REPORT

MIRROR LAKE WATERSHED INVESTIGATIONS AND MANAGEMENT PLAN

Prepared for
Mirror Lake Association
Mirror Lake, Sauk County, Wisconsin

January 1994

Woodward-Clyde

Woodward-Clyde Consultants
8383 Greenway Boulevard
Middleton, Wisconsin 53562

Project Number 92C6694

LPL-156

Woodward-Clyde Consultants

Engineering & sciences applied to the earth & its environment

January 13, 1994

Mr. Waldo Peterson, President
Mirror Lake Association
6417 Odana Road
Madison, Wisconsin 53705

Dear Mr. Peterson:

Woodward-Clyde Consultants is pleased to transmit the attached copy of the Lake Management Plan for Mirror Lake. This document fulfills the provisions of the contract between the Town of Delton/Mirror Lake Association and Woodward-Clyde Consultants.

We want to personally thank you and the rest of the Mirror Lake Association Board for your cooperation and assistance during this study. This document provides a sound basis for taking actions regarding the protection and improvement of Mirror Lake.

The study shows that the lake has periods of poor water quality conditions during the summer months. The major source of pollution to the lake is nonpoint source runoff from the rural portions of the lake's watershed. Several recommendations are made in the study to assist the Association and local groups in reaching the goal of improved water quality for Mirror Lake.

We trust you will find this document helpful in meeting your lake management needs. Thank you again for your cooperation. Please give us a call if there are any other services that we could provide regarding the protection of Mirror Lake.

Sincerely,

WOODWARD-CLYDE CONSULTANTS

James A. Bachhuber
Senior Project Scientist

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BACKGROUND

In September of 1992 the Mirror Lake Association, through sponsorship with the Town of Delton, received a Lake Planning Grant from the Wisconsin of Department of Natural Resources (DNR). The purpose of the grant was to:

- Conduct a study of the lake's pollution sources;
- Assess the quality of the lake's water based on existing data;
- Predict future trends of the lake's trophic status; and
- Provide recommendations for future lake management needs.

This study was conducted through a contract between the Town of Delton, and Woodward-Clyde Consultants, of Middleton, Wisconsin. The Mirror Lake Association funded the local portion of the Lake Planning Grant.

WATER QUALITY

Method of Analysis

Water quality on Mirror Lake from several sources was analyzed to determine present, and past conditions of the lake. DNR sampling from the mid 1970's and early 1980's was found to be the earliest water quality data available for Mirror Lake. Secchi disk measurements for spring, summer, and fall months were available for the period of 1987 to present. This data was collected by the Mirror Lake Association through a volunteer monitoring program administered by the DNR. In 1993, this volunteer sampling program was expanded to include data on the lake's dissolved oxygen, total phosphorus, and chlorophyll *a* concentrations.

This data was used to evaluate trends in Mirror Lake's water quality, and to compare the water quality with other lakes of the area.

Results of Water Quality Analysis

Water quality analysis indicated that Mirror Lake has a high nutrient content which results in nuisance levels of macrophyte, algal, and duckweed growth. These water quality conditions did not appear to change significantly between the monitoring conducted in 1975-1976 by DNR and the monitoring in 1993 by the Mirror Lake Association.

Dissolved oxygen conditions at the bottom of the lake were found to be insufficient to support fish in the June, 1993 sampling. This is not uncommon for lakes high in nutrient content. During most other sampling periods, the lake did not stratify, and dissolved oxygen concentrations were adequate for supporting fish life.

Comparing Mirror Lake with other lakes in southwestern Wisconsin found that the lake's water quality was generally about average, or a little below average when using the parameters of total phosphorus, Secchi disk measurements, and chlorophyll *a* concentration for comparison.

TROPHIC STATUS TRENDS

Method of Analysis

The available water quality data was used to classify Mirror Lake as to it's "trophic status" using an index system developed by Carlson (1977) and used by the DNR. The lake's current trophic status was then modeled using six different models commonly applied to midwestern lakes. The model which best fit the monitored conditions of Mirror Lake was the Bachman and Canfield model for artificial lakes. This model was then used to predict future conditions of Mirror Lake under various levels of phosphorus source reductions.

Results of Trophic Status Trends Analysis

Water quality monitoring conducted on Mirror Lake indicates that the lake's Carlson Trophic Status Index value is in the range of 54-60 ("poor" condition). The trophic status modeling indicated that a 50% reduction in annual phosphorus loading to Mirror Lake would generally result in an improvement of 40% to 50% in the lake's phosphorus concentrations, chlorophyll *a* concentration and water clarity. These changes in water quality would result in a trophic status index value in the range of 50-54 ("fair" conditions). The study notes that a 50%

reduction of phosphorus to Mirror Lake could only be accomplished with a very aggressive and comprehensive program to control nonpoint source pollution.

POLLUTION SOURCES

Method of Analysis

The pollution source investigation focused on sources of phosphorus and sediment to the lake. These two pollutants have the most direct impact on the lake's water quality, and aesthetics. Pollutant sources investigated included: upland erosion, barnyard runoff, improperly functioning septic systems, streambank erosion, construction erosion, atmospheric deposition, and lake bed sediments. Also, allowances were made to account for the removal of phosphorus from the lake system through the summer duckweed/macrophyte harvesting that had taken place on Mirror Lake prior to 1993.

Average annual quantities (or pollution loads) from each of these sources were estimated to construct a "nutrient budget" for Mirror Lake. The results of this effort indicated the sources of nutrients and sediments most important in their contribution to Mirror Lake. With this information, recommendations could be made to focus local governments' efforts to best protect Mirror Lake.

Results of Pollution Source Analysis

The largest source of sediment to Mirror Lake appears to be cropland erosion from the agricultural fields in the lake's watershed. Although this land use accounts for about 37% of the area in the watershed, it contributes about 86% of the sediment to Mirror Lake on an annual basis. Sediment from construction sites was not quantified in this study. However, two specific sites of sediment deposition were noted in the lake. Local residents believe that these sediment deposits are the result of construction at a nearby campground, and from runoff from the interstate highway bridge. Runoff from the bridge has since been modified and there is no evidence of continued sediment deposits from the highway runoff. The construction at the campground has been completed and there is no evidence of recent sediment deposits at the second site.

The largest source of phosphorus to Mirror Lake also appears to be cropland erosion from the agricultural fields in the lake's watershed. Cropland erosion accounted for about 84% of the annual phosphorus load to the lake. The next largest source was barnyard runoff (6%) Septic systems, and atmospheric deposition, do not appear to be significant sources of phosphorus to the lake. The phosphorus contribution from the lake sediments is unknown. A level of analysis beyond the scope of this report would need to be conducted to estimate the significance of this source.

RECOMMENDATIONS

As a result of this study a set of recommendations were developed for the Mirror Lake Association, and/or the Town of Delton. These recommendations were prepared to serve as a guide to the local groups on what actions could be taken to have the most significant impact on improving or protecting the water quality of Mirror Lake.

A summary of the recommendations included:

- Re-establishment of the duckweed/Ceratophyllum harvesting at the Dell Creek inlet area of the lake.
- Reduce nonpoint sources of pollution through the designation of Dell Creek as a "priority watershed" through DNR's Nonpoint Source Pollution Abatement Program.
- Develop local information/education material to help local homeowners in minimizing potential sources of pollutants from yard and household activities.
- Encourage the Town of Delton (with enabling legislation from Sauk County) to develop a construction erosion control ordinance.
- Subsequent studies to consider are: 1) a study of the nutrient content of the Lake's sediment (as a potential source of phosphorus to the lake); and 2) a field septic survey to identify failing septic systems. Analyzing the sediment phosphorus contribution is critical to know the significance of this potential source of phosphorus to the lake system.

1.0
INTRODUCTION

In July of 1992, the Mirror Lake Association selected a lake study proposal prepared by Woodward-Clyde Consultants (WCC) to submit for funding through Wisconsin's Lake Planning Grant Program. The program is administered by the Wisconsin Department of Natural Resources (DNR) and in September of 1992, the association was awarded a state grant for 75% of the cost of the study. The remainder of the study is funded by the Mirror Lake Association. The grant application for this study received widespread local community support. Local groups including the Town of Delton, the Blass Lake Association, and the Lake Delton Lake District were involved in the development of the grant application.

The study, as described in the proposal, set out the following objectives:

1. Develop the Lake's Nutrient Budget (phosphorus)

   The nutrient budget will help focus remediation measures to the most significant pollutant sources and help predict the potential water quality goals for the lake.

   To develop the nutrient budget a watershed evaluation estimating the quantity and quality of runoff to the lake would be conducted. The nonpoint source pollution will be quantified by land use type within the watershed.

2. Water Quality Monitoring/Trends in Lake Trophic Status

   The DNR and Lake Association have collected water quality data on the lake over the past several decades. In 1993, the Lake Association increased its monitoring effort by becoming involved in DNR's Expanded Self-Help Monitoring program. Through this program, the Lake Association collected nutrient, chlorophyll *a*, temperature, dissolved oxygen, and Secchi disk measurements at three locations on the lake, bi-monthly from April through October. This data will be analyzed and used to help document water quality trends. With the use of a computer model, future trophic conditions will be predicted with various levels of nutrient control.

3. Develop a Lake/Watershed Management Plan

The topics included in the plan are:

- Recommendations on the types of management measures and approaches to best control the pollution sources, and manage the lake to meet the user needs.
- Estimated costs of the various management measures.
- A description of potential funding sources to implement the recommendations.
- The use of a lake trophic status model to predict changes in the lake's quality as a result of the recommended nonpoint source control measures.

The study is documented within this report.

2.0 BACKGROUND AND SETTING OF MIRROR LAKE

2.1 GENERAL INFORMATION

Mirror Lake is a 137 acre impoundment in Sauk County, Wisconsin (see Figure 2-1). The maximum depth is about 19 feet. The lake is considered nutrient rich (eutrophic), and has experienced duckweed nuisance conditions for many years. There is also an abundance of rooted macrophytes in the littoral zone of the lake. Algae blooms on the lake have not been reported at nuisance levels. The Wisconsin Dells, a popular tourist area, is within five miles of the lake.

2.2 THE WATERSHED AND LAND USE

The Mirror Lake watershed encompasses approximately 65 square miles. The topography of the area consists of gentle hills with steep sandstone outcrops along the river and creek valleys. The soils are generally glacial outwash sands.

The land use of the watershed is mostly rural agricultural. The agricultural land use is dominated by dairy farming operations. Public lands also make up a significant portion of the rural land use. Mirror Lake State Park is 2,050 acres in size and accounts for a majority of the shoreline property on the lake. Also, the Dell Creek State Wildlife Area encompasses 2,125 acres within the watershed. Commercial properties on, or near the lake include two private campgrounds and a restaurant/resort. The private campgrounds have a total of about 650 camp sites. Mirror Lake State Park has a total of 144 camp sites. There is one condominium complex on the lake near the outlet. The rest of the shoreline land use is in single family houses. There are approximately 35 homes around the lake. There are no incorporated communities in the watershed. Table 2-1 shows a breakdown of the land use.

