Lake, Polk County: Feasibility Study Results and Management Alternatives (Bureau of Water Resources Management-Department of Natural Resources, 1986).

2.0 Water Quality

2.1 Background Information

The water quality in Big Butternut Lake was previously assessed in 1983 by the Bureau of Water Resources Management of the Wisconsin Department of Natural Resources. The results of this assessment were summarized in a report titled "*Big Butternut Lake, Polk County: Feasibility Study Results and Management Alternatives*," which was issued in 1986. During 1983, the trophic status of the lake was classified as eutrophic. Temperature and dissolved oxygen profiles indicate that the lake may have intermittently stratified and mixed during that summer, and that hypolimnetic oxygen was depleted during stratification. The report included several recommended management strategies for the watershed, such as minimizing phosphorus-based fertilizer use, controlling soil erosion of agricultural lands through correct tillage practices, controlling macrophyte growth by mechanical harvesting, and curtailing septic system runoff by replacement of failing systems.

During the past few years the Big Butternut Lake Protection and Rehabilitation District (BBLPRD), in conjunction with the Village of Luck and Luck Township, has worked to implement management strategies detailed in the 1986 report. Ordinances banning the use of phosphorus-based fertilizers were passed by the Village of Luck and Luck Township. All septic systems in the lake's watershed have been inspected; failing systems were replaced with holding tanks. Agricultural runoff has probably decreased during the past few years due to a decline in farming activities in the watershed. Subsequently, the BBLPRD was interested in measuring the current water quality of the lake, and assessing whether any improvement has occurred since the 1983 study. This section discusses the results of the water quality analysis completed during 1995.

2.2 Water Quality Educational Overview

Within a lake system, water quality problems and accelerated biological activity are often caused by sediments and nutrients deposited into the lake by tributary streams which drain the lake's watershed. The process of nutrient enrichment and resulting biological activity is called eutrophication. During the process of eutrophication, a lake accumulates sediments and nutrients from its watershed. The biology and chemistry of the lake may change, as well. Increased macrophyte and algal growth may occur as part of the eutrophication process; the dissolved oxygen in the lake may be affected as the plant matter dies and decomposes. As the process progresses, a lake is converted from oligotrophic (nutrient poor) to eutrophic (nutrient rich) status.

It is important to note that the process of eutrophication is natural and results from normal environmental forces, and usually occurs slowly over many years. However, in many lakes "cultural eutrophication," the accelerated degradation resulting from human activity, is the process that actually takes place. This accelerated degradation may result from point-source nutrient loadings, such as effluent from wastewater treatment plants and septic tanks. It may also be caused by diffuse (i.e., non-point) sources of nutrients and sediments, such as stormwater runoff from urban and agricultural areas. The accelerated rate of water quality degradation caused by these pollutants results in unpleasant consequences. These include profuse and unsightly growths of algae (algal blooms).

Individual lakes will respond differently to the process of cultural eutrophication. Therefore, criteria have been established to evaluate lakes to denote their nutrient status. Four "trophic" descriptions are frequently used to describe the effects of the nutrients on the general water quality water body. They are:

1. Oligotrophic
2. Mesotrophic
3. Eutrophic
4. Hypertrophic

Oligotrophic (Greek for "food-poor") describes a water body with few nutrients, and a clear or pristine appearance. **Mesotrophic** describes a water body that is moderately nourished, and has an appearance midway between an oligotrophic and eutrophic lake. **Eutrophic** (Greek for "food-rich") describes a water body that is rich in nutrients. Significant weed growth and green and/or murky colored water from algal blooms and suspended sediment are generally found in eutrophic water bodies. **Hypereutrophic** describes a water body extremely rich in nutrients. Such water bodies experience heavy algal blooms and/or very dense weed growths all summer.

The determination of the trophic status (stage of eutrophication/ degradation) of Big Butternut Lake is an important aspect of the diagnosis of its problem. The trophic status indicates the severity of a lake's algal problems and the degree of change needed to meet its recreational goals. However, it does not indicate the cause of the algal growth, or the means of reducing such growth.

The trophic states of a lake or pond is usually determined by the concentration of an essential element or dissolved nutrient, which is referred to as the "limiting nutrient". This nutrient will generally control the amount of algae a particular lake can produce. Aquatic weeds, on the other hand, derive most of their nutrients from lake or pond sediments. The limiting nutrient concept is a widely applied principle in the study of eutrophication. It is based on the concept that, in considering all of the substances needed for biological growth, one will be present in limited quantity. The availability of this limiting nutrient will, therefore, control the rate of algal growth. The identification of a lake's limiting nutrient may point the way toward possible solutions for its algal problems.

Algal growth is generally phosphorus-limited in most waters similar to Big Butternut Lake. It has been amply demonstrated, in experiments ranging from laboratory bioassays to fertilization of in-situ enclosures to whole-lake experiments, that most often phosphorus is the nutrient that limits algal growth. Algal abundance is nearly always phosphorus-dependent. A reduction in the phosphorus concentration in a lake is, therefore, necessary in order to reduce algal abundance and improve water transparency. Failure to reduce phosphorus concentrations will allow the process of eutrophication to continue at an accelerated rate.

Nitrogen is also a naturally occurring nutrient important for aquatic plant growth. While phosphorus typically stimulates excess algal growth, in some cases nitrogen may play a part as well. Also, several forms of nitrogen will be present in runoff. These include: ammonia nitrogen, nitrate + nitrite nitrogen, and total Kjeldahl nitrogen. These nutrients were all measured as a part of this study. A complex biological nitrogen cycle determines the form of nitrogen present in natural waters. For example, microbial decomposition of organic nitrogen waste will produce ammonia; however, over time another type of microbe may convert the ammonia to nitrate and nitrite. Possible sources of nitrogen include fertilizers, malfunctioning septic systems, and animal wastes.

2.1.1 General Chemical Characteristics

2.1.1.1 Temperature and Dissolved Oxygen

Determination of a lake's temperature and dissolved oxygen dynamics is crucial in understanding the in-lake biological and chemical cycles. The degree of thermal stratification that takes place in a lake can be determined from temperature data collected from various depths. Stratification occurs when the surface water is warmed during the late spring and through the summer. A layer of warm, less dense water (called the "epilimnion") is formed at the surface of the lake, while a layer of cool, more dense water (called the "hypolimnion") is formed near the lake bottom. The epilimnion is exposed to the atmosphere, and the effect of the wind ensures that the lake surface is constantly mixed and replenished with oxygen. However, the hypolimnion is isolated from the lake surface by the epilimnion, which forms a barrier preventing the replenishment of oxygen. As stated previously, dead algae, weeds, and other organic matter will sink to the lake bottom and decompose, using much of the available oxygen.

As a lake becomes more productive, the amount of algae and weeds reaching the hypolimnion increases, and all the oxygen may be used up by decomposition. The lack of oxygen will change the chemical environment of the lake bottom, catalyzing the release of phosphorus and other nutrients from the sediments to the water. In a strongly stratified lake, this phosphorus will remain trapped in the hypolimnion, unavailable for algal growth near the lake surface. However, if the lake is not strongly destratified, the epilimnion and hypolimnion would mix together. Phosphorus previously isolated in the bottom waters would be transported to the lake surface, where it would be available for algal growth.

2.1.1.2 Conductivity

Conductivity is a measure of a water sample's ability to conduct an electrical current. Electrical currents are transported by ions (dissolved, charged particles) in solution; therefore, conductivity is an indirect measure of the concentration of ions in a lake water sample. The concentration of ions in a lake is dependent on several factors—the geology and chemistry of weathered rocks and soils in the watershed, point source and non-point source pollution to the lake, and in-lake chemical cycles. The conductivity of natural waters may vary from 50–1,500 µmhos/cm.

2.1.1.3 pH

pH is a measure of the concentration of hydrogen ions in a lake water sample; it is most commonly used as a measure of the acidity of a sample. A pH value of 0 is highly acidic, a pH value of 14 is highly basic, and a pH value of 7 is considered neutral. The pH balance of a lake is crucial, as most aquatic organisms can survive in only a narrow range of pH values. Most natural water bodies have a pH in the range of 4 to 10.

2.1.1.4 Alkalinity

The alkalinity of a lake water sample is a measure of its ability to buffer the pH of the water; that is, the ability of the water to neutralize the effects of acids or bases added to the system, thereby keeping the pH in a safe range for aquatic life. Most alkalinity in a lake is present as ions called carbonates and bicarbonates. These ions are mainly the result of geologic weathering of rocks, however the concentration is somewhat regulated by respiration and photosynthesis. The alkalinity of a lake water also provides an estimate of the hardness of the water.

2.1.1.5 Color

The water color of a lake sample can give an indication of the amount and type of dissolved organic matter present. Decomposition of organic matter in wetlands and bogs results in the release of "tea-colored" organic acids, which may be transported to a lake through overland runoff or through tributary streams and rivers. These organic acids are not harmful to the lake or aquatic organisms, however they can affect the transparency of the lake water. Therefore, the Secchi disc transparency of a highly colored lake may be less than would be otherwise expected. The water color measurement scale used in this study can be interpreted as follows: a measurement of 0 would be expected for extremely clear, colorless waters, while a measurement of 300 would result from highly colored bog waters.

2.2 Methods

Water quality samples and field data were collected by BBLPRD volunteers and by personnel from the Polk County Land Conservation Department. Dissolved oxygen and temperature data were collected using a YSI Model 57 oxygen and temperature meter. Conductivity data was collected using a YSI Model 33 meter. Water samples were collected using a Van Dorn sampler. Samples intended for analysis of dissolved constituents were filtered using Millipore 0.45 µm filters. Samples were placed in bottles provided by the WDNR, and the appropriate samples were preserved with acid as per WDNR protocol. The samples were immediately placed on ice and shipped to the Wisconsin State Laboratory of Hygiene (Madison, WI) for analysis.

2.3 Results

All laboratory and field water quality data collected during this study are tabulated in Appendix A at the end of this report. The results of the data analysis is discussed in the following paragraphs.

2.3.1 Temperature and Dissolved Oxygen

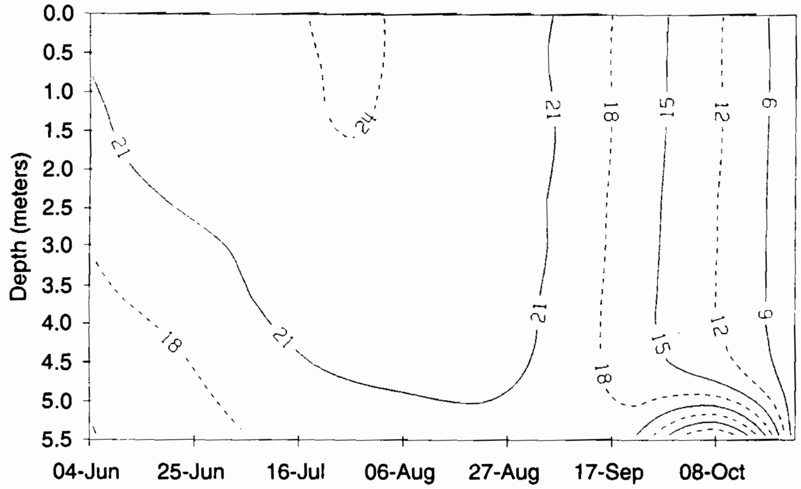
Time-depth diagrams of temperature and dissolved oxygen isopleths are illustrated in Figure 2. These diagrams indicate that the lake began to stratify during early June, and was weakly stratified during July and beginning of August. The lake was completely mixed again by early September. The diagram of dissolved oxygen isopleths indicates that during the period of summer stratification, the hypolimnion (the near sediment water layer) became anoxic (devoid of oxygen). Anoxia occurs when biological and chemical processes (such as decomposition and reduction) occur in the water just overlying the sediments. Hypolimnetic anoxia causes several negative effects in lakes; the most important is that the chemistry of the lake bottom sediments change. In Big Butternut Lake, it is apparent that hypolimnetic anoxia caused the sediments to release a large mass of phosphorus. This will be discussed further in the section of Big Butternut Lake phosphorus dynamics.

2.3.2 Conductivity

The time-depth diagram of conductivity isopleths are also illustrated in Figure 2. This diagram confirms that the anoxic hypolimnion in Big Butternut Lake caused a change in sediment chemistry. During the period of anoxia, the conductivity of the near bottom waters was extremely high, indicating the presence of high concentrations of dissolved ions.

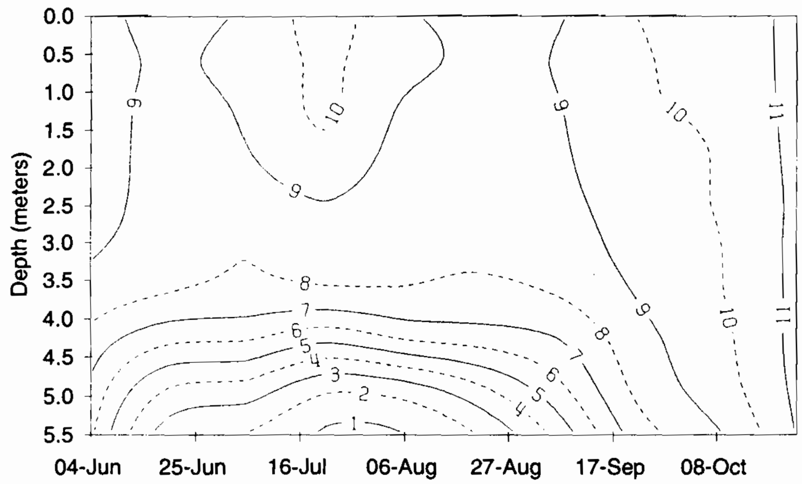
Big Butternut Lake 1995

Time-Depth Diagram of Temperature (C) Isopleths



Big Butternut Lake 1995

Time-Depth Diagram of Dissolved Oxygen (mg/L) Isopleths



Big Butternut Lake 1995

Time-Depth Diagram of Conductivity (umhos/cm) Isopleths

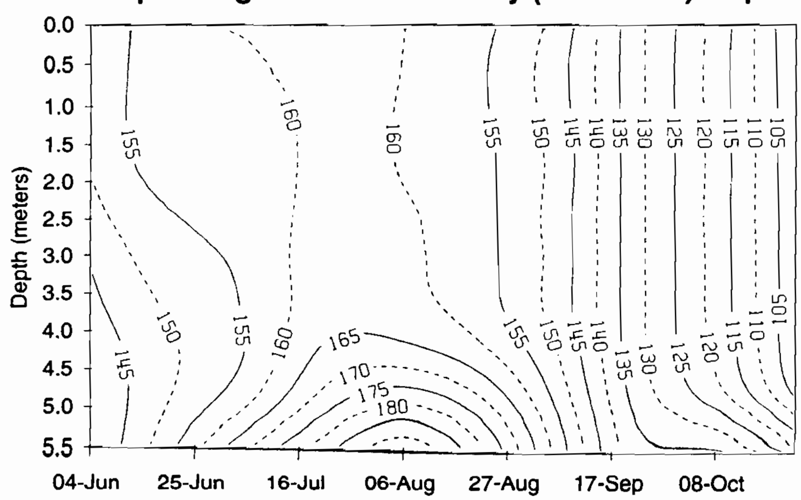


Figure 2

2.3.3 General Water Quality Parameters

The surface water color, pH, and alkalinity observed in Big Butternut Lake during 1995 are illustrated in Figure 3. The water color was within the range that would be expected for similar Wisconsin and Minnesota lakes. The slight increase in color that occurred during July through September was most likely due to algal pigments.

The pH and alkalinity values observed during 1995 were within the normal range for northern temperate lakes. The pH values increased slightly throughout the summer, most likely due to carbon dioxide uptake by algae.

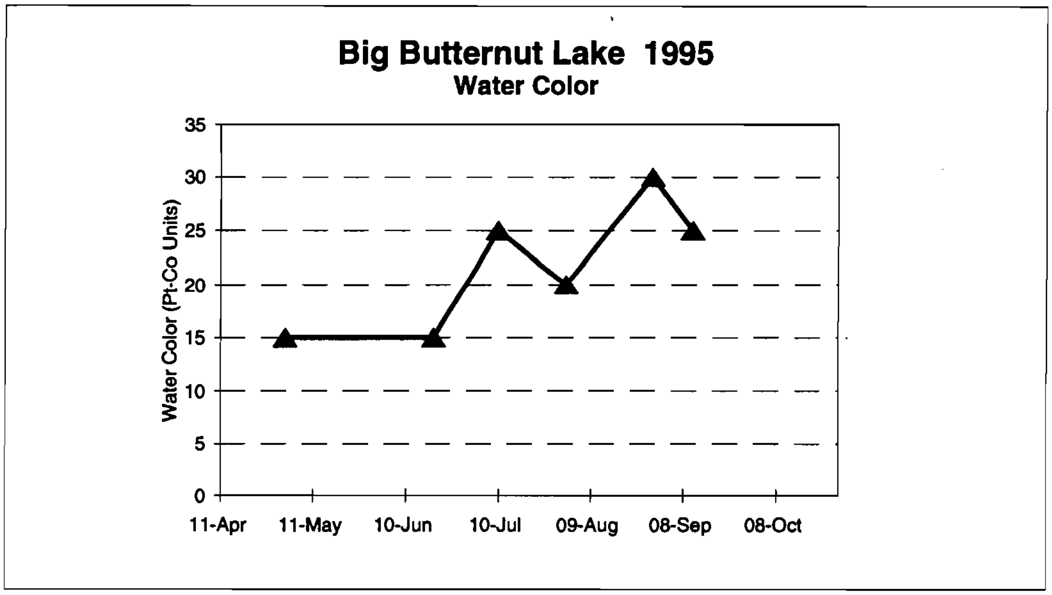
2.3.4 Nutrients

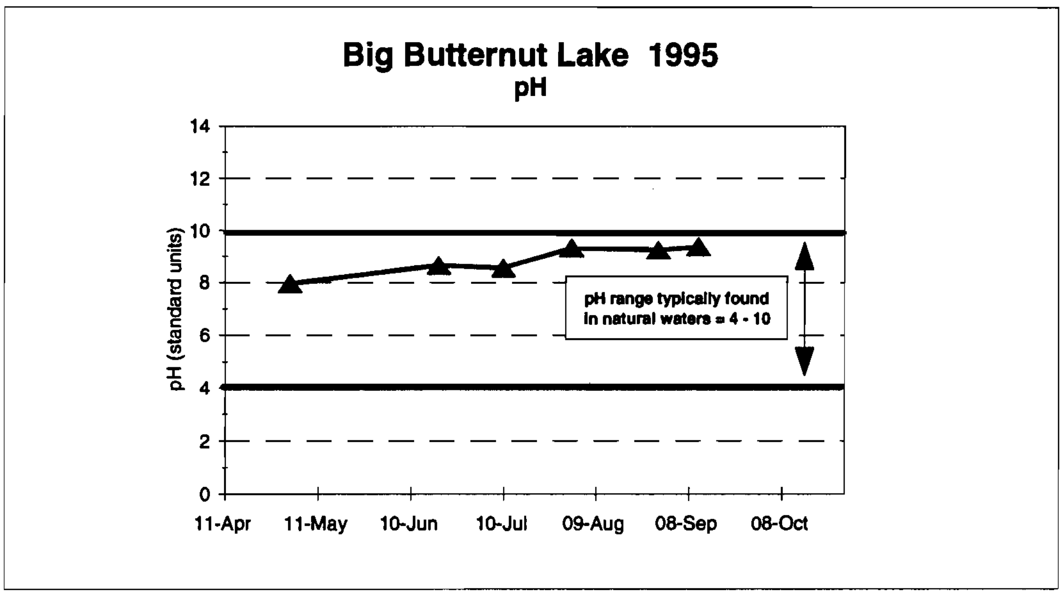
Phosphorus and nitrogen are the two nutrients most likely to control algal growth in Big Butternut Lake. The ratio of total nitrogen to total phosphorus is often used as a cursory indicator of which nutrient is limiting algal growth; a ratio of greater than 10 is generally interpreted as a sign of phosphorus limitation, while a ratio of less than 10 is generally interpreted as a sign of nitrogen limitation. Figure 4 illustrates the total nitrogen to total phosphorus ratios observed in Big Butternut Lake during 1995. As would be expected, phosphorus appears to be the limiting nutrient in the lake. Therefore, watershed and lake management activities should focus on phosphorus reduction to control algal growth.

2.3.4.1 Nitrogen

Three forms of nitrogen were measured in Big Butternut Lake during 1995: total nitrogen (the sum analysis of all forms of nitrogen), nitrate-nitrogen, and ammonia-nitrogen. Both nitrate-nitrogen and ammonia-nitrogen are both readily available for uptake by algae. The total nitrogen observed in the lake during 1995 is illustrated in Figure 5. The concentrations of nitrate- and ammonia-nitrogen were consistently below the detection level of the Wisconsin State Laboratory of Hygiene's instruments, and were therefore not plotted.

