Report

2008 Lake Sampling and Analysis

Prepared for

Board of Managers
Riley Purgatory Bluff Creek Watershed District

April 2009

CH2MHILL

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1. Introduction and Overview

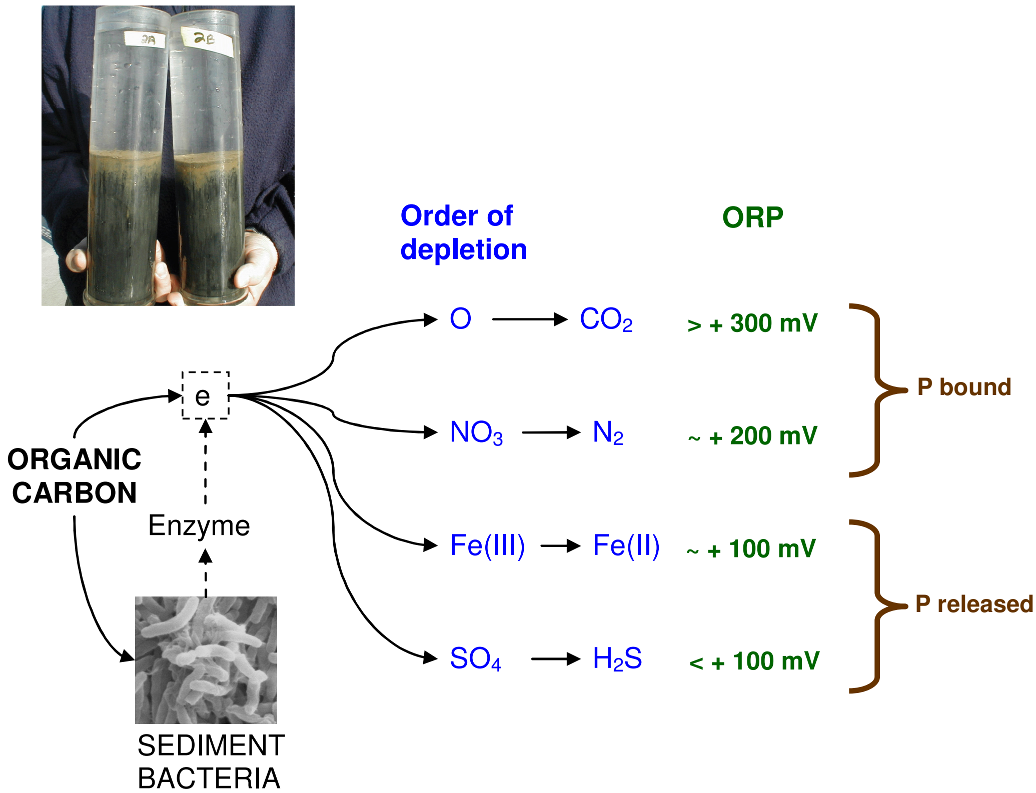
Historical water quality data for each of the six target lakes (Round, Riley, Mitchell, Lotus, Susan, Ann) provided clear evidence that measures must be implemented to improve the water quality of the lakes. Monitoring was conducted in 2008 to supplement the historical data and provide new data required to design and implement future improvements. Analysis of lake information, historical monitoring data, and 2008 monitoring data was synthesized into general lake characteristics (Exhibit 1-2). Each lake was tested for the following parameters during the 2008 growing season; temperature, pH, dissolved oxygen, oxidation reduction potential (ORP), photosynthetically active radiation (PAR), chlorophyll *a*, phycocyanin, total phosphorus, orthophosphate, ammonia, nitrite, nitrate, Total Kjeldahl Nitrogen (TKN), and Secchi disk depth. Each parameter provides a key to understanding the current ecology of the lake.

EXHIBIT 1-1
Lake Morphometric Characteristics

Lake	Area, ha	Littoral zone area, ha	Average/max depth, m	Area under Thermocline, ha	Summer stratification
Round	12.1	9.4	3.4 / 11.3	5.3	Strong
Mitchell	45.3	44.1	1.8 / 5.8	4.1	Polymictic in 5 of 6 sub-basins. Stratified basin may turn over in summer
Lotus	97.1	73.7	3.0 / 8.8	31.0	May turn over in summer
Riley	115.7	44.4	7.0 / 15.2	76.6	Strong
Ann	46.9	34.4	5.2 / 12.2	25.4	Strong
Susan	35.2	30.4	3.0 / 5.2	22.9	Polymictic

A few of the parameters measured this year had not been collected in the district. PAR is a measure of the amount of light available for photosynthesis and is measured in micro-Einsteins (µE) per m^2 per second. An Einstein is a number of photons, more precisely, it is a mole of photons. PAR is used to measure the depth of the euphotic zone of the lake, which is defined as the depth to which one percent of the surface light reaches. ORP is a measure of the tendency of a solution to gain or loose electrons in reference to a standard solution. A higher ORP indicates that stronger oxidizing agents like oxygen or nitrate are present in the solution. A lower ORP indicates a dearth of the stronger oxidizing agents, which is a cause of summer time water quality problems. Under these conditions, weaker oxidizing agents, like ferric iron and sulfate, are reduced to ferrous iron and sulfide. When insoluble ferric iron is reduced to soluble ferrous iron, phosphate bound to ferric iron is released into the water column (Exhibit 1-2). Sulfide binds to ferrous iron to form insoluble ferrous sulfide (FeS) and pyrite (FeS_2). Thus the control iron has on phosphate is lost at low ORP conditions at the sediment-water interface. Summer water quality rapidly deteriorates after low ORP conditions are established at the sediment/water interface.

EXHIBIT 1-2
ORP Schematic
Columns of sediment exhibit ferric (oxidized, Fe[III]) iron formation at the surface. Black muck underneath ferric iron is characteristic of ferrous (reduced, Fe[II]) iron. Phosphorus binding by iron depend on redox (ORP) condition of the water column above the sediment.



2. Methods

Water quality monitoring entailed both collection of water samples and multi-probe (Hydrolab) data readings, and Secchi disk depth measurements as well as general site conditions. Below are the materials and methods used to gather the water quality data during the 2008 sampling season. In 2008, early summer samples were not taken because of delays in procuring materials needed for the monitoring program.

2.1 Monitoring and Sampling

2.1.1 In-situ Monitoring

The Hydrolab multi-probe (sonde) was used three times per month on Round, Mitchell, and Lotus Lakes. Sonde readings were obtained monthly for lakes Ann, Susan and Riley. Differences in frequency are due to a rotating three-year cycle of intensive monitoring on three lakes. Sonde readings measured the temperature, pH, dissolved oxygen, PAR, chlorophyll *a*, and phycocyanin. At the same time as sonde readings were collected, a Secchi disk depth measurement was taken and recorded. General site conditions related to weather and other observations were recorded on the data sheets. See Appendix A for methods of monitoring.

2.1.2 Sampling

Routine monthly water sampling was conducted typically within the first week of every month between June and October. The water samples were analyzed for chlorophyll *a*, total phosphorus, orthophosphate, ammonia, nitrite, nitrate, and Total Kjeldahl Nitrogen, by the Metropolitan Council Environmental Services Lab. Sub-samples were also sent to BSA Environmental for plankton analyses. See Appendix A for methods of sampling.

2.2 Collection and Analyses

2.2.1 Table of Standard or EPA Methods

Parameter	Standard Method
Alkalinity water	SM 2320B
Ammonia water	EPA 350.1
Chlorophyll *a*-pheophytin	SM 10200H
Nitrate + nitrite waters	SM4500 F
Orthophosphate, water	EPA 365.3
Phosphorus, total water	EPA 365.3
TKN water and total phosphorus	EPA 351.2

2.2.2 Plankton

2.2.2.1 Sampling Handling, Logging, and Tracking

The chain-of-custody requirements for all laboratory operations for each plankton sample (i.e., record keeping associated with sample acquisition, sample labeling, sample tracking to establish chain-of-custody, and shipping and packing) and laboratory analysis (i.e., laboratory coding, storage, check-out, and documentation of sample movement) are fully documented. Samples are stored in a refrigerated secure location in the laboratory, restricted to authorized personnel. Dated and signed entries by appropriate personnel on all worksheets and logbooks are required for data validation. The client is informed of the presence and condition of all samples upon arrival to BSA.

2.2.2.2 Phytoplankton Analyses

Phytoplankton slides were prepared using standard membrane filtration technique (McNabb, 1960). This technique preserved cell structure and provided good resolution, which allowed the samples to be examined at high magnifications. Samples were thoroughly mixed as a part of the filtering process to ensure that the organisms were evenly distributed and represented completely. The abundance of common taxa was estimated by random field counts. Rarer taxa were quantified by scanning an entire strip of the filter. In the case of rare, large taxa, half of the filter was scanned and counted at a lower magnification. A Leica DMLB compound microscope (100X, 200X, 400X, 630X, 1000X) was used for counting filtered phytoplankton samples. The magnification used was dependent upon the size of dominant taxa and presence of particulates. The goal was to count at multiple magnifications such that enumeration and identification of taxa which vary over several orders of magnitude in size was achieved. When a sample was dominated by cells or natural units below 10-20 µm, or when cells were fragile and difficult to identify, the majority of counting was completed at 630X.

At least 400 units (colonies, filaments, unicells) were enumerated to the lowest possible taxonomic level from each sample. In colonies with numerous small cells (e.g., *Microcystis*), cells were enumerated from a small representative area of the colony containing at least 100 cells. For common filamentous taxa, the total cells per filament were determined by first quantifying the cell number within a known length (e.g., 100 um). This process was repeated for 25 filaments of each abundant filamentous taxon, and subsequently used to calculate the mean number of cells per filament length for that taxon. This quantity was applied to measurements of the length and width of each filament encountered so that the total number of cells per filament can be estimated.

For samples with common colonies or filaments, the counts are likely to include several thousand cells since total cell numbers of multi-cell units (colonies, filaments) were quantified. In accord with Lund et al. (1958), the counts are accurate within 90 percent confidence limits.

Cell biovolumes of all identified phytoplankton taxa were quantified on a per milliliter basis. Biovolumes were estimated using formulae for solid geometric shapes that most closely match the cell shape (Hillebrand et al., 1999). Biovolume calculations were based on measurements of 10 organisms per taxon for each sample where possible.

2.3 Statistical Methods

2.3.1 Kendall Tau

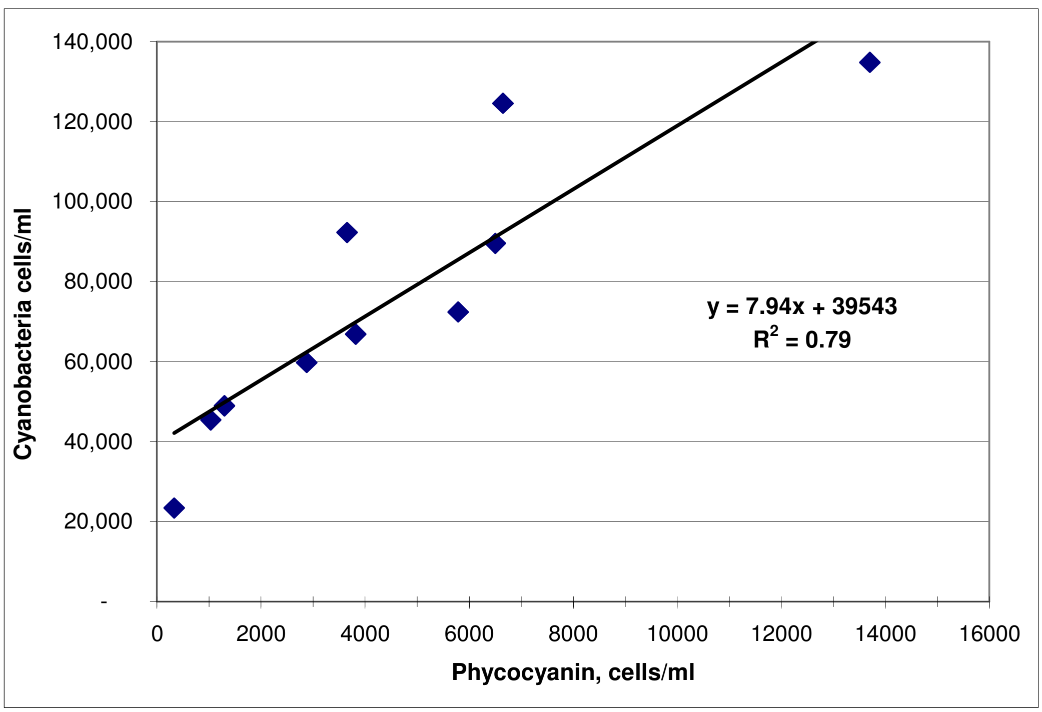
The Kendall tau test is a statistical used in this study to determine existence of trend over time in three parameters: total phosphorus (mg/m^3), chlorophyll *a* (mg/L) and Secchi disk depth (m). In particular, it is desirable to determine whether there is a trend over time by analyzing July and August measurements separately. The Kendall tau test is a statistical parameter that measures the correlation between two rankings and assesses there significance to each other. See Appendix B for further information regarding method.