2.3 WATER RESOURCES OF THE WATERSHED

Besides Mirror Lake, there are no other named lakes within the watershed. According to DNR records, a log mill dam on Dell Creek (at the current dam location) was constructed in 1857. The dam underwent improvements and rehabilitation several times

TABLE 2-1
LAND USE COVER IN THE MIRROR LAKE WATERSHED

Land Use Type	Acres (%)
Cropland	15,591 (37%)
Pasture	3,176 (8%)
Woodland/Open Lands	22,211 (53%)
Residential	935 (2%)
Commercial	187 (<1%)
Total:	**42,100 (100%)**

Source: WCC 1993 Lake Management Study.

over the years. The latest refurbishment was conducted in 1976 - 1977. In 1977, Sauk County took over ownership of the dam.

The lake supports a warm water fishery including walleye, northern pike, large mouth bass, and panfish (DNR 1991). The lake has a no wake restriction on motor boats throughout the lake.

The named tributaries to Mirror Lake are Dell Creek and Harrison Creek. There are several other unnamed tributaries to Mirror Lake on the north and south sides of the lake. In addition to these tributaries, Beaver, and Camel Creeks feed Dell Creek. Dell Creek, Camel's Creek, Harrison Creek, and Beaver Creek are all classified as "Class II" trout streams by the Wisconsin Department of Natural Resources.

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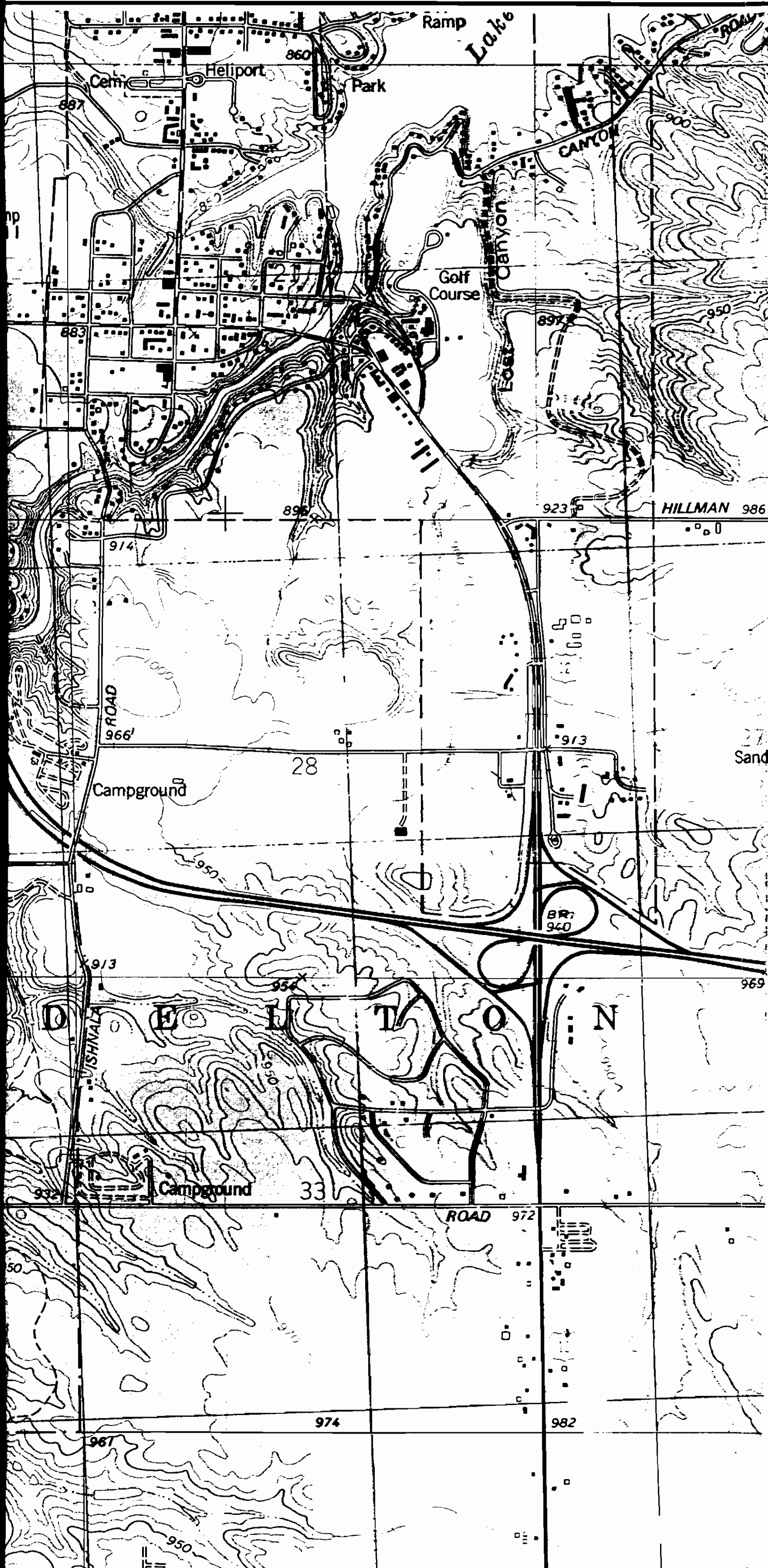

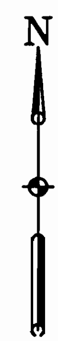

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SOURCE:
UNITED STATES GEOLOGICAL SURVEY TOPOGRAPHIC MAPS; SAUK (1986) AND JUNEAU (1986) COUNTY.

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	CHECKED JAB	MIRROR LAKE	DRAWING
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	PROJECT MANAGER		
	DATE 1-11-94		SHEET 1 OF 1

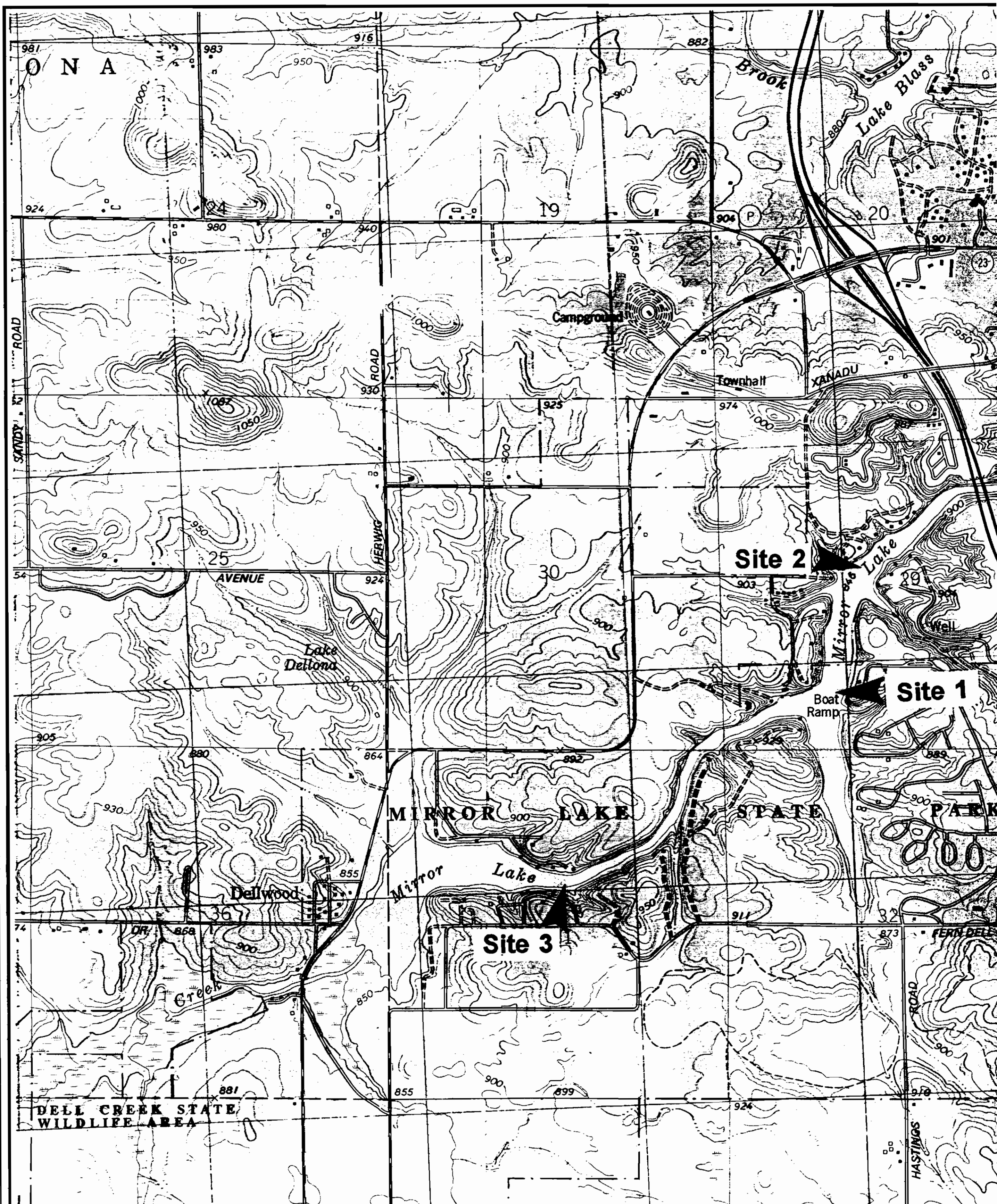
3.0 WATER QUALITY CONDITIONS/TRENDS

3.1 METHODS

Water Quality sampling of Mirror Lake was conducted by local volunteers through two DNR programs. The first program is the Self-Help Monitoring Program. Since 1987, local volunteers have collected Secchi disk measurements about every two or three weeks between April and October. These measurements were obtained from three sites on the lake (see Figure 3-1). Results from this sampling are summarized below on Table 3-1.

Beginning in the Spring of 1993, the Mirror Lake Association became involved in a second monitoring program called the Expanded Self-Help Monitoring Program. Through this program, additional water quality parameters were measured by local citizen volunteers. In April, June, July, and August, the three sites used for the Secchi disk monitoring were also sampled for temperature, dissolved oxygen, chlorophyll *a*, and total phosphorus. The dissolved oxygen, temperature, and total phosphorus measurements were obtained for the entire "profile" of the site. This means that the parameters were sampled at various depths at each site. The results of this sampling are summarized below on Table 3-2.

Between 1975 and 1977 the DNR Bureau of Research sampled water quality at a single site on Mirror Lake four times a year. The analyses included a dissolved oxygen and temperature profile, nutrient concentrations, and Secchi disk measurements. These data are shown on Table 3-3 following.