Figure 3


Big Butternut Lake 1995
Water Color
Water Color (Pt-Co Units)
35
30
25
20
15
10
5
0
11-Apr
11-May
10-Jun
10-Jul
09-Aug
08-Sep
08-Oct


Big Butternut Lake 1995
pH
pH (standard units)
14
12
10
8
6
4
2
0
pH range typically found in natural waters = 4 - 10
11-Apr
11-May
10-Jun
10-Jul
09-Aug
08-Sep
08-Oct

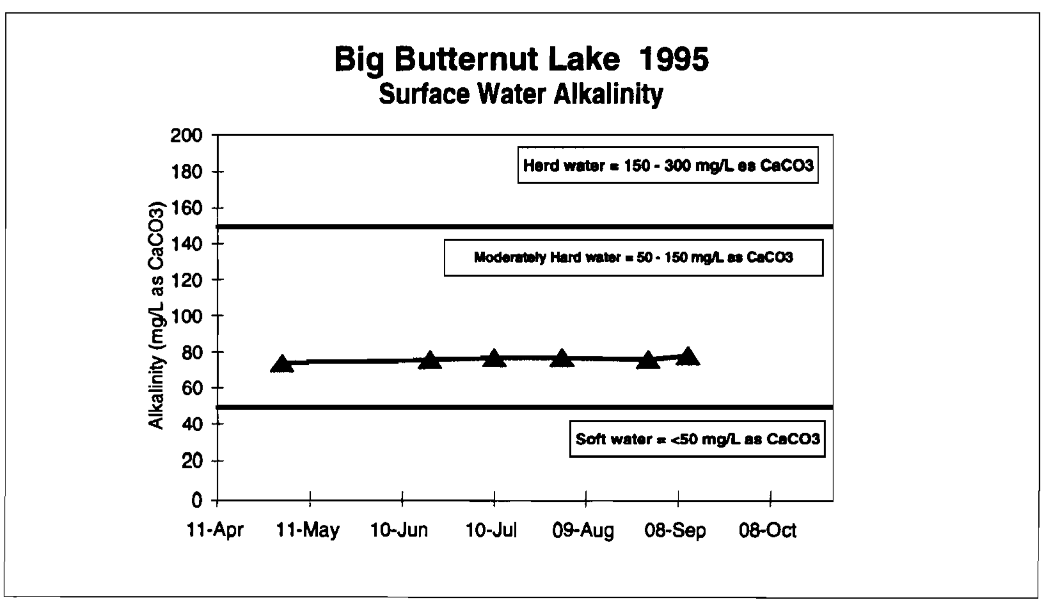

Big Butternut Lake 1995
Surface Water Alkalinity
Alkalinity (mg/L as CaCO3)
200
180
160
140
120
100
80
60
40
20
0
Hard water = 150 - 300 mg/L as CaCO3
Moderately Hard water = 50 - 150 mg/L as CaCO3
Soft water = <50 mg/L as CaCO3
11-Apr
11-May
10-Jun
10-Jul
09-Aug
08-Sep
08-Oct

Figure 4
Big Butternut Lake 1995
Surface Water TN:TP Ratio

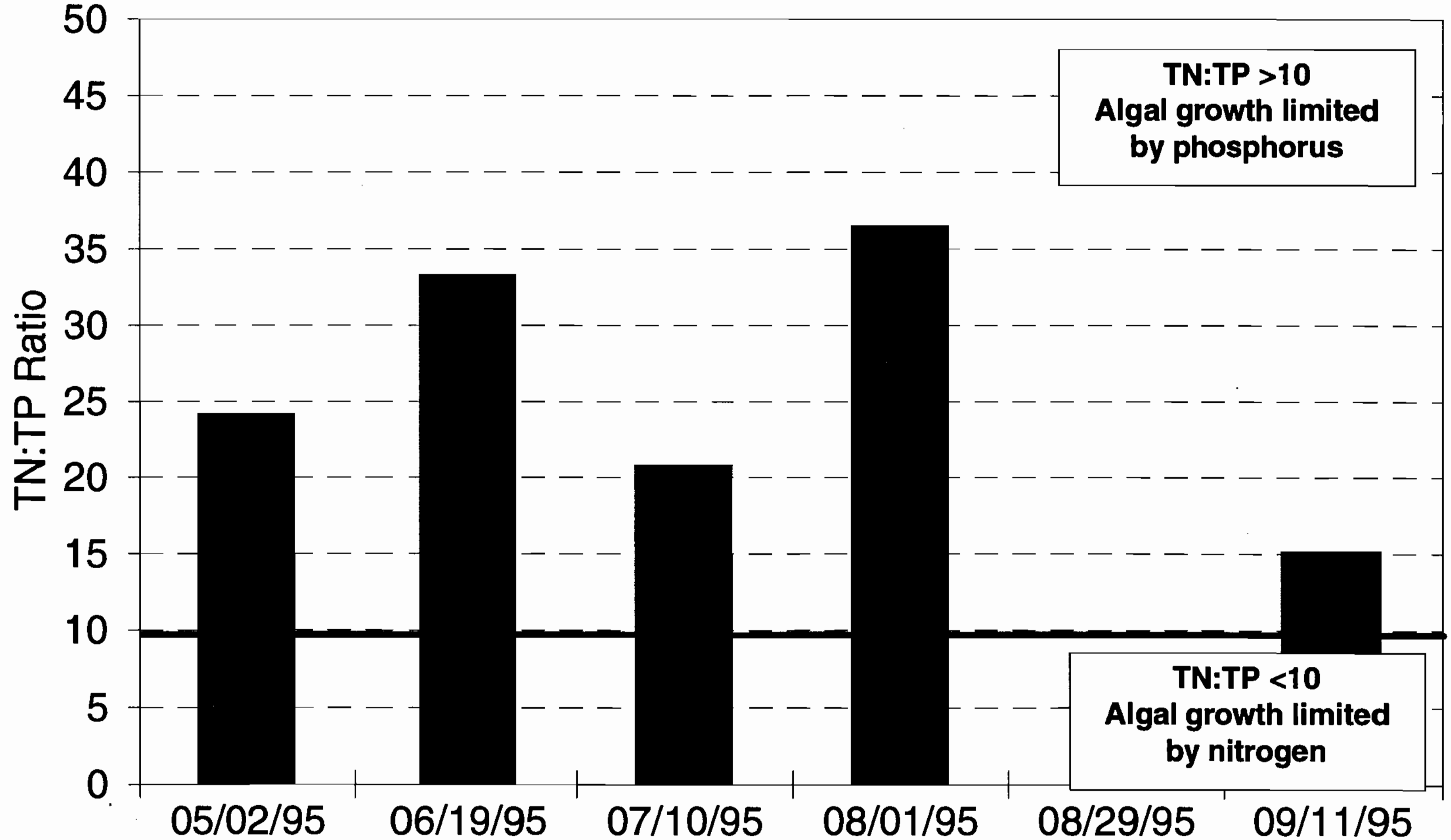
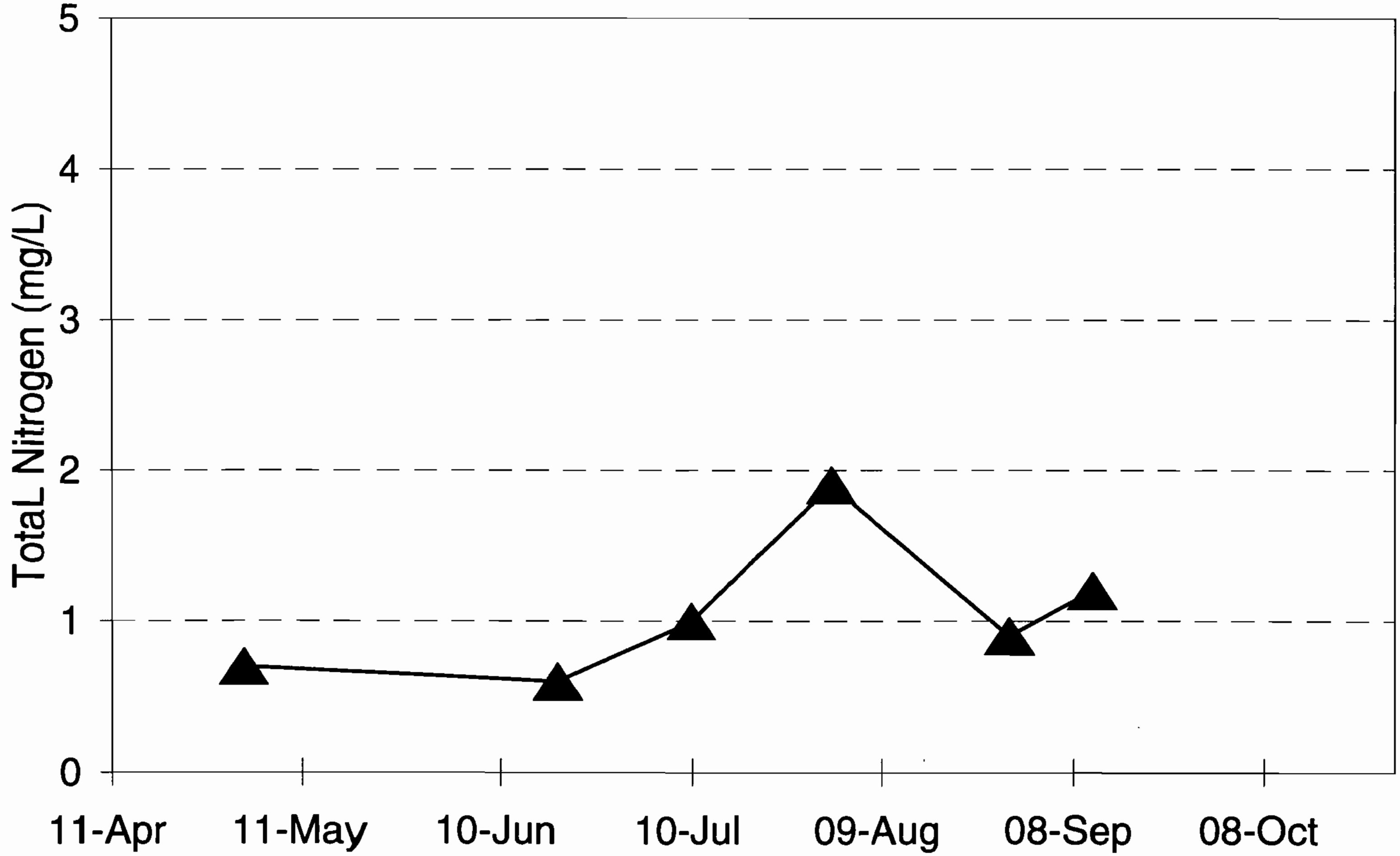


Figure 5
Big Butternut Lake 1995
Surface Water Total Nitrogen



2.3.4.2 Phosphorus

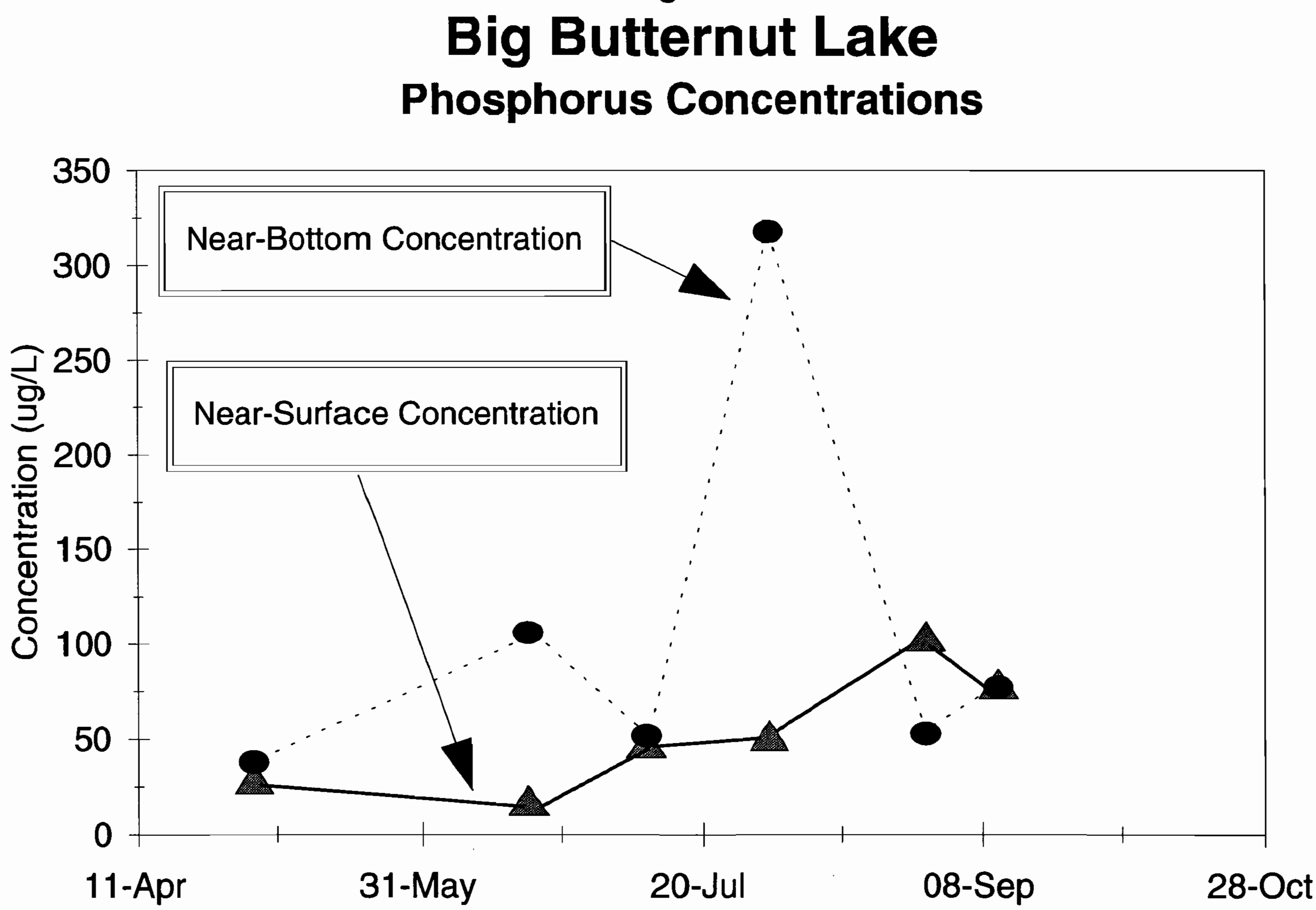
As stated previously, Big Butternut Lake appears to be phosphorus-limited, and therefore both lake and watershed management activities to control algal growth in the lake should focus on the reduction of phosphorus. As discussed in the introductory sections, phosphorus can be transported to a lake by stormwater runoff from the surrounding watershed, by point-source loads (such as sewage treatment plants), or from sediment internal load when the hypolimnion is anoxic (devoid of oxygen).

The total phosphorus concentrations observed in the surface and near-sediment waters during 1995 are plotted in Figure 6. It is apparent that phosphorus accumulated in the hypolimnion during the summer months. It is certain that most of this accumulated phosphorus originated in the lake sediments, and was released as internal load. However, it must be noted that some of the accumulated phosphorus may have been due to decomposition of curlyleaf pondweed, which grows in dense beds at the northeast end of the lake (See Section 3.0). The near-surface phosphorus concentration increased throughout the summer, due either to entrainment and transport of the hypolimnetic phosphorus to the lake surface, or to stormwater runoff. It appears that the lake may have mixed during early July (due to similarity in surface and near-sediment phosphorus concentrations) and again during early September. Figure 7 illustrates just the near-surface phosphorus concentrations and the associated trophic state. The lake was mesotrophic-eutrophic during late May, and by the end of the summer was hypereutrophic. The decrease in water quality is most certainly due to phosphorus release from within the lake; mostly likely from sediment phosphorus release and phosphorus released from decomposing curlyleaf pondweed.

2.3.5 Chlorophyll a/Phytoplankton and Zooplankton

Phytoplankton (algae) and zooplankton (animal plankton) identification and enumeration were completed by Barr Engineering Company biologists at the Barr laboratory. Phytoplankton samples were collected at the lake surface, while zooplankton samples were collected using a plankton net. Samples were preserved using Lugol's solution. The phytoplankton and zooplankton data are included in Appendix B. Chlorophyll a analyses were completed at the Wisconsin State Laboratory of Hygiene. Apparently the lab had difficulties with the analyses throughout the summer - several analyses were rejected by the lab, and several results reported by the lab do not correspond with the phytoplankton densities observed in the lake. The chlorophyll a results that were reported by the lab are plotted in Figure 8. The phytoplankton analyses show that blue-green algae are

Figure 6



Big Butternut Lake
Phosphorus Concentrations
Concentration (ug/L)
350
300
250
200
150
100
50
0
11-Apr
31-May
20-Jul
08-Sep
28-Oct
Near-Bottom Concentration
Near-Surface Concentration

Figure 7

Big Butternut Lake 1995

Near-Surface TP Concentrations

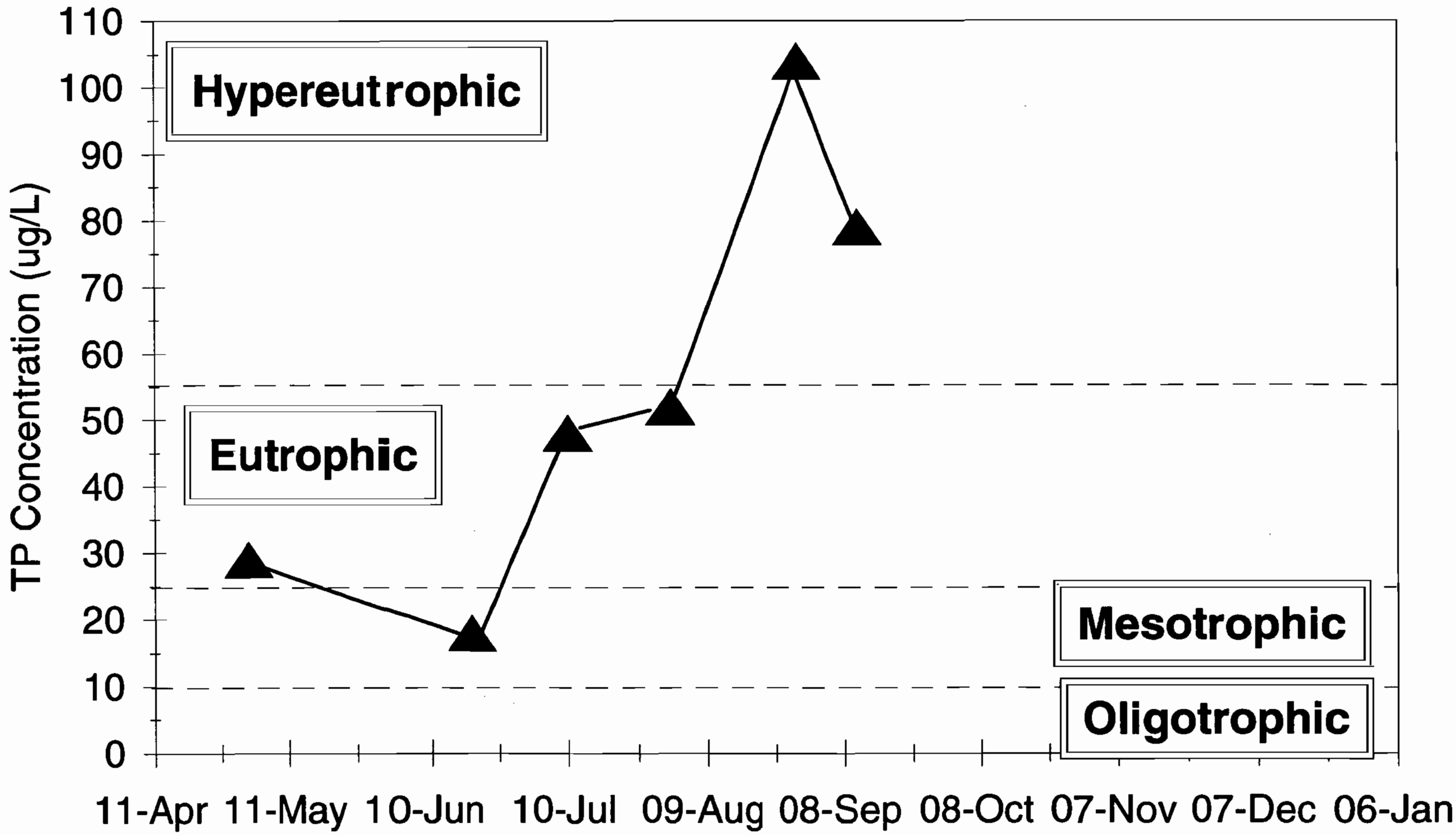
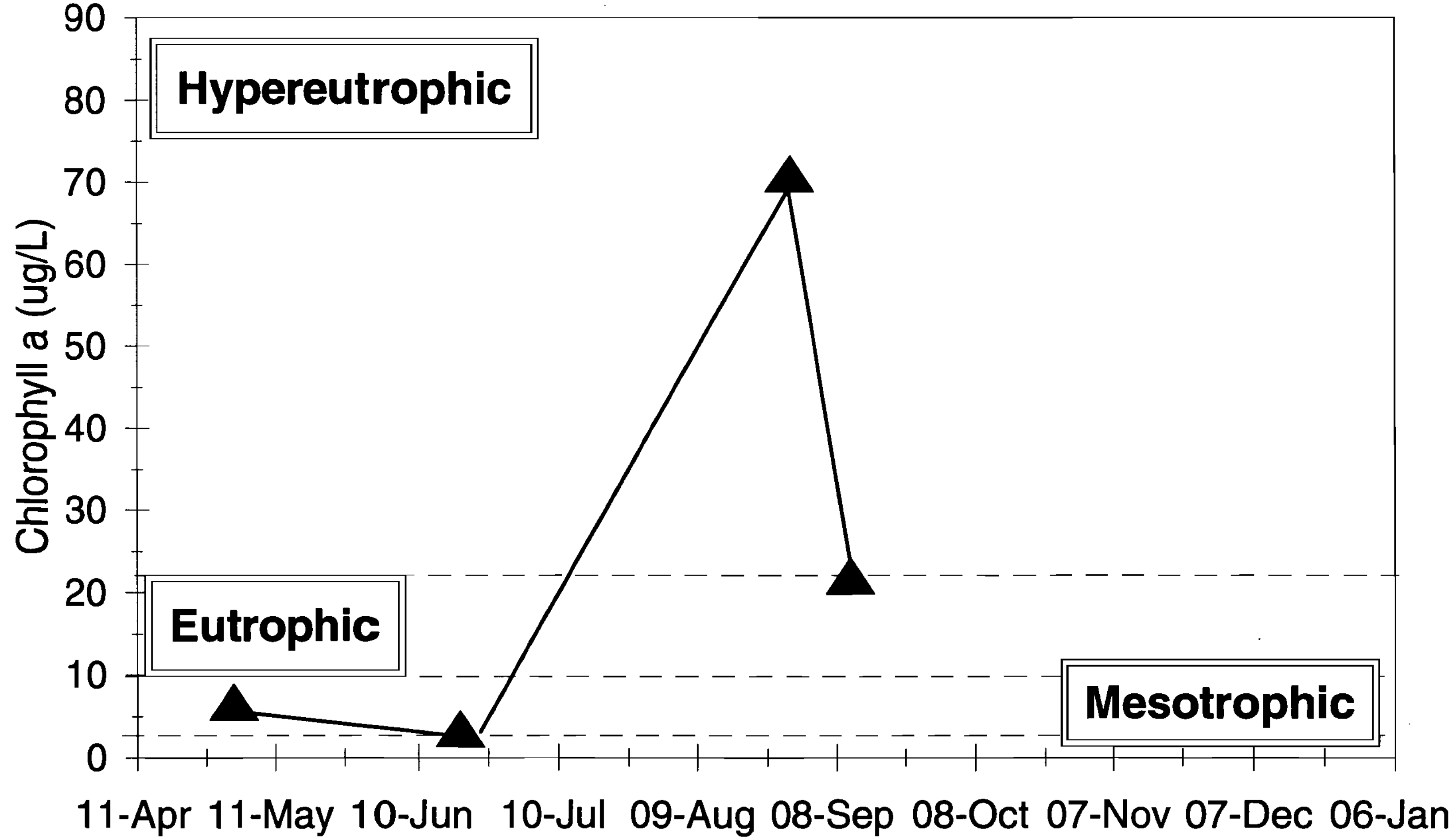


Figure 8

Big Butternut Lake 1995

Chlorophyll a Concentrations



dominate in the lake throughout the summer. Blue-green algae typically form the dense mats observed during nuisance algae blooms in mid-to-late summer.