2.3.2 Regressions/Correlations

Phycocyanin concentration (cells/mL) was correlated with the cyanobacteria density (cells/mL) that was enumerated from surfaces samples (Exhibit 2-1). One data point (Mitchell point E 9/18/08) was removed from the correlation because it was considered an outlier[1] and the fact that the phycocyanin concentration at that point decreased by factor of 2 with in one week. The correlation of phycocyanin concentration with cyanobacteria density is defined by the function below:

cyanobacteria (cells/mL) = 7.94 × phycocyanin concentration (cells/mL) + 39,543 (cells/mL)

EXHIBIT 2-1
Phycocyanin Cyanobacteria Correlation Plot



[1] For this point, the Cook's distance was 0.72. The Cook's distance is a measure of the influence of the point in a regression analysis. It is used to judge whether a point is an outlier or within the variability of the rest of the data set. A value tending to unity warrants scrutiny of a particular data point but various criteria may be applied if using Cook's distance to exclude or include a point. The criterion adopted here is within literature values to justify this point as an outlier.

The instrument is not capable of measuring below 100 cells/mL which, according to the manufacturer, is why the correlation function does not pass through the origin.

2.4 Graphic Analysis

Much of the data was plotted on an isopleth. Isopleths are contour graphs comparing values over a time period and, in this case, over a depth. Measured values are then plotted using contours to illustrate changes over time. DPlot software was used to create the isopleths. Data such as Secchi disk depth, chlorophyll *a*, and others were plotted in Microsoft Excel using bar and line graphs. Speciation information for plankton is presented on a pie chart illustrating the prevalence of each species relative to all others.

2.5 Trophic Indices

Trophic Indices relate water quality parameters to health of a lake. Categorizing lakes in terms of relative health helps the public and other entities understand the health of a lake and track progress of lake improvements or degradation. It should be noted that these values are general and may not indicate the health of any specific lake; intensive monitoring is required to diagnosis a specific lake. Trophic indices help to categorize lakes generally and may be altered for a specific lake with enough supporting evidence.

The most popular method for determining a lake's trophic index is the Carlson Trophic State Index (CTSI). CTSI uses up to three parameters (total phosphorous, chlorophyll *a*, and Secchi disk depth) to determine trophic state and diagnose specific influences on the lake. Trophic index values are calculated based on values of each parameter and then assigned a trophic state. Inequality relationships between indices calculated by different parameters (e.g. Secchi TSI less than phosphorus TSI) provide additional insight into water quality.

Another method to calculate the trophic index of a lake is the Indiana Trophic State Index (ITSI). This method involves the combination of many parameters to yield a trophic index value and accompanying trophic state. Physical, chemical, and biological parameters are utilized by the ITSI method. Developed by the State of Indiana as a version of the BonHomme Method, the method invokes both measured and calculated values. Although much more robust, in terms of parameters included, than the CTSI method, it is unknown if the results are more accurate.

See Appendix C for detailed information regarding the methods and assumptions made during calculation of the trophic state of each lake.

2.6 Public Health Assessment

The primary public health concern from the 2008 sampling season is the number of instances that WHO (World Health Organization) risk thresholds for cyanobacteria were exceeded. These thresholds are based on the probability of an adverse health outcome from exposure to cyanotoxins.[2] According to the cyanobacteria-phycocyanin correlation function, the WHO threshold for moderate risk (100,000 cyanobacteria cells/mL) is exceeded when the phycocyanin concentration exceed 8,000 cells/mL (Exhibit 2-2). The WHO threshold for low risk of 20,000 cells/mL cannot be directly assessed this year because the correlation function does not intersect the 20,000 cells/mL line. However, the correlation does reveal that phycocyanin concentrations of 1,000 cells/mL correspond to a cyanobacteria concentration of just less than 50,000 cells/mL. Therefore, phycocyanin concentrations between 1,000 and 8,000 cells/mL are considered to be within the WHO low-risk threshold. Exhibit 2-2 lists the number of times and the dates when the WHO moderate risk threshold was exceeded. Exhibit 2-3 lists the number of times and the dates when the WHO low risk threshold was exceeded. All of the lakes monitored in 2008 cross the WHO low risk threshold at some point in the sampling season.

EXHIBIT 2-2
Instances of Surface Phycocyanin Level Exceeding WHO Moderate Risk during 2008 Sampling Season

Lake	Occurrences (n)[a]	Dates of Occurrence
Ann	0 (6)	
Lotus	0 (12)	
Mitchell–A	1 (13)	August 6
Mitchell–B	1 (13)	September 18
Mitchell–C	0 (13)	
Mitchell–D	0 (11)	
Mitchell–E	6 (13)	August 11, August 20, August 25, September 3, September 8, September 18
Riley	0 (6)	
Round	0 (12)	
Susan	4 (6)	August 7, August 19, September 17, October 15

Note: Phycocyanin levels greater than 8,000 cells/mL are in the WHO moderate risk zone for exposure to cyanotoxins.
[a]n is the number of times the lake was sampled.

[2] Low risk corresponds to acute, but transient outcomes. These include nausea, flu-like symptoms, symptom similar to a severe cold or hay-fever, and skin rashes. Moderate risk includes all of these symptoms but also includes risk of long-term illnesses, such as liver damage.

EXHIBIT 2-3
Instances of Surface Phycocyanin Level Exceeding WHO Low Risk during 2008 Sampling Season

Lake	Occurrences (n)[a]	Dates of Occurrence
Ann	3 (6)	July 24, September 17, October 15
Lotus	10 (12)	August 2, 6, 11, 20, 25; September 3, 8, 18; October 1, 14
Mitchell–A	11 (13)	July 23, 30; August 6, 11, 29; September 3, 8, 18, 26; October 1, 14
Mitchell–B	12 (13)	July 23, 30; August 6, 11, 25, 29; September 3, 8, 18, 26; October 1, 14
Mitchell–C	11 (13)	July 23, 30; August 6, 11, 29; September 3, 8, 18, 26; October 1, 14
Mitchell–D	2 (11)	August 6, September 8
Mitchell–E	13 (13)	July 23, 30; August 6, 11, 20, 25, 29; September 3, 8, 18, 26; October 1, 14
Riley	5 (6)	July 24, August 7, 19; September 17, October 15
Round	9 (12)	July 23, August 6, 11, 20, 25; September 3, 8, 18, 24
Susan	6 (6)	June 23, July 24, August 7, August 19, September 17, October 15

Note: Phycocyanin levels greater than 1,000 cells/mL are in the WHO low risk zone for exposure to cyanotoxins.
[a]n is the number of times the lake was sampled.

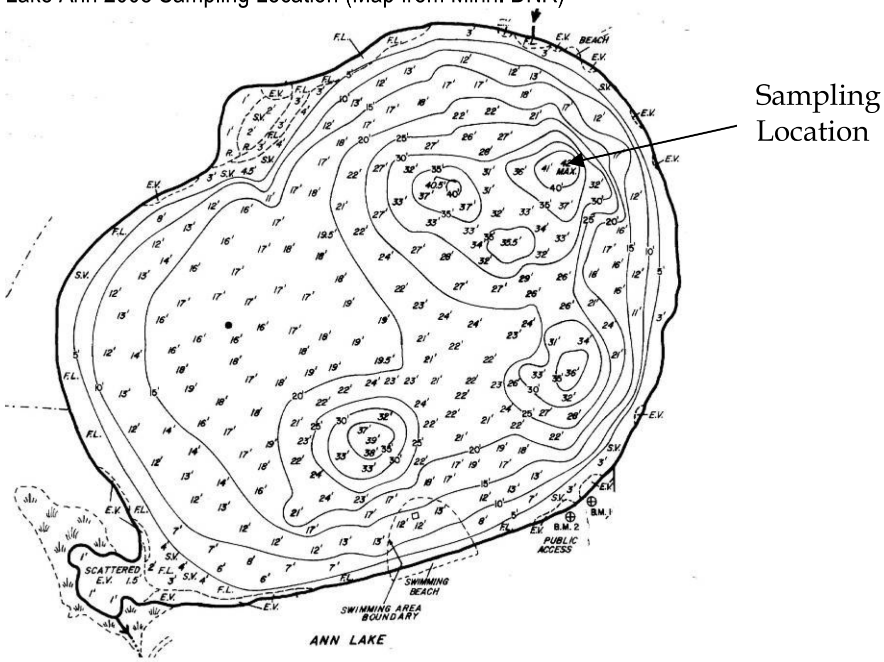
3. Lakes

3.1 Lake Ann

3.1.1 Introduction

In-Situ water quality measurements were collected using the sonde and water quality samples were collected monthly (Exhibit 3.1-1).

EXHIBIT 3.1-1
Lake Ann 2008 Sampling Location (Map from Minn. DNR)



3.1.2 In-Situ Parameters

3.1.2.1 Dissolved Oxygen and Temperature

The dissolved oxygen in Lake Ann stayed above 5 mg/L in the top 4 meters of the lake throughout the entire sampling season, but in the mesolimnion (between 4 and 6 meters), dissolved oxygen decreased rapidly (Exhibit 3.1-2). Below the thermocline (6 meters), the dissolved oxygen was less than 1 mg/L through the summer (Exhibit 3.1-3). Dissolved oxygen concentration profiles are consistent with a well-stratified lake.

Lake Ann is a deep, well-stratified lake. It appears that turnover of the lake occurred in November after the cessation of the field season. During the hottest part of the summer, the top 4 meters of the lake were well-mixed, forming a well-defined epilimnion.

EXHIBIT 3.1-2
Lake Ann Dissolved Oxygen 2008 Isopleth (mg/L)

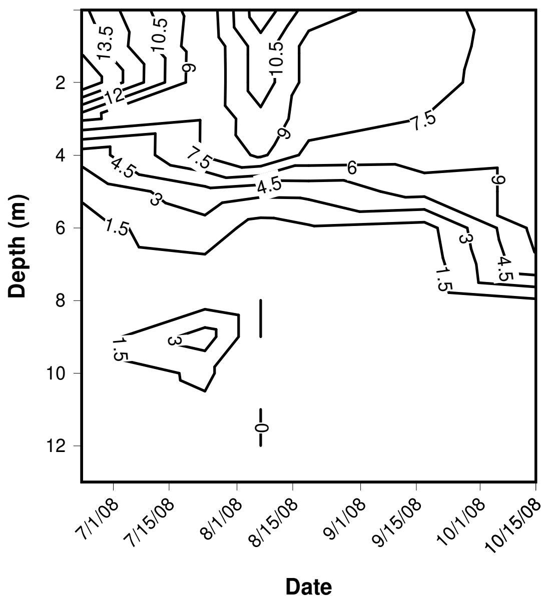
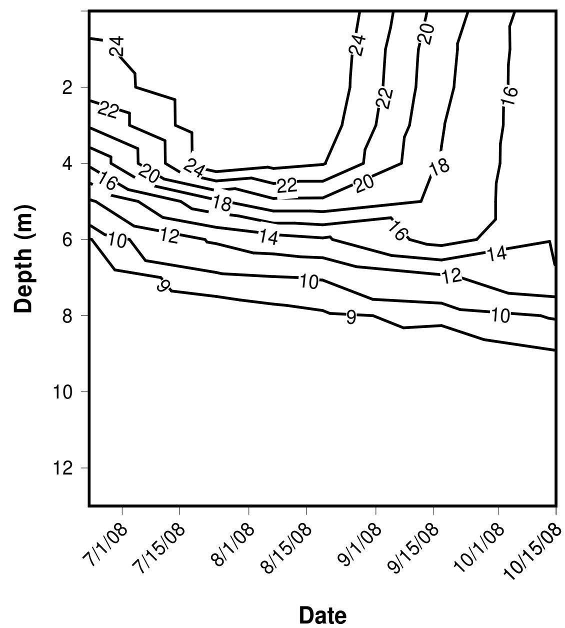


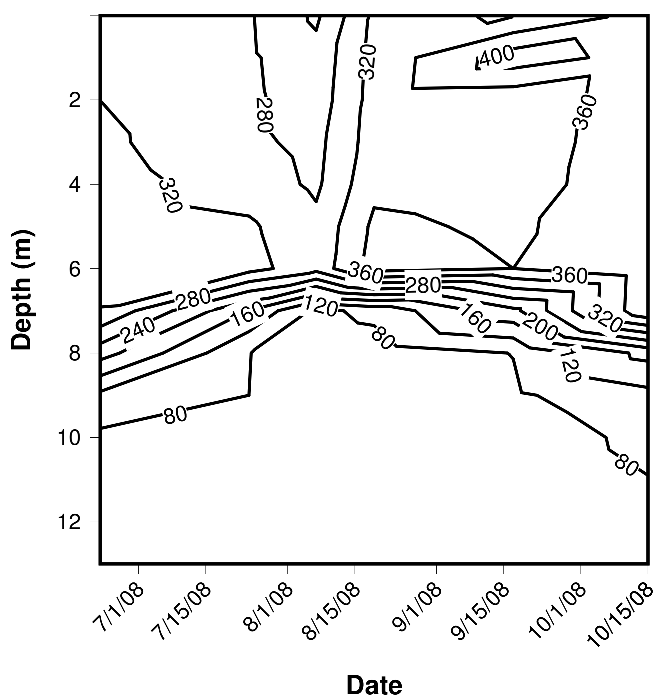
EXHIBIT 3.1-3
Lake Ann Temperature 2008 Isopleth (°C)



3.1.2.2 Oxidation Reduction Potential

Oxidation reduction potential values reveal strong reducing conditions within the hypolimnion. A value of approximately +180 mV appears to be the threshold of anaerobic conditions in Lake Ann (Exhibit 3.1-4). The higher TP, orthophosphorus, and ammonia values at the bottom of the lake correspond with the ORP values less than +180 mV. Mean TP in water with ORP less than + 180 mV is 0.36 mg/L, whereas at greater ORP values mean TP is 0.02 mg/L. Mean ammonia concentrations were 2.3 mg/L for ORP less than +180 mV and 0.05 mg/L for greater ORP values. The difference is statistically significant for both TP and ammonia (p less than 0.1). Anaerobic conditions in the hypolimnion, therefore, are the principal driving force for nutrient dynamics within Lake Ann.