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3.2 WATER QUALITY SAMPLING RESULTS

TABLE 3-1: MIRROR LAKE MONITORING SUMMARY
SECCHI DISK MEASUREMENTS
(all measurements in feet)

		Summer Measurements *			All Year Measurements		
Year	Site #	Avg.	Standard Deviation	Count	Avg.	Standard Deviation	Count
1980+		4.2	--	2	4.2	--	2
1987	1	4.5	1.2	11	4.9	1.5	15
	2	4.6	1.2	11	4.8	1.3	15
	3	--	--	--	--	--	--
1988	1	4.2	1.3	14	4.0	1.1	8
	2	3.9	1.0	8	4.3	1.5	14
	3	6.1	1.2	4	3.9	1.4	7
1989	1	5.0	1.1	8	4.6	1.1	12
	2	5.7	1.4	8	5.1	1.7	12
	3	6.0	1.4	8	6.6	1.7	12
1990	1	5.1	1.6	7	4.9	1.6	8
	2	5.3	1.4	7	5.1	1.3	8
	3	6.7	1.7	7	7.0	1.7	8
1991	1	3.6	0.7	10	3.7	0.8	12
	2	4.1	0.9	10	4.1	0.9	10
	3	6.5	1.8	10	6.4	1.7	11
1992	1	4.1	1.1	8	4.7	1.5	10
	2	4.4	1.3	4	5.1	1.9	5
	3	5.4	1.3	4	5.7	1.3	5
1993	1	3.3	1.6	7	3.3	1.4	9
	2	3.3	1.4	7	3.4	1.3	9
	3	5.1	2.7	7	5.1	2.4	9

* Summer Measurements are from June, July, and August
+ Data from DNR files; all other data from Mirror Lake Self-Help Monitoring

TABLE 3-2: 1993 MIRROR LAKE
EXPANDED SELF-HELP MONITORING RESULTS

Date/ Site #	Depth (ft)	Total Phosphorus (mg/l)	Chloro-phyll *a* (ug/l)	Dissolved Oxygen (mg/l)	Temp. (F)
4/22/93 #1	3	0.101	NA	11.0	47
	9	--		10.5	45
	10	0.110		--	--
4/22/93 #2	1	0.100	NA	8.0	46
	3	--		10.0	46
	5	0.091		--	--
4/22/93 #3	1	0.084	NA	11.0	47
	3	--		11.8	47
	4	0.109		--	--
6/19/93 #1	1	0.156	NA	5.0	67
	2	--		6.8	67
	4	--		3.0	65
	6	--		3.5	60
	8	--		2.0	59
	10	0.181		1.8	59
6/19/93 #2	1	0.176	NA	--	--
	5	0.196		--	--
6/19/93 #3	1	0.212	NA	--	--
	4	0.212		--	--
7/27/93 #1	1	0.082	NA	8.0	72
	2	--		9.3	72
	4	--		8.5	70
	6	--		8.8	66
	10	0.097		7.3	68
	12	--		7.5	--
7/27/93 #2	1	0.077	NA	--	--
	5	0.082		--	--
7/27/93 #3	1	0.078	NA	--	--
	4	0.077		--	--
8/29/93 #1	1	NA	NA	12.5	71
	2	--		12.3	71
	4	--		10.3	70
	6	--		7.0	69
	8	--		6.0	68
	10	--		6.0	68
8/29/93 #2	1	NA	NA	--	--
	5	--		--	--
8/29/93 #3	1	NA	NA	--	--
	4	--		--	--

NA: results not available at this time

TABLE 3-3: PRE-1993 MIRROR LAKE MONITORING *

Date	Secchi depth (ft)	Depth (ft)	Total Phosphorus (mg/l)	Total Kjeldahl Nitrogen (mg/l)	Chloro-phyll a (ug/l)	Dissolved Oxygen (mg/l)	Temp. (F)
7/10/75	3.8	0	0.090	0.72	--	10.0	72
		11	--	--		8.6	55
		14	--	--		3.5	51
		18	0.960	0.96		3.2	50
10/21/75	4.0	0	0.150	0.89	--	12.7	51
		6	--	--		--	50
		9	--	--		--	50
		14	0.130	1.03		--	--
		18	0.140	1.61		11.0	49
2/24/76	1.2	0	0.220	2.77	--	7.5	33
		5	0.250	2.76		7.3	33
		9	0.270	2.87		7.5	33
4/13/76	3.0	0	0.080	0.97	--	12.2	50
		10	--	--		--	50
		18	0.120	1.46		11.1	49
4/25/77	3.0	0	0.060	0.67	--	12.5	62
		10	--	--		7.1	49
		16	0.070	1.77		5.2	43
6/12/80	NA	0	--	--	17.00	--	--
8/21/80	NA	0	--	--	28.00	--	--

* Source: DNR; Bureau of Research

3.3 WATER QUALITY DATA DISCUSSION

Mirror Lake has historically been a eutrophic lake (that is, a lake high in nutrients with occasional nuisance levels of algae and/or aquatic weeds). DNR sampling in 1975 - 1977 showed that the lake was high in total phosphorus, total Kjeldahl nitrogen, and chlorophyll a. Secchi disk and phosphorus conditions have not measurably changed compared with the 1993 sampling.

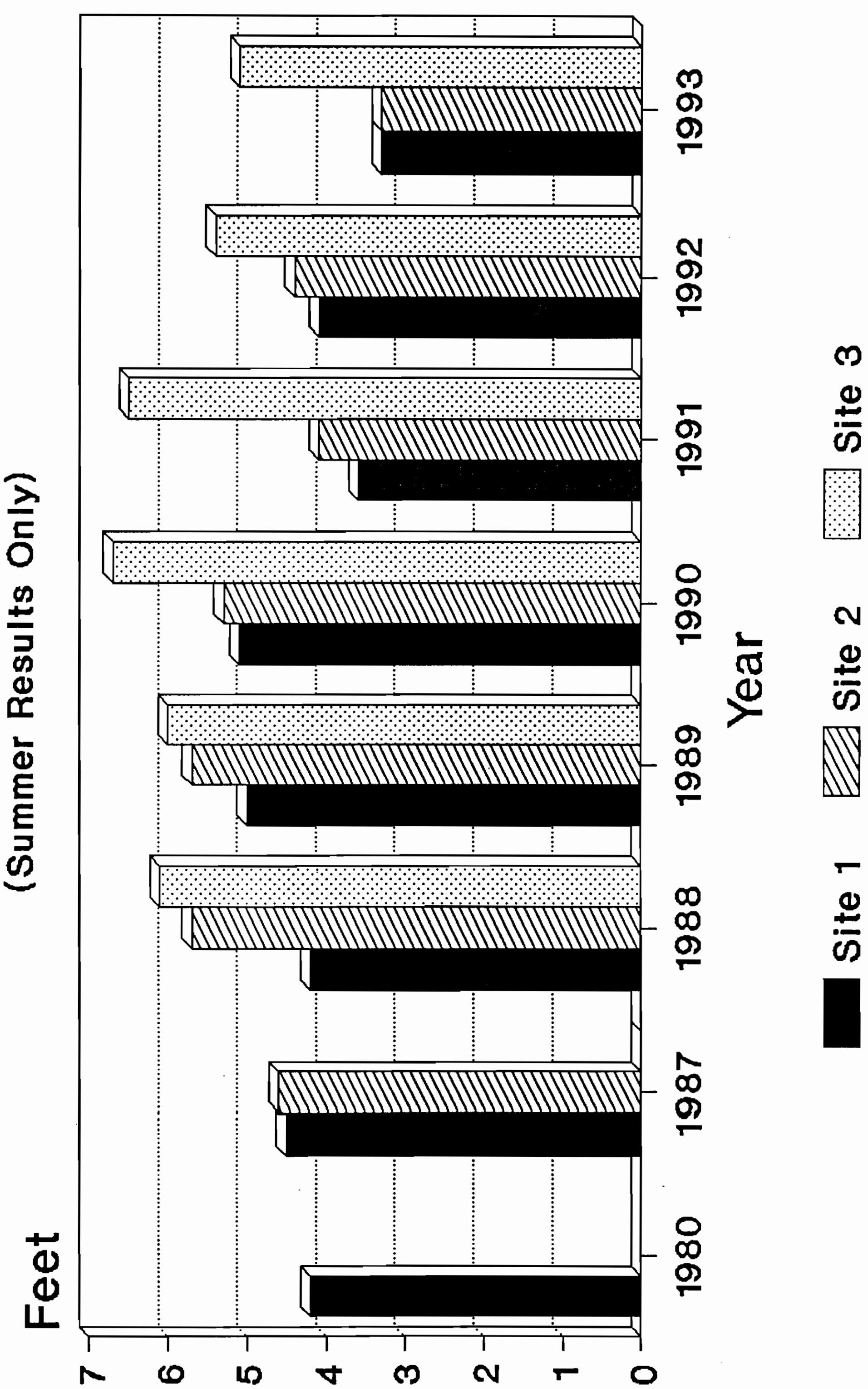
The 1993 lake monitoring showed high levels of phosphorus, and nuisance levels of duckweed were noted during the self-help monitoring trips especially in July and August. Duckweed harvesting was not conducted in the summer of 1993 in the upper portions of the lake. Duckweed was harvested near the Mirror Lake Dam by the Village of Delton. This, along with the exceptionally high rainfall amounts in the summer of 1993, could account for the high levels of duckweed on Mirror Lake. The numerous rainfall events in 1993 meant that increased amount of phosphorus and nitrogen were carried into Mirror Lake, which in turn, increased the amount of nutrients available for aquatic plant growth.

Monitoring of Mirror Lake in the 1970's and in 1993 showed that the lake does not stratify, or only weakly stratifies during the summer months. This means that the water stays mixed from surface to the bottom. Also, the dissolved oxygen levels for the most part, remained adequate for fish and other aquatic life throughout the monitored period. In June of 1993 the bottom dissolved oxygen concentration fell to levels that would not support fish (1.8 mg/l).

Secchi disk monitoring trends are shown on figure 3-2 (next page). No clear trend can be determined over the monitored period (1980 - 1993). Of the three sites monitored within Mirror Lake, Site 3 consistently had the highest average readings, and Site 1 consistently had the lowest readings.

Figure 3-2: Mirror Lake Secchi Measurements Summary

(Summer Results Only)



Source: Mirror Lake Self-Help Monitoring & WDNR

4.0 LAKE TROPHIC STATUS/TRENDS

4.1 BACKGROUND INFORMATION

One measure of a lake's water quality is by the classification of it's "trophic status". The trophic status is a general description of the nutrient level in a lake. Mirror Lake is considered eutrophic based upon past monitoring results. This eutrophic condition can be characterized by frequent blooms of blue-green algae and/or dense growths of macrophytes (lake weeds). Mirror Lake often has nuisance levels of duckweed (a floating macrophyte) and rooted macrophytes (especially *Ceratophyllum demersum* - coontail).

Three measurements of a lake's trophic status are water clarity, (measured with a Secchi disk), Chlorophyll-*a* concentrations, and total phosphorus concentrations.

Water Clarity Measuring water clarity with a Secchi disk is an easily understood indication of "how green" a lake is perceived to be. Classification of clarity depths related to a trophic status index is shown on Table 4-1.

Chlorophyll-*a* Chlorophyll-*a* is a photosynthetic pigment found in algae. This parameter is a direct measure of the algal biomass. This measurement varies widely throughout the summer depending on the algal bloom cycle. Table 4-1 shows the classification of Chlorophyll-*a* concentrations relative to perceived water quality.

Phosphorus Concentrations Phosphorus is generally the nutrient most responsible for supporting the excessive algae growths. When a lake's surface layer of water is high in phosphorus, high algae production can be expected. Classification of total phosphorus concentrations are shown in Table 4-1.