2.3.6 Water Transparency

Secchi disk transparency measurements were taken during May through October 1995, and are plotted in Figure 9. Secchi disk transparency provides a quick measure of the surface water clarity in a lake. Water transparency is affected by several parameters, such as water color, density of aquatic macrophytes (weeds), density and type of algae. The water transparency in Big Butternut Lake appears to be most affected by the density of algal growth in the lake. Therefore, as phosphorus concentrations in the lake increase, algal density will increase, and water transparency will decrease. From Figure 8, it is apparent that water transparency decreased coincident with the increase in phosphorus concentration.

2.3.7 Lakeshore Resident Survey

During March 1995, surveys were distributed to all lakeshore residents of Big Butternut. The survey requested daily ratings of water level and water quality. Close to 100 copies of the survey were distributed; only 10 copies were returned. However, the lake residents who took the time to complete the survey each day appeared to do a complete and conscientious job. A copy of the survey is included in Appendix C. The results of the water quality portion of the survey will be addressed in this section; the results of the lake water level portion is discussed in Section 4.3.1. Figure 10 displays a plot of the survey results. Residents were asked to rate the water quality each day on a scale of 1 to 5, with 1 equivalent to very poor water quality, 2 equivalent to poor water quality, 3 equivalent to good water quality, 4 equivalent to very good water quality, and 5 equivalent to excellent water quality. The survey results show that residents felt the water quality was very good to excellent during April and early May, and that the water quality declined throughout the summer until late July and August, when residents rated it poor to very poor. Residents observed an improvement in quality during late September and October, when the average rating was good. The lakeshore residents observations about water quality corresponded nicely with the both the water transparency and the total phosphorus data collected during the same period. During late-July and August, water transparency declined to less than 2 feet, while near-surface phosphorus concentrations increased to greater than 80 μg/L.

Figure 9

Big Butternut Lake 1995

Secchi Disk Transparencies

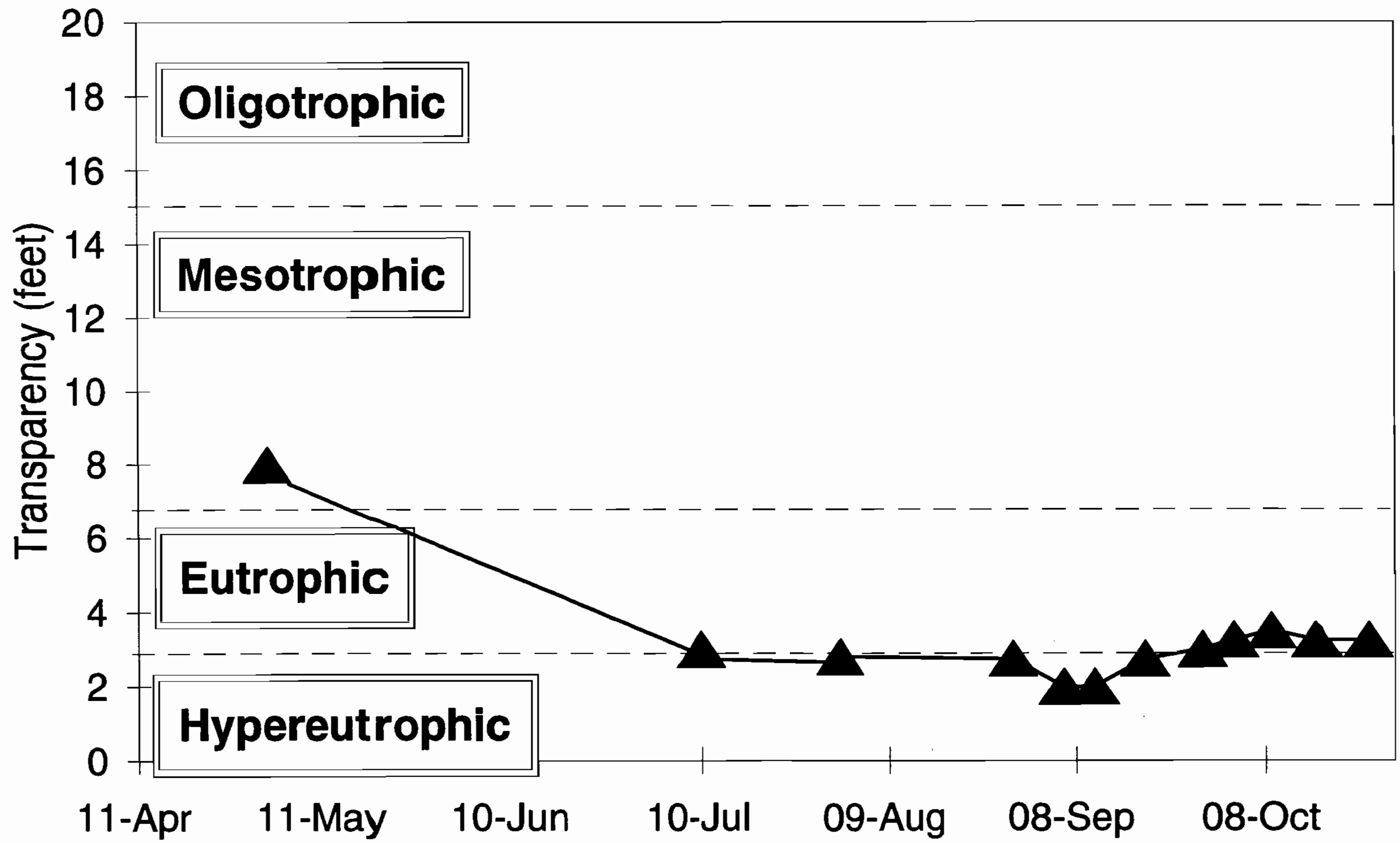
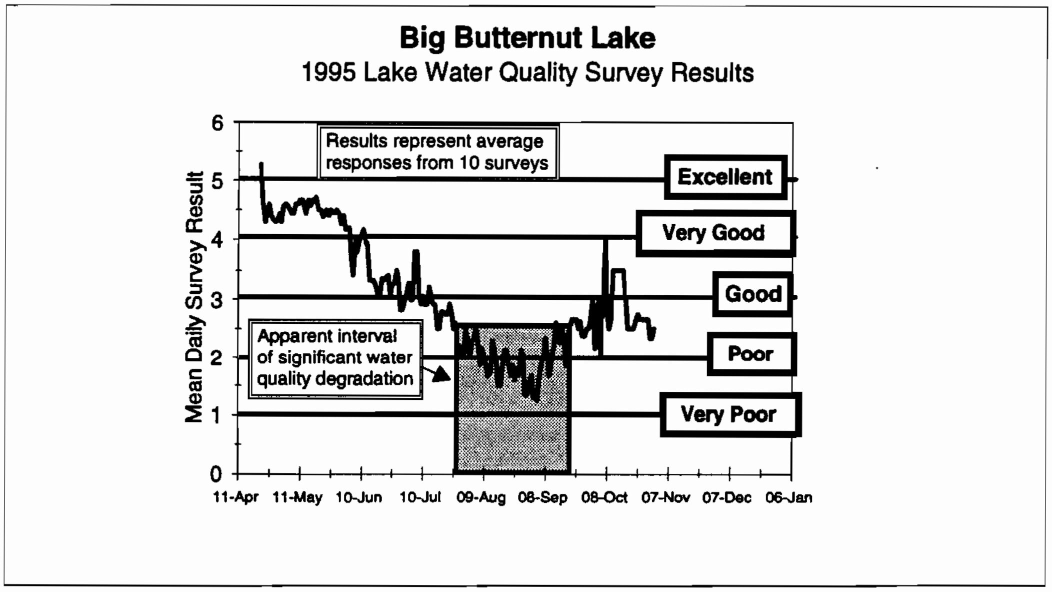
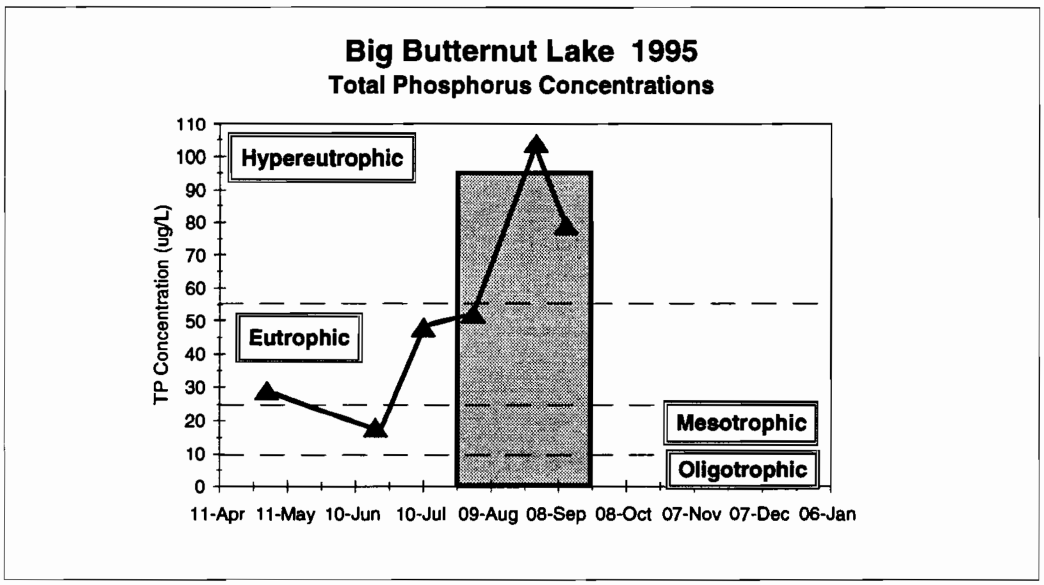


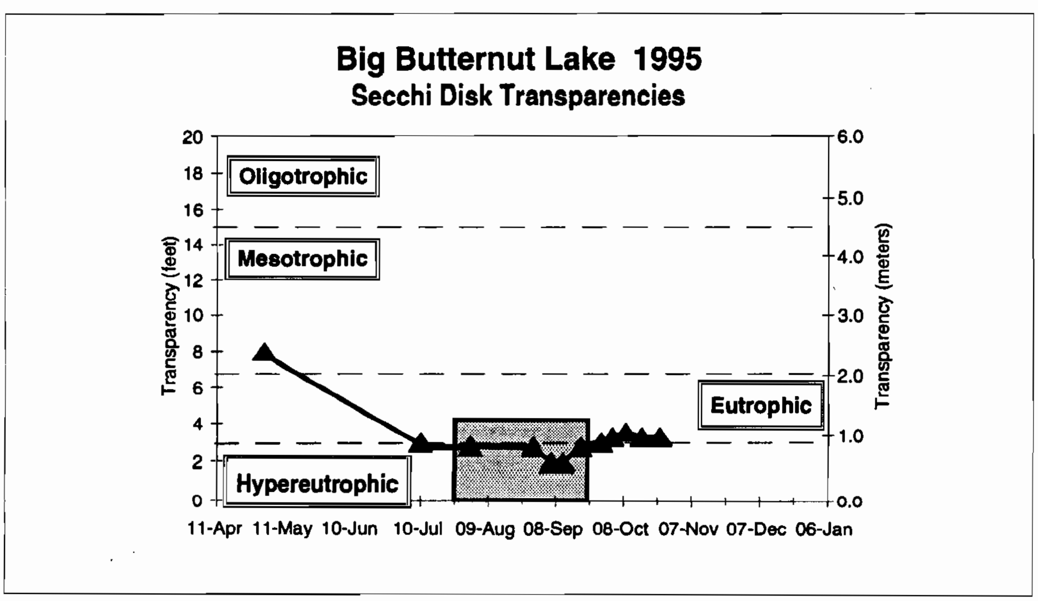
Figure 10



Big Butternut Lake
1995 Lake Water Quality Survey Results
Mean Daily Survey Result
Results represent average responses from 10 surveys
Excellent
Very Good
Good
Poor
Very Poor
Apparent interval of significant water quality degradation
0
1
2
3
4
5
6
11-Apr 11-May 10-Jun 10-Jul 09-Aug 08-Sep 08-Oct 07-Nov 07-Dec 06-Jan



Big Butternut Lake 1995
Total Phosphorus Concentrations
TP Concentration (ug/L)
Hypereutrophic
Eutrophic
Mesotrophic
Oligotrophic
0
10
20
30
40
50
60
70
80
90
100
110
11-Apr 11-May 10-Jun 10-Jul 09-Aug 08-Sep 08-Oct 07-Nov 07-Dec 06-Jan



Big Butternut Lake 1995
Secchi Disk Transparencies
Transparency (feet)
Transparency (meters)
Oligotrophic
Mesotrophic
Eutrophic
Hypereutrophic
0
2
4
6
8
10
12
14
16
18
20
0.0
1.0
2.0
3.0
4.0
5.0
6.0
11-Apr 11-May 10-Jun 10-Jul 09-Aug 08-Sep 08-Oct 07-Nov 07-Dec 06-Jan

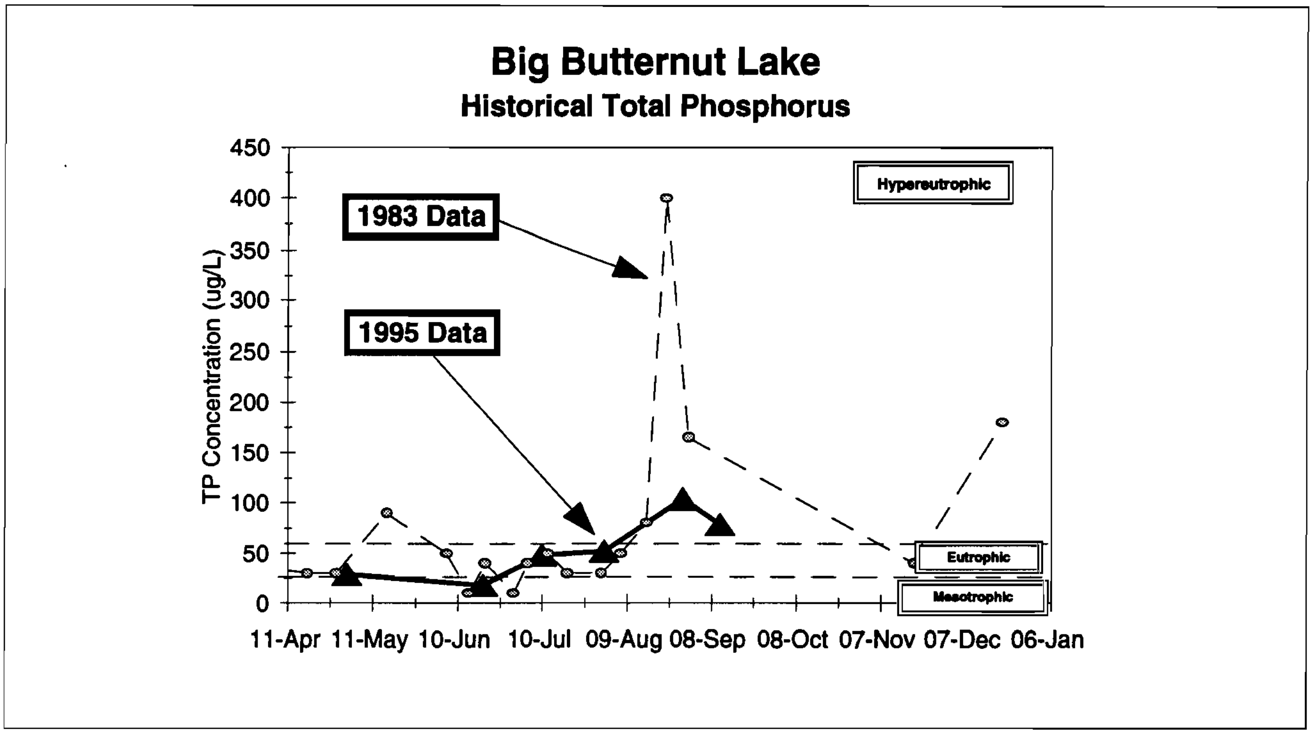
2.3.8 Historical Water Quality

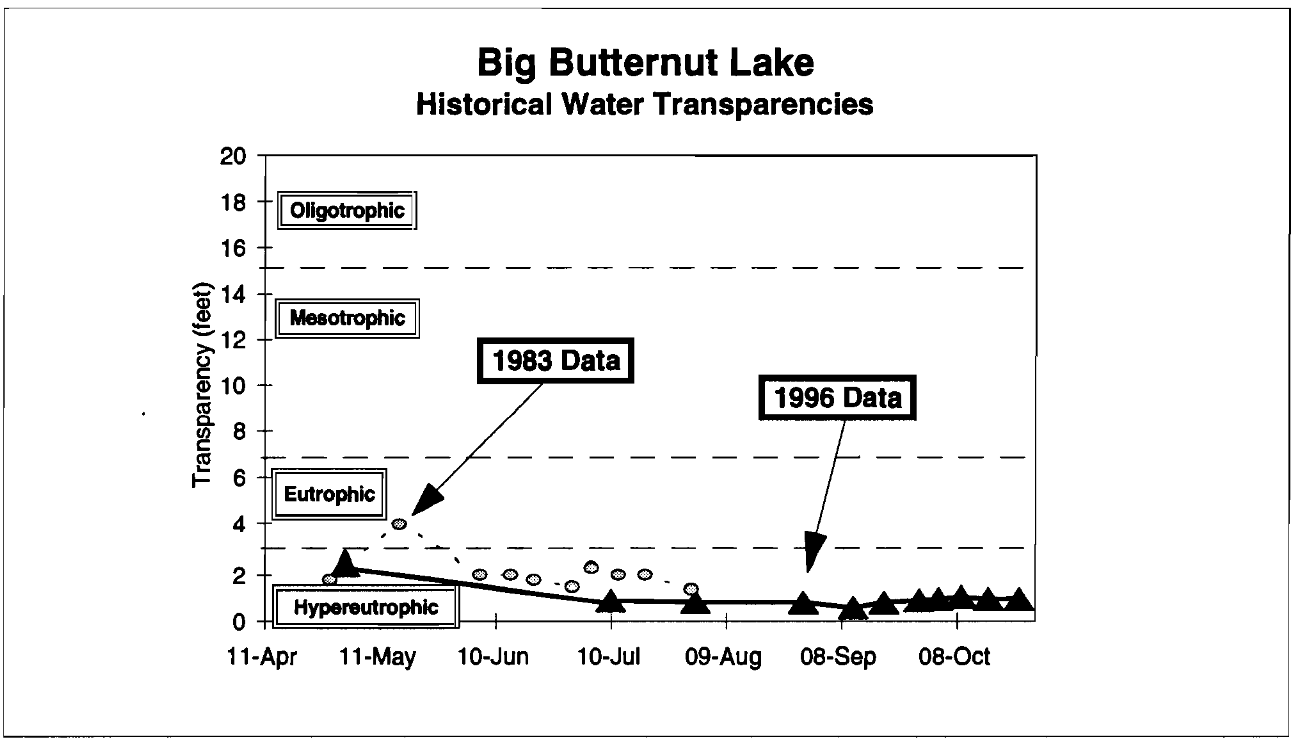
The water quality data collected during 1995 was compared to the data collected during the previous study conducted by the WDNR in 1983 (Figure 11). The 1983 laboratory data were generated by Dairyland Industries. Subsequently, the WDNR found that the quality assurance/quality control data generated by the lab during 1983 were not acceptable; therefore all water chemistries from 1983 are questionable. From the water transparency data, it appears that the lake water clarity was slightly greater during 1983 than during 1995. It is important to note that annual climatic conditions, such as annual precipitation, average summer temperature, average summer cloud cover, average summer wind speed and direction can drastically influence lake water quality. Therefore, it is impossible to draw conclusions as to water quality trends with only two years of data. However, the BBLPRD was enrolled in the WDNR volunteer monitoring program during 1995. Each year, surface water samples will be collected for phosphorus and chlorophyll a analyses; in addition, lake volunteers will continue to monitor the lake water transparency. Some conclusions about water quality trends may be drawn after 4 to 5 years of such data are collected.