EXHIBIT 3.1-4
Lake Ann ORP 2008 Isopleth (mV)



Hypolimnetic ORP values of +100 mV or less in mid summer were associated with sulfate reduction. Samples had a strong hydrogen sulfide smell. Under these low ORP values there are changes in water chemistry that are fundamental to phosphorus release:

Ferric iron (Fe[III]) binds phosphorus under high (greater than +200 mV) ORP values. Reduction of ferric iron to ferrous iron (Fe[II]) releases phosphorus into the water column as ORP values drop below +200 mV.

As first, release of phosphorus does not significantly increase internal P loading. Both ferrous iron and soluble phosphorus diffuse into the water column. As this water meets positive dissolved oxygen at the mesolimnion, iron oxidizes and binds once again.

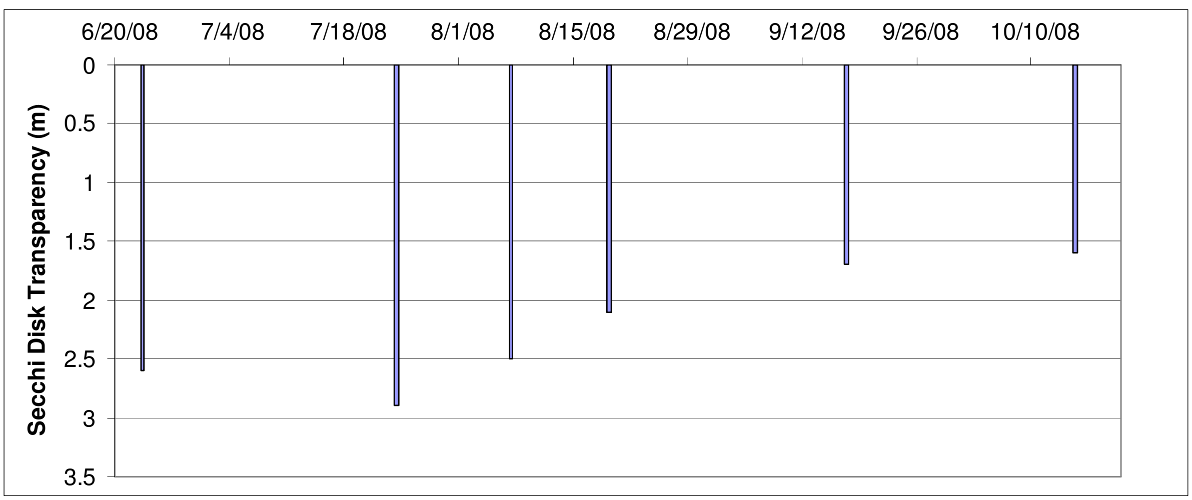
Once sulfide reduction starts, probably at ORP values less than +100 mV, but possibly higher, insoluble iron-sulfide bonds form, taking iron out of solution.

Phosphorus continues to diffuse into the hypolimnion but no longer binds with iron as it meets water with oxygen. At this point anaerobic conditions result in phosphorus loading of the epilimnion.

3.1.2.3 Water Clarity

Secchi Disk. Secchi disk depth measurements were greater than 1.5 meters throughout the sampling season (Exhibit 3.1-5). The lowest measurements of the year (lowest visibility) occurred in September and October.

EXHIBIT 3.1-5
Lake Ann 2008 Secchi Disk Data



Photosynthetic Active Radiation. The PAR graph shows the greatest penetration of light occurring in the warmest seasons of the year (Exhibit 3.1-6). The euphotic zone in Lake Ann extends to between 3.5 to 7 meters, reflecting the high water clarity of Lake Ann throughout the year.

EXHIBIT 3.1-6
Lake Ann Percent Incident Light Penetration 2008 Isopleth

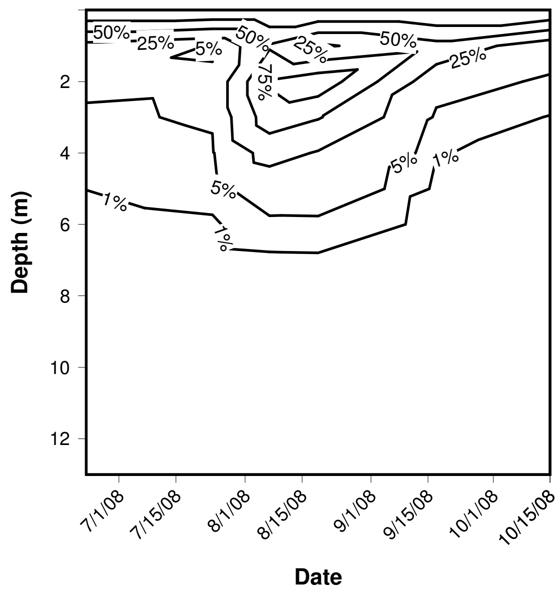
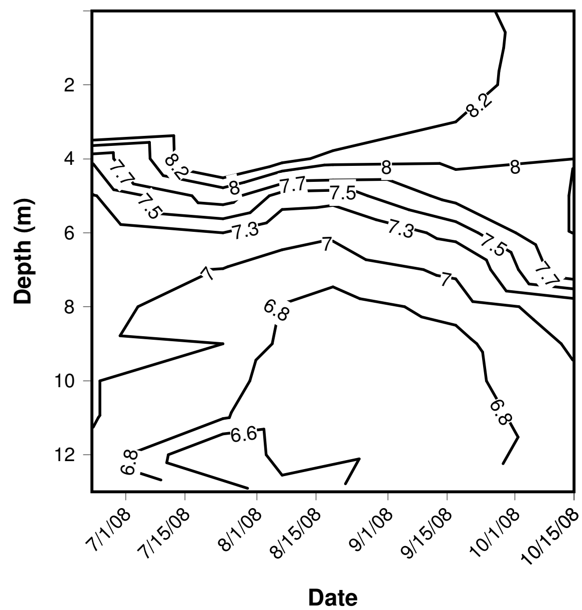


EXHIBIT 3.1-7
Lake Ann pH 2008 Isopleth (SU)



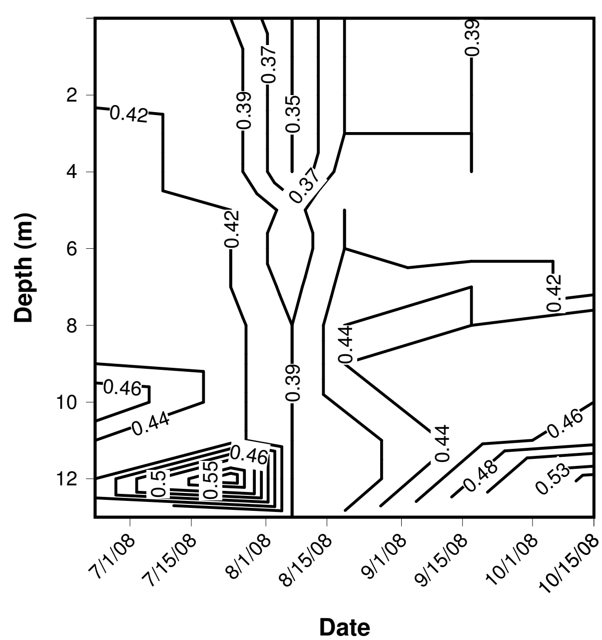
3.1.2.4 pH

Observed pH values in Lake Ann are characteristic of a mesotrophic, stratified lake (Exhibit 3.1-7). Surface pH values above 8.0 reflect algae photosynthesis. Fish stress can occur when pH increases above 9.0–9.3, therefore pH is not a significant source of stress for fish in Lake Ann.

3.1.2.5 Conductivity

Conductivity is lower near the surface than in the deeper waters, as would be expected in a well-stratified lake (Exhibit 3.1-8).

EXHIBIT 3.1-8
Lake Ann Conductivity 2008 Isopleth (mS/cm)



3.1.3 Nutrients

3.1.3.1 Phosphorus Species

The TP and orthophosphate concentrations are highest at the bottom of the lake throughout the sampling season (Exhibits 3.1-9 and 3.1-11). This concentration gradient is evidence of strong internal phosphorus loading. The concentrations of TP and orthophosphate at the top of the lake are much lower than the bottom samples through all the sampling dates. Low TP in the epilimnion is indicative of uptake of phosphorus by algae; algae will uptake phosphorous and the sink to the bottom of the lake. It also provides evidence for the significance of internal phosphorus loading. External P loading from stormwater would tend to raise epilimnetic phosphorus. Comparing ORP and OP (Exhibit 3.1-10), indicates an important relationship. Anaerobic conditions, as noted by ORP (See previous ORP discussion), in the hypolimnion promote phosphorus release from sediments.

EXHIBIT 3.1-9
Lake Ann 2008 Total Phosphorus Isopleth (mg/L)

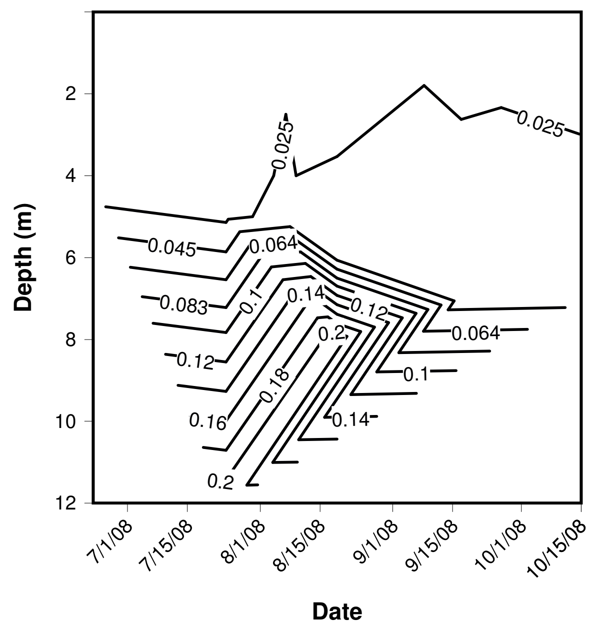
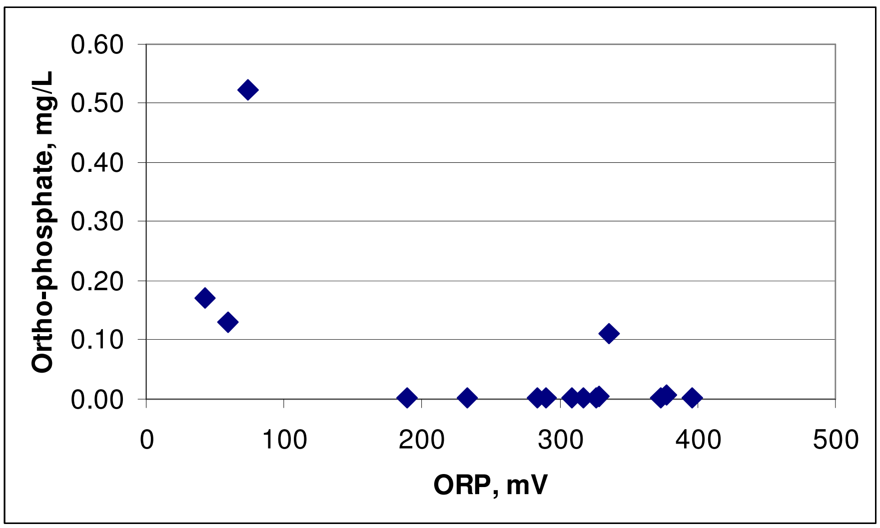


EXHIBIT 3.1-10
Lake Ann 2008 Orthophosphate Concentrations as Function of ORP



3.1.3.2 Nitrogen

Ammonia concentrations peaked with the August 19, 2008, measurement at 8 meters, but were also nearly as high on July 24, 2008, at a depth of 12 meters (Exhibit 3.1-12). Ammonia is primarily a product of protein breakdown (hydrolysis) in the sediments; some may also be from reduction of nitrate, although nitrate is low. The concentration of ammonia decreases in the lake from sediment to surface according to a typical concentration gradient due to diffusion. Ammonia could also be affected by algae uptake in the euphotic zone and nitrification in the aerobic zone. Total ammonia concentrations at associated pH and temperature values set un-ionized ammonia below the 0.02 mg/L threshold value, above which it is considered to cause acute stress in fish.