For purposes of predicting potential future changes in Mirror Lake the Bachman and Canfield, 1979 model for artificial lakes was chosen. Although the modeled values do not closely match the monitored conditions, the per cent of change in the parameters

TABLE 4-1: WATER QUALITY INDEX FOR WISCONSIN LAKES BASED ON TOTAL PHOSPHORUS, CHLOROPHYLL *A* CONCENTRATIONS, AND WATER CLARITY

Water Quality	Approximate Total Phosphorus (mg/L)	Secchi disk Depth (ft)	Approximate Chlorophyll a (µg/L)	Approximate Trophic Status Index*
Excellent	<.001	>20	<1	<34
V. Good	.001-.01	10-20	1-5	34-44
Good	.01-.03	6-10	5-10	44-50
Fair	.03-.05	5-6	10-15	50-54
Poor	.05-.15	3-5	15-30	54-60
V. Poor	>.15	<3	>30	>60

*After Carlson (1977) — "<" means "less than"
Source: DNR Technical Bulletin 138 (1983) — ">"means "greater than"

** Shaded values show Mirror Lake condition based on average of 1987-1993 sampling.

may be applicable to predict future changes in Mirror Lake's condition. These predicted changes are shown on Table 4-4 for various phosphorus reduction levels.

4.2 MODEL SELECTION

A trophic status model predicts the lake's future water quality in terms of these parameters based on projected reductions in nutrient (phosphorus) pollution from the watershed. For example: "The average summer Secchi disk is currently 'X' feet. With a reduction of phosphorus pollution of 'Y %' (through nonpoint source control practices), the future summer Secchi disk measurements can be expected to be 'Z' feet."

The trophic status modeling was conducted using software available from the DNR for common lake situations in Wisconsin. There are several models to chose from to compare to the actual monitored conditions within Mirror Lake. Table 4-3 compares the trophic models' results with the monitored conditions. The models tested did not produce results very close to the monitored conditions. The reason for this is likely the unusual shape of Mirror Lake. The lake has distinct lobes to the west and south which meet to form the central area. The western lobe is connected to the rest of the lake by a long, narrow.

channel. At times, this configuration may cause Mirror Lake to act like two separate lakes.

Table 4-2, below, shows the input data used to run the trophic status models.

TABLE 4-2: PARAMETERS USED FOR INPUT TO THE MIRROR LAKE TROPHIC STATUS MODELING

Parameter	Value
Water Surface Area (acres)	137
Maximum Depth (feet)	19
Mean Depth (feet)	8
Lake Volume (acre feet)	1,096
Average Annual Inflow Rate (cfs)	30
Average Annual Flow Volume (acre feet)	21,719
Average Annual Residence Time (days)	18.4
Average Annual Phosphorus Load (lbs/yr.) *	24,385

* Model Input Used Phosphorus Loading From 1993 WCC Watershed Investigation.

4.3 TROPHIC MODELING RESULTS

TABLE 4-3: COMPARISON OF LAKE TROPHIC MODEL WITH MONITORED CONDITIONS

Model	Tot. Phos. (mg/l)	Secchi (feet)	Chlor *a* (ug/l)
Monitored *	0.08	4.2	22.5
Dillon Rigler 1974B	0.25	1.4	213.0
Vollenweider, 1975	0.32	1.2	312.0
Vollenweider, 1976	0.32	1.2	306.0
Bachman & Canfield, 1979 (natural lakes)	0.26	1.3	230.0
Bachman & Canfield, 1979 (artificial lakes) **	**0.18**	**1.7**	**138.0**
Reckhow, et.al., 1980	0.27	1.3	242.0

* Spring total P from 4/13/76, 4/25/77 (DNR) & 4/22/93 site #1 (Self-Help) data. Secchi Disk from site #1; summer 1980, 1987 - 1992 (DNR & Self-Help) data. Chlor *a* from 6/12/80, 8/20/80 (DNR).

** model selected for predictive use.

TABLE 4-4: PREDICTED CHANGES IN TROPHIC STATUS INDICATORS WITH PHOSPHOROUS REDUCTIONS

% Phosphorus Reduction	Predicted Conditions *					
	Total Phosphorous		Secchi Disk		Chlorophyll a	
	(mg/l)	(% change)+	(ft)	(% change)	(ug/l)	(% change)
0%	0.18	0%	1.7	0%	138.0	0%
10%	0.17	-6%	1.8	+6%	124.0	-10%
20%	0.16	-11%	1.9	+12%	110.0	-20%
30%	0.14	-22%	2.0	+18%	96.0	-30%
40%	0.13	-28%	2.2	+29%	82.0	-41%
50%	0.11	-39%	2.4	+41%	67.0	-51%

* Using Bachman and Canfield, 1979 (artificial lakes)
+ % change compared to current condition (0% phosphorous reduction)

4.4 DISCUSSION ON MIRROR LAKE TROPHIC STATUS

4.4.1 Current Trophic Status

The lake's trophic status (nutrient condition) is generally indicated by the Secchi disk depths, the surface water's phosphorus concentrations, and the surface water's chlorophyll *a* concentration. The table below shows how Mirror Lake compares to 26 other lakes in southwestern Wisconsin for these parameters. The information on the 26 lakes was obtained from a 1983 DNR publication by Dick Lillie and Jack Mason.

TABLE 4-5: COMPARISON OF MIRROR LAKE TROPHIC CONDITIONS WITH OTHER LAKES IN SOUTHWESTERN WISCONSIN

	Secchi disk (ft)	% of SW Wis. Lakes in Each Category	Chlorophyll a (ug/l)	% of SW Wis. Lakes in Each Category	Total Phosphorus (mg/l)	% of SW Wis. Lakes in Each Category
Best	> 19.7	0%	0-5	0%	<.010	0%
	9.8-19.7	0%	5-10	13%	.010-.020	23%
	6.6-9.8	7%	10-15	17%	.020-.030	7%
	3.3-6.6	32%	15-30	30%	.030-.050	20%
	<3.3	61%	>30	40%	.050-.100	20%
Worst					.100-.150	23%
					>.150	7%

* Data Source for SW Wisconsin Lakes: D. Lillie, J. Mason; 1983; DNR
** Shaded values show Mirror Lake condition based on average of 1987-1993 sampling

The table above indicates that most lakes in southwestern Wisconsin exhibit the conditions of high nutrient lakes. In relation to Secchi disk measurements, 93 per cent of the lakes in this region do not experience measurements greater than 6.6 feet in the summer. Occasionally, Mirror Lake has been measured near this level, but the average summer Secchi depth over the past six years was 4.2 feet.

Relative to total phosphorus, only 7% of the lakes in southwestern Wisconsin have summer phosphorus concentrations greater than Mirror Lake, and 70% of the lakes have phosphorus less than that of Mirror Lake (as measured in 1975 - 1977 and in 1993).

Chlorophyll *a* concentrations in Mirror Lake (as measured in 1980) were higher than 30% of the lakes; and lower than 40% of the lakes in southwestern Wisconsin.

4.4.2 Predicted Future Conditions

Table 4-4 shows the changes that are predicted to the lake's trophic status with various levels of phosphorus control. The highest level of control used is 50%. This level of control could only be attained through a very aggressive and comprehensive management program throughout the watershed. With this type of effort the model shows a change of average summer Secchi depth readings from 1.7 to 2.4 feet. This is about a 40% improvement in water clarity. The model did a poor job of predicting the current conditions in Mirror Lake using actual monitoring data. If the per cent improvement is applicable to Mirror Lake for predictive purposes, the current average summer Secchi disk measurements (4.2 feet) may increase to an average of 5.9 feet (a 40% increase) with a reduction of phosphorus input by one half. This is a significant change in water clarity, and would result in a noticeable difference in the lake's aesthetics by the lake users.

It should be noted that the trophic modeling effort did not account for the potential impacts (if any) of the nutrients available to the lake from the lake bed sediments.

The predicted changes in water quality from various levels of phosphorus control may put Mirror Lake into a "fair" trophic status category (as defined on Table 3-2. This is probably the best condition that can be expected for Mirror Lake. The lake cannot reasonably be rehabilitated to match the conditions found in many of Wisconsin's clear deep lakes. There are several reasons for this. First, many of the soils in the watershed are naturally rich in nutrients and even under "natural" land cover conditions, the runoff contains some level of nutrients. Second, the large size of the watershed (relative to the lake size) means that a large volume of runoff waters are funneled to the lake and thus a large volume of nutrients are also carried to the lake.

It should be noted, however, that although improvements in the lake's condition may not be as dramatic as some would hope for; a decline in the lake's condition will likely occur unless measures are taken to control the current and new sources of nutrients.

5.0 POLLUTION SOURCE ASSESSMENT

5.1 POLLUTION SOURCE INVENTORY METHODS AND RESULTS

5.1.1 General Background

Nonpoint source pollution is the pollution that enters Mirror Lake from rain fall runoff, or snow melt runoff. As water from rain or snow melt flows over the land, it picks up whatever pollutants that may be on the surface. These pollutants include: sediment, nutrients (from fertilizer, vegetative material, or livestock manure), pesticides, road salt, and bacteria (from livestock manure). These pollutants can be delivered to the lake at different times of the year and can result in turbid water, algae blooms, duckweed and macrophyte growths, and unsafe swimming conditions.

The inventories conducted as a part of this study were done for several reasons including:

- to quantify the amount of various pollutants entering Mirror Lake every year;
- to identify the cultural activities that contribute the most significant amounts of pollutants to Mirror Lake; and
- to determine how much reduction of pollutants could be achieved through various management approaches.

The inventories concentrated on two pollutants: sediment and phosphorus. Sediment is a concern from a water quality perspective because sediment can cause turbid waters, impede boat navigation where sediment is deposited, and destroy fish spawning habitat. Also, sediment will often carry with it several other pollutants that are "attached" to the sediment particles such as metals and nutrients. Phosphorus is a concern because it is the major source of nutrients for supporting algae and duckweed. If control can be achieved on these two pollutants, then many other pollutants of concern will also be controlled.

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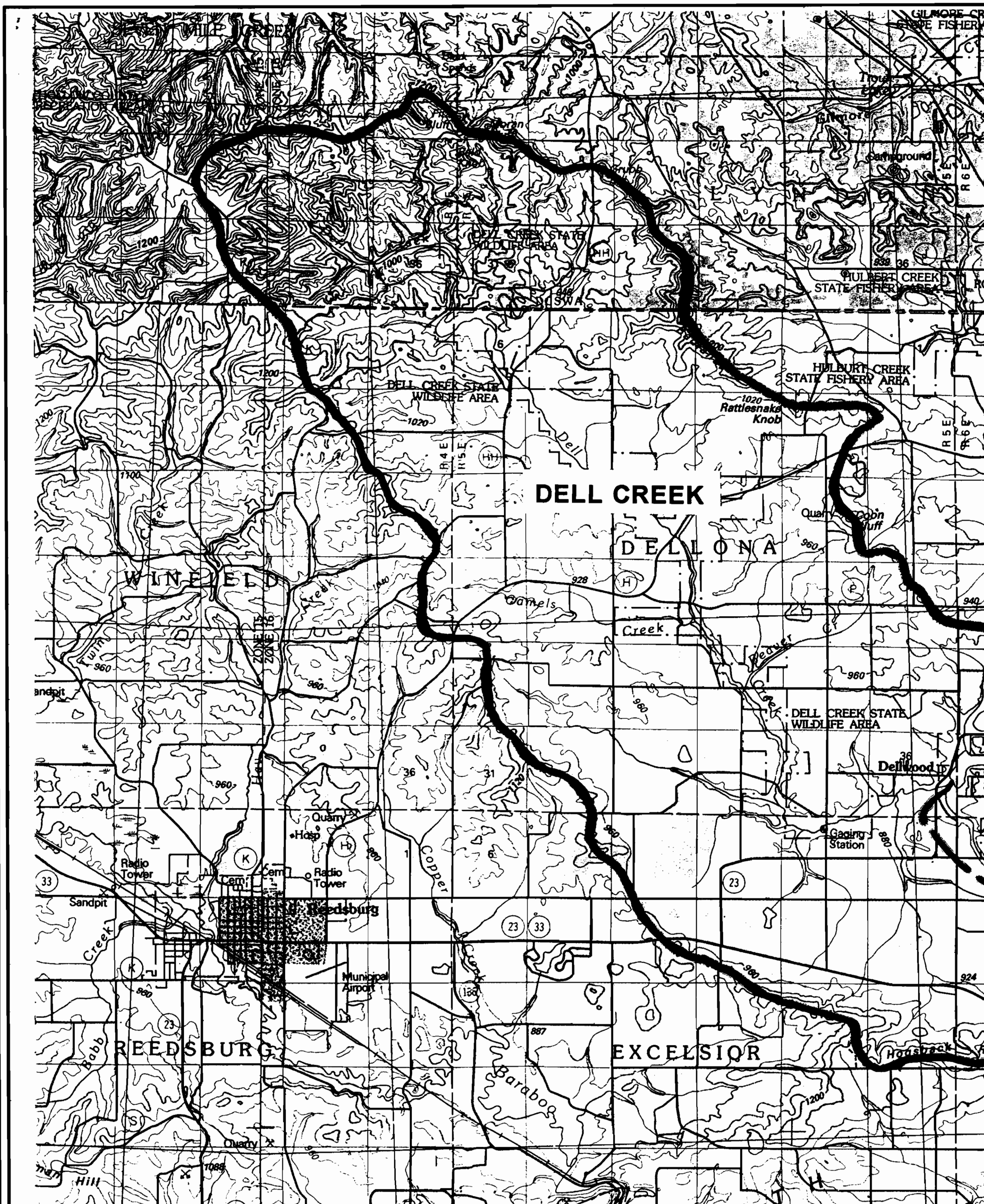