2.3.9 1996 Water Quality

During 1996, volunteers collected additional water quality data from Big Butternut Lake as part of the WDNR volunteer monitoring program. That data was not available during the preparation of this report. However, lakeshore residents made several observations about the water quality in the lake during that period. The water quality was observed to be fairly normal until shortly before July 4, 1996 when an unusually large rain storm occurred. Several beaver dams upstream of the lake on the inlet creeks were washed loose; quite a bit of sediment and debris that apparently had been stored behind the dams was washed into the lake. Within a week, an algal bloom occurred. Many residents observed that the algal bloom was as severe as any observed during the last 20 years. Barr Engineering personnel visited the lake during early July and collected a single sample for phytoplankton analysis, which revealed the bloom consisted of blue-green algae.

Figure 11


Big Butternut Lake
Historical Total Phosphorus
TP Concentration (ug/L)
450
400
350
300
250
200
150
100
50
0
1983 Data
1995 Data
Hypereutrophic
Eutrophic
Mesotrophic
11-Apr 11-May 10-Jun 10-Jul 09-Aug 08-Sep 08-Oct 07-Nov 07-Dec 06-Jan


Big Butternut Lake
Historical Water Transparencies
Transparency (feet)
20
18
16
14
12
10
8
6
4
2
0
Oligotrophic
Mesotrophic
Eutrophic
Hypereutrophic
1983 Data
1996 Data
11-Apr 11-May 10-Jun 10-Jul 09-Aug 08-Sep 08-Oct

2.4 Conclusions

The water quality in Big Butternut Lake was assessed during 1995. While the water quality during May was quite good (mesotrophic), by late-July the water quality had significantly degraded (hypereutrophic). From the laboratory analyses performed during 1995, it does appear the lake is phosphorus limited. The mid-summer water quality degradation appears to be due to an increase in surface water phosphorus concentrations, which in turn caused increased algal growth and decreased water transparency. The increase in surface water phosphorus is most likely due to a combination of the following: internal phosphorus release from the lake sediments, internal phosphorus release from decomposing curlyleaf pondweed, and stormwater runoff from the lake's watershed. The dynamics of curlyleaf pondweed will be discussed in Section 3.0 of this report.

2.5 Recommendations

Based on the results of the water quality assessment of Big Butternut Lake, the following remedial actions are recommended:

1. **Estimate the mass of phosphorus entering Big Butternut Lake annually from the watershed, and identify any potential problem sources of phosphorus within the watershed.** While a similar analysis was performed by the WDNR during the 1983 study, some of that study's results seemed questionable to members of BBLPRD. To complete this recommendation, several tasks must be completed. Land use within the Big Butternut Lake watershed must be identified. Drainage patterns within the watershed must be delineated. A ground survey should be completed to identify any problem areas within the watershed, such as eroded stream beds, farm feedlots, large areas of disturbed soil, etc. The ground survey would also be used to identify any areas upstream of the lake which provide water quality benefits to the lake, and which should be protected. (An example of this may be the wetland/beaver dam complexes upstream of the lake). The annual phosphorus mass entering the lake can then be estimated from statistical relationships that have been developed between land use and associated phosphorus mass load. In addition, the mass of phosphorus released each year during decomposition of curlyleaf pondweed in the lake can be estimated.

2. **Complete a phosphorus and water balance for Big Butternut Lake.** Phosphorus and water balances are basically calculations which determine the relative importance of all the sources of water and phosphorus to Big Butternut Lake. Components of a phosphorus balance would include the mass of phosphorus entering the lake each year from watershed stormwater runoff, from atmospheric deposition, and from internal phosphorus load. Once the magnitude of the various phosphorus sources has been determined, specific management strategies can be identified and prioritized. Possible management strategies that may provide significant water quality benefit for Big Butternut Lake include application of aluminum sulfate (alum) to prevent internal phosphorus release from the lake sediments, installation of a hypolimnetic aerator to increase oxygen concentrations near the lake bottom, construction of stormwater detention basins to remove phosphorus prior to entry to the lake, and construction of feedlot detention basins to treat animal wastes prior to discharge to the watershed. Both items 1 and 2 could be completed through a WDNR Lake Planning Grant Project with an approximate budget of $13,333. The WDNR would provide $10,000, while the BBLPRD would provide $3,333. The deadline for the grant application is January 31, 1997.

3. **Implement a long-term strategy for decreasing curlyleaf pondweed in Big Butternut Lake.** Water quality analyses performed during 1995 indicate that the curlyleaf pondweed beds may contribute to the degradation of the water quality in the lake. The dense growth of curlyleaf pondweed in the lake contributes both to the oxygen depletion in the lake's hypolimnion and to the lake phosphorus concentrations during decomposition of the dead weeds. Therefore, a decrease in curlyleaf pondweed density will most likely result in a positive water quality benefit for the lake. See Section 3.0 for specific recommendations and costs.

4. **Continue to participate in the WDNR's volunteer monitoring program.** The information collected through this program will be invaluable in identifying any water quality trends in Big Butternut Lake. It may be necessary to collect four to five years of data before any conclusions can be drawn as to water quality degradation or elevation. While volunteers are required to collect four or five samples per year, it is recommended that secchi disk transparency readings be collected more frequently. Weekly or biweekly measurements would provide a great deal of information as to the state of the water quality in the lake. Cost for this option is minimal, due to support from the WDNR and time donated by volunteer monitors.

3.0 Macrophyte Management

3.1 Background Information

Each summer nuisance beds of macrophytes, primarily curlyleaf pondweed, grow in several areas of Big Butternut Lake. The mats of vegetation interfere with lake use and recreation. Curlyleaf pondweed (*Potamogeton crispus*) is an exotic (non-native) macrophyte which became established in northern lakes in the early 1900s. The young curlyleaf plants emerge from the sediments during fall, remain dormant during winter, and after ice-out in spring grow rapidly, forming dense surface mats over expansive meadows. This growth cycle gives curlyleaf pondweed the opportunity to outcompete other macrophyte species for nutrients, sediment area, and light. It grows especially well in areas where mechanical harvesting or herbicides are used without careful planning. The curlyleaf population collapses naturally by the first week of July (Pullman, 1992); the dead vegetation tends to either wash up onto the lakeshore or sink to the lake bottom. Decay of the dead vegetation likely creates a hypolimnetic oxygen demand which may precipitate internal release of phosphorus from the lake sediments. Pullman (1992) recommends early seasonal control of curlyleaf pondweed during the initial stages of growth, so it can be controlled before the June/July population collapse causes hypolimnetic oxygen depletion, and before it interferes with lake recreation. Chemical treatment of the young curlyleaf pondweed plants during fall or spring may prevent formation of nuisance mats and depletion of oxygen, and may allow other native macrophyte species to revegetate those areas.

Both mechanical harvesting and chemical treatment have been used in the past to control the curlyleaf pondweed growth in Big Butternut Lake. The BBLPRD decided to conduct macrophyte surveys and experimental treatments of curlyleaf pondweed in order to develop a long-term management plan to control nuisance growth of macrophytes.

Specific activities performed during this phase of the project included the following:

- Completion of lake-wide macrophyte surveys. Two surveys were performed. The first was conducted during early-June during peak growth of curlyleaf pondweed. The second was conducted during August after the collapse of curlyleaf pondweed. Each survey was conducted using the grid sampling method of Jessen and Loud (1962).

- Performance of a controlled experimental treatment of curlyleaf pondweed beds to assess potential long-term management strategies. After completion of the first macrophyte survey described above, three curlyleaf pondweed plots were delineated using GPS at the northeast end of the lake. One plot was designated as the control, and was not be treated or altered in any way. The remaining two were designated as treatment plots and were treated with the aquatic herbicide endothall during late and early-Spring 1996. (**Note: The chemical treatments were arranged and financed independently by the Big Butternut Lake Protection and Rehabilitation District. No Planning Grant funds were used for the application of chemicals.**)

3.2 Macrophyte Educational Overview

Macrophytes (aquatic plants or "weeds") are naturally present to some extent in all northern lakes, and are an important part of the aquatic environment. Macrophytes form fish "nurseries", providing tangled shelters which protect eggs and fry from predators. Macrophytes also provide food and cover for waterfowl and adult fish. Insects, snails, algae, and microcrustaceans are all supported by macrophytes, which are also important food for both waterfowl and fish. Macrophytes also supply oxygen to the water column through the process of photosynthesis.

Four general types of macrophytes are typically found in northern lakes. "Emergents" are plants which are rooted in the lake bottom, but the stems grow above the lake surface. Examples of emergents are cattails (*Typha* spp.) and bulrush (*Scripus* spp.). Emergents generally grow in the shallow waters found near the lake shore. While emergents may sometimes form problems for boat access, they provide shoreline protection from the action of waves and waterfowl nesting habitat. "Free-floating" macrophytes, such as duckweed (*Lemna* spp.), are not rooted in the lake bottom but have an extensive root system which hangs beneath the free-floating leaves. These plants are often quite small, and may completely cover the water surface in small, stagnant water bodies. In larger lakes, they are generally not a nuisance. Duckweed, as the name implies, provides food for waterfowl. "Floating-leaved" macrophytes have leaves which float on the lake surface, with a long rooted stem; an example is the yellow water lily (*Nuphar* spp.). The leaves of these plants are quite fragile and are easily torn by wave action; therefore, they are typically found only in quiet bays. The "submergents" grow entirely underwater. Some submergents, such as the naiads (*Najas* spp.) generally grow close to the lake sediments, while others, such curlyleaf pondweed (*Potamogeton crispus*) may grow to the lake surface and form a thick mat. Submergent macrophytes may form a barrier to wave action and water currents. They also accelerate the removal of suspended solids from turbid water by trapping the particles on leaf and stem surfaces.

In some instances, macrophytes can become overabundant, causing detrimental effects to the lake ecosystem and decreasing the enjoyment of lake users. Dense macrophyte growth can interfere with boat navigation, overwhelm swimming beaches, and diminish the amount of oxygen available to aquatic life when they die and decompose. Contrary to popular opinion, nuisance macrophyte growth is not directly caused by increased phosphorus loads to a lake. Macrophytes generally extract nutrients from the lake bottom sediments, and do not use the dissolved nutrients which cause nuisance algae blooms. The process of eutrophication does tend to increase the amount of phosphorus found in lake sediments, and this may accelerate macrophyte growth. More likely, nuisance macrophyte growth occurs from the invasion of exotic (non-native) species, such as Eurasian watermilfoil and curlyleaf pondweed. The aquatic ecosystem depends on a macrophyte community formed of many plant species. Since exotic species have few natural predators, they tend to crowd out the native species, forming large single-species colonies. Unfortunately, the exotic plant species also tend to form dense, troublesome surface mats.

To properly manage nuisance macrophytes, it is important to understand their growth patterns, and understanding these patterns can lead to possible management strategies for controlling nuisance colonies. In general, the most common techniques for macrophyte control are herbicide application, mechanical harvesting, manual harvesting, and installation of benthic barriers. Common herbicides include Diquat, Aquathol-K, 2,4-D, and Sonar; the application rate and type of herbicide used must be closely monitored and controlled to eliminate negative impacts on the lake. Aquatic herbicides should only be applied by a trained technician. One drawback of herbicide use is that unless they are removed, the treated macrophytes will sink to the lake bottom and decompose, decreasing the concentration of oxygen in the water column and releasing nutrients into the water column which can promote algal growth.

Mechanical harvesting provides immediate results, and can be used to selectively treat only nuisance colonies. Drawbacks of mechanical harvesting are that the process is expensive and time consuming, and small fish may inadvertently be killed during harvesting. The harvested macrophytes must be removed from the lake, and disposed of on shore. Manual harvesting with a rake or scythe can be used to remove macrophytes from around small beaches or dock areas, with little adverse affects.

Benthic barriers are structures placed on the lake bottom to block macrophyte growth. Advantages of benthic barriers include: no toxic substances are released, their use is confined to small, specific areas, they can be removed, and they are effective on all species of macrophytes. Disadvantages include: they are expensive, they may be difficult to install on steep slopes, they must be cleaned off each year to prevent macrophyte rooting, and they may float to the surface if gases are trapped beneath them (Cooke et. al., 1993). Aquascreen, a commercially available fiberglass screen coated with polyvinyl chloride, has been proved effective in controlling macrophyte growth. Burlap has also been used, but it typically rots within one to three years.

It is important to note that any macrophyte control carried out in a lake should be undertaken as a scientific, coordinated effort. Indiscriminate macrophyte treatment can actually exacerbate the problem. A macrophyte control plan formulated for the lake is usually the best management practice.

The Wisconsin Department of Natural Resources estimates that 25 of the 150 different macrophytes that are found in Wisconsin lakes can form nuisance infestations (WDNR, 1989). The following lists the common nuisance plants found in Wisconsin (adapted from WDNR, 1989):

Common Name	Scientific Name
*Coontail	*Ceratophyllum demersum*
*Northern watermilfoil (native)	*Myriophyllum spp.*
Eurasian Watermilfoil (exotic)	*M. spicatum*
*Canada waterweed or elodea	*Elodea canadensis*
*Sago Pondweed	*Potamogeton pectinatus*
*Flatstem Pondweed	*P. zosteriformis*
*Curlyleaf Pondweed	*P. crispus*

*Present in Big Butternut Lake during 1995.

Curlyleaf pondweed is an exotic (non-native) macrophyte which became established in northern lakes in the early 1900s. It tends to emerge early each spring, and collapses by the first week of July (Pullman, 1992). Curlyleaf pondweed tends to form dense surface mats over expansive meadows. *It grows especially well in areas where mechanical harvesting or herbicides are used without careful planning.* Pullman (1992) recommends early seasonal control of curlyleaf pondweed, so it can be removed before it interferes with summer recreation, and before the July die-off causes lake water oxygen depletion. Research has shown selective control can be achieved through early season application of fluridone (Sonar) or endothall (Aquathol-K, at low concentrations).

Eurasian Watermilfoil is also an exotic macrophyte species. It is extremely aggressive, and capable of displacing most native species. Like curlyleaf pondweed, it forms dense surface mats, and spreads rapidly. It is spread by fragmentation of plant parts, and is usually introduced to a lake via boats and boat trailers. Once it is established in a lake, it is usually controlled only by use of aquatic herbicides, especially 2,4-D and fluridone (Sonar).

The other macrophytes on the list, which were found in Big Butternut Lake, such as native watermilfoil, Canada waterweed, sago pondweed, flatstem pondweed, and coontail, are native species and typically grow in patchy distributions of low growing meadows (Pullman, 1992). Occasionally, these species will cover more expansive areas, or will form surface mats; only at these times should these plants be managed as nuisance macrophytes.

3.3 Methodology

3.3.1 Macrophyte Survey Methodology

Each survey was conducted using the grid sampling method of Jessen and Loud (1962). A copy of the methodology is included in Appendix D. Global Positioning Satellite (GPS) coordinates were used to locate the sampling transects; maps were prepared showing both the locations of the transects and the macrophyte densities. Two lake-wide macrophyte surveys were completed; the first on June 11, 1995 and the second on August 23, 1995.

3.3.2 Treatment Plot Delineation

From the distribution of curlyleaf pondweed determined during the June survey, three treatment plots were delineated at the northeast end of the lake. The plots were delineated using the GPS coordinates collected during the macrophyte surveys and a Laser and Atlanta ProSurvey 1000 laser range-finder to measure the length of each plot side. Each plot was approximately 1 hectare in size, and was marked at the four corners with yellow buoys. Plot 1 was originally designated as the experimental control (and was not treated), Plot 2 was designated originally for fall treatment, and Plot 3 was designated for spring treatment. Some of the buoys marking the treatment plots were moved by ice flows during spring 1996. Since no treatments had occurred at that time, the buoys were simply retrieved and replaced in approximately the same locations.

3.4 Results

The results of the two macrophyte surveys completed during 1995 are tabulated in Appendix E. The results were converted to densities of native macrophytes and curlyleaf pondweed, and are displayed graphically in Figures 12 and 13. It is apparent that curlyleaf pondweed was the dominant macrophyte during June. By August 1995, the curlyleaf pondweed had died-off, leaving only native macrophyte species. It is important to note that there does appear to be native macrophytes established in and around the curlyleaf pondweed beds. Native macrophytes were detected in the vicinity of the curlyleaf pondweed beds during the August survey, and to a lesser degree during the June survey.

During July 1995, after the three experimental plots had been delineated, a cursory survey of turion (curlyleaf pondweed reproductive pod) density in the sediments was completed. An Eckman dredge was used to collect sediment samples throughout the three plots. Once collected, each sediment sample was washed through a sieve to remove the turions, which were then counted. The number of turions observed in each sample was then converted to an areal density (# per square meter) based on the area sampled by the dredge (150 mm by 150 mm). Ten sediment samples were collected from each of the three plots. The results are listed in Table 2.

Table 2 Big Butternut Lake Curlyleaf Pondweed Turion Densities

	Turion Densities (#per m^2)			
Plot	Number of Samples	Maximum (# per m^2)	Minimum (# per m^2)	Mean (# per m^2)
1	10	930	0	360
2	10	1600	180	720
3	10	2800	130	760

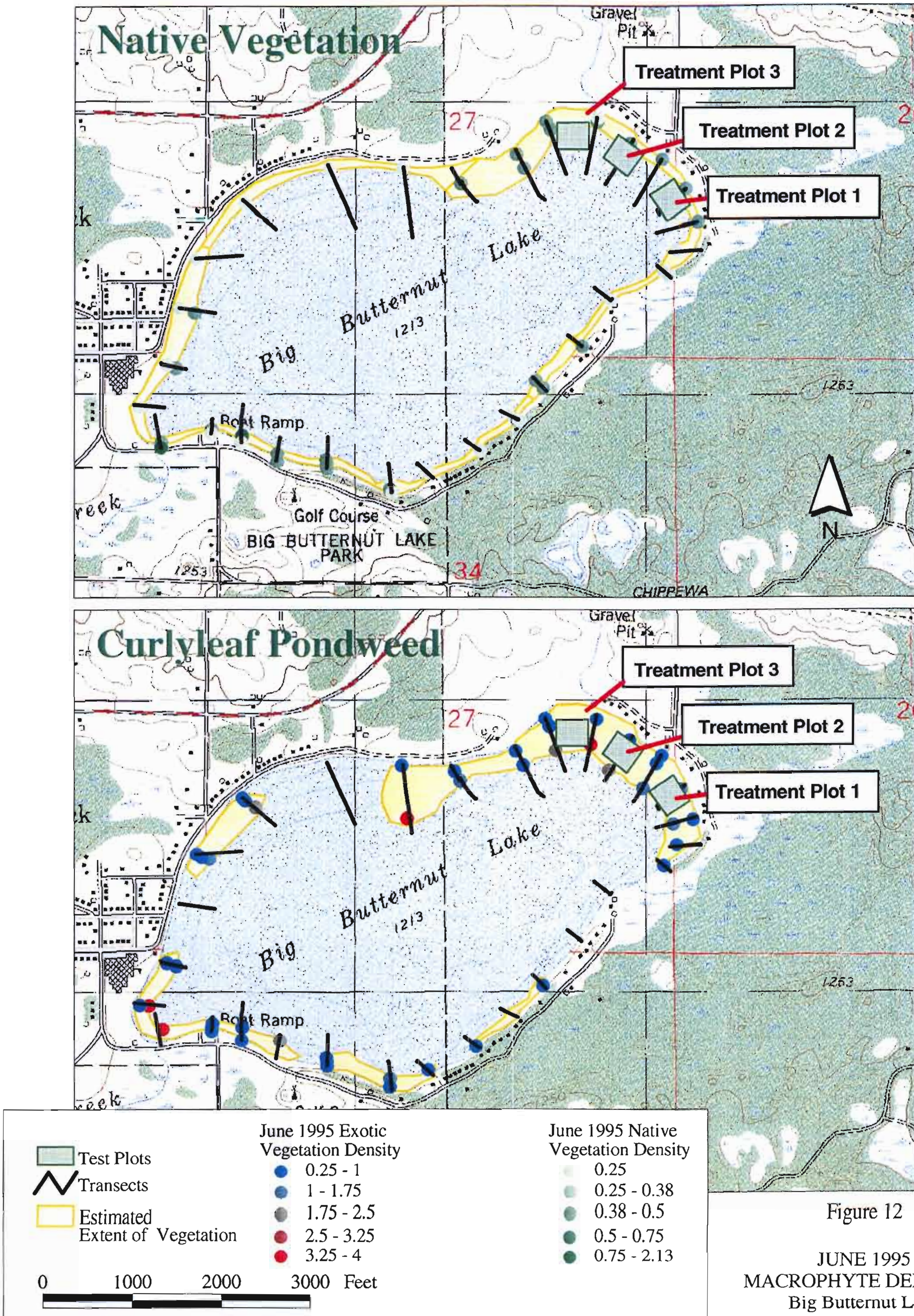
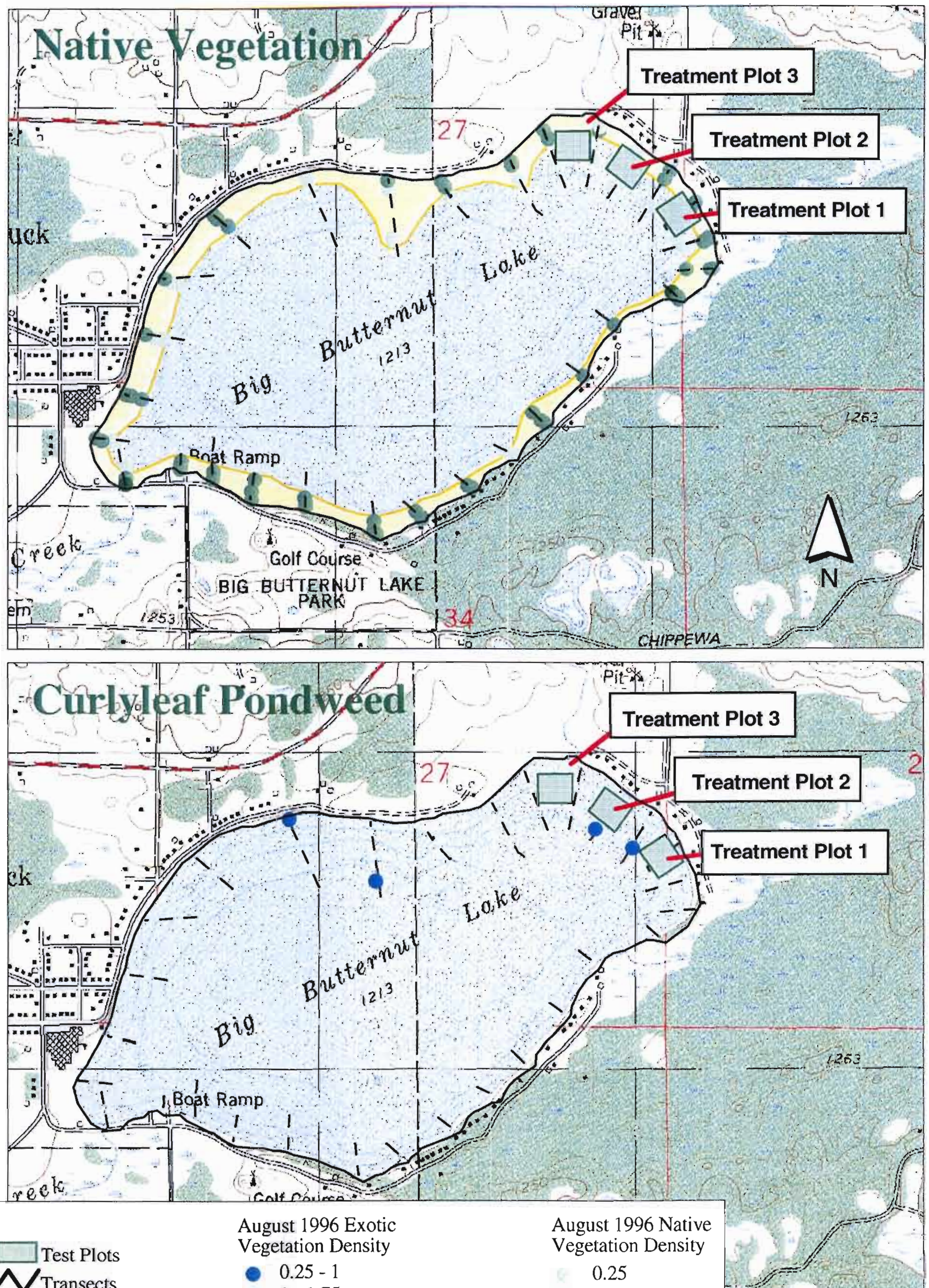