EXHIBIT 3.1-11
Lake Ann 2008 Orthophosphate Isopleth (mg/L)

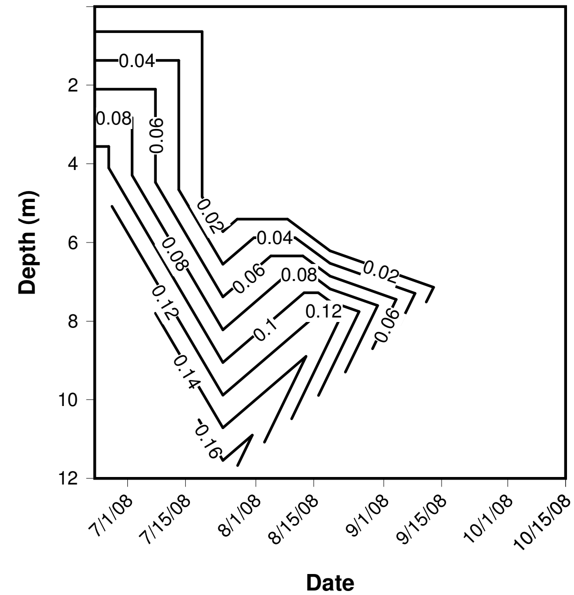
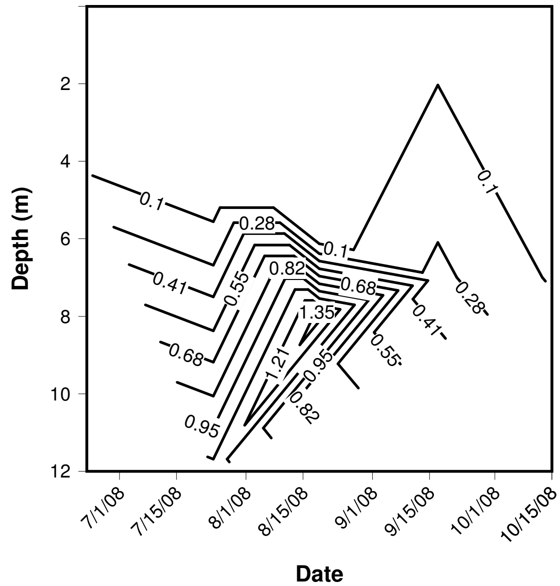


EXHIBIT 3.1-12
Lake Ann 2008 Ammonia Isopleth (mg/L)



Nitrate and nitrite were undetectable in all samples taken in the 2008 sampling season. This indicates that the ammonia in the water column is either taken up into algae directly, or quickly nitrified and then denitrified under low dissolved oxygen conditions.

The patterns of TKN and TN concentrations are identical, reflecting that the nitrate and nitrite concentrations were below the detection limit throughout the 2008 sampling season (TN = TKN plus nitrate+nitrite) (Exhibits 3.1-13 and 3.1-14). Concentrations of TKN and TN peaked on August 15, 2008.

EXHIBIT 3.1-13
Lake Ann 2008 TKN Isopleth (mg/L)

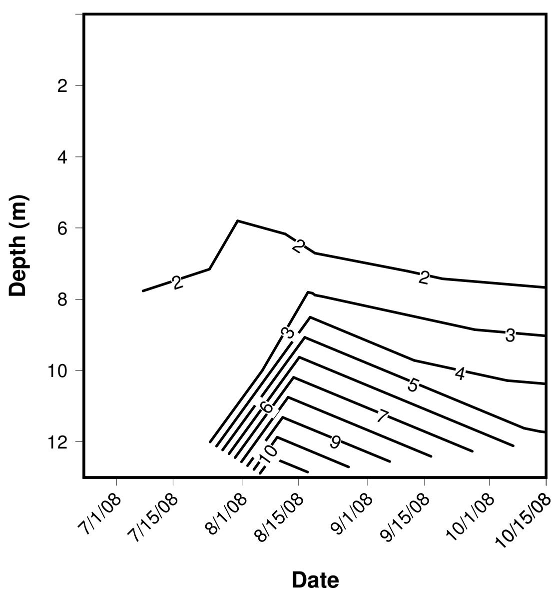
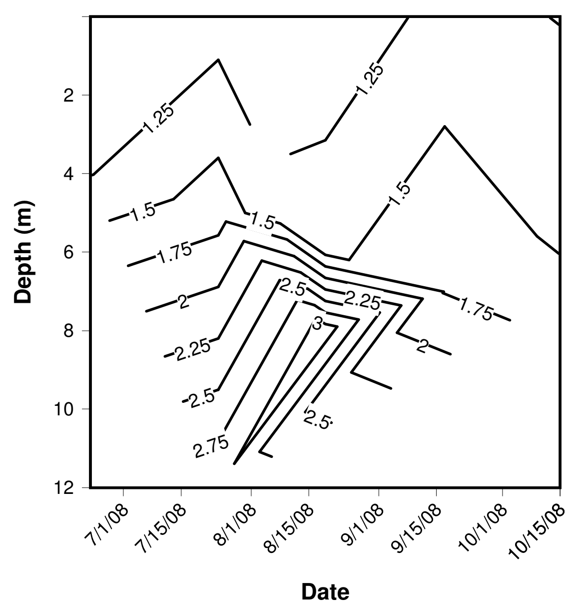


EXHIBIT 3.1-14
Lake Ann 2008 Total Nitrogen Isopleth (mg/L)



3.1.4 Biological parameters

3.1.4.1 Chlorophyll *a*

The chlorophyll *a* concentrations were higher in September and October than earlier in the year (Exhibit 3.1-15). This trend is consistent with diffusion of phosphorus, ammonia, or micronutrients from the hypolimnion allowing increase algae growth.

3.1.4.2 Phycocyanin

The phycocyanin measurements taken on July 24 were the highest recorded (Exhibit 3.1-16). The measurements indicate that the lake is in the WHO low risk category (1,000–8,000 cells/mL of

EXHIBIT 3.1-15
Lake Ann Chlorophyll *a* Surface Concentration (µg/L)

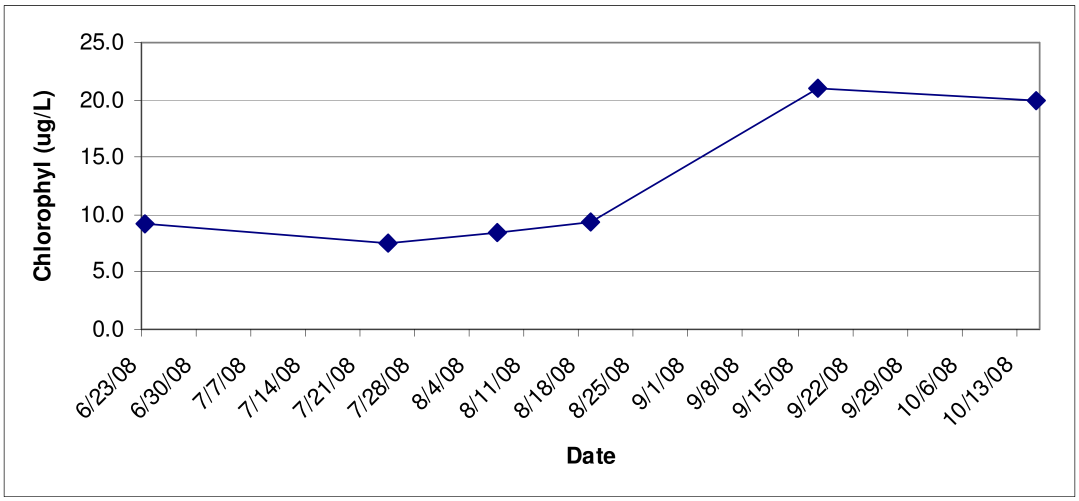
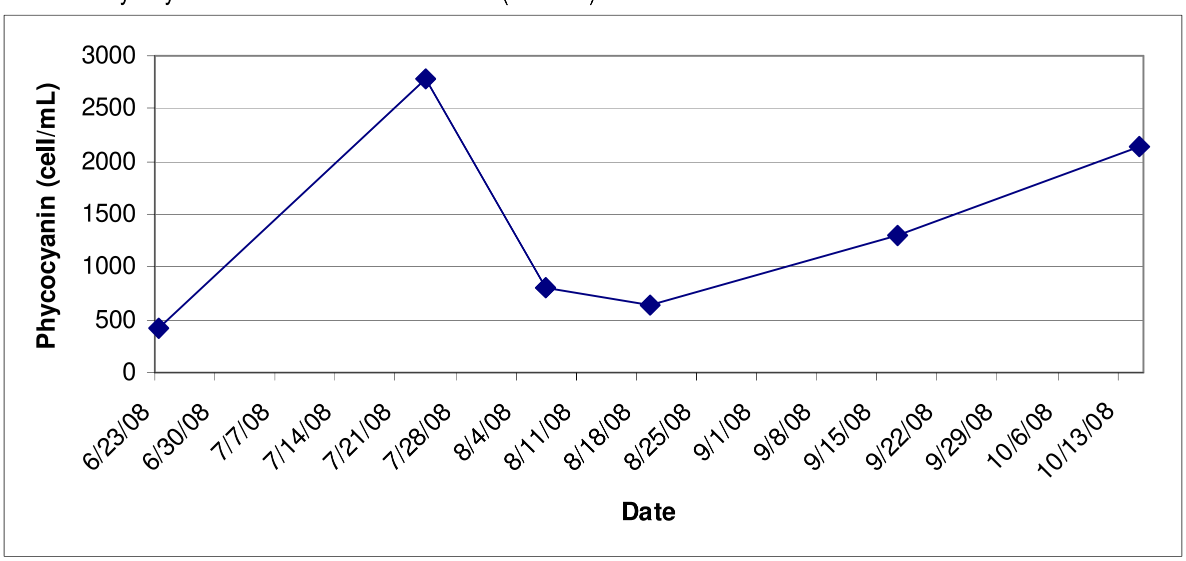


EXHIBIT 3.1-16
Lake Ann Phycocyanin 2008 Surface Concentration (cells/mL)



phycocyanin) for part of July and in September and October. Spike noted in late July could be an anomaly, due to a low number of data points it is hard to assess. Correlations between phycocyanin and chlorophyll *a* are not possible due to the differences in units expressed.

3.1.4.3 Plankton and Cyanotoxin Assessment

Phyto- and zooplankton samples taken on September 17, 2008, were evaluated for count and biovolume. Phytoplankton biovolume was dominated (70 percent) by cyanobacteria, comprising two species known to produce toxins, *Aphanizomenon flos-aquae* and *Oscillatoria* spp. (Exhibits 3.1-17 and 3.1-18). Although it is not possible to predict cyanotoxin production, the WHO moderate risk threshold is 100,000 cells/mL. The total cyanobacteria cell density was 49,000 cells/mL, which is above the low-risk threshold of 20,000 cells/mL. Cyanobacteria should be monitored in 2009 to further assess potential risk to public health as the phytoplankton community was dominated by cyanobacteria.

EXHIBIT 3.1-17
Phytoplankton Density, September 18, 2008

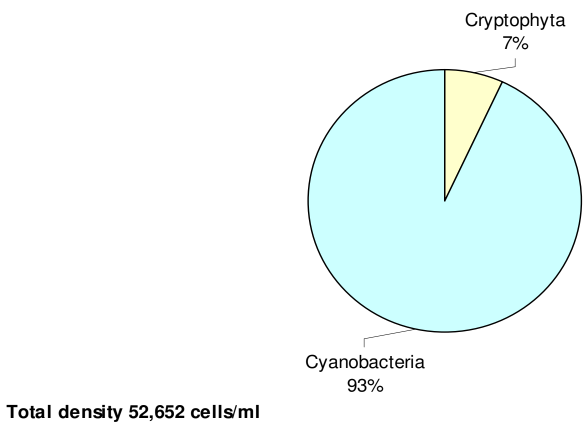
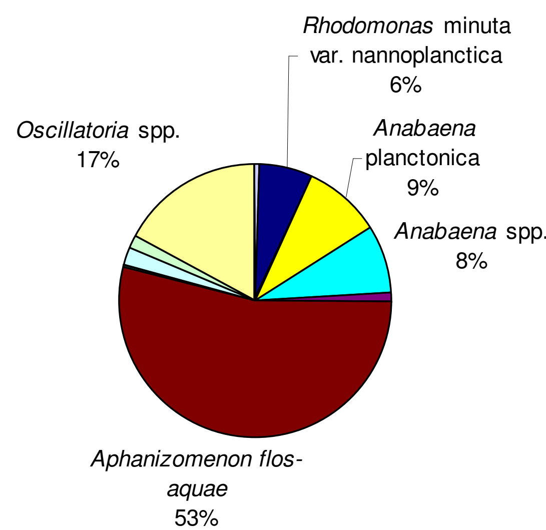


EXHIBIT 3.1-18
Dominant Phytoplankton by Genus or Species, September 18, 2008



The zooplankton population was dominated by small-bodied organisms that can lead to algal growth (Exhibits 3.1-19 and 3.1-20). The absence of large-bodied Cladoceran zooplankton, is an important element in the conditions arising for an algae bloom.

3.1.5 Trophic Indices

3.1.5.1 Current

The Carlson Trophic Indices for Chlorophyll *a* (Chla) and Secchi disc depth (SD) show Lake Ann to be mesotrophic to eutrophic throughout the sampling season, with CTSI values peaking in September and October (Exhibit 3.1-21). The CTSI values for TP are not in keeping with Secchi disc or chlorophyll *a* values except at the July. This relationship is typical in a phosphorus limited condition in which most phosphorus in the epilimnion is taken up by algae and settled out. It is not indicative of an oligotrophic trophic state. Lake Ann is mesotrophic to eutrophic based on chlorophyll *a* and Secchi disc depth.