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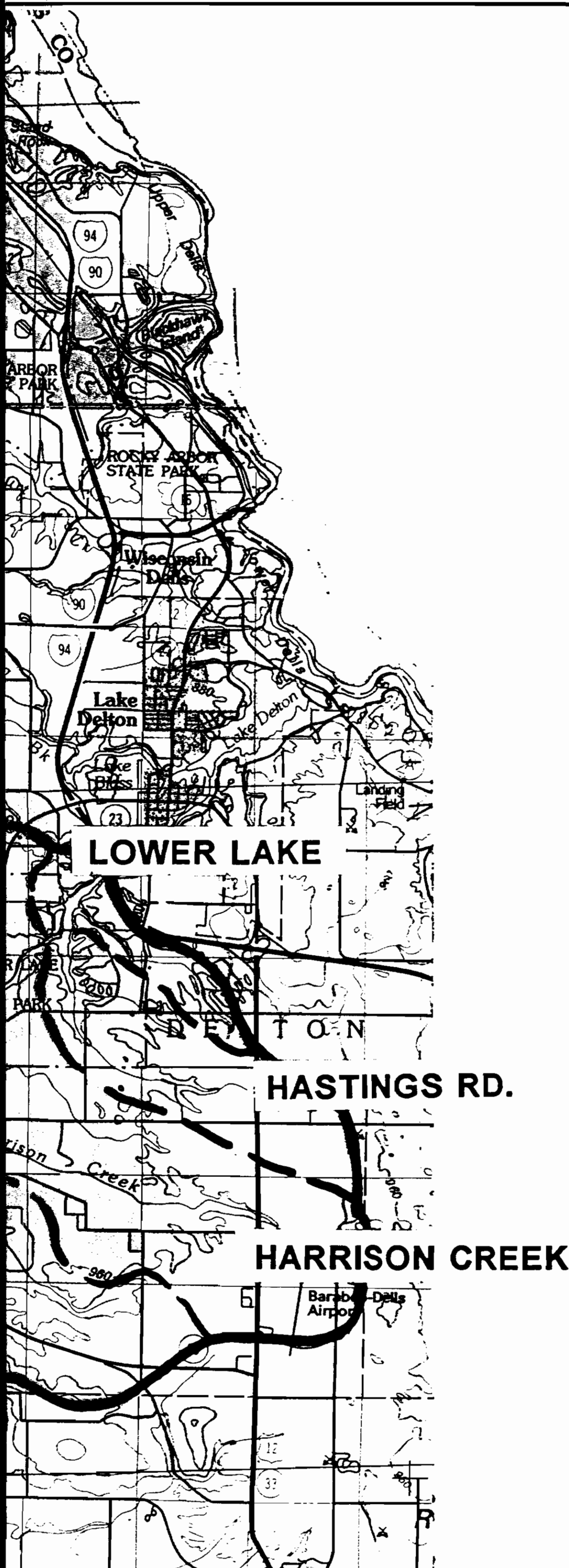

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APPROX. SCALE :

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SOURCE:

UNITED STATES GEOLOGICAL SURVEY TOPOGRAPHIC MAPS; SAUK (1986) AND JUNEAU (1986) COUNTY.

WARNING 0 1/2 1 IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE	DESIGNED ---	FIG. 5-1 : SUBWATERSHED DIVIDES	REVISION
	DRAWN MAS		
	CHECKED JAB	MIRROR LAKE WATERSHED	PROJECT 92C6718
	PEER REVIEWED		DRAWING
	PROJECT MANAGER		
	DATE 1-11-94		SHEET 1 OF 1

The Mirror Lake watershed was subdivided into four smaller, sub-watershed areas. These smaller areas are: Dell Creek, Harrison Creek, Hastings Road, and Lower Lake sub-watersheds. These areas are shown on Figure 5-1. By sub-dividing the Mirror Lake watershed into smaller areas, the sources of pollutants can be identified by their geographic area as well as land use or cultural activity.

5.1.2 Sediment - Upland Sources

Sediment runoff from upland sources is a function of the land use, soil type, topography, and climate. Different areas of a watershed will contribute different levels of sediment depending on these factors.

The land use of the Mirror lake watershed was determined based on an analysis of 1988 aerial photographs. Land cover was digitized from the photographs and the areas of each land use were calculated. The land use was categorized as: woodlot, cropland, open grassland, residential, livestock area, and pasture. These areas are shown on Figure 5-2.

The amount of sediment coming from these various land uses was estimated using data collected by the Sauk County Land Conservation Department in 1990 on the Narrows Creek/Little Baraboo River Priority Watershed Project. This project was done in cooperation with Department of Natural Resources (DNR) and Department of Agriculture, Trade, and Consumer Protection (DATCP). The watershed is located in Sauk County and includes the lands draining to the Baraboo River between Reedsburg and Baraboo. This watershed is adjacent to, and just south of the Mirror Lake watershed; thus, conditions found in this project are applicable to the Mirror Lake watershed.

During the Narrows Creek/Little Baraboo Watershed Project, sediment from various land uses was calculated using a detailed modeling effort called the Wisconsin Nonpoint Model (WIN) model. This model calculated sediment loads in tons/square mile/year for various types of land uses (such as cropland, pasture, woodlots, etc). The sediment loading rates are shown on Table 5-1. The rates found in the Copper Creek sub-watershed (an area within the Narrows Creek/Little Baraboo River watershed) were applied to the rural land uses in the Mirror Lake watershed. The rates of annual sediment loss were then applied to the various land uses inventoried for the Mirror Lake watershed. The results of this analysis are shown in Table 5-2.

TABLE 5-1: SEDIMENT LOADING RATES FOR COPPER CREEK SUBWATERSHED

Land Use	Sediment Load (tons/sq.mile/year)
Cropland	155.0
Woodlots	4.1
Grasslands	6.9
Pasture	44.7

* Source: "Narrows Cr./Baraboo River Priority Watershed Plan", Sauk County LCD, DNR, and DATCP.

5.1.3 Sediment - Streambank Erosion Source

Streambank erosion can be another major source of sediment in a rural watershed. Again, the streambank erosion inventories conducted in Copper Creek as part of the Narrows Creek/Baraboo River Watershed Project were used to estimate this sediment source in the Mirror Lake Watershed. Inventories conducted by the Sauk County LCD found that there were 3.03 tons of sediment per year from eroding streambanks for each square mile of Copper Creek watershed. This per square mile rate was applied to each subdivision of the Mirror Lake watershed (Dell Creek, Harrison Creek, Hastings Road, and Lower Lake) to estimate the annual sediment amount from streambank erosion to Mirror Lake. The results of the estimates are shown on Table 5-2.

5.1.4 Sediment - Construction Site Erosion

Erosion from construction sites can be severe. Although the construction phase is a temporary condition at each site; the exposed soil and soil piles can erode at very high rates during a rain storm. There are very few vacant properties around Mirror Lake which are potential development sites. It should be noted, however, that construction activities anywhere in the watershed have a potential for contributing sediments to the tributary system and eventually into Mirror Lake.

Table 5-2
Nonpoint Sources of Sediment to Mirror Lake

Subwatershed		LAND USE: Crop-land	(%)	Pasture	(%)	Woodlot	(%)	Open Grassland	(%)	Residential	(%)	Livestock Yards **	(%)	Streambank Erosion	(%)	Total	(%)
Dell Creek	acres	13,675	38%	3,150	9%	15,770	44%	2,659	7%	570	2%	166	0%		0%	35,990	86%
	sediment load *	3,312	85%	220	6%	101	3%	29	1%	8	0%	40	1%	170	4%	3,881	88%
Harrison Cr.	acres	1,274	39%	26	1%	1,198	36%	640	19%	152	5%	4	0%		0%	3,294	8%
	sediment load	309	90%	2	1%	8	2%	7	2%	2	1%	1	0%	16	5%	344	8%
Hastings Rd	acres	575	32%	0	0%	859	48%	285	16%	85	5%	0	0%			1,804	4%
	sediment load	139	88%	0	0%	6	3%	3	2%	1	1%	0	0%	9	5%	158	4%
Lower Lake	acres	67	7%	0	0%	668	67%	132	13%	128	13%	0	0%			995	2%
	sediment load	16	57%	0	0%	4	15%	1	5%	2	7%	0	0%	5	16%	29	1%
Total Watershed	acres	15,591	37%	3,176	8%	18,495	44%	3,716	9%	935	2%	170	0%	0	0%	42,083	100%
	sediment load	3,776	86%	222	5%	119	3%	41	1%	14	0%	41	1%	199	5%	4,411	100%

* Sediment load is expressed in tons/year

** Sediment load for livestock yards estimated using cropland unit area load (155 tns/sq.mi.)

Basis for Table:

Total acres for each subwatershed based digitized 1985 aerial photographs.

Land Use areas are based on digitized air-photo interpretation of 1988 aerial photos

Rural Sediment load based on unit area load calculated for Copper Creek Subwatershed in the "Narrows\Baraboo Priority Watershed, Sauk County; Sediment load calculated using WIN sediment model (unit area load = Cropland: 155 tns/sq.mi; Woodlots: 4.1 tns/sq.mi.; Pasture: 44.7 tns/sq. mi.; Grassland 6.9 tns/sq.mi); Modeling done by Sauk Co. LCD and DNR.

Urban sediment and phosphorus loads based on Source Load and Management Model (SLAMM) run by Woodward-Clyde Consultants using site visits information.

Streambank erosion sediment based on 3.03 tns/sq. mi/yr., Copper Cr. subwatershed; "Narrows Cr./Baraboo R." Project, Sauk Co.