Figure 12

JUNE 1995
MACROPHYTE DENSITIES
Big Butternut Lake



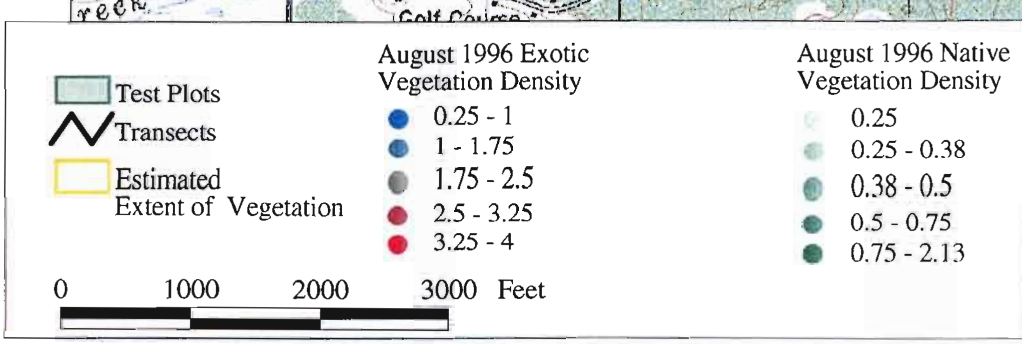


Figure 13

AUGUST 1995
MACROPHYTE DENSITIES
Big Butternut Lake

The sediment turion densities were greatest in Plots 2 and 3; this corresponded well to the observed density of curlyleaf pondweed growth in each of the plots. Originally, Plot 3 was set aside as the control plot while Plots 1 and 2 were treatment plots. However, after reviewing the densities of both turions and curlyleaf pondweed plants in each plot, it was decided that Plot 1 would be set aside as the control plot, and Plots 2 and 3 would be treated with herbicide.

The first application of herbicide was scheduled for Fall 1995 in Plot 2. However, a cursory examination of the curlyleaf plants during October revealed that all plants were less than six inches high, each consisting of approximately 3 to 4 leaf nodes. It was decided that the plant growth was not sufficient to eradicate the plants; therefore the fall herbicide treatment was reschedule for early-Spring 1996.

During February 1996, several holes were drilled through the ice and plant samples were collected. The collected plants were somewhat larger than those observed in the fall, approximately 8 inches high with about 6 leaf nodes each. The winter of 1995 - 1996 was quite severe, with ice thicknesses and snow depths well above average.

Plot 3 was treated on May 6, 1996 with 19 gallons (3 parts-per-million) Aquathol K (Atochem Inc., active ingredient = endothall) by Lake Restoration, Inc. of Hamel, Minnesota. WDNR personnel were present to observe the treatment and to note any adverse affects to the fishery. No adverse affects were observed during the treatment.

Plot 2 was treated on May 21, 1996 with 19 gallons (3 parts-per-million) Aquathol K (Atochem Inc., active ingredient = endothall) by Lake Restoration Inc. of Hamel, Minnesota. Barr Engineering personnel were present to observe the treatment and to note any adverse affects to the fishery. No adverse affects were observed during the treatment.

A final macrophyte survey was completed to assess the effects of the herbicide application on the treatment plots on July 3, 1996. The results of that survey are illustrated in Figure 14. While very low densities of curlyleaf pondweed were detected in treatment plots 2 and 3, similarly low densities were detected both in plot 1 (the experimental control) and in the other curlyleaf pondweed beds in Big Butternut Lake as well. Lakeshore residents of other lakes in the vicinity of Big Butternut Lake observed minimal growth of curlyleaf pondweed at that time, as well. Dr. Sandy Engel of the WDNR believes that the extremely cold temperatures and unusually large snowfall which occurred during the winter of 1995 - 1996 stunted the growth of curlyleaf pondweed during the summer of 1996.

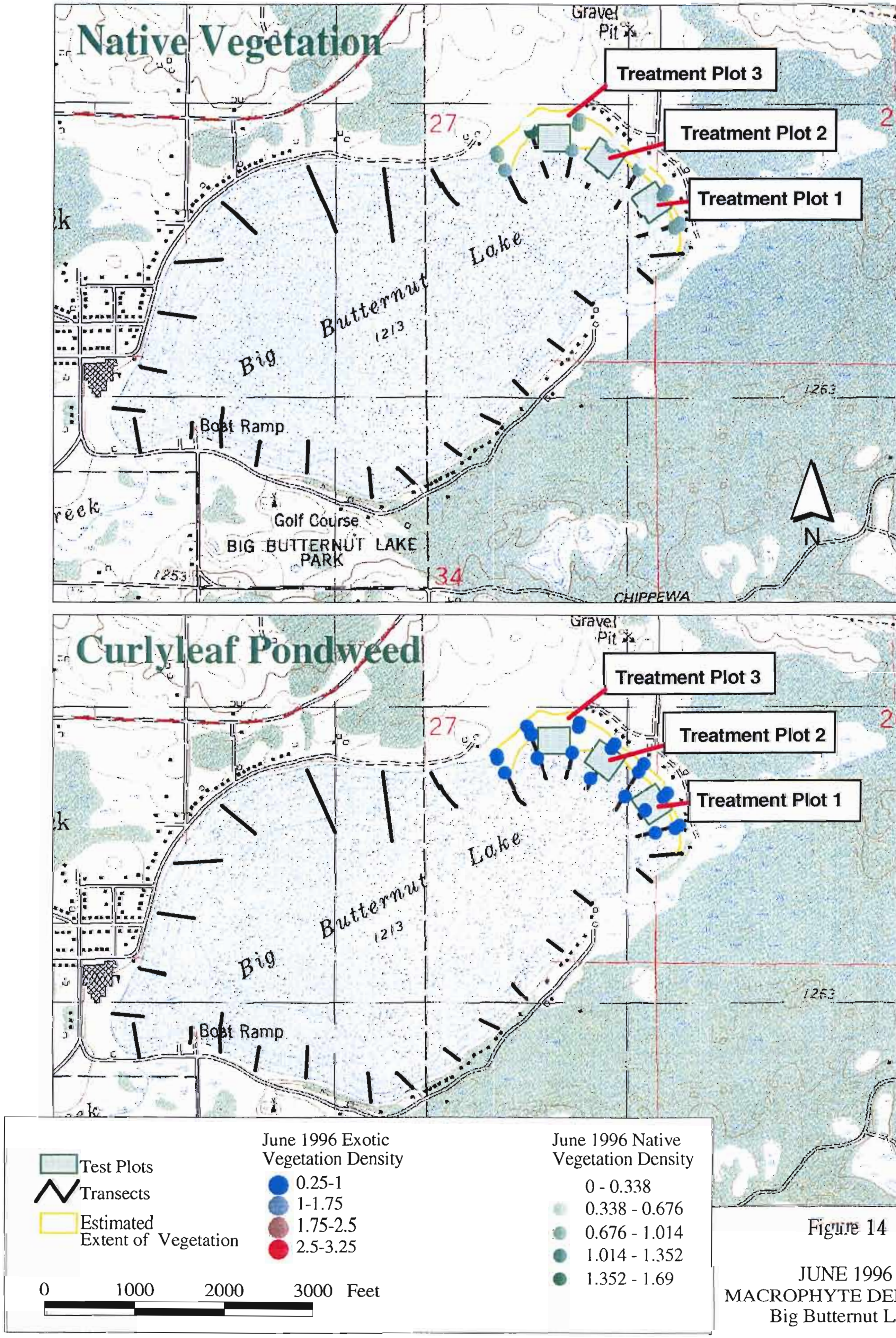


Figure 14

JUNE 1996
MACROPHYTE DENSITIES
Big Butternut Lake

3.5 Conclusions

Macrophyte surveys conducted during 1995 show that dense beds of curlyleaf pondweed are established at the northeast end of the lake, as well as along the north and southwest shores. Three treatment plots were delineated, and two were treated during Spring 1996 with the herbicide Aquathol. A subsequent survey showed that the curlyleaf pondweed growth both in the treatment plots and in the surrounding areas was greatly reduced; however it is likely the reduction in growth was due to harsh winter conditions during 1995–1996 rather than to effects of the herbicide treatments. It is not possible to draw any conclusions as to the effect of the early season application of herbicide to the treatment plots.

3.6 Recommendations

Based on the results of the curlyleaf pondweed assessment of Big Butternut Lake, the following remedial actions are recommended:

1. **Develop lake-wide goals for the management of curlyleaf pondweed and other aquatic weeds in Big Butternut Lake.** Currently, the BBLPRD provides macrophyte control/removal at the public beach and near the boat landing. On the rest of the lake, each individual lakeshore owner contracts for weed removal or control for the area in front of their property. While this option serves each lakeshore owner, it has several disadvantages. It has been shown that exotic macrophytes, such as curlyleaf pondweed, spread readily in areas where indiscriminate macrophyte removal of native species occurs. Therefore, the current method of macrophyte management in the lake may cause the continued spread of curlyleaf pondweed. Also, the current method of macrophyte management in the lake will do little to improve the water quality in the lake. The amount of curlyleaf pondweed growing in the lake probably affects the water quality in the lake to some extent.

   The Wisconsin DNR may be more flexible in allowing management of the aquatic weeds in the lake if the BBLPRD developed a set of specific lake-wide macrophyte management goals. Examples of macrophyte management goals include: to reduce the growth of curlyleaf pondweed in the lake to promote the re-establishment and regrowth of native weed species; to reduce the growth of curlyleaf pondweed in the lake to improve water quality in the lake; to educate lakeshore owners about the importance of native weed species to the health of Big Butternut Lake and its fishery. It is important that lakeshore property owners be willing to accept and support the macrophyte management goals. Development and implementation of these goals may mean that property owners may not be able to remove weeds from the lakeshore in front of their property as completely as they'd like. Therefore, educating lakeshore property owners about proper macrophyte management is an important part of this process.

2. **Repeat the herbicide treatment plot experiment.** Frank Koshere of the WDNR would like more conclusive results showing the benefits of early season treatment of curlyleaf pondweed before he would permit large scale application of herbicides to the curlyleaf pondweed beds. With what was learned during this study, the plot experiments could be repeated on a smaller scale. It is recommended that two plots are marked with buoys in the vicinity of Plots 2 and 3. One plot would be treated with the herbicide Aquathol during mid-May 1997, while the other would not be treated and would act as the control plot. During late-June 1997, a Barr Engineering Company biologist would survey the plots and provide a comparison of the curlyleaf pondweed growth in the two plots. Approximate cost for the herbicide application would be $2,000; approximate cost for a biologist to survey the plot would be $500.

3. **Provide educational material to the lakeshore homeowners.** As stated early, most of the macrophyte management in Big Butternut Lake is arranged by individual homeowners. Many homeowners may be arranging for removal of native species of macrophytes; this leaves their property vulnerable to infestation to curlyleaf pondweed. It is recommended that the BBLPRD provide educational information to each homeowner regarding the effects of macrophyte removal. Some lakeshore residents may find any weed growth unacceptable; of course, macrophytes are beneficial, and necessary, for a healthy fishery within the lake. Educational materials provided through newspaper articles, through the BBLPRD's newsletters, and through information presented at the annual meetings may change homeowner attitudes and expectations about macrophyte growth in the lake.

4. **Plan to aggressively manage the curlyleaf pondweed in the future.** Frank Koshere of the WDNR would like two pieces of evidence before he would allow large scale application of herbicides to the curlyleaf pondweed beds. He would like an analysis of impact of the curlyleaf pondweed growth on water quality in Big Butternut Lake, and he would like an assessment of the possibility of native species regrowth in areas currently covered with curlyleaf pondweed. The water quality modeling project recommended for next year would provide an estimate of the mass of phosphorus released to the lake from curlyleaf pondweed each year, as well as providing an estimate of the amount of oxygen removed from the lake

during decomposition of the curlyleaf pondweed. The macrophyte surveys completed during this study indicate that native macrophyte species currently are present in and around the curlyleaf pondweed beds; removal of the curlyleaf pondweed would most likely be followed by reestablishment of native vegetation. The results of the treatment plot study recommended for next year will hopefully provide conclusive results on the benefits of early season application of herbicide for curlyleaf pondweed control. Also, several lakes in Minnesota are arranging for large scale early season application of herbicides to curlyleaf pondweed beds. The results of these application will be quantified within the next year, so this information will be available, as well. If the WDNR does allow future treatment of all the curlyleaf beds within the lake, no additional permits for macrophyte treatment will be granted. Therefore, the BBLPRD and the lakeshore owners would need to be committed to the treatment and reduction of curlyleaf growth in the lake. No permits would be allowed for individual homeowners to contract herbicide applications. However, mechanical harvesting would be allowed. Approximate cost for herbicide treatment of the curlyleaf beds within the lake would range from $15,000 to $25,000. Such a treatment will most likely greatly decrease the growth of curlyleaf pondweed within the lake; however treatments may need to be repeated to a lesser degree during subsequent years to ensure the turions within the lake sediments are destroyed.

4.0 Lake Level and Butternut Creek Survey

4.1 Background Information

Occasional high water levels during the past few years has caused both bank and shoreline erosion in Big Butternut Lake. The lake has one surface outlet—Butternut Creek—which discharges from the lake on the southwest shore. At times during the summer months, submerged and emergent macrophytes in the creek have seemed to restrict the lake outflow, causing the lake water level to rise. In these instances, chemical treatment of the macrophytes appeared to increase the lake outflow. At other times, the lake level has seemed to be controlled by other physical factors, such as the Butternut Creek channel morphometry, road culverts, or beaver dams. Rather than continuing a random and haphazard approach to managing the lake level, the BBLPRD decided to determine the actual controls of the lake outflow, enabling them and the WDNR to set water level goals for the lake and to prepare a long-term plan for managing the lake level.

Activities pursued during this portion of the project include the following:

Completion of a survey of the lake outlet channel, Butternut Creek, from Big Butternut Lake to Little Butternut Lake. During this survey, all road culvert invert elevations were measured, as well as cross sections of the channel morphometry.

- Installation of a staff gage to monitor lake levels. The staff gage was installed near the boat access, at the southwest corner of the lake. Daily precipitation data collected in Luck were compared to the daily staff gage measurements to determine the seasonal effects of watershed runoff on the level of the lake.

- Development and distribution of a survey to lakeshore residents. This survey allowed lakeshore residents to rate the lake water level on a daily basis during the 1995 ice-free period.

4.2 Methodology

Barr Engineering staff surveyed the elevations of the Big Butternut Lake outlet, as well as all culverts downstream on Butternut Creek on May 2, 1995. Staff gauges were installed in Big Butternut Lake near the lake outlet, and in Butternut Creek just upstream of Minnie's Road. Both staff gauges were read daily by Village of Luck personnel. Village of Luck personnel also collected daily precipitation data in cooperation with the Wisconsin State Climatologist Office and the National Weather Service. In addition, Village of Luck personnel estimated flow through each culvert along Butternut Creek on a weekly basis using the following procedure:

1. The water depth in each culvert was measured on both the upstream and downstream end.

2. A stopwatch was used to measure the time necessary for a ball to float through the length of culvert. This was repeated three times, and the results were averaged.

The lake level and precipitation data collected by the Village of Luck are included in Appendix F.

During 1995-1996, the WDNR set Regional Flood Elevations (RFE) for both Big Butternut Lake and Little Butternut Lake. The WDNR used the survey information collected during this study, as well as additional information collected by Polk County Survey of St. Croix Falls, WI at the request of the BBLPRD.

4.3 Results

The results of the survey of Butternut Creek are illustrated in Figure 15. The figure illustrates water level elevations from Big Butternut Lake through Butternut Creek to Little Butternut Lake. The elevations of all road crossings and sizes of all culverts are also displayed. The Big Butternut Lake location map (Figure 1) also shows the flow path of Butternut Creek from Big Butternut Lake to Little Butternut Lake.

Figure 16 shows the relationship between precipitation and lake level during 1995. The lake level dropped throughout May and June from elevation 1213.0 to 1212.1. Occasional rain events did elevate the water level for brief periods. During early August, a series of large rainstorms did elevate the water level until mid-September. Obviously, stormwater runoff from the watershed greatly influences the water levels in the lake.

The WDNR used the survey data collected by Barr Engineering Company and Polk County Surveying to set RFE (Regional Flood Elevations) for Big Butternut Lake and Little Butternut Lake; the RFEs for the two lakes are 1215.4 and 1210.3, respectively. The RFEs were determined by the WDNR using a single storm event hydrologic model. A 100-year (i.e., 1% probability) return interval, 24-hour duration rainfall event was modeled for this analysis.