EXHIBIT 3.1-19
Zooplankton Density, September 18, 2008

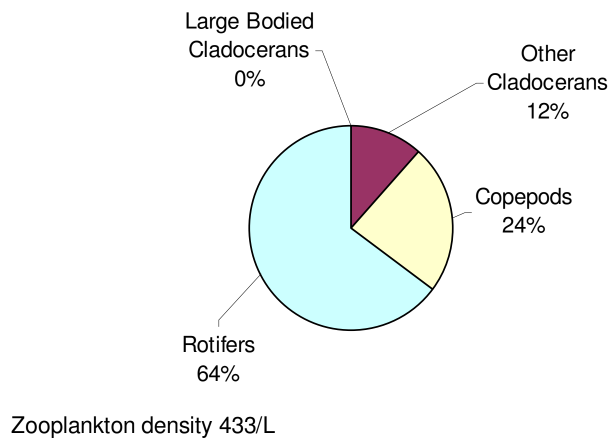
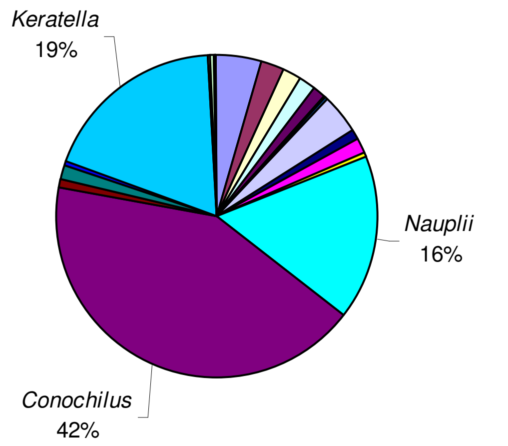
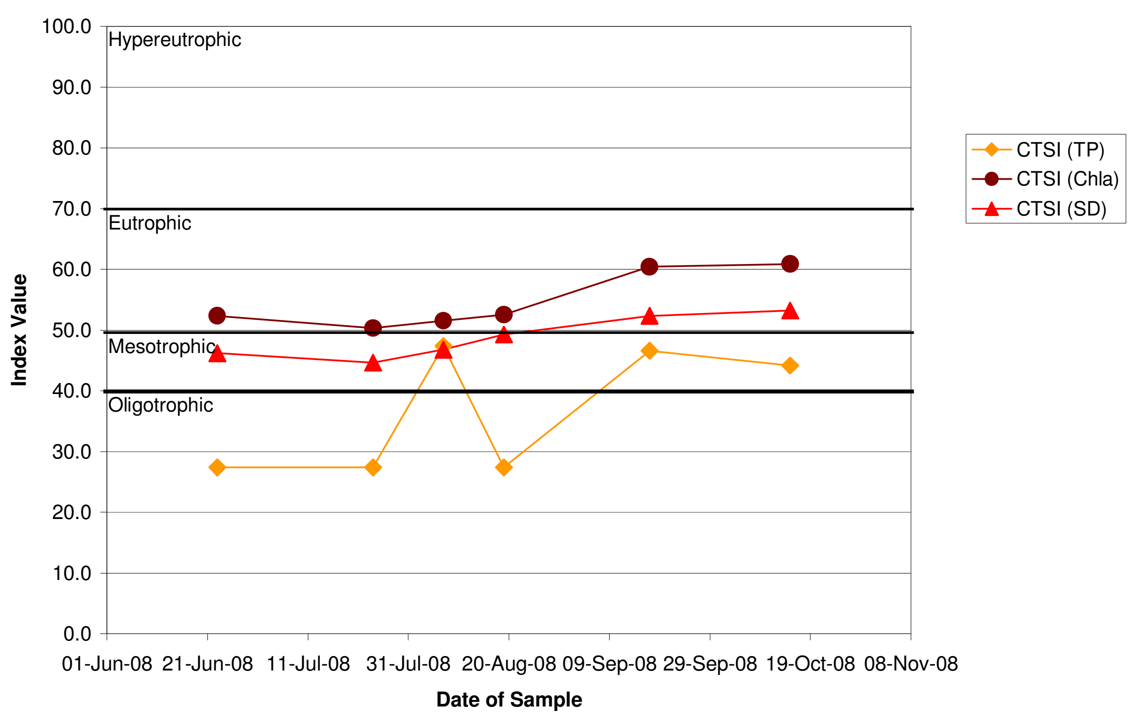


EXHIBIT 3.1-20
Dominate Zooplankton by Genus or Species, September 18, 2008.



Note: Nauplii are juvenile crustacean zooplankton.

EXHIBIT 3.1-21
Lake Ann 2008 CTSI



The Indiana State Trophic Index level for the sampling event on Sept. 17, 2008 showed the lake to be mesotrophic with a score of 21. ISTI scores between 16 and 31 are deemed to be mesotrophic, while a measurement of 32 to 46 is eutrophic.

The CTSI measurements vary between mesotrophic and eutrophic, while the ISTI shows Lake Ann to be mesotrophic in September (on a date upon which the CTSI classed the lake as eutrophic).

3.1.5.2 Historic trends

Historical Secchi disk depths for the months of July and August indicate variable transparency with no clear trend, according to the Kendall tau analysis (Appendix B) (Exhibits 3.1-22 and 3.1-23). This lack of a clear trend indicates variability of the lake ecology.

EXHIBIT 3.1-22
Historical Secchi Disk Depth Averages for July and August

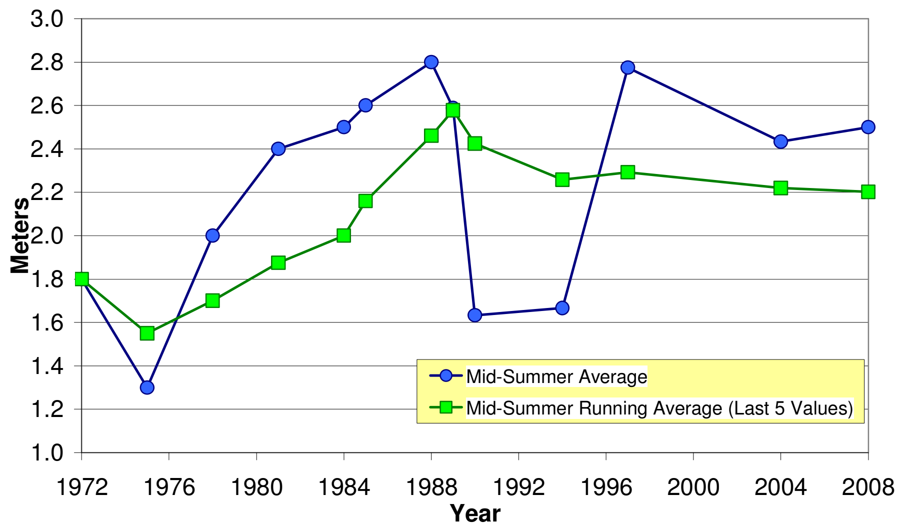


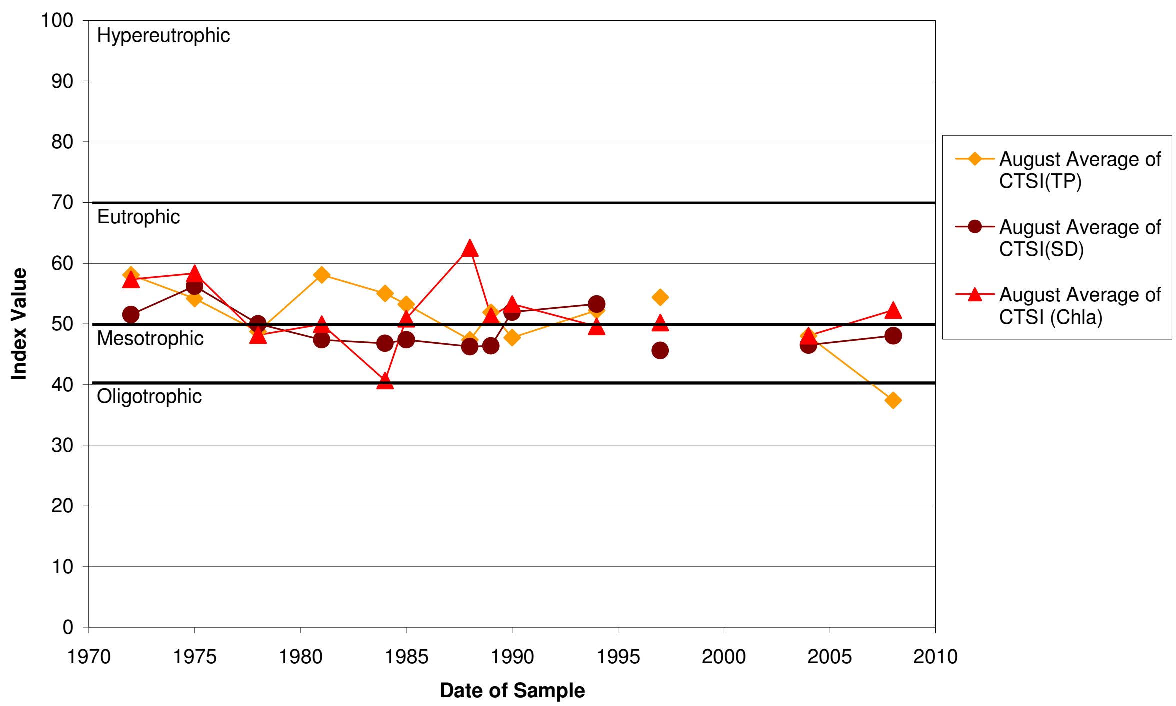
EXHIBIT 3.1-23
Results from Kendall Tau Test

Period	Parameter	2008 Median	Historical Median	Statement of Trend
July	TP (mg/L)	5	20	X
July	Chla (µg/L)	7.5		NA
July	SD (m)	2.9	2.7	X
August	TP (mg/L)	12.5	28	Y
August	Chla (µg/L)	8.95		X
August	SD (m)	1.95	2.35	X
July–August	TP (mg/L)	5	24	Y
July–August	Chla (µg/L)	8.5		X
July–August	SD (m)	2.1	2.4	X

X: H_0 cannot be rejected; i.e., there is insufficient evidence to prove a trend.
Y: H_0 is rejected; i.e., there is sufficient evidence to prove a trend.
NA: Not applicable as the Kendall tau test could not be performed due to insufficient data.

Historical CTSI values have remained relatively constant during the reporting period (Exhibit 3.1-24). The 2008 and historical CTSI values show Lake Ann to be between mesotrophic to eutrophic. The Kendall tau test indicates that there is a significant decrease in the total phosphorus concentration but no trend to the historic chlorophyll *a*, and Secchi disk data.

EXHIBIT 3.1-24
Ann Lake Historic CTSI



3.1.6 Conclusions

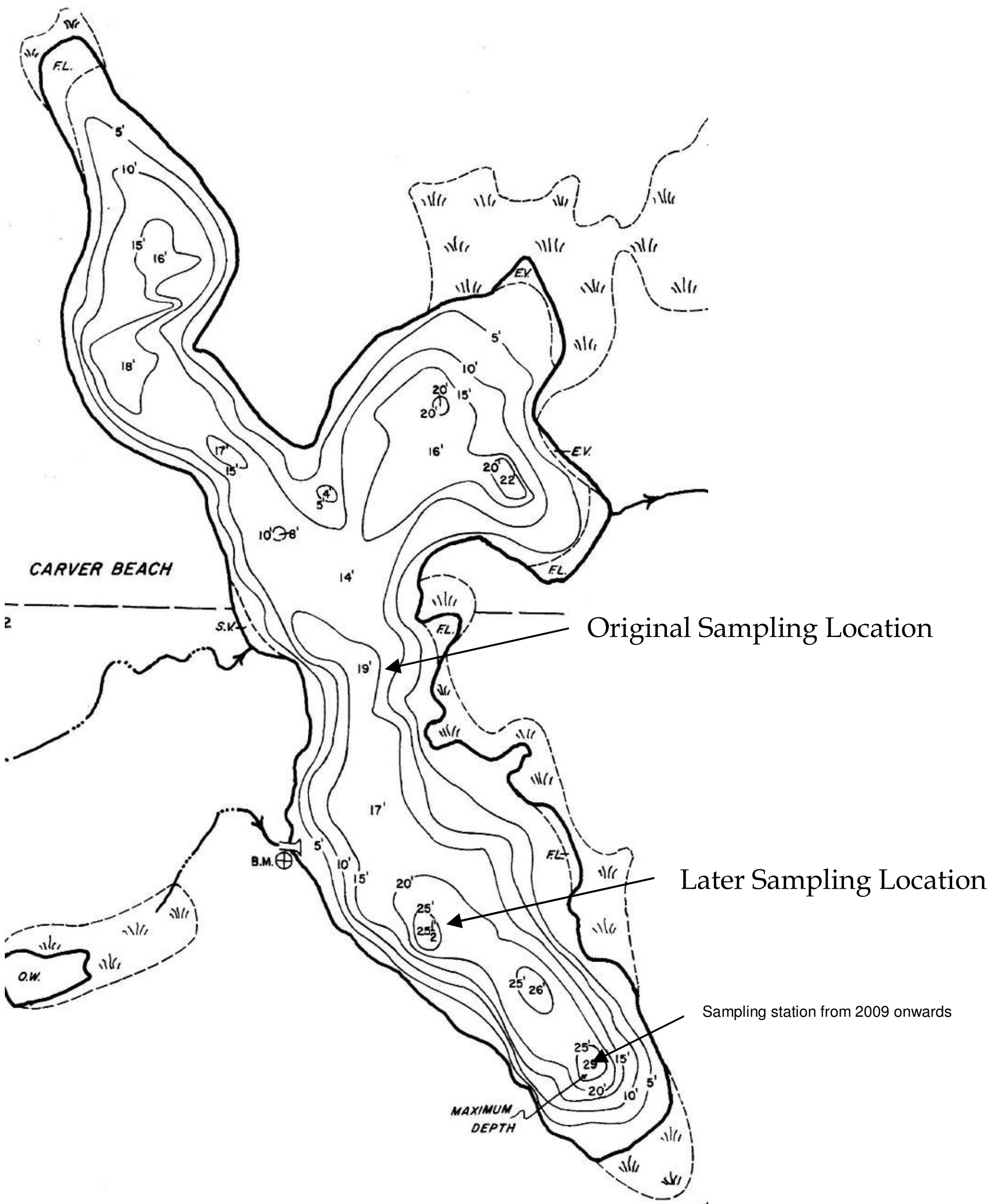
The results of the 2008 sampling season indicate that Lake Ann is a deep, strongly stratified mesotrophic to eutrophic lake. The primary productivity of the lake is driven by the relative abundance of bio-available phosphorus. The lack of large bodied zooplankton to keep the algae concentration in balance allowed blooms of harmful cyanobacteria to develop. A significant source of phosphorus is internal loading from lake sediments.