Sediment depositional areas were noted in the lower part of Mirror Lake, near the interstate highway bridge. According to local citizens, one sediment depositional area was the result of runoff from the highway directed down the steep sides of the bluffs at this location of the lake. The highway drainage system has since been modified, and it appears that this is no longer a source of sediment to the lake. A second sediment depositional area is believed by local citizens to have originated during the construction phase of a parking lot and boat ramp at a riparian commercial campground. There is no evidence of recent sediment deposition at this site.

Because of the sporadic nature of construction site erosion no estimates were made of the average annual contribution of sediment to Mirror Lake. As pointed out in Section 6.0 (Recommendations) this does not mean that sediment from construction site erosion is insignificant. The local units of government (Town and County) do have the authority to enact ordinances to require sediment controls measures at construction sites.

5.1.5 Phosphorus - Barnyard Runoff

Phosphorus loads to Mirror Lake attributed to barnyard runoff were estimated using a computer model called "The Wisconsin Barnyard Runoff Model" (BARNY version 2.0). The model is based on a model developed by the United States Department of Agriculture - Agricultural Research Service. The model was extensively revised by the Wisconsin Department of Natural Resources for use in the state's Nonpoint Source Pollution Abatement Program. This model estimates the amount of pollutants (phosphorus) that is picked up by runoff water flowing through a barnyard area over an average year. The model takes into account:

- Number and type of livestock;
- physical characteristics of the drainage area contributing runoff to the lot;
- size of the animal lot
- physical characteristics of the area between the lot and the nearest channel or stream; and
- annual rainfall intensities and quantities for the location.

Barnyards within the Mirror Lake watershed were identified on 1992 aerial photographs. Each identified site was verified through field checks. At each site information was gathered on the number and type of livestock, the characteristics of the drainage area above the animal lot, and the physical characteristics of the area between the animal lot and the nearest channel or stream. The slope and soil information for each lot was obtain from the *Soil Survey of Sauk County* and the *Soil Survey of Juneau County*. Thirty two barnyards were inventoried in the Mirror Lake watershed.

Data from each yard was input into the BARNY model and the model calculated an annual phosphorus load for each barnyard. The results of this analysis are shown on Table 5-3.

5.1.6 Phosphorus from Septic Systems

The residences, commercial properties, and state park around Mirror Lake all have individual, private, sewage handling systems. For systems that use a conventional septic tank and drainage field, there is a potential that some of the sewage may leach into Mirror Lake and contribute nutrients to the lake. The potential for this is enhanced by the generally sandy soils of the area.

The two private campgrounds near the lake both have holding tank systems for their sewage. This means that the sewage is held in a sealed tank, pumped out by tank trucks on a routine basis, and the sewage is taken to a municipal treatment facility. The Mirror Lake State Park has both holding tank and septic field type systems within the park. There are about 35 residences around the lake. Approximately 15 are used as a primary residence, and the rest are second homes. It was assumed for this study that all of the homes use a conventional septic tank and drain field system.

The process for estimating phosphorus from septic systems was conducted using the best available data. A more precise measurement could be determined with additional information on groundwater hydrology, residence numbers, and an inspection of each septic system. This recommendation is discussed in Section 6.0. The method for estimating the phosphorus loading from septic systems followed three steps shown below. The actual calculation for this estimate is shown on Table 5-4.

TABLE 5-3: BARNYARDS IN MIRROR LAKE WATERSHED RANKED BY ESTIMATED ANNUAL PHOSPHORUS LOAD

	I.D. #	County	Tn-Rg	S.	Annual Phosphorus Load Pounds/ Year	Annual Phosphorus Load Cumulative Per Cent
1	D-29	Juneau	14N05E	32	173.9	12%
2	D-28	Juneau	14N05E	32	132.8	22%
3	HA-1	Sauk	12N06E	6	128.3	30%
4	D-3	Sauk	13N05E	28	84.4	36%
5	D-26	Sauk	13N04E	12	76.1	42%
6	D-9	Sauk	13N05E	29	74.4	47%
7	D-25	Sauk	13N04E	12	69.1	52%
8	D-32	Juneau	14N04E	35	60.3	56%
9	D-19	Sauk	13N05E	19	54.3	60%
10	D-22	Sauk	13N04E	13	48.4	63%
11	D-30	Juneau	14N05E	30	46.2	66%
12	D-8	Sauk	12N05E	5	41.0	69%
13	D-20	Sauk	13N05E	19	40.5	72%
14	D-4	Sauk	13N05E	29	36.1	75%
15	D-18	Sauk	13N05E	20	35.7	77%
16	D-13	Sauk	13N05E	10	35.4	80%
17	D-27	Sauk	13N05E	6	31.9	82%
18	D-6	Sauk	13N05E	30	30.5	84%
19	D-2	Sauk	12N05E	1	27.5	86%
20	D-31	Juneau	14N05E	30	26.8	88%
21	D-14	Sauk	13N05E	17	22.3	89%
22	D-17	Sauk	13N05E	20	22.1	91%
23	D-15	Sauk	13N05E	20	21.6	93%
24	D-21	Sauk	13N05E	18	19.7	94%
25	D-5	Sauk	13N05E	29	16.9	95%
26	D-23	Sauk	13N05E	7	14.9	96%
27	D-12	Sauk	13N05E	10	14.2	97%
28	D-16	Sauk	13N05E	20	10.3	98%
29	D-7	Sauk	12N05E	3	8.8	98%
30	D-24	Sauk	13N05E	7	7.8	99%
31	D-11	Sauk	13N05E	11	7.5	100%
32	D-10	Sauk	13N05E	20	6.7	100%
			TOTAL:		1,426.4	100%

1. Estimate the number of "capita years".

   This term is an expression of how many septic systems are around the lake, and how intensely the systems are used during the year. Thus, capita years is the product of the number of people around the lake, and the length of time people are residing at locations that use septic systems for sewage disposal. This estimate includes the visitors to Mirror Lake State Park, and the residents around the lake.

2. Estimate the average pounds of phosphorus generated per person per year.

   A literature value was chosen based on a study conducted by DNR and the Long Lake Fishing Club published in a report in March of 1991. The value selected is 1.32 pounds/person/year.

3. Estimate a "soil retention factor"

   This factor is basically an estimate of how effective a septic tank, drainage field, and the soil in the field are at removing phosphorus from the sewage. The soils around Mirror Lake are generally of a coarse (sandy) texture. This means that water flows relatively quickly and easily through the soil. Similar conditions were found in the DNR study referenced above. A soil retention factor of 0.55 was used in the Long Lake situation and was also applied for the Mirror Lake estimation.

The above three factors multiplied, will result in an estimate of the annual phosphorus load to Mirror Lake from septic systems. This estimate is only used to provide a general indication of how significant this potential source of phosphorus may be to Mirror Lake. Table 5-4 below shows the actual calculations conducted for the septic system estimation.

Table 5–4: Estimated Annual Septic Contribution of Phosphorous to Mirror Lake

1. Estimating the Number of "Capita Years"
(total number of people/year using septic systems)

Private Residences:	(avg. # of people/unit) x	(# years at unit/year) x	(# of living units)
	2	1	15 (primary residence, full time occupancy)
	2	0.5	20 (2nd homes, half time occupancy)
# of capita years =	**50**		

State Park: **	(# of visitor days/year) / (365 days/year)		
	250,000		
# of capita years (total park) =		685	
# of capita years (1/2 use holding tank) =		**342**	(park is served by both holding tanks & septic fields, assume each system used equally)

Total capita years = **392**

2. Export coefficient (pounds of phosphorous/capita/year) = 1.32 *

3. Phosphorous Removed by Septic Systems: 55% *
(This factor is "Soil Retention Factor")

4. Estimated Phosphorous Loading to Mirror Lake from septic systems:

P Load (lbs/year) = (capita years) x (export coefficient) x (1–Soil Retention Factor)

	capita years	export coefficient	1–Soil Retention Factor
P Load (lbs/year)	392	1.32	0.45

233 pounds/year

* Based on WDNR & Long Lake Fishing Club study, March, 1991
** visitor days based on data from Mirror Lake State Park

5.1.7 Phosphorus - Upland Erosion

Erosion from cropland, pastures, woodlots, and other lands also contribute phosphorus to streams and lakes in a watershed. Two sources of information were used to estimate the contribution of phosphorus to Mirror Lake from upland erosion.

The first data source was water quality monitoring conducted by the United States Geological Survey (USGS) on rural watersheds in Wisconsin. For this study the monitoring conducted in the Black Earth Creek watershed (Dane County) from 1985 - 1991 was used. Monitoring at four different sites over this period found that for every ton of suspended sediment in the stream there is an average of 5.82 pounds of phosphorus. This ratio is applied to the sediment loads calculated for the Mirror Lake Watershed to estimate the phosphorus loads in the runoff waters. The calculation of the sediment pollutant load for Mirror Lake was previously described. These phosphorus loads are shown on Table 5-5.

There is one consideration which must be taken into account when using the sediment to phosphorus ratio. The phosphorus monitored by the USGS includes phosphorus from both barnyards and upland sources. The fraction of the phosphorus coming from the barnyards based on the BARNY modeling was subtracted from the phosphorus load calculated for the Mirror Lake watershed. The remaining phosphorus is then attributed to the upland sources since there were no other significant sources of phosphorus in the rural portion of the watershed.

5.1.8 Atmospheric Sources

Dust and precipitation falling through the atmosphere, carry with it phosphorus (along with other compounds). This atmospheric source from dust and/or precipitation falling directly on the lake's surface is another source of nutrients to the lake.

No direct measurements of this source were conducted as part of this study. Values from other research efforts in similar conditions were used to estimate the significance of this source of phosphorus. A United States EPA publication (Reckhow, et al, 1980) provides information on the phosphorus loading from atmospheric sources for Madison, Wisconsin. Measurements averaged 1.00 kilogram/hectare/year. This converts to an annual average of 0.89 pounds/acre (of lake surface/year). Since Mirror Lake is 137 acres in size, the estimated phosphorus loading to the lake from atmospheric deposition is 122 pounds/year. This is less than 0.5 per cent of the annual phosphorus load to Mirror Lake and the figure does not represent a significant source.

5.1.9 Lake Bottom Sediment Phosphorus Source

The muck and sediment at the bottom of Mirror Lake is also a potential source of phosphorus to the water, and thus to the algae and aquatic weeds in the lake. Phosphorus, that is contained in the sediment can become soluble and be released into the water under certain conditions. It is commonly believed that phosphorus release from sediments in oxygenated water is less than in water with no or low dissolved oxygen

Table 5-5
Nonpoint Sources of Phosphorus to Mirror Lake

Subwatershed		LAND USE: Cropland	(%)	Pasture	(%)	Woodlot	(%)	Open Grassland	(%)	Residential	(%)	Livestock Yards (#)	(%)	Septic Systems **	(%)	Total	(%)
Dell Creek	acres	13,675	38%	3,150	9%	15,770	44%	2,659	7%	570	2%	166	0%	--	0%	35,990	86%
	phosphorus load	18,068	84%	1,199	6%	548	3%	156	1%	117	1%	1,342	5%	--	0%	21,430	88%
Harrison Cr.	acres	1,274	39%	26	1%	1,198	36%	640	19%	152	5%	4	0%	--	0%	3,294	8%
	phosphorus loa	1,717	89%	10	1%	43	2%	39	2%	30	2%	85	4%	--	0%	1,923	8%
Hastings Rd.	acres	575	32%	0	0%	859	48%	285	16%	85	5%	0		--	0%	1,804	4%
	phosphorus loa	810	92%	0	0%	32	4%	18	2%	17	2%	0	0%	--	0%	878	4%
Lower Lake	acres	67	7%	0	0%	668	67%	132	13%	128	13%	0		--	0%	995	2%
	phosphorus loa	94	24%	0	0%	25	6%	8	2%	26	7%	0	0%	233	60%	387	2%
Total Watershed	acres	15,591	37%	3,176	8%	18,495	44%	3,716	9%	935	2%	170	0%	0	0%	42,083	100%
	phosphorus load	20,689	85%	1,209	5%	648	3%	221	1%	190	1%	1,427	6%	233	1%	24,402	100%

* Phosphorus load is expressed in pounds/year

** Septic systems were all placed in the same subwatershed for convenience purposes

Basis for Table:

Total acres for each subwatershed based digitized 1985 aerial photographs.