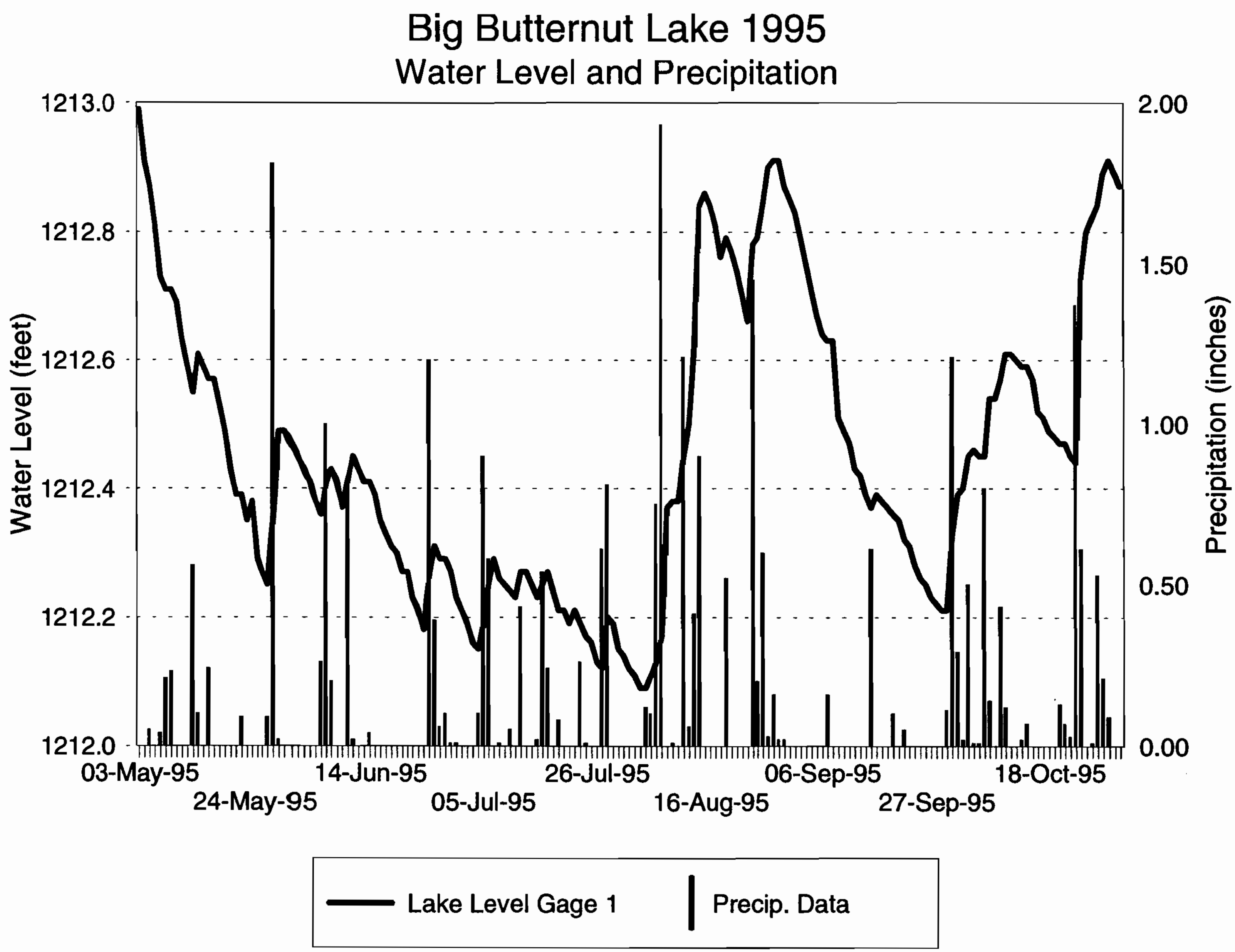
Barr Engineering Company analyzed the survey data and the flow data collected during 1995. It is our opinion that the control for the lake outflow is the twin 36-inch culverts at Chippewa Trail (Minnie's Road). However, depending on the lake and stream elevations, the slope of the channel between Big Butternut and Chippewa Trail can control the discharge from the lake. Vegetation and macrophyte build-up in the stream probably does not greatly affect the lake outflow rate given the size of the channel. The WDNR has also concurred with this hydraulic assessment.

Ed Slaminski of the WDNR was consulted as to the possibility of adding an overflow pipe at Chippewa Trail to enhance lake level draw-down during periods of high water. Mr. Slaminski stated that he would prefer to leave the culvert configuration at Chippewa Trail (and along the entire reach of Butternut Creek) as it is. He is concerned about the effects the potential increased outflow from Big Butternut Lake will have on the water level of Little Butternut Lake.

4.3.1 Lake Residents Survey Results

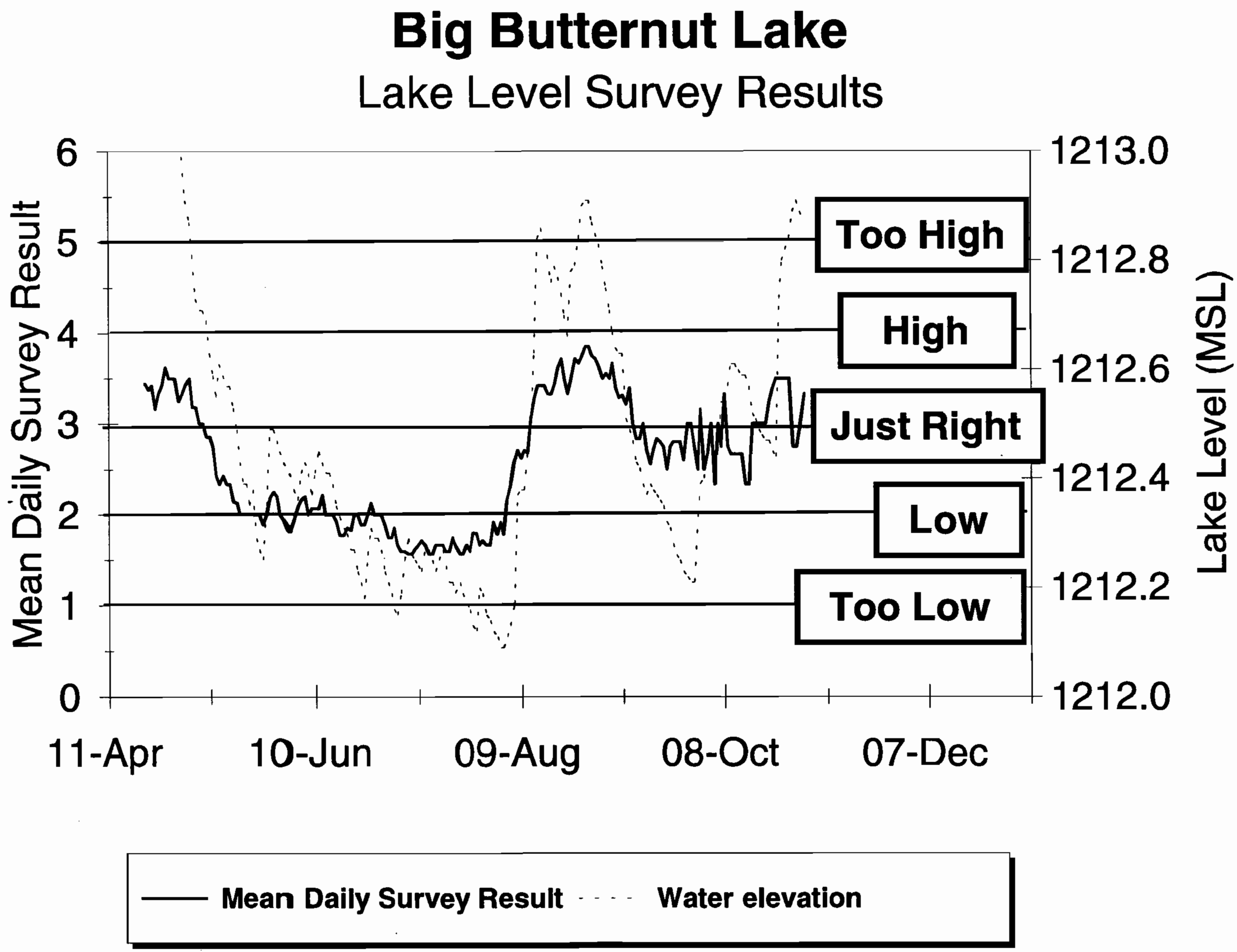
During March 1995, surveys were distributed to all lakeshore residents of Big Butternut Lake. The survey requested daily ratings of water level and water quality. Close to 100 copies of the survey were distributed; only 10 copies were returned. However, the lake residents who took the time to complete the survey each day appeared to do a complete and conscientious job. The results of the lake water level portion of the survey will be addressed in this section; the results of the lake water quality portion is discussed in Section 2.3.7. Figure 17 displays a plot of the survey results, along with the water level elevations observed during 1995. It appears from the survey results that most respondents felt that the lake level was low during most of summer 1995. The water level in the lake rose during late August and September; it appears that survey respondents

Figure 16



Big Butternut Lake 1995
Water Level and Precipitation
Water Level (feet)
1213.0
1212.8
1212.6
1212.4
1212.2
1212.0
Precipitation (inches)
2.00
1.50
1.00
0.50
0.00
03-May-95
24-May-95
14-Jun-95
05-Jul-95
26-Jul-95
16-Aug-95
06-Sep-95
27-Sep-95
18-Oct-95
Lake Level Gage 1
Precip. Data

Figure 17



Big Butternut Lake
Lake Level Survey Results
Mean Daily Survey Result
Lake Level (MSL)
6
5
4
3
2
1
0
1213.0
1212.8
1212.6
1212.4
1212.2
1212.0
Too High
High
Just Right
Low
Too Low
11-Apr
10-Jun
09-Aug
08-Oct
07-Dec
Mean Daily Survey Result
Water elevation

felt that water levels between 1212.6 and 1212.4 were about right for the configuration of their lakeshore landscaping and docks. Note that the RFE (Regional Flood Elevation) set by the WDNR for Big Butternut Lake is 1215.4.

4.4 Conclusions

Lake water level, precipitation, and culvert flow data were collected during 1995. In addition, all culverts and road crossings along Butternut Creek were surveyed. According to lakeshore residents, the lake water level was low during 1995. From the flow data and survey information collected along Butternut Creek, it appears that under normal precipitation conditions the twin 36-inch culverts at Chippewa Trail (Minnie's Road) control the outflow of Big Butternut Lake. However, depending on the lake and stream elevations, the slope of the channel between Big Butternut and Chippewa Trail can control the discharge from the lake, as well. Vegetation and macrophyte build-up in the stream probably does not greatly affect the lake outflow rate given the size of the channel.

RFEs (Regional Flood Elevations) were determined by the WDNR for both Big Butternut and Little Butternut Lakes; the RFEs for the two lakes are 1215.4 and 1210.3, respectively.

4.5 Recommendations

From the data collected during this study, the following recommendations are made:

1. **Continue to monitor the water level elevation of Big Butternut Lake.** The staff gauge should be reinstalled near the lake outlet and should be surveyed to determine exact elevation. The gage installation and surveying can be completed by Village of Luck staff; Barr Engineering can provide directions for gage installation. Lake water elevations should be taken biweekly. It is recommended that any shoreline erosion or other negative effects from persistent high water be documented with photographs and written descriptions. This information then can be presented to the WDNR as proof of the negative effects of high water in the lake. Cost for this action should be minimal, given the continued support from the Village of Luck.

2. **Continue to inspect and clear all culverts along Butternut Creek.** Currently, personnel from the Village of Luck perform weekly inspections of all culverts along the creek to ensure that debris and/or beaver dams do not constrict flow in the creek. Special attention should be

given to the culverts at the Gandy Dancer Trail. Two culverts were damaged during removal of a beaver dam; further damage to these culverts may seriously restrict flow in the creek. Cost for this action should be minimal, given the continued support from the Village of Luck.

3. **Perform a feasibility study to determine the effects of an overflow culvert at Chippewa Trail on the water levels in Big Butternut and Little Butternut Lakes.** Ed Slaminski of the WDNR has stated that a hydraulic modeling study would need to be completed in order for a permit to be issued for installation of an overflow culvert at Chippewa Trail. Such a study would use a hydraulic model (such as HEC-2) along with the WDNR's existing HEC-1 flood event model to analyze the effects of such a culvert on the water level in both lakes. Information provided by such a study would confirm or deny the benefits of the overflow pipe on the water level in Big Butternut Lake, and would identify any negative effects that may occur in Butternut Creek or in Little Butternut Lake. Approximate costs for such a study would range from $5,000 to $10,000.

5.0 Review of Project Recommendations

This section has been assembled to aid the BBLPRD in developing a long-term management plan for the lake. Several recommendations have been discussed in this report; members of the BBLPRD will need to prioritize the recommendations in order to develop a management scheme, to apply for appropriate grants and funding, and to assemble volunteer monitors. The importance of lake water quality, lake level, and macrophyte density to lakeshore residents seems to vary from year-to-year depending on which issue is most problematic. During the early 1990's, water level concerns were of most importance due to frequent high water levels and shoreline erosion, however during 1995 and 1996 lake water levels were low, and water level concerns were minimal. During 1996, lakeshore residents felt that water quality in the lake was unusually poor, and therefore this issue was paramount. The BBLPRD must balance the current concerns of lakeshore residents with the long-term management of the lake and its watershed.

To aid the BBLPRD in formulating a long-term management plan, we recommend the following schedule. A list of agency contacts is listed in Table 3, and a schematic of the proposed schedule is presented in Figure 18.

Task 1: Apply for a Wisconsin Lake Planning Grant to investigate watershed phosphorus sources. This Grant Study will result in a list of specific Best Management Practices (BMPs) for both in the lake and within the watershed to improve the water quality in the lake. The deadline for the grant application is January 31, 1997. Barr Engineering Company would be willing to prepare the grant application and the study work plan, and to perform the study. Approximate budget for this study would be $13,333 ($10,000 grant funds and $3,333 cost share from the BBLPRD).

Task 2: Apply for a herbicide application permit during March 1997 to treat a curlyleaf pondweed plot. With what we learned during this study, the members of the BBLPRD could mark two plots with minimal assistance or cost. One plot would be treated during mid-May, and in late-June, a Barr Engineering Company biologist could survey and compare the two plots. The data would be presented to the WDNR, and a long-term management strategy for the curlyleaf pondweed could be discussed. Approximate cost for this task is $2,500. This task would not be covered by a Planning Grant Study, however the WDNR may provide some funds for exotic macrophyte control.

Task 3: Village of Luck personnel should re-install the lake level staff gauge and collect biweekly readings from May through October. Collected on an annual basis, the lake level data will provide evidence of water level trends and/or problems in the lake.

Task 4: Continue to collect volunteer monitoring data. In addition to the samples funded by the WDNR, a volunteer should collect weekly or biweekly Secchi disk transparency readings. This data will provide a continuous record of water quality within the lake.

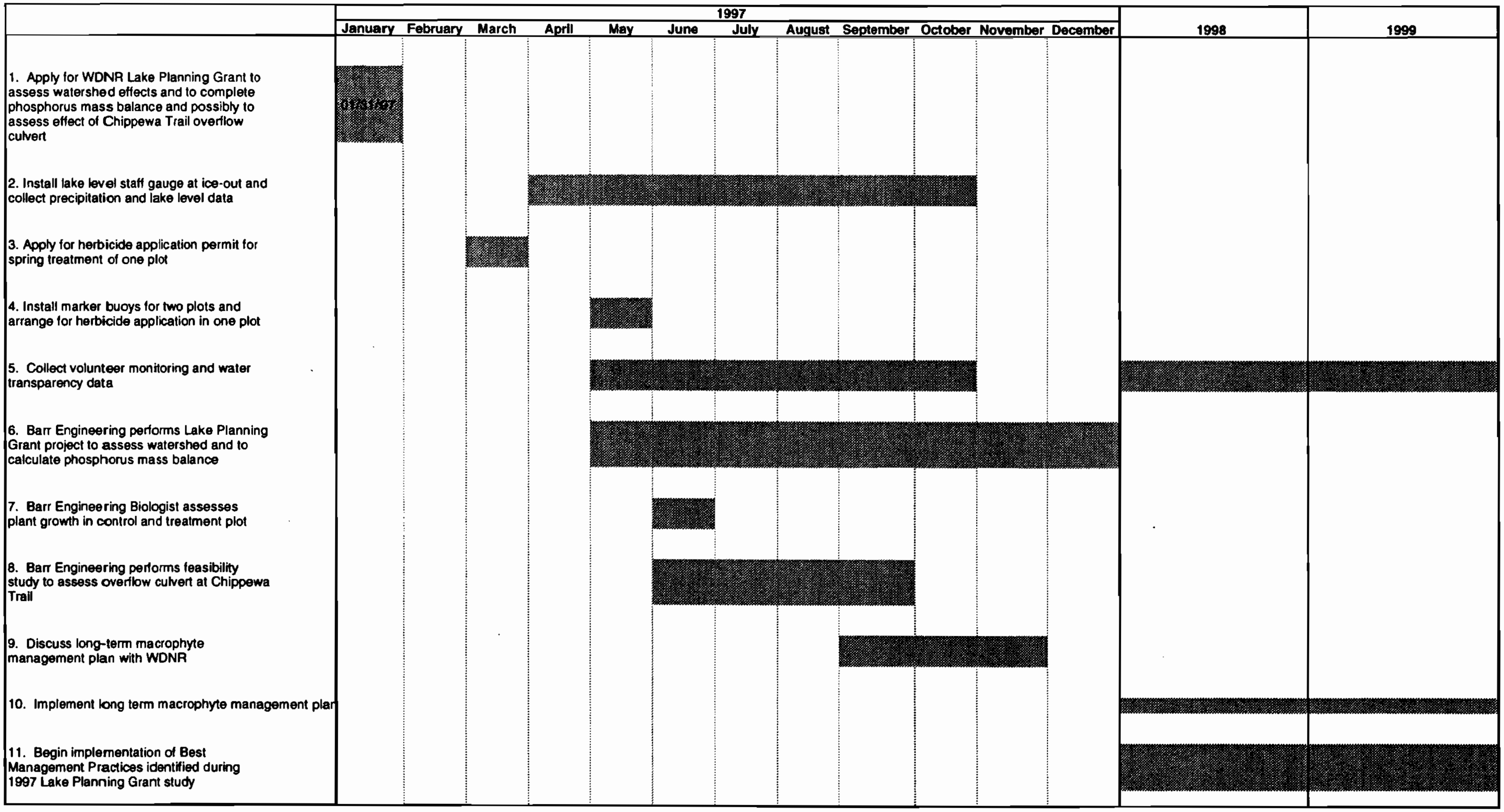
Task 5: Perform a feasibility study to assess the effects of an overflow culvert at Chippewa Trail. The WDNR would require such a study before granting a permit for any change to the lake outlet. We estimate the approximate cost for such a study to be $5,000 to $10,000.

Table 3 Agency Contacts

Activity	Agency	Contact	Address/Phone
1. WDNR Lake Planning Grant Applications	WDNR-Spooner Office	Dan Ryan	WDNR Northwest District Headquarters Box 309 Spooner, WI 54801 phone: 715.635.2101
2. Macrophyte Management Permits	WDNR-Spooner Office	Frank Koshere	WDNR Northwest District Headquarters Box 309 Spooner, WI 54801 phone: 715.635.2101
3. Herbicide Applications	Lake Restoration, Inc.	Kevin Kretsch	Lake Restoration, Inc. 620 Hamel Road Hamel, MN 55340 phone: 612.478.9421
4. Regional Flood Elevations	WDNR-Madison Office	Frank Dallam	WDNR Madison Office 101 South Webster Street P.O. Box 7921 Madison, WI 53707-7921 phone: 608.267.2766
5. Lake Level Management	WDNR-Cumberland Office	Ed Slaminski	WDNR Cumberland Office 1341 2nd Avenue Box 397 Cumberland, WI 54829 phone: 715.822.3590

Activity	Agency	Contact	Address/Phone
6. Study Report Questions	Barr Engineering Company	Karen Jensen Hal Runke	Barr Engineering Company 8300 Norman Center Drive, Mpls, MN 55437 phone: 612.832.2600 fax: 612.832.2601 e-mail: kjensen@barr.com hrunke@barr.com
7. Project Support	Polk County Land Conservation Department	Cheryl Bursik	Polk County Land Conservation Department P.O. Box 460 Balsam Lake, WI 54810 phone: 715.485.3725

Figure 18: Big Butternut Lake Long Term Management Scheme



Big Butternut Lake 1995 Water Quality Data

Date	Depth (m)	Temp. (C)	Diss. Oxygen (mg/L)	Field Conductivity (umhos/cm @25 C)	Secchi Transparency (ft)	Secchi Transparency (m)	Chlorophyll a (ug/L)	Total P (ug/L)	SRP (ug/L)	TKN (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Alkalinity (mg/L as CaCO3)	pH (stnd. units)	Color (pt-co units)
05/02/95	0	14.0	9.8		8.0	2.4	6.8	29	2	0.7	<0.027	<0.01	74	7.96	15
05/02/95	1	14.0	9.8												
05/02/95	2	14.0	9.8												
05/02/95	3	14.0	9.6												
05/02/95	4	14.0	9.0					37	*						
05/02/95	5	12.0	8.4												
05/02/95	5.5	12.0	5.2					38	*						
06/04/95	0	21.2	9.6	150											
06/04/95	1	20.8	9.8	152											
06/04/95	2	20.0	9.7	150											
06/04/95	3	18.0	9.2	145											
06/04/95	4	16.5	8.0	142											
06/04/95	5	15.0	6.6	140											
06/04/95	5.5	14.9	6.2	140											
06/12/95	0	18.0	8.6	143											
06/12/95	1	17.7	8.6	144											
06/12/95	2	17.7	8.4	142											
06/12/95	3	17.0	8.0	140											
06/12/95	4	16.8	7.6	140								<0.010	77	8.55	25
06/12/95	5	16.5	6.0	142											
06/12/95	5.5	16.0	4.6	148											
06/19/95	0	26.0	8.8	170			3.52	18	2	0.6	<0.027	<0.01	76	8.64	15
06/19/95	1	26.0	8.8	170											
06/19/95	2	25.7	9.2	170											
06/19/95	3	21.5	9.8	158											
06/19/95	4	18.0	9.7	150				39	2						
06/19/95	5	16.5	1.3	150											
06/19/95	5.5	16.0	0.2	151				106	30						
06/27/95	0	25.0	7.5	169											
06/27/95	1	25.0	7.3	170											
06/27/95	2	25.0	7.2	170											
06/27/95	3	24.0	8.3	170											
06/27/95	4	19.0	3.5	160											
06/27/95	5	17.0	0.7	158											
06/27/95	5.5	16.2	0.6	158											
07/05/95	0	21.0	8.0	152											
07/05/95	1	21.0	8.0	152											
07/05/95	2	21.0	7.9	152											
07/05/95	3	21.0	7.9	152											