3.2 Lotus Lake

3.2.1 Introduction

In-situ water quality measurements were collected biweekly using the sonde, and water quality samples were collected monthly. The initial sampling location for Lotus Lake was determined by outdated bathymetry data and an on-boat depth finder. The sampling location was changed in July, when a deeper location in the lake was observed. Updated bathymetry data were obtained toward the end of the sampling season. The future sampling site is noted (Exhibit 3.2-1).

EXHIBIT 3.2-1
Lotus Lake 2008 Sampling Locations (Map from Minn. DNR)



3.2.2 In-Situ Parameters

3.2.2.1 Dissolved Oxygen and Temperature

The dissolved oxygen and temperature isopleths indicate that Lotus Lake is weakly stratified even in the middle of the summer (Exhibits 3.2-2 and 3.2-3). The epilimnion extends down to 6 meters on August. The large epilimnion with temperature exceeding 25 degrees Celsius combined with the episodic depletion of dissolved oxygen to below between 0.5 mg/L as shallow as 3 meters will physiologically stress the game fish population. Thermal stratification is not strong in Lotus Lake, as seen by the early September turnover.

EXHIBIT 3.2-2

Lotus Lake Dissolved Oxygen 2008 Isopleth (mg/L)

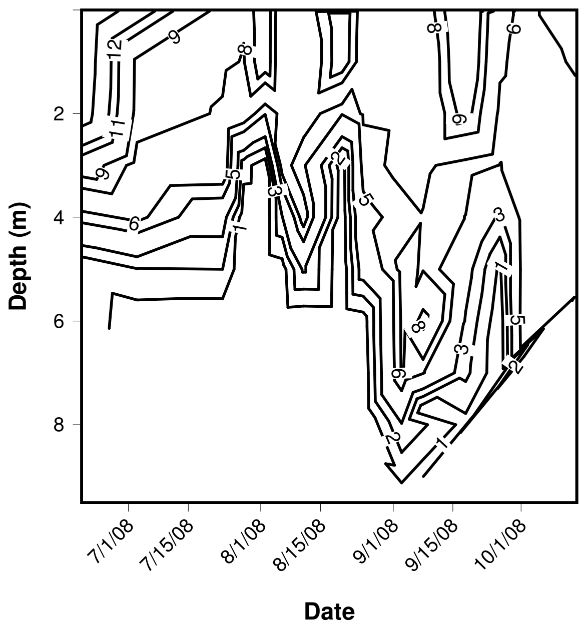
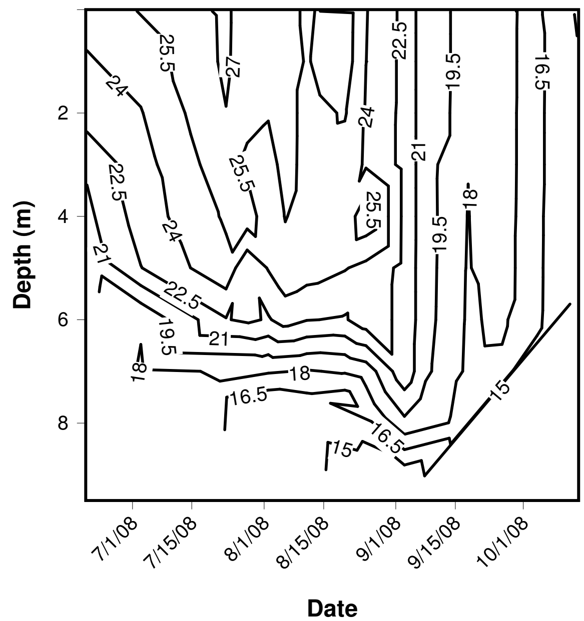


EXHIBIT 3.2-3

Lotus Lake Temperature 2008 Isopleth (°C)

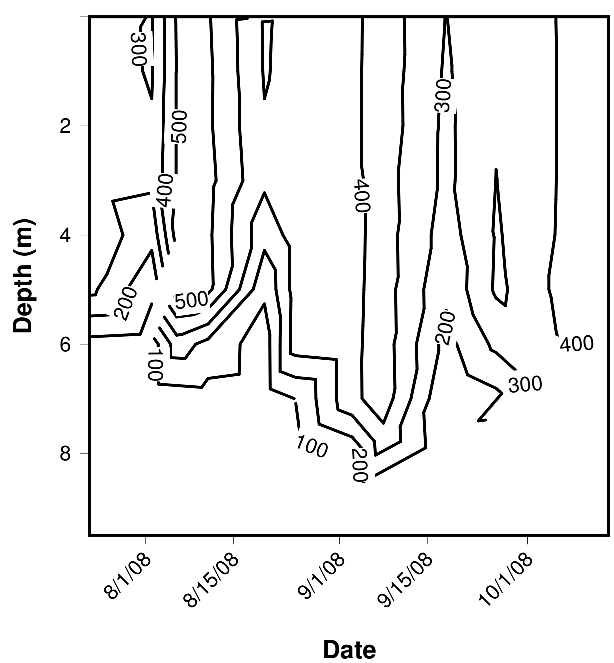


3.2.2.2 Oxidation Reduction Potential

The OPR decreases to below +200 mV near the bottom of the lake (Exhibit 3.2-4). The drop in OPR allows for the release in phosphorus from the sediments. Problems with choice of sampling site render the data of limited use because the full depth profile of the lake was not observed.

EXHIBIT 3.2-4

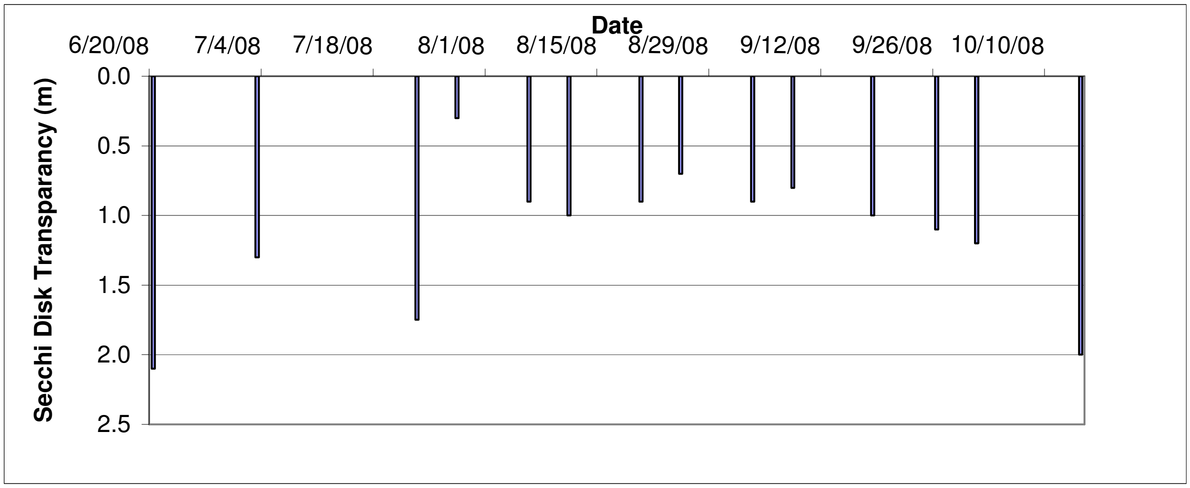
Lotus Lake ORP 2008 Isopleth (mV)



3.2.2.3 Water Clarity

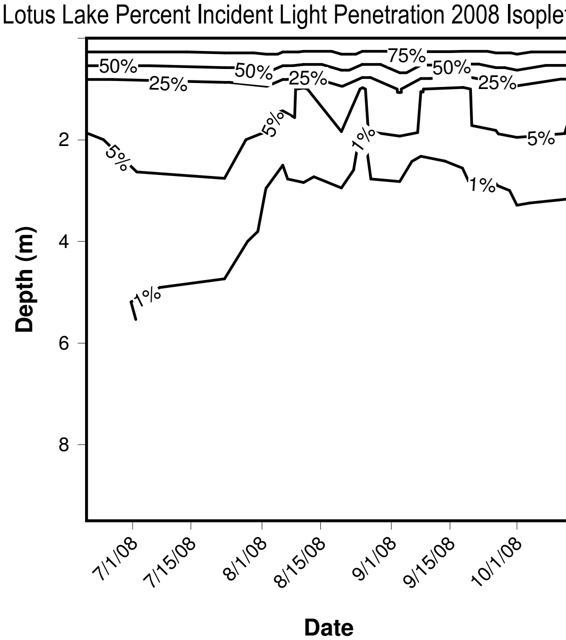
Secchi Disk. Secchi disk depth decreases from its peak in early June and remains around 1 meter through most of the summer before recovering in September (Exhibit 3.2-5). The decrease in Secchi disk depth correlates well with the increase in chlorophyll *a* and phycocyanin concentration.

EXHIBIT 3.2-5
Lotus Lake 2008 Secchi Disk Data



Photosynthetic Active Radiation. The euphotic zone as measured by PAR extends down to 5 meters in the early summer but decreases to three meters by August and then remains constant for the remainder of the season (Exhibit 3.2-6).

EXHIBIT 3.2-6
Lotus Lake Percent Incident Light Penetration 2008 Isopleth



3.2.2.4 pH

Fish stress can occur when pH increases above 9.0–9.3, therefore pH is not a significant source of stress for fish in Lotus Lake. In early August pH becomes less of an issue (Exhibit 3.2-7). Another use of pH is as an indicator for photosynthesis; an increase in pH is related to an increase in photosynthesis. The increase in pH in mid September is well correlated to the increase in chlorophyll *a* and phycocyanin concentration.

3.2.2.5 Conductivity

Conductivity was consistent throughout the sampling season, showing a minimal concentration gradient (Exhibit 3.2-8).

EXHIBIT 3.2-7
Lotus Lake pH 2008 Isopleth

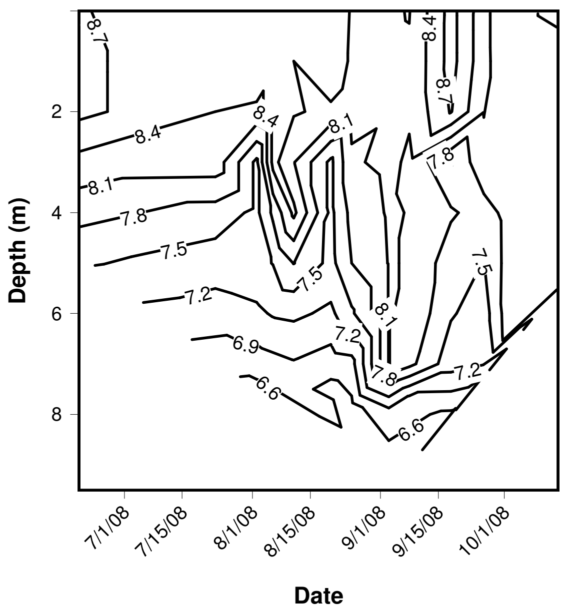
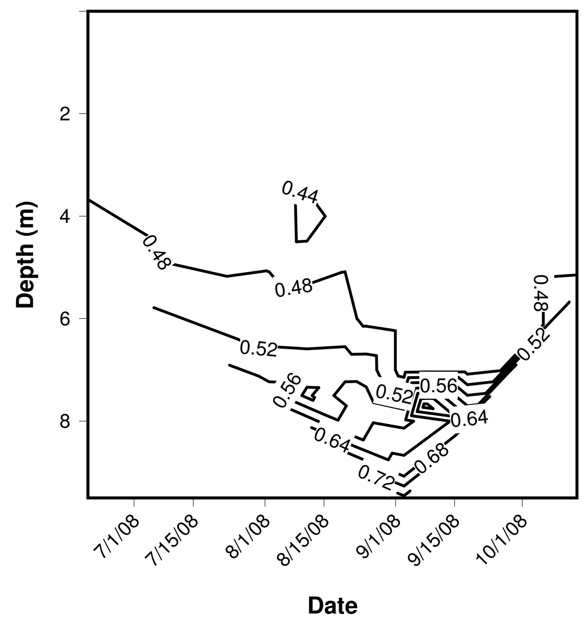