Land Use areas are based on digitized air-photo interpretation of 1988 aerial photos

Rural phosphorus load based on suspended solids to total phosphorus ratio from 1985-1991 USGS monitoring in Black Earth Creek, Brewery Creek, and Garfoot Creek; Dane County (average ratio = 5.82 lbs. phosphorus/1 tons of sediment)

Barnyard phosphorus loads based on BARNY model run for each year (model input from site visit to each yard)

Urban phosphorus loads based on Source Load and Management Model (SLAMM) run by Woodward-Clyde Consultants using site visits information levels (Holdren 1977). This assumption, however has been challenged by other studies (Lee 1976) that have found similar phosphorus release rates from sediments regardless of the water's dissolved oxygen levels.

Because of this uncertainty, this potential source is not included in the Mirror Lake phosphorus budget. Additional sampling of the lake's sediment could be conducted to determine if phosphorus from sediment is a significant source.

5.1.10 Phosphorus Removal from Duckweed/Ceratophyllum Harvesting

The Mirror Lake Association has assisted the Village of Lake Delton in funding a duckweed harvesting operation near the Dell Creek inlet on Mirror Lake for the past several years. This practice was discontinued, and the Village of Lake Delton removed duckweed at the outlet of Mirror Lake in 1993. Floating duckweed has been a nuisance in Mirror Lake. In a 1990 Masters Thesis, L. Gardner (UW-Madison) studied the potential of the duckweed and Ceratophyllum (a rooted macrophyte) harvesting to reduce phosphorus to Mirror Lake. The study concluded that the harvesting removed up to 20% of the summer phosphorus loading to Mirror Lake. The annual phosphorus loading to Mirror Lake is calculated to be 24,402 pounds. The summer flow (mid-May through August) accounts for about 30% of the annual flow (based on USGS records at Dell Creek station). Thus, the summer phosphorus loading can be estimated at 30% of 24,402 pounds or 7,321 pounds. If the duckweed harvesting program is 20% effective, this would account for a removal of 1,464 pounds of phosphorus during the period of mid-May through August.

This figure matches closely the amount of annual phosphorus removal from the harvesting operation using L. Gardner's total dry weight and per cent phosphorus content measured during the harvesting operation. In 1989 152,920 kilograms (169 tons) dry weight of duckweed and Ceratophyllum were harvested. The average phosphorus content of the material was 0.46 per cent. This amount of plant material converts to 1,555 pounds of phosphorus removed in 1989. The figure of 1,464 pounds was applied to reduce the phosphorus load received by Mirror Lake and is reflected in Table 5-5.

5.2 POLLUTION SOURCE DISCUSSION

The Figures 5-3 and 5-4 on the following pages show the sources of pollution to Mirror Lake from the various land use activities.

5.2.1 Sediment

Figure 5-3 shows the relative significance of the sediment sources analyzed. Cropland is the major of this pollutant to Mirror Lake. Cropland makes up a large portion of the land use within the watershed and this type of land use can be prone to erosion and sediment runoff.

Sediment runoff causes several problems relative to lake use and water quality. First, the sediment causes turbidity in the lake which degrades the aesthetics of the lake. This turbidity can also interfere with sight-feeding fish (such as bass) and the suspended sediment can abrade fish gills. The sediment also carries with it several other pollutants such as nutrients, pesticides, and heavy metals, that can be harmful to a lake's water quality. Finally, sediment deposition areas can impede boat navigation.

Although the croplands are the major source of sediment to the overall lake, local sediment impacts can occur from small, exposed areas near the lake. Construction sites, if not managed properly can be a serious source of sediment to a local area of the lake. From a single large rain storm, a sediment delta can be formed in the lake from an unprotected area.

5.2.2 Phosphorus

Croplands in the watershed contribute the most significant amount of phosphorus to Mirror Lake (see Figure 5-4). This is not unusual for the type of land use and the size of the watershed contributing runoff waters to the lake.

Runoff from livestock yards is the next most significant source of phosphorus. Although this animal lot runoff is responsible for only 6 per cent of the phosphorus entering Mirror Lake, runoff from this source is a concern for more reasons than just the phosphorus content. Manure contains bacteria and high nitrogen levels. Under certain conditions, the nitrogen in runoff from manure can form ammonia, which can be harmful to fish and other aquatic organisms.

Septic systems do not appear to be a concern as a source of phosphorus to Mirror Lake. Even with the rough assumptions that were made for this estimation, the quantity of phosphorus from this source is not significant relative to the other sources.

This does not mean that systems which are obviously failing, should be ignored. Just like animal waste, the septic waste can contribute bacteria and ammonia to Mirror Lake under certain circumstances.

5.2.3 Nonpoint Pollution Control Costs

Section 6.0 discusses state programs that are available to assist in the funding of nonpoint source control practices. Based on estimates used for rural nonpoint source control measures to Copper Creek (in the Narrows Creek/Baraboo River Watershed Project); and on the inventories conducted by WCC in the Mirror Lake watershed; a breakdown of estimated costs for the practices is shown below in Table 5-6.

TABLE 5-6: ESTIMATED NONPOINT SOURCE CONTROL COSTS FOR MIRROR LAKE WATERSHED *

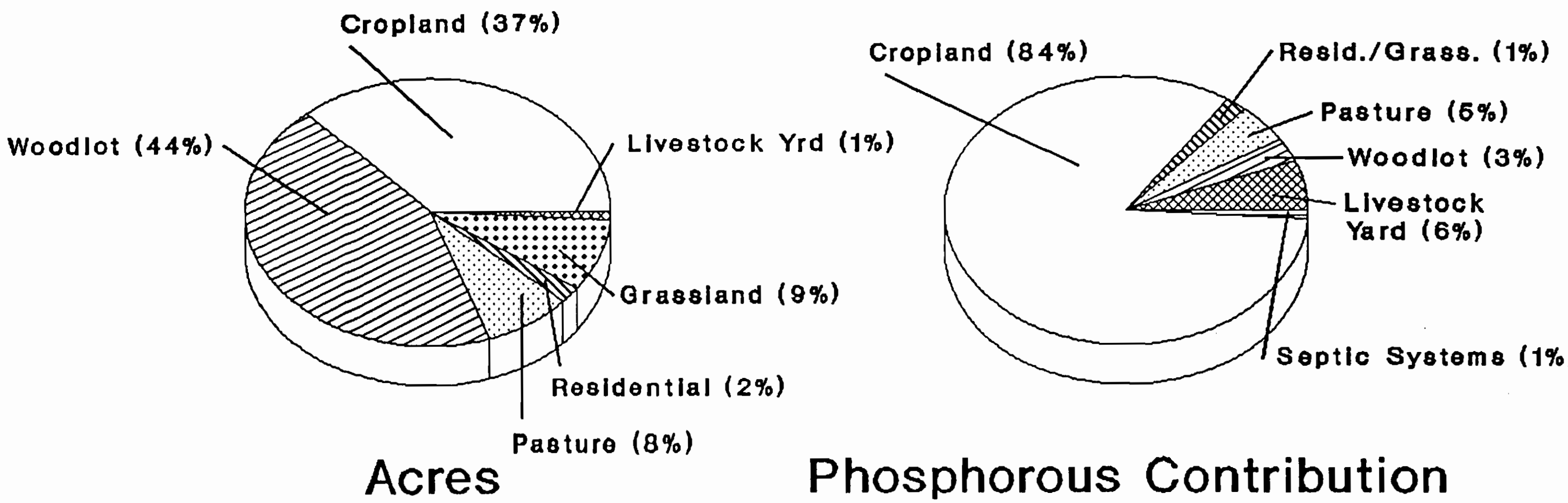
Management Practice	Number of Units	Cost per Unit	Total Cost
Cropland Controls [1]	4,000 acs.	$18/ac	$72,000
Other Upland NPS Controls [2]	42,100 acs.	$6.50/ac	$273,600
Barnyard Runoff Control	23 unts	$25,000/unts	$575,000
Total Estimate:			$848,600

* All cost estimates based on rates and practice needs from the *Narrows/Little Baraboo River Priority Watershed Plan* DNR, DATCP, and Sauk County.

1 Cropland controls based on average cost per acre of crop rotation, contour cropping, contour strip cropping, and reduced tillage.

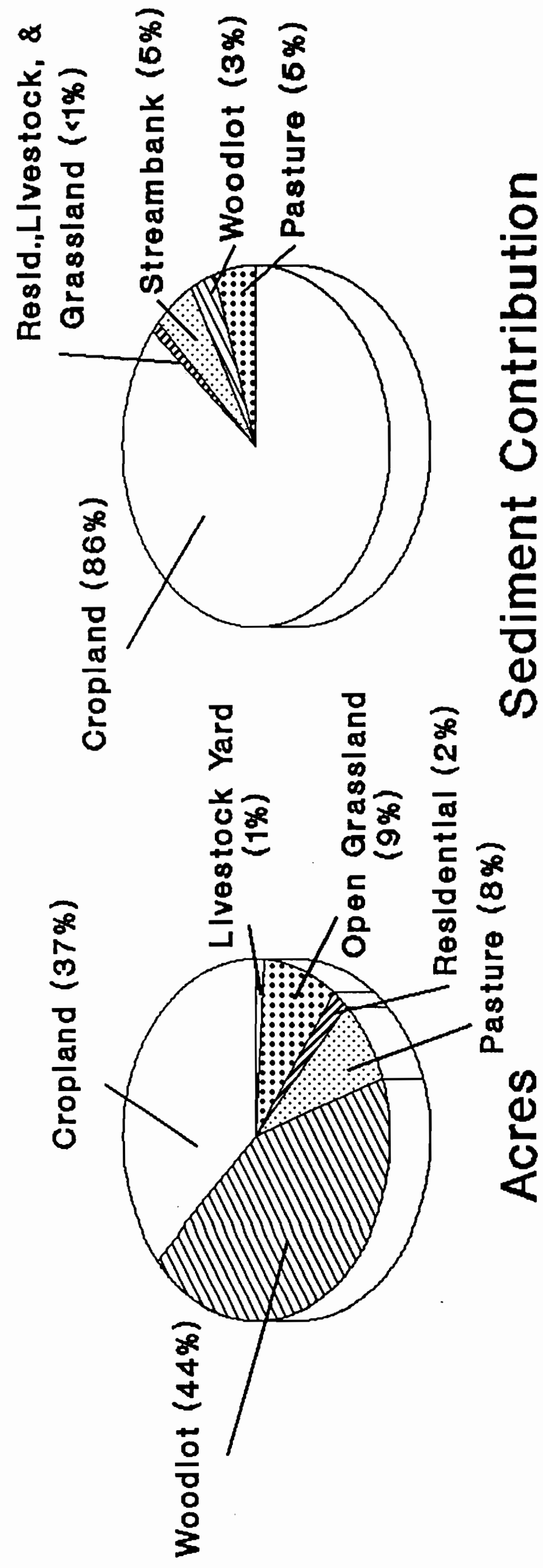
2 Other upland NPS controls based on average cost on a per acres basis of critical area stabilization, pasture stabilization, waterways, field diversions, grade stabilization, nutrient management, and pesticide management.