Big Butternut Lake 1995 Water Quality Data

Date	Depth (m)	Temp. (C)	Diss. Oxygen (mg/L)	Field Conductivity (umhos/cm @25 C)	Secchi Transparency (ft)	Secchi Transparency (m)	Chlorophyll a (ug/L)	Total P (ug/L)	SRP (ug/L)	TKN (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Alkalinity (mg/L as CaCO3)	pH (stnd. units)	Color (pt-co units)
07/05/95	4	21.0	7.9	152											
07/05/95	5	19.0	2.2	158											
07/05/95	5.5	18.0	0.7	190											
07/10/95	0	22.0	10.4	167	3.0	0.9	*	48	4	1	<0.027	<0.01	77	8.55	25
07/10/95	1	22.0	10.4	152											
07/10/95	2	21.2	9.7	152											
07/10/95	3	20.0	6.8	152											
07/10/95	4	20.0	6.9	151				31	3						
07/10/95	5	19.5	4.9	150											
07/10/95	5.5	19.0	3.8	153				52	19						
07/17/95	0	24.5	9.6	165											
07/17/95	1	24.3	9.6	165											
07/17/95	2	24.2	9.5	165											
07/17/95	3	24.0	9.5	168											
07/17/95	4	23.0	8.6	169											
07/17/95	5	19.5	0.8	169											
07/17/95	5.5	18.7	0.6	179											
07/25/95	0	26.5	12.6												
07/25/95	1	26.0	12.8												
07/25/95	2	25.0	11.2												
07/25/95	3	24.5	9.2												
07/25/95	4	23.0	3.2												
07/25/95	5	21.0	0.6												
07/25/95	5.5	19.0	0.5												
08/01/95	0	24.0	9.3	161	2.8	0.9	*	52	2	1.9	<0.027	<0.01	77	9.32	20
08/01/95	1	24.0	8.9	160											
08/01/95	2	24.0	8.4	160											
08/01/95	3	24.0	7.9	162											
08/01/95	4	23.5	7.9	162				46	2						
08/01/95	5	20.7	0.6	185											
08/01/95	5.5	19.0	0.6	200				318	101						
08/29/95	0				2.8	0.8	71.4	104	4	0.9	<0.027	<0.01	76	9.24	30
08/29/95	1														
08/29/95	2														
08/29/95	3														
08/29/95	4							53							
08/29/95	5														
08/29/95	5.5							53	4						
09/06/95	0	23.5	9.2	150	2.0	0.6									

Big Butternut Lake 1995 Water Quality Data

Date	Depth (m)	Temp. (C)	Diss. Oxygen (mg/L)	Field Conductivity (umhos/cm @25 C)	Secchi Transparency (ft)	Secchi Transparency (m)	Chlorophyll a (ug/L)	Total P (ug/L)	SRP (ug/L)	TKN (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Alkalinity (mg/L as CaCO3)	pH (stnd. units)	Color (pt-co units)
09/06/95	1	23.5	9.2	150											
09/06/95	2	23.4	9.2	152											
09/06/95	3	23.2	8.3	152											
09/06/95	4	22.5	5.7	152											
09/06/95	5	22.0	3.2	153											
09/06/95	5.5	21.4	0.6	160											
09/11/95	0	19.0	8.3	149	2.0	0.6	22	79	2	1.2	<0.027	0.013	78	9.37	25
09/11/95	1	19.6	8.5	149											
09/11/95	2	19.6	8.4	150											
09/11/95	3	19.6	8.4	150											
09/11/95	4	19.5	8.4	150				88	4						
09/11/95	5	19.6	8.4	150											
09/11/95	5.5	19.5	8.4	150				77	2						
09/19/95	0	17.0	9.1	130	2.8	0.8									
09/19/95	1	17.2	9.0	130.2											
09/19/95	2	17.2	9.0	130.3											
09/19/95	3	17.2	8.9	130.4											
09/19/95	4	17.1	8.9	130.4											
09/19/95	5	17.1	8.8	130.5											
09/19/95	5.5	17	8.2	130.6											
09/28/95	0	14.9	11.6	126	3	0.9									
09/28/95	1	14.5	11.6	126											
09/28/95	2	13.9	11	125											
09/28/95	3	13.4	10.6	124											
09/28/95	4	13	9.2	124											
09/28/95	5	13	9	124											
09/28/95	5.5	12.9	8.2	124											
10/03/95	0	12	9.6	120	3.25	1.0									
10/03/95	1	14	9.4	122											
10/03/95	2	14	9.4	122											
10/03/95	3	14	9.4	122											
10/03/95	4	14	9.4	124											
10/03/95	5	14	9.4	125											
10/03/95	5.5	14	9.4	126											
10/09/95	0	13	10.2	119	3.5	1.1									
10/09/95	1	12.5	10	118											
10/09/95	2	12.3	9.5	119											
10/09/95	3	12.2	9.3	120											
10/09/95	4	12.2	9.2	120											

Big Butternut Lake 1995 Water Quality Data

Date	Depth (m)	Temp. (C)	Diss. Oxygen (mg/L)	Field Conductivity (umhos/cm @25 C)	Secchi Transparency (ft)	Secchi Transparency (m)	Chlorophyll a (ug/L)	Total P (ug/L)	SRP (ug/L)	TKN (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Alkalinity (mg/L as CaCO3)	pH (stnd. units)	Color (pt-co units)
10/09/95	5	12.2	9.2	120											
10/09/95	5.5	120	7.2	160											
10/16/95	0	12.7	10.3	119	3.25	1.0									
10/16/95	1	11.6	10.3	117											
10/16/95	2	11.5	10.2	117											
10/16/95	3	11.2	10.2	118											
10/16/95	4	11.1	10.2	118											
10/16/95	5	11	10	118											
10/16/95	5.5	11.2	9.6	140											
10/24/95	0	7	11.4	100	3.25	1.0									
10/24/95	1	7.2	11.4	101											
10/24/95	2	7	11.3	101											
10/24/95	3	7	11.3	101											
10/24/95	4	7	11.3	101											
10/24/95	5	7	11.2	101											
10/24/95	5.5	7	11	123											

* = lab result rejected by the WI State Lab

Feasibility Study Results

Water Loading

Stream inflow, groundwater inflow and precipitation are the primary sources of water to Big Butternut Lake. Water losses from the lake are predominantly in the form of stream outflow. Table 2 summarizes water loading to Big Butternut Lake.

Surface water runoff from the direct drainage basin was estimated by using a regional runoff coefficient of .75 feet/year (from USGS Hydrological Atlas).

Groundwater flow was monitored by 15 wells installed at 6 sites around the lake. Flow direction and gradients were obtained from water level measurements in the wells over the course of the study (see Figure 3). Permeabilities were estimated using grain size distribution data and lab permeability tests. The groundwater flow, based upon data from the wells, suggested that at all sites flow was into the lake. Darcy's Law estimated groundwater inflow to account for 15% of the water loading to Big Butternut Lake.

The average residence time, the time it takes to flush one volume of water through the lake, is 1.2 years (455 days).

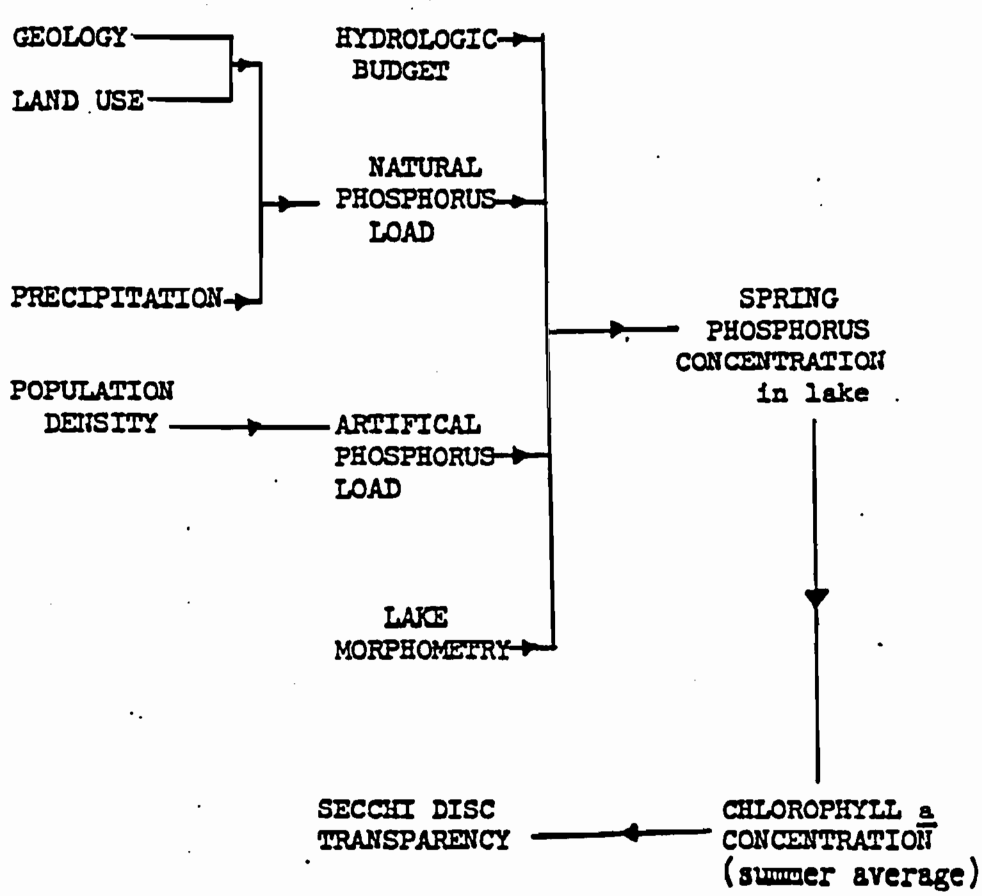
Table 2. Water Budget to Big Butternut Lake for Study Year

Average Inflow	CFS	Acre ft/year	Percent
Diffused Surface Water Runoff	0.4	290	6
Precipitation	1.4	1,010	21
Groundwater Inflow	1.0	720	15
Stream Inflow	4.0	2,890	58
Total	6.8	4,910	100
Average Outflow			
Stream Outflow	5.5	3,975	83
Evaporation	1.0	720	15
Storage	0.1	70	2
Total	6.6	4,770	100

Water Quality

In many lakes, water quality problems are associated with excessive phosphorus loading. As phosphorus levels increase, there is a corresponding increase in chlorophyll-a, a decrease in water clarity, and an increase in oxygen demand. These variables are interrelated and are good indicators of water quality or trophic status.

FIGURE 4 A simple empirical model used to assess effects of development on trophic status of lakes (after Dillon and Rigler. 1975. Journ. Fish. Res. Bd. Canada)



Phosphorus Loading

In order to understand the effect of nutrients on the water quality of Big Butternut Lake, a phosphorus budget was calculated to estimate the amount and sources of phosphorus reaching the lake. The phosphorus loading and concentration are factors used in predicting the productivity, water clarity, dissolved oxygen concentrations, and fish populations one might expect in a lake. Figure 4 represents a scheme of simple empirical phosphorus related models used to access the effects of the watershed upon lake water quality. Human activities (including land use), watershed characteristics, and climate are the general determinants of phosphorus transport to lakes.

The total mass flow of phosphorus into Big Butternut Lake was calculated by summing the annual contributions of phosphorus from each source within the watershed. The phosphorus loading rates from each source are presented in Table 3 (Appendix 1 describes how the phosphorus loading was calculated).

The greatest percentage of phosphorus appears to enter the lake from agricultural lands. The contribution from the remaining septic tanks around the lake appears low.

The predicted phosphorus concentration using Vollenweider's 1976 model was .033 mg/l compared to actual phosphorus concentration at spring turnover of .05 mg/l. This difference may be due to the flux of phosphorus being released from the sediments (internal recycling). Utilizing the Vollenweider-type phosphorus models, a plot of the trophic level for the lake was developed based upon watershed phosphorus loadings. The phosphorus loadings and the relationship to lake eutrophy are presented on the loading curve in Figure 5. The figure is divided into three lake trophic categories: oligotrophic (nutrient poor), eutrophic (nutrient rich), and mesotrophic (moderately fertile). Big Butternut Lake falls into the eutrophic category.

Table 3. Total Phosphorus Loading to Big Butternut Lake

Source	lbs/yr	kg/year	Percent
Woodlands to lake	77	35	10
Atmosphere to lake	71	32	10
Wetlands to lake	13	6	2
Residential to lake	15	7	2
Agriculture to lake	540	245	73 ?
Septics to lake	22	10	3
Total	738 lbs/yr	335 kg/yr	100%

Trophic State Index

A lake's trophic state describes the existing condition of a lake relative to its water quality and productivity. A trophic state index was developed by Carlson which ranges from 0 to 110 and groups lakes into 3 trophic categories: oligotrophic (0-40, nutrient poor lakes with no algae problems),

Fig. 5

TROPHIC STATUS OF LAKES AS PREDICTED BY THE MODEL OF VOLLENWEIDER (1976)

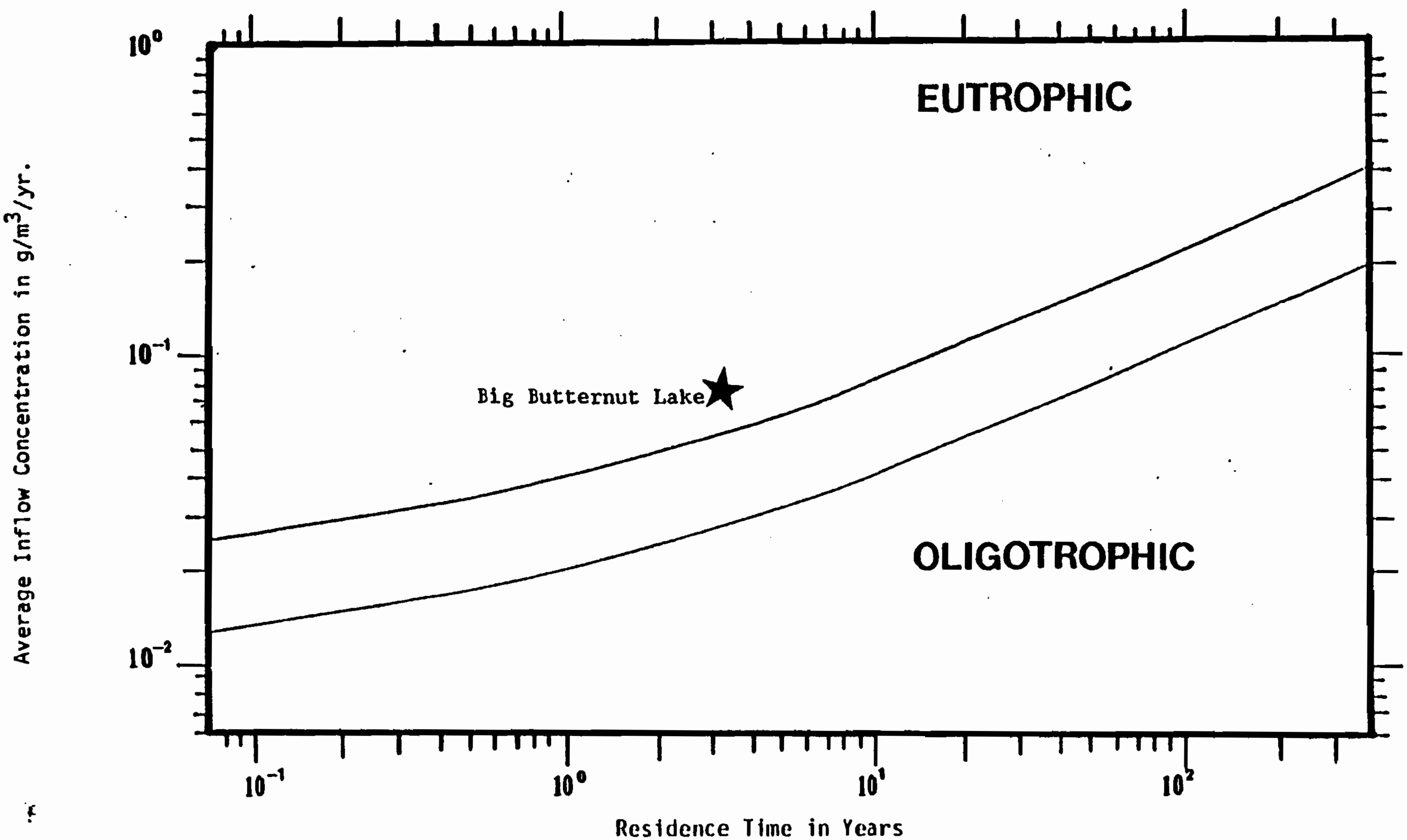


Figure 6. Trophic State Index for Big Butternut Lake

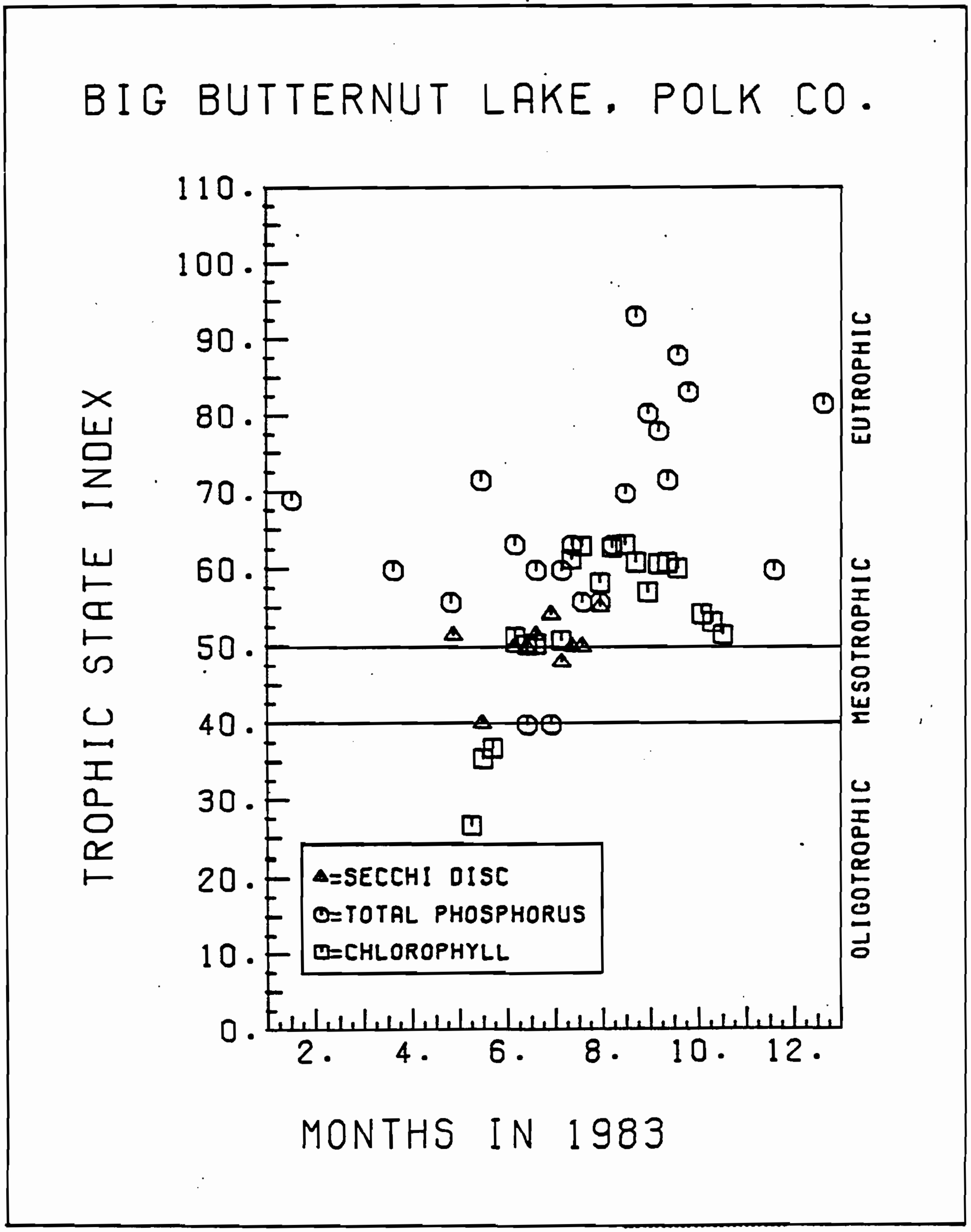
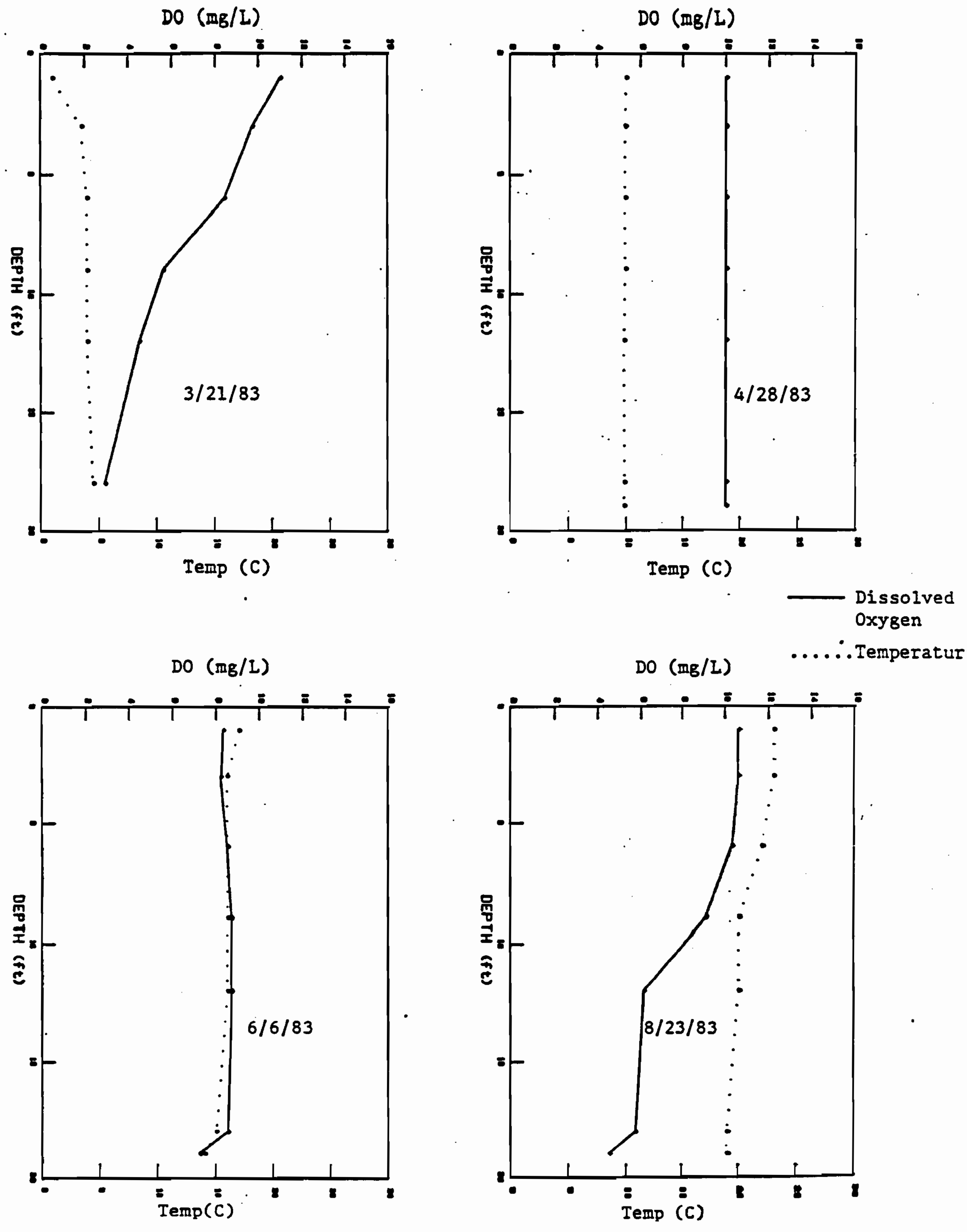


Figure 7. Temperature and Dissolved Oxygen Depth Profiles



mesotrophic (40-50, moderately fertile lakes with occasional algae problems), and eutrophic lakes (50-100, nutrient rich lakes with algae problems). This index combines the nutrient parameter phosphorus, the biological parameter chlorophyll-a, and the physical parameter of light transparencies (secchi disc) and transforms them into a trophic state index.