EXHIBIT 3.2-8
Lotus Lake Conductivity 2008 Isopleth



3.2.3 Nutrients

3.2.3.1 Phosphorus Species

The TP and the orthophosphate both indicate a minimal/high level of phosphorus in the epilimnion and the mesolimnion (Exhibits 3.2-9 and 3.2-11). Both the TP and

EXHIBIT 3.2-9
Lotus Lake 2008 Total Phosphorus Isopleth (mg/L)

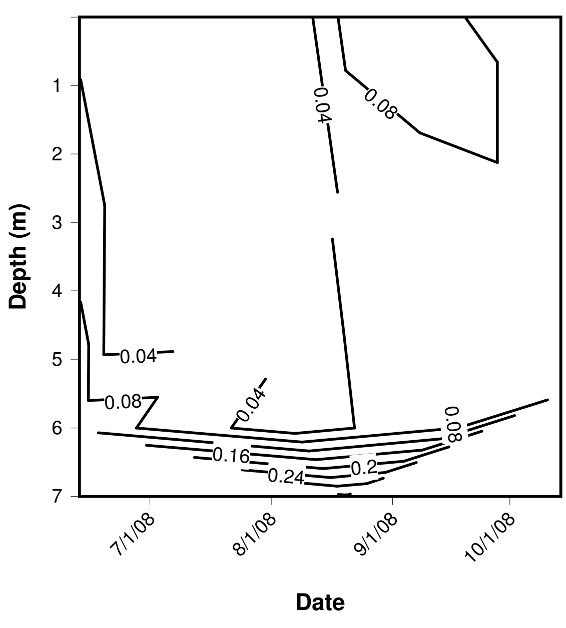
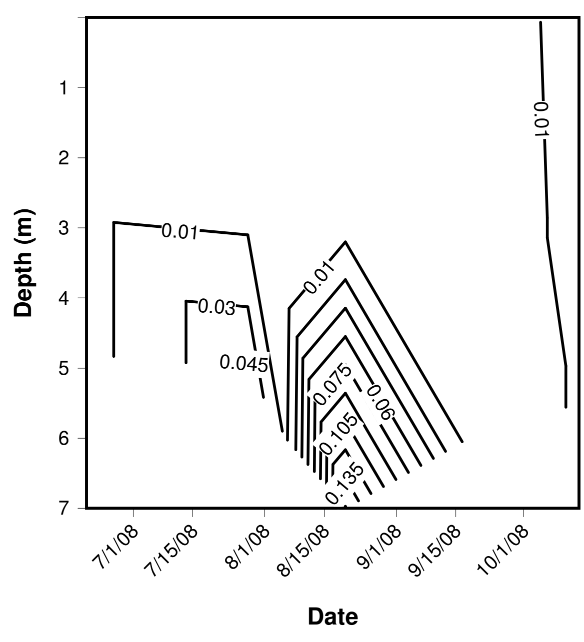


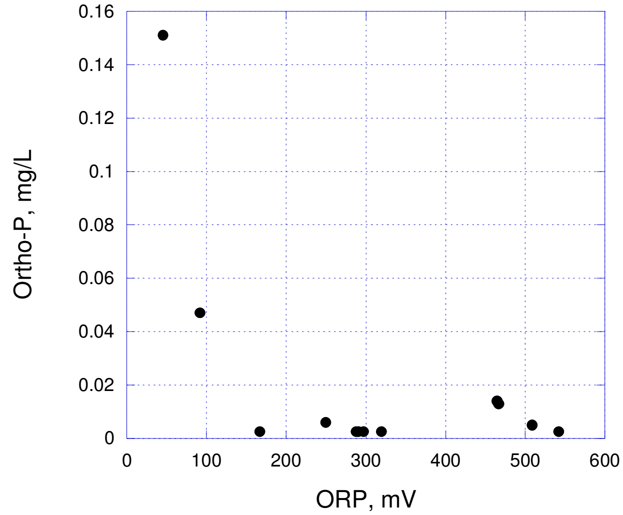
EXHIBIT 3.2-11

Lotus Lake 2008 Orthophosphate Isopleth (mg/L)



orthophosphate isopleths show that phosphorus is being released from the lake sediments. The OPR of the water at the bottom of the lake was below +200 mV from July until September. Values of ORP less than +200 mV in this lake system represent a threshold at which ferric iron (Fe[III]) is reduced to ferrous iron (Fe[II]). Phosphorus is bound by Fe(III), but not Fe(II). Release of phosphorus from sediments is thus a direct result of low ORP values. Limited data suggest that significant release of soluble phosphorus only begins at ORP values less than +100 mV, probably as result of iron sequestration in the sediments by insoluble sulfide bonds (Exhibit 3.2-10).

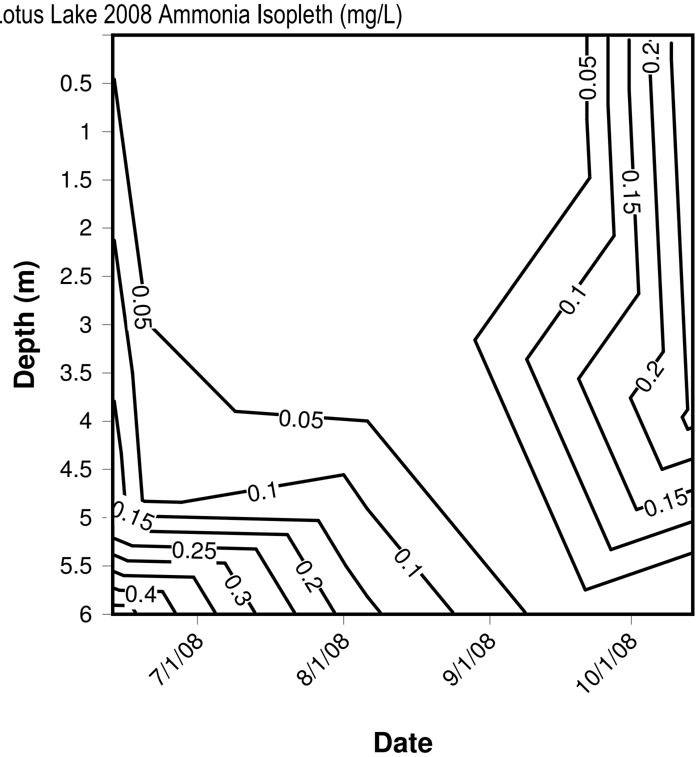
EXHIBIT 3.2-10
Lotus Lake 2008 Orthophosphate Concentrations as a Function of ORP



3.2.3.2 Nitrogen Species

The ammonia concentration in Lotus Lake was greatest at the bottom of the lake during early spring and summer (Exhibit 3.2-12). Ammonia is primarily a product of protein breakdown (hydrolysis) in the sediments; some may also be from reduction of nitrate, although nitrate is low. The concentration of ammonia decreases in the lake from sediment to surface according to a typical concentration gradient due to diffusion, consistent with phosphorous, ammonia, or micro-nutrients. Ammonia could also be affected by algae uptake in the euphotic zone and nitrification in the aerobic zone. However, when temperatures decreased and algal concentrations increased the phosphorous flux continued unabated.

EXHIBIT 3.2-12
Lotus Lake 2008 Ammonia Isopleth (mg/L)



The nitrite concentration in the lake was never detected above the analytical detection limit throughout the sampling

EXHIBIT 3.2-13
Lotus Lake 2008 TKN Isopleth (mg/L)

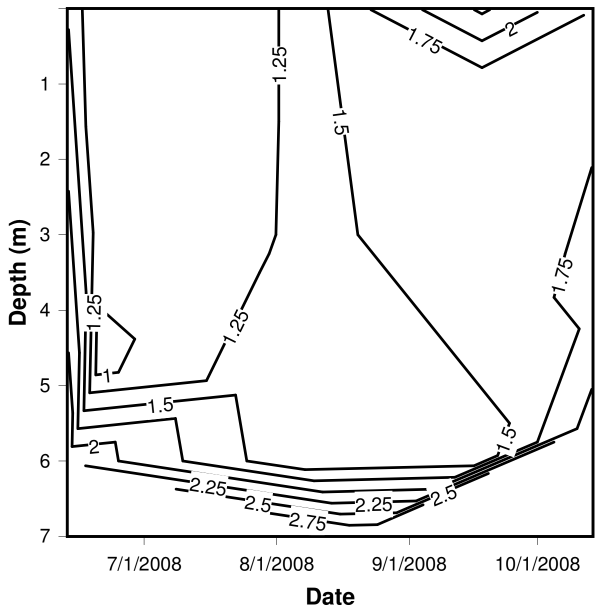
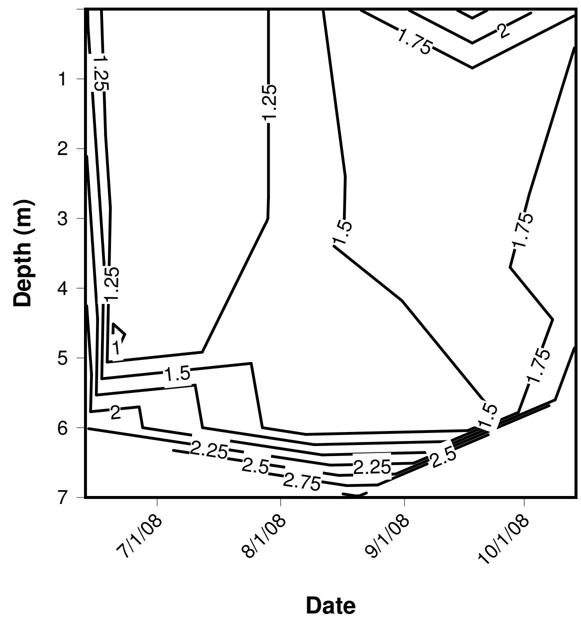


EXHIBIT 3.2-14
Lotus Lake 2008 Total Nitrogen Isopleth (mg/L)



season. Nitrate was measured above the detection limit only once on June 13 at a depth of 5 meters. The lack of nitrite and nitrate in the lake probably indicates rapid assimilation of ammonia by algae and nitrification within the water column.

The TKN and the total nitrogen isopleths are almost identical for Lotus Lake because of the minimal nitrate and nitrite concentration (Exhibits 3.2-13 and 3.2-14). This is an indication that both TKN and TN may not been to be measured in the future. The TKN and the TN show higher nitrogen concentrations at the bottom of the lake with a diffusion gradient in the hypolimnion. The June 13 sampling event shows a minimal concentration gradient, likely due to the weak thermal stratification also observed that day.

3.2.4 Biological parameters

3.2.4.1 Chlorophyll *a*

The chlorophyll *a* concentration in the surface samples Lotus Lake begins to increase in July and peaks in September (Exhibit 3.2-15). This pattern is indicative of a late season algae bloom.

3.2.4.2 Phycocyanin

The phycocyanin and surface concentration follow the same pattern that was observed in the chlorophyll *a* lab samples (Exhibit 3.2-16), however a correlation cannot be made due to differences in units. Phycocyanin value in early September could be an anomaly, it is difficult to assess due to number of monitoring events. The cyanobacteria population begins to increase in July and peaks in late August. The surface bloom causes a spike in the dissolved oxygen at the surface of the lake and is also correlated with the decrease in the transparency of the water as measured by the Secchi disk depth. The phycocyanin measurements indicate that the lake is in the WHO low risk category (1,000 to 8,000 cells/mL of phycocyanin) for the complete sampling season.

EXHIBIT 3.2-15
Lotus Lake Chlorophyll *a* Surface Concentration (µg/L)

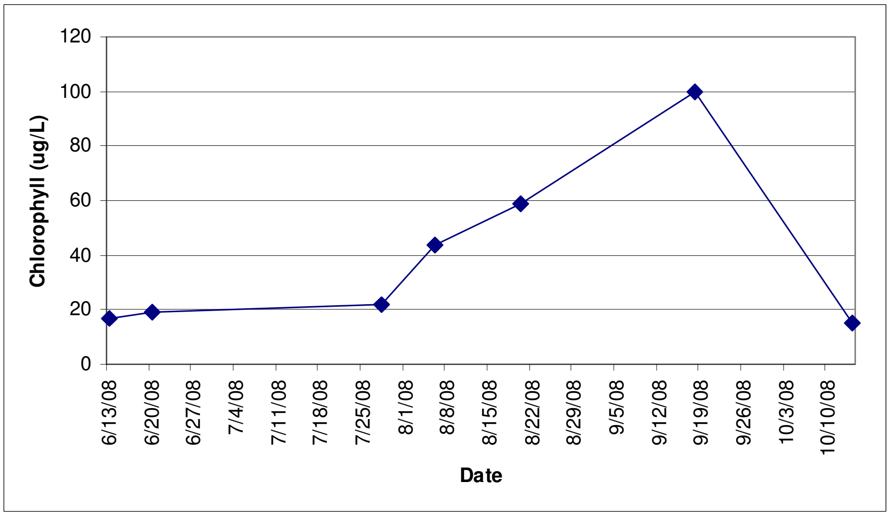
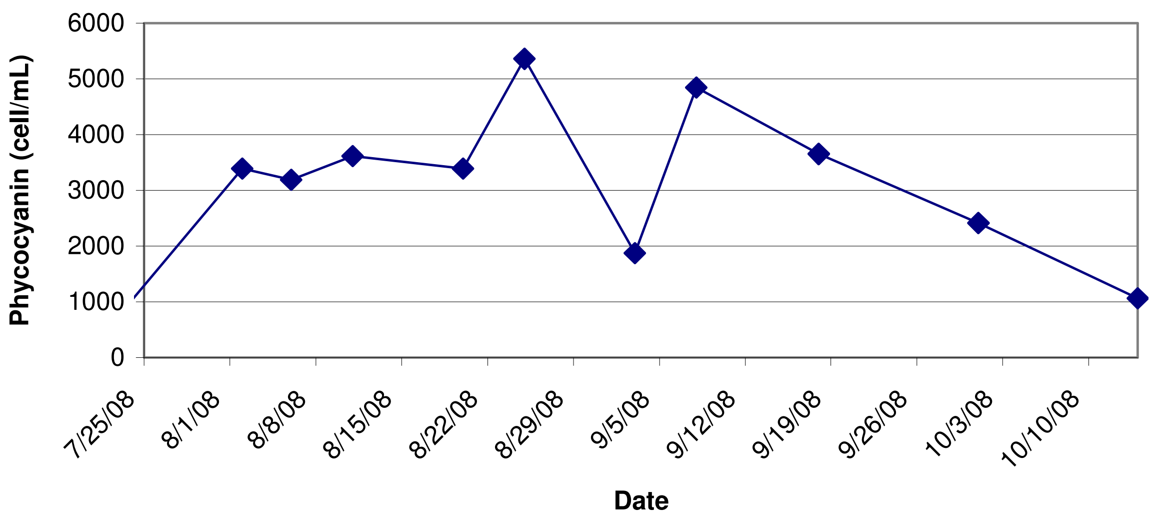


EXHIBIT 3.2-16
Lotus Lake Phycocyanin 2008 Surface Concentration (cells/mL)



3.2.4.3 Plankton and Cyanotoxin Assessment

Phyto- and zooplankton samples taken on September 18, 2008, were evaluated for count and biovolume. Phytoplankton biovolume was dominated (66 percent) by the dinoflagellate *Ceratium hirundinella* (Exhibits 3.2-17 and 3.2-18). Approximately 32 percent of phytoplankton were cyanobacteria, comprising almost entirely two species known to produce toxins: *Aphanizomenon flos-aquae* and *Oscillatoria* spp. Although it is not possible to predict cyanotoxin production, the WHO moderate risk threshold is 100,000 cells/mL. The total cyanobacteria cell density was 92,000 cells/mL. A value this close to the moderate risk threshold is cause for concern. It is advisable to closely monitor cyanobacteria in 2009 to further assess potential risk to public health. An increase in the TKN and TN was also noted

EXHIBIT 3.2-17
Phytoplankton Density, September 18, 2008

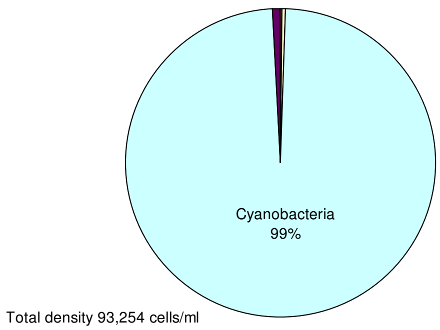


EXHIBIT 3.2-18
Dominate Phytoplankton by Genus or Species, September 18, 2008

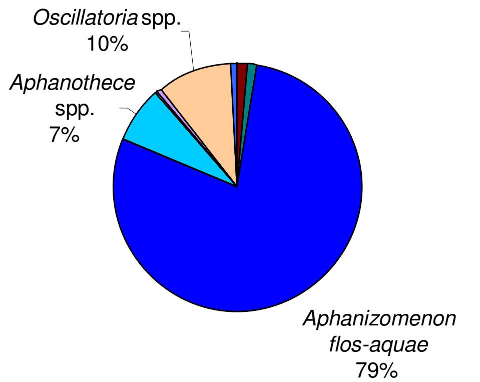


EXHIBIT 3.2-19
Zooplankton Density, September 18, 2008

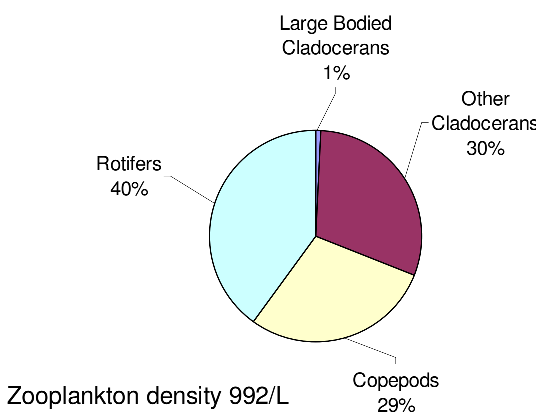
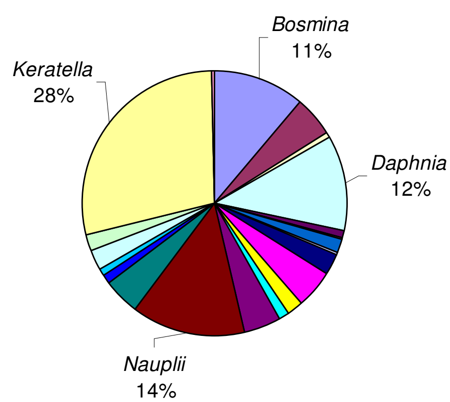


EXHIBIT 3.2-20
Dominate Zooplankton by Genus or Species, September 18, 2008.



Note: Nauplii are juvenile crustacean zooplankton.

during the phytoplankton sampling. A nitrogen-fixing cyanobacterium (*Aphanizomenon flos-aquae*) formed a substantial part of the algae biovolume, likely causing the noted increase.

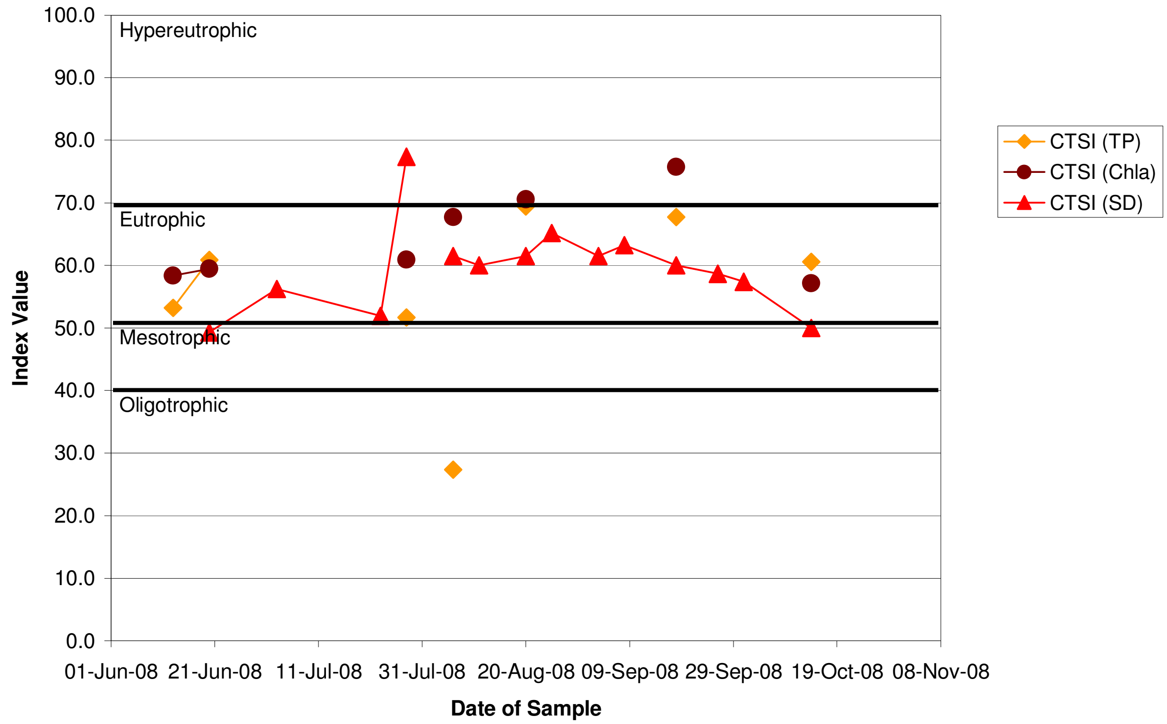
The zooplankton population was dominated by small-bodied organisms that can lead to algal growth (Exhibits 3.2-19 and 3.2-20). The absence of large-bodied Cladoceran zooplankton, is an important element in the conditions arising for an algae bloom.

3.2.5 Trophic Indices

3.2.5.1 Current

All three components of the CTSI show that Lotus Lake is eutrophic through most of the sampling season (Exhibit 3.2-21). The CTSI values for the Secchi disk depth (SD) indicate that the lake is mesotrophic at the beginning and end of the sampling season. In late summer, the CTSI values for chlorophyll *a* (Chla) peak at hypereutrophic levels. While there

EXHIBIT 3.2-21
Lotus Lake 2008 CTSI



are some differences in the trophic indices, they all follow the same pattern and indicate that the lake is eutrophic to hypereutrophic.

The Indiana Trophic Index for Lotus Lake as measured on September 18, 2008 was 37 out of 75, which classifies the lake as eutrophic. Appendix A contains the details of these calculations. The Indiana Trophic and Carlson Trophic indices both classify the lake as eutrophic to hypereutrophic.

3.2.5.2 Other Studies

The sediment oxygen demand of Lotus Lake was measured in 2008 as 3.74 g oxygen/m^2/day and is discussed in a separate report.

3.2.5.3 Historical Trends

Historical Secchi disk depths for July and August indicate variable transparency with no clear trend, according to the Kendall tau analysis (Appendix B) (Exhibits 3.2-22 and 3.2-23). This lack of a clear trend indicates variability of the lake ecology.

A Kendall tau test of the historic chlorophyll *a*, total phosphorus, or secchi disk data indicates that there is no significant trend to the data (Exhibit 3.2-24). In 1991 a decrease in TP was observed that was correlated by an improvement in secchi disk depth. At this point it is not known if this was a natural occurrence of the result an anthropological intervention.

Regardless of the cause of the improvements in 1991, by 1992 the lake was back to its previous eutrophic state.

EXHIBIT 3.2-22
Historical Secchi Disk Depth Averages in Lotus Lake for July and August

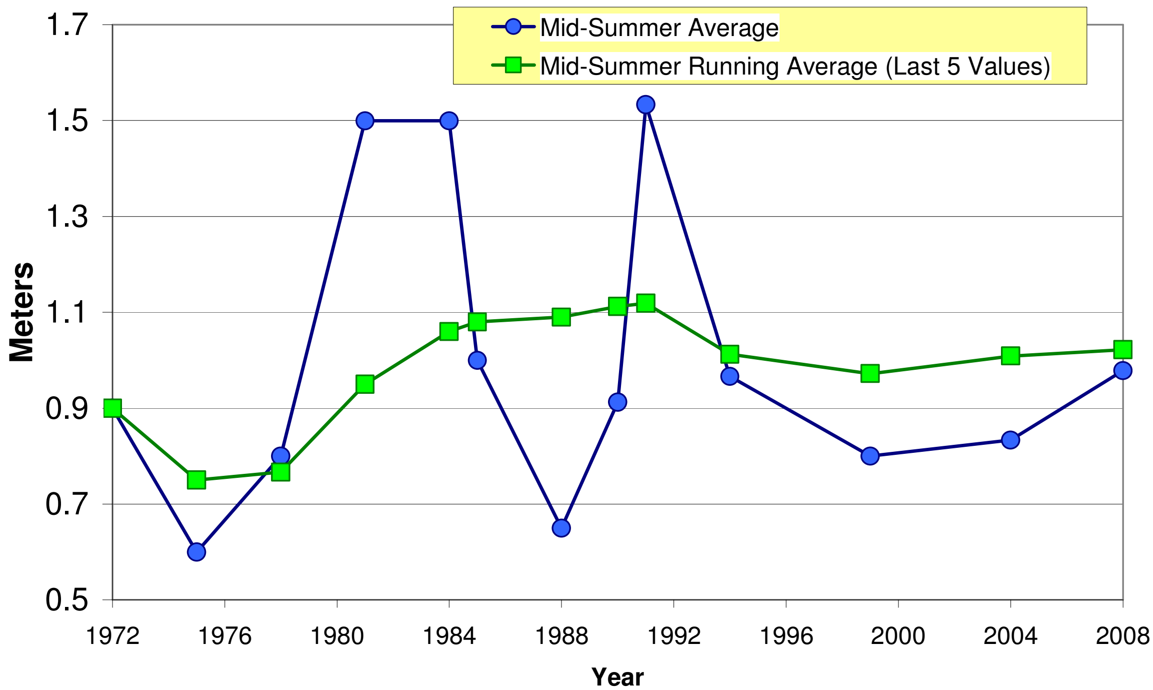