Figure 5-4:
NPS Phosphorous Sources to Mirror Lake



Source: WCC Watershed Analysis, 1993

Figure 5-5:
NPS Sediment Sources to Mirror Lake



Source: WCC Watershed Analysis, 1993

6.0 RECOMMENDATIONS

Described below are a list of recommendations to the Mirror Lake Association and/or other local units of government. Several of these recommended actions can take place simultaneously. The recommendations were developed to help the Lake Association to begin certain actions immediately, for short term benefits, and to begin on larger actions for longer term solutions to the lake management needs of Mirror Lake.

6.1 CONTINUE DUCKWEED AND MACROPHYTE HARVESTING OPERATION

The duckweed and macrophyte harvesting efforts in the upper reaches of Mirror Lake were significantly reduced in 1993. The Village of Lake Delton concentrated their duckweed harvesting efforts at the Mirror Lake Dam. Prior to 1993, the duckweed was harvested by a modified aquatic weed cutter near the inlet of Dell Creek. This method removed rooted macrophytes and the floating duckweed which was caught in the rooted macrophytes. Continuing the harvesting operation near the Dell Creek inlet to Mirror Lake resulted in two benefits:

1) it directly removed the floating macrophytes (duckweed) and rooted macrophytes (ceratophyllum) that cause nuisance conditions in Mirror Lake (and in Lake Delton below Mirror Lake), and

2) the removal of this plant material is an effective way of reducing the amount nutrients entering Mirror Lake during the summer months.

The reduction in plant material will help to reduce the deposition of dead plants (and the nutrients in the plant material) on the lake bed following plant die-offs. This reduction, in turn, will help reduce the amount of nutrients available to support algae blooms in the summer.

While the removal of duckweed at the dam (as done in 1993), helps to alleviate the short-term negative aesthetic impacts upon Lake Delton; this method does not benefit Mirror Lake nor is it as effective in reducing the amount of nutrients from entering Mirror Lake or Lake Delton.

Also, removal of the duckweed at the Mirror Lake Dam does not remove the rooted macrophytes (especially the *Ceratophyllum*). The study conducted by L. Gardner in 1990 estimated nutrient reductions for the operation when both the duckweed and Ceratophyllum were removed. Thus, the credits for phosphorus removal from the system discussed in Section 5.1.10 are applicable only for the harvesting as it was conducted prior to 1993. These reductions in nutrients attributed to the duckweed and macrophyte harvesting effort benefit both Mirror Lake and Lake Delton.

Recommendation:

The Mirror Lake Association should negotiate with the Village of Lake Delton to arrive at an acceptable approach for returning the duckweed and macrophyte harvesting to the Dell Creek inlet area.

6.2 REDUCE NONPOINT SOURCES OF POLLUTION TO MIRROR LAKE

The calculations made in this study clearly show that the major sources of phosphorus and sediment, to the lake are from the agricultural areas. Because of the large watershed above Mirror Lake, and the diffuse nature of the sources, the local government (Town of Delton and other towns in the watershed) do not have significant authority to address these sources. In 1993 the Village of Lake Delton, and Sauk County with the support of the lake associations of Mirror Lake, Lake Delton, and Blass Lake, applied for the Dell Creek watershed to be included in Wisconsin's Nonpoint Source Pollution Abatement Program (commonly called "priority watershed program"). This program provides funding and administrative resources to allow for a comprehensive approach to control the rural (and urban) nonpoint sources of pollution. The program has been used successfully in two other watershed projects within Sauk County. The project was not selected in 1993, however, another selection of priority watersheds to receive funding will be conducted in 1994.

Recommendation:

It is recommended that the Mirror Lake Property Owner's Association, along with the other local groups contact the DNR's Southern District Nonpoint Source Coordinator to re-confirm their interest in being selected as a priority watershed through Wisconsin's Nonpoint Source Pollution Abatement Program. In addition to the DNR, the Sauk County Land Conservation

Department, UW-Extension, and USDA Soil Conservation Service should be contacted to solicit their continued support and assistance in the selection process.

6.2.1 Additional Local Initiatives to Reduce Nonpoint Source Pollution to Mirror Lake

- Initiate a citizen's information/education program

  Many of the pollutants that come from developed areas can be controlled by property owners changing some common habits. Reducing lawn fertilizers, properly disposing waste automobile oil, not storing or burning leaves and grass in the road ditches, and redirecting roof downspouts away from driveways or other impervious areas are all examples of low cost approaches that can help reduce the pollution problem. The Mirror Lake Association in cooperation with other local groups could develop posters, newsletters, mailings, or other approaches to informing citizens of ways to reduce runoff from their property. Although these types of issues may be more applicable to lake property in a more urban or suburban setting; property owners around Mirror Lake can also re-evaluate how their household practices may affect the water quality of Mirror Lake.

- Develop and enforce a local construction erosion control ordinance

  The Town of Delton (with enabling legislation from Sauk County) has the authority to establish a construction erosion control ordinance. The ordinance would provide required erosion control measures to be used during the construction phase of a project. The effectiveness of the ordinance will depend on the enforcement procedures implemented. Because of the nature of the pollution source, the water quality is impacted after a single intense rainfall. This ordinance could apply to the commercial, as well as the private developments in the Mirror Lake watershed.

  Although the DNR does not have the authority to enforce a construction erosion control ordinance, additional information on how to develop such an ordinance can be obtained from the DNR Nonpoint Source Coordinator for the Southern District Office in Madison.

The costs for the preparation of such ordinances may be eligible for partial state funding through the state's Lake Projection Grant Program (see Section 7.0 for further discussion on this program).

6.3 CONTINUE WATER QUALITY MONITORING EFFORTS

The Mirror Lake Association has been a cooperator with DNR's Self Help Monitoring Program since 1987. In 1993, the Association increased their the monitoring efforts by becoming involved in the "Expanded" Self Help Monitoring Program. In addition to the regular Secchi disk sampling, the expanded program includes temperature, dissolved oxygen, nutrients and chlorophyll a sampling on the lake by a citizen volunteer. The long term continuation of this monitoring will help to show trends in the lake's condition.

Recommendation:

The Mirror Lake Association should continue its involvement in the DNR's Expanded Self-Help Monitoring Program.

6.4 FOLLOW UP STUDIES FOR CONSIDERATION

6.4.1 Septic System Survey

Although this study indicated that phosphorus from septic systems is not likely to be a major source of phosphorus to Mirror Lake, there are other, localized impacts that improperly management septic systems may contribute to. Because of the sandy soils and high bedrock conditions around the lake, the potential for individual septic systems to contribute pollutants to the lake is significant. Failing systems could cause localized impacts in the narrow bays of the lake. Also, bacteria from failing septic systems could cause unsafe swimming conditions.

A septic system survey would test individual systems with a tracer dye to indicate systems which do not fully treat the sewage. This study may be eligible for state assistance through the Lake Planning Grant Program.

Recommendation:

The Mirror Lake Association (or another local government) should consider sponsoring a septic system survey to determine if any sites may cause a potential impact on localized areas of Mirror Lake.

6.4.2 Determination of Lake Bed Sediment Nutrient Content

A potential source of phosphorus which was not quantified in this study is the sediments on the bottom of Mirror Lake. If future watershed nonpoint sources of phosphorus are reduced through management practices, this sediment phosphorus source may become more critical to the long term condition of Mirror Lake.

A lake bed sediment sampling program would help indicate the potential significance of this source of phosphorus. A study to address this need may be eligible for funding under the Lake Planning Grant Program.

Recommendation

The Mirror Lake Association (or another local government) should consider sponsoring a study to determine the potential significance of the lake bed sediments as a source of nutrients to the lake.

7.1.2 Lake Planning Grant

These grants are open to qualified lake districts, towns, villages, cities, or counties. The maximum grant for any one year is $10,000 of state funds. The local sponsor must match at least 25% of the state grant. Each qualified lake is eligible for a maximum of 3, $10,000 grants. The total amount of state dollars cannot exceed $10,000 during each two-year state budget period. The contact person is Jim Leverance of DNR's Southern District Office.

The purpose of the grant is to conduct studies on a lake's water quality, pollution sources, recreational issues, use conflicts, fisheries, or other topics related to general lake management.

7.1.3 Lake Protection Grant

This new lake program came on line in the fall of 1993. DNR administers the program. Funding for this program is aimed at protecting lake water quality through such actions as: 1) purchase of land or conservation easements, 2) restoration of wetlands, or 3) development of local regulations to protect and/or improve a lake's water quality. The contact person is Jim Leverance of DNR's Southern District Office.

7.1.4 Stewardship

The purpose of this program is to assist local governments and selected nonprofit groups to purchase property or easements on land. The purpose of the land acquisition must be to protect water resources, wildlife or fishery habitat, or the establishment of urban parkways. The state will provide up to a 50% matching grant. The program is administered by DNR; and Andy Morton (of DNR's Southern District Office) is the contact person.

7.1.5 Wisconsin Waterways Commission (Recreational Boating Facilities Program)

This program is administered by the Wisconsin Waterways Commission, which is a Governor appointed board. Projects that are eligible for funding include: 1) construction/ repair of public boat ramps and docks; 2) structures such as bulkheads and breakwaters necessary to provide safe boating conditions; 3) selected dredging for boating access; 4) support facilities such as parking lots and rest rooms for boaters; 5) management of locks and facilities which provide access between waterways for boaters; and 6) weed harvesting equipment. Qualified lake groups may apply for these funds. The funding rates vary from project to project. The contact person is Darlene Karow of DNR's Southern District Office.

7.1.6 Dam Repair Grants

Dam repairs may be partially funded under a DNR administered program. An approved dam is eligible for a 50-50% cost sharing up to $200,000 in state funds per dam. The dam must be owned by a municipality or lake district. Funding is available for maintenance, repair, modification, or abandonment of a dam. The dam must be inspected by DNR before funding is approved. The contact person for this program is Richard Knitter (DNR Central Office - Madison).

7.2 CONTACT LIST FOR STATE AND LOCAL WATER RESOURCE PROGRAMS:

Wisconsin Department of Natural Resources

Andy Morton
Southern District Nonpoint Source Coordinator
3911 Fish Hatchery Road,
Fitchburg, Wisconsin 53711
(608) 275-3311

Jim Leverance
Southern District Lakes Management Coordinator
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Rebecca Wallace; Chief
Nonpoint Source and Land Management Section
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Wisconsin Department of Natural Resources (Continued)

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Southern District Community Services Specialist
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Richard Knitter
Bureau of Water Regulation and Zoning
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Sauk County Land Conservation Department

Joe VanBerkel
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Sauk County UW-Cooperative Extension

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Baraboo, Wisconsin 53913
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