Using Carlson's Trophic State Index, Big Butternut Lake falls in the eutrophic range (see Figure 6). It displays typical eutrophic features such as high chlorophyll values which are a result of excessive algal growth.

Chlorophyll

The biological manifestation of the nutrients in Big Butternut Lake is an important component of the overall analysis of water quality. Chlorophyll-a concentration (a plant pigment) is a measure of algal biomass. The greater the concentration of chlorophyll-a, the more visible the algal material will be to an observer. The summer average of chlorophyll-a (June-September) for Big Butternut was found to be 28.86 mg/m^3. Average summer chlorophyll-a concentrations between 0 and 4 mg/m^3 indicate nutrient poor water (oligotrophic). Moderately fertile waters (mesotrophic) have chlorophyll concentrations ranging between 4 and 10 mg/m^3 and fertile lakes (eutrophic) have summer average chlorophyll-a values greater than 10 mg/m^3. Big Butternut Lake falls into the fertile lake category (eutrophic according to this classification scheme). This means that concentrations of phosphorus are high enough to produce nuisance algal blooms.

The algal growth pattern (seasonal succession of species) in Big Butternut Lake during the summer of 1983 began in spring with the diatom Melosira. During the month of June, blue greens began and continued through August. Predominant species of blue greens found were Anabaena, Aphanizomenon and Microcystis. These blue green species have gas vacuoles which enable them to move up or down in the water column. During periods of low water transparency, these algae can physiologically adjust their gas vacuoles to float near the surface thereby creating a scum like appearance. When these mats of algae begin to decay, they wash up on the lake shore and become a smelly nuisance. The 3 species of blue greens underlined above are indicators of eutrophic conditions.

By September, with cooler temperatures the green algae and diatoms were once again the predominant species.

Dissolved Oxygen/Temperature Profiles

Figure 7 illustrates the temperature and dissolved oxygen profiles for Big Butternut Lake. On March 21, 1983, the temperature profile shows ice on the lake and dissolved oxygen decreasing with depth. The dissolved oxygen did not decrease enough during March, 1983, to have a negative impact on the fishery. (Big Butternut Lake does not have a history of fishkills due to oxygen depletion.) On April 28, 1983, the lake was homiothermal (same temperature from surface to bottom), and the water mass was completely mixed. This is commonly referred to as spring turnover.

Big Butternut Lake does not stratify for the entire summer due to its shallowness. Stratification is the thermal layering of water by density into a cold lower region (hypolimnion) and a warm upper region (epilimnion) with a zone of temperature change, separating the two regions (thermocline). The bottom waters in the lake periodically show low dissolved oxygen levels during calm summer weather (see Figure 7 for 6/6/83). These low levels of dissolved oxygen lead to the release of phosphorus and nitrogen from the sediment. Subsequent wind action may disrupt the weak thermal stratification and mix the bottom waters (which are high in nutrients) throughout the lake. These pulses of nutrients entering the euphotic zone (warm upper layer of lake water where algae grows) cause the increase in algal biomass. If the lake were mixed at all times it is likely that these pulses of nutrient release into the upper waters of the lake would not occur.

Macrophytes

Rooted vegetation plays an important role in lake ecosystems. A zone of macrophytes extending around the shore offers important habitat for fish and wildlife. Many aquatic insects which inhabit aquatic plants are a significant source of fish and wildlife food. Plant root systems are helpful in stabilizing the near shore sediments against erosion. They are also useful in intercepting runoff, storing nutrients, retarding algal blooms, and improving water clarity.

Excessive macrophyte growth can interfere with lake recreation and cause slow, poor growth in young fishes. Too sparse a community of macrophytes also creates problems.

Macrophytes were surveyed both in June and August of 1983. The only difference was an increase in plant density in August. The dominant submersed species are: Myriophyllum exalbescens, Potamogeton sp., Elodea, and Cerstophyllum. Densities of these plants appear higher at the inlets and outlet. Table 4 is a plant species list from the 1983 survey.

Table 4. 1983 Macrophyte Species List for Big Butternut Lake

Scientific Name	Common Name
Floating Leaf	
Numphur variegatum	Yellow water lily
Lemna triscula	Duckweed
Submergent	
Anacharis canadensis	American elodea
Najas flexilis	Bushy pondweed
Potamogeton crispus	Curly pondweed
Potamogeton pusillus	Slender pondweed
Potamogeton pectinatus	Sago pondweed
Potamogeton richardsonii	Clasping-leaf pondweed
Potamogeton zosteriformes	Flatstem pondweed
Ceratophyllum demersum	Coontail
Myriophyllum exalbescens	Northern milfoil
Ranunculus trichophyllus	Buttercup
Sarganium androcladum	Burr reed
Emergent	
Scirpus validus	Bulrush

Fishery

Big Butternut Lake, overall, has an excellent and well balanced fishery. Walleyes, stocked since 1934 are the primary gamefish as the result of both natural reproduction and stocking. Northern pike are also present, primarily using marshy areas associated with inlets and outlets for spawning. Big Butternut Lake also provides ideal habitat for largemouth bass, another common gamefish.

The most abundant panfish are yellow perch. Black crappies are second in abundance. Both species have high populations with good growth and are desirably sized. Other panfish found during the 1977 fish survey include pumpkinseed, rock bass, and bluegills.

Perch and crappies are heavy grazers of zooplankton, the small aquatic insects which graze upon algae. The absence or low population of zooplankton would imply low grazing pressure on the algae in Big Butternut Lake.

Management Alternatives

The management alternatives presented here are designed to provide information and direction to the Lake District for possible formulation of an Integrated Lake Management Plan. The following alternatives can help in creating this management plan:

1) Watershed practices (land management)

2) Macrophyte and algae management

   a. Macrophyte (weed) harvesting
   b. Macrophyte control with screens
   c. Aquatic nuisance control
   d. Biological control
   e. Aeration

1) Watershed Practices/Land Management

Inlake conditions are partially dependent upon "people" activities in the watershed. Many of these activities may seem "insignificant," bearing no direct impact on water quality, but when taken together they do have a negative effect on water quality. The following is a list of good land management practices individuals should follow to maintain and improve Big Butternut's water quality.

a. Bag or compost grass clippings and leaves.

b. Keep gardens on level ground or plant rows of crops across the hill.

c. Use pesticides and fertilizers carefully and sparingly (see Lawn Fertilization Section).

d. Direct roof downspouts to grass areas (not to driveways or other impervious surfaces).

e. Consider bank stabilization measures if your property is along a stream or lakeshore (consult the SCS, UW-Extension, or the DNR for help and advice on this).

f. Cover all bare soil with mulch (see Control of Soil Erosion in Construction Site Section).

g. Collect oil from car and machine maintenance; turn it in at a gas station which has an oil pickup service.

h. In urban areas, clean up pet wastes.

i. Maintain septic systems (see Septic Systems Section).

j. For the rural landowner: identify the areas where there are gullies and sediment deposits after rainfalls. Consult your SCS representative, County Extension Agent, or the DNR for help and advice on good land management. Agricultural activities play a major role in determining Big Butternut's water quality.

k. Leave a buffer strip of tall grass along stream banks or lake shores (see Buffer Zone Section).

l. Protect wetlands (see Wetland Protection Section).

In summary, the goal for all homeowners/landowners is to minimize the amount of water flowing off your land and to prevent polluting materials such as leaves, fertilizers, and soil from being washed into the lake.

What follows is a more detailed discussion of a few of these land management practices and a brief discussion on how the Big Butternut Lake District members can involve themselves in these activities.

Stormwater Management

Urban runoff controls can effectively limit the transport of nutrients and other pollutants from developed areas to the lake.

Stormwater management objectives should include the following.

a. Maximize the distance of stormwater travel from developed land to a collection area, stream or lake.

b. Slow the rate of stormwater runoff from the land. (See section on Erosion Controls and Buffer Zones.)

c. Minimize the volume of overland flow per unit area of land. Increase infiltration capacity (the ability of water to penetrate the soil surface and be directly absorbed).

d. Divert stormwater away from or around critical features such as steep slopes, unstable soils, or valued habitats.

Measures aimed at limiting overland flow include:

1. on-site retention of stormwater (see Buffer Zone section),

2. consideration of alternatives to conventinal stormsewers (artificial, impervious drainage channels concentrate and intensify water flows and pollutants),

3. diversion of low quality water to sump and retention basins,

4. maintenance of wetlands, floodplains and natural stream channels.

A stormwater runnoff control ordinance would help to implement the above management objectives and control measures. To obtain model ordinances and further information on the development of urban runnoff programs, Lake District members should contact the DNR's Lake Management Program.

Lawn Fertilization

A careful analysis of plant and nutrient needs is important to ensure good growth and to prevent over application of fertilizers. When lawns are overfertilized, available sites for phosphorus attachment on soil grains are occupied and phosphates are transported into the groundwater increasing the possibility of transport to the lake. The soil retention capacity for phosphate is limited. Once the phosphate sites are occupied, phosphorus can get into the lake.

If a lake property owner feels that lawn fertilization is necessary, soil samples should be analyzed to determine the exact nutrient requirements, and excessive application should be discouraged. The results of a soil test will determine if the soil needs fertilization, and if it does, the rate to apply it and which type to use. The County Extension office can supply information regarding soil analyses. An alternative to use of fertilizer is periodic watering of the lawn with lake water which already contains a fair amount of nutrients.

Control of Soil Erosion From Construction Sites

Due to increased development activities on the north side of Big Butternut Lake, planning will be necessary for control of erosion and sedimentation. Construction activities can increase surface water runoff over the bare ground, thereby increasing the amount of sediment and nutrients delivered to the lake. It is important to prevent this by covering all bare ground with mulch and by using settling basins, underground absorption fields, or retention structures. Agencies such as the Soil Conservation Service and the Land Conservation Committee can provide guidance in designing and building these systems. For more information see Appendix 3.

Lake District Involvement

The Lake District may wish to sponsor a soil analysis program for homeowners, offer information on the types and availability of fertilizers that should be used, and sponsor a leaf pickup service. Additionally, the Lake District could help landowners develop a landscaping design using the objectives of maximizing runoff water infiltration, minimizing soil erosion and optimizing shoreline aesthetics. Information on buffer zones and soil stabilization techniques could be provided on a districtwide basis. Formal ordinances should be adopted by the village to control stormwater runoff and construction erosion.

Wetland Protection

Wetlands provide critical habitat for a variety of fish and wildlife, and are effective in preserving the water quality of lakes. Protection of the existing 245 acres of wetlands about Big Butternut Lake and its watershed should be a concern of the Lake District. Care should be exercised especially on the north side of the lake in new development areas (see Appendix 2).

In order for the wetlands to operate effectively in nutrient removal, the water flow through them should be slow and not channelized. Efforts should be made to restrict channel cuttings through the wetlands and to control the development of upland areas that drain to the wetlands. If areas above the wetlands are modified to produce a more rapid runoff of surface drainage, then the retention of the receiving wetland will be changed from both a hydrologic and nutrient point of view. It is recommended, therefore, that any development in the watershed not be allowed to change the existing hydrologic patterns. It is also of concern that the existing wetlands in the entire watershed not be artificially filled. It is therefore essential that the Lake District take an active role in local zoning matters that may adversely affect the existing wetlands. Close cooperation between local zoning administrators and the Lake District is essential to insure the Lake District's interests are recognized (See Appendix 2).

Buffer Zones (control of nutrients/sediments in overland flow)

It is desirable to have a strip of land paralleling the shoreline and extending inland from the water a minimum of 20 feet (buffer zone) that is allowed to develop with vegetation. On Butternut Lake, buffer zones would be helpful along the public school shoreline and between the road and county park along the southwest shoreline area.

The creation of this vegetative "buffer zone" will serve to intercept nutrients before they flow into the lake.

The planting of buffer zones can be accomplished by the selective planting of terrestrial species observed growing in this zone at other sites around the lake. In surveying the surrounding habitats for selection of the species to be incorporated, attention should be paid to the comparison and contrast of the two areas with respect to soil type, moisture content, depth of water table, and slope.

When selecting species for the buffer zone, a combination of deep-rooted and shallow-rooted plants should be considered for optimal drainage interception as well as inclusion of a suitable mixture of ground species. This will, ideally, result in a three-storied complex of tall trees, shorter trees and shrubs, and ground level vegetation, such as ferns, creepers, and grasses. When species are selected, their relative compatibility to one another must be considered. Professional guidance by a landscape architect or other expert may be desirable.

While much of the nutrient uptake by the vegetative buffer strip may be expected to return to the soil surface in leaf fall at the onset of winter, any interruption of the flow of nutrients to algae and weeds during the spring and summer growing season helps. Raking of the fallen leaves for decomposition in a compost pile set well back from the shore will further help reduce the nutrient loading to the lake. The burning of leaves in the watershed should be discouraged as this practice breaks the organic material down thus making it easier to be lost to the lake, and once there, more readily available for algal uptake.

The lakefront property homeowners on Big Butternut Lake who take considerable pride in their lawns will hopefully consider the environmentally sound benefits of vegetative buffer strip landscaping.

Each property owner should be encouraged to observe where runoff occurs during a heavy rainfall event on his or her property. The construction of small berms to encourage ponding and infiltration of this runoff water should be considered. Runoff from downspouts or from driveways should be directed to gravel trenches or other areas where seepage can occur. Additionally, construction of impervious areas such as driveways or patios should be kept to a minimum. Several types of porous paving materials are available which will prevent erosion of those heavily used areas while still allowing infiltration. Their use should be encouraged.

2) <u>Management of Macrophytes and Algae</u>

a. Harvesting Lake Weeds (Macrophytes)

Harvesting can be used to improve accessibility to various areas of the lake where aquatic weeds have become a nuisance. Integration of harvesting and fiberglass screens can be used as alternatives to herbicide application. Harvesting may be desirable for creation of boat lanes and designated swimming areas.

It would never be desirable to harvest all areas of macrophyte growth. Areas must be left for angling, fish spawning, waterfowl, and in terms of water quality, to stabilize sediments, store nutrients, intercept runoff, retard algae blooms and to maintain water clarity.

Figure 2 shows areas that should not be harvested. They have been identified by the area DNR fish manager as northern pike spawning areas, areas containing significant fish habitat, or areas important for wildlife habitat.

Ted Smith, the lake management coordinator in Spooner should be contacted for more information on macrophyte management.

b. Lake Weed Control with Fiberglass Screen

Vinyl covered fiberglass screen has been used in many lakes in Wisconsin. The screen comes in rolls 7 feet by 100 feet and can be stitched together easily into larger panels. Rolls of screen are estimated to cost between $150 to $175. The screen can be laid along shorelines, pier areas, to create boating lanes, and in deep areas where harvestors can't reach. Since the screen is 3 times denser than water it sinks to the bottom but must be pressed to the lake bed with metal stakes, stones, or bricks. The screen must be held down to prevent movement caused by wave action and to keep it out of motor props. The screen is installed in the spring but must be removed every year to be cleaned in soft bottom lakes and every few years in hard bottom lakes. (If silt builds up on the screen, plants will begin growing.)

Vinyl fiberglass screen is an option used for breaking up continuous stands of plants, reducing summer biomass, reducing internal phosphorus loading, and forming boat lanes. Bottom screening used in conjunction with selective harvesting can improve near shore zones. Careful planning by the lake district to manage certain areas of the lake rather than the entire lake for enhanced recreation can reduce lake district costs without sacrificing biological diversity.

A DNR permit is required before applying the screen. For further details, contact the DNR Area Office in Cumberland.

c. Aquatic Nuisance Control (ANC)

Big Butternut Lake was chemically treated with copper sulfate prior to 1969, and during the 70's with Aquathol, Diquat, and endothal. Chemical control of algae/macrophytes has been a source of controversy for the Lake District. In 1985, harvesting was attempted as an alternative to chemical control.

Many compounds have been approved by the U.S. Environmental Protection Agency for usage on public waters. However, copper sulfate is the only effective algicide, and only three herbicides -- endothal, 2,4-D, and Diquat -- are in general use in Wisconsin for macrophyte control. Herbicides can be effective, but chemical control of macrophytes is not recommended unless other practices such as harvesting and/or fiberglass screening prove to be impractical or ineffective. (See following sections.) Herbicides leave plants to decompose in place thereby making nutrients available for another new generation of growth.

d. Biological Control of Algae

The most abundant species of panfish in the lake at present, yellow perch and black crappies are heavy grazers upon zooplankton. Zooplankton, if free from predation pressure by fish, can reduce the blue green algae population.

If the predators of zooplankton can be controlled, both zooplankton abundance and their average size will increase. Large zooplankton such as <u>Daphnia magna</u> will graze on blue green species. A population of <u>Daphnia</u>, if it is able to grow without constant threat of predation, will reduce the blue green algae population and cause a shift in the dominant algal species. Biological control of blue green algae in this manner will improve water quality. Pursuit of this alternative would require working closely with DNR fish managers and water quality specialists. The Lake District would also have to make a sincere and long term commitment to managing the lake's fishery and the habitat which now favors the present forage species.

e. Aeration

An aeration system could be designed to ensure that the lake continually mixes and the entire water column remains oxygenated during the summer. This could retard phosphorus release from the sediments and reduce the algal problem. Even under oxic conditions, however, some phosphorus will be released as a result of decomposition of algal material. A drastic change in the trophic status of the lake should not be expected. At this time, there is no concern for operating an aeration device during the winter. The winter dissolved oxygen concentration has been more than adequate to maintain a good fishery.

A very rough estimate of aeration costs would be approximately $40,000. (This would include purchasing, installation, and operating costs.) If the Lake District has an interest in pursuing this course of action a more detailed analysis could be completed. In order to place an aeration device on the bed of a lake, permits must be acquired from the DNR Area Office in Cumberland.

Appendix 1: Phosphorus Loading Calculation

Total annual mass flow of phosphorus into Big Butternut Lake was estimated by summing the annual contributions of phosphorus from each source within the watershed. This phosphorus loading can be expressed as:

$$P_t = [E_{cr} \times Area_r) + (E_{ca} \times Area_m \times R_w) + (E_{cf} \times Area_f) + (E_{cu} \times Area_u) + (E_{ca} \times Area_o) + (\text{Septic Contribution})$$

Where:

P_t = Total mass of phosphorus delivered to the lake (kg/year)

E_{cf} = .09 export coefficient for woodland (kg/ha/yr)

E_{cu} = .28 export coefficient for low density residential area (kg/ha/yr)

E_{ca} = .21 export coefficient for atmospheric input (kg/ha/yr)

E_{cr} = .75 export coefficient for agricultural land (row crops) (kg/ha/yr)

$Area_f$ = 387 ha of woodlands

$Area_u$ = 25 ha of low density residential

$Area_o$ = 153 ha of lake

$Area_r$ = 327 ha of agricultural land

$Area_m$ = 99 ha of wetlands

Whenever a specific land use was separated from the lake by a wetland, a 70 percent reduction was applied to the export coefficient (R_w = .70). Export coefficients were taken from, "A Manual and Compilation of Export Coefficients" by Rechow et al., U.S. EPA 440/5-80-011. The annual contribution of phosphorus from septic systems can be calculated as follows:

P_s = (# of persons/house) (# of homes/grams of P/person/day) (# of days occupied) (1-Rs)

Where:

Ps = annual phosphorus loading from septic systems into lake

# of persons/house	3.2 (from survey)
# of homes	9 Permanent, 33 Seasonal
grams of P/person/day	2.2 (Low), 4.1 (High) Permanent 1.8 (Low), 3.4 (High) Seasonal
# of days occupied	365 Permanent, 60 Seasonal

R_s = Soil retention coefficient .80

Phosphorus loading from septic systems was calculated using "Recommended Methods for Classifying Lake Conditions, Determining Lake Sensitivity and Predicting Lake Impact" by H. S. Garn and H. Parrot, Hydrology Paper No. 2, U.S.D.A., Forest Service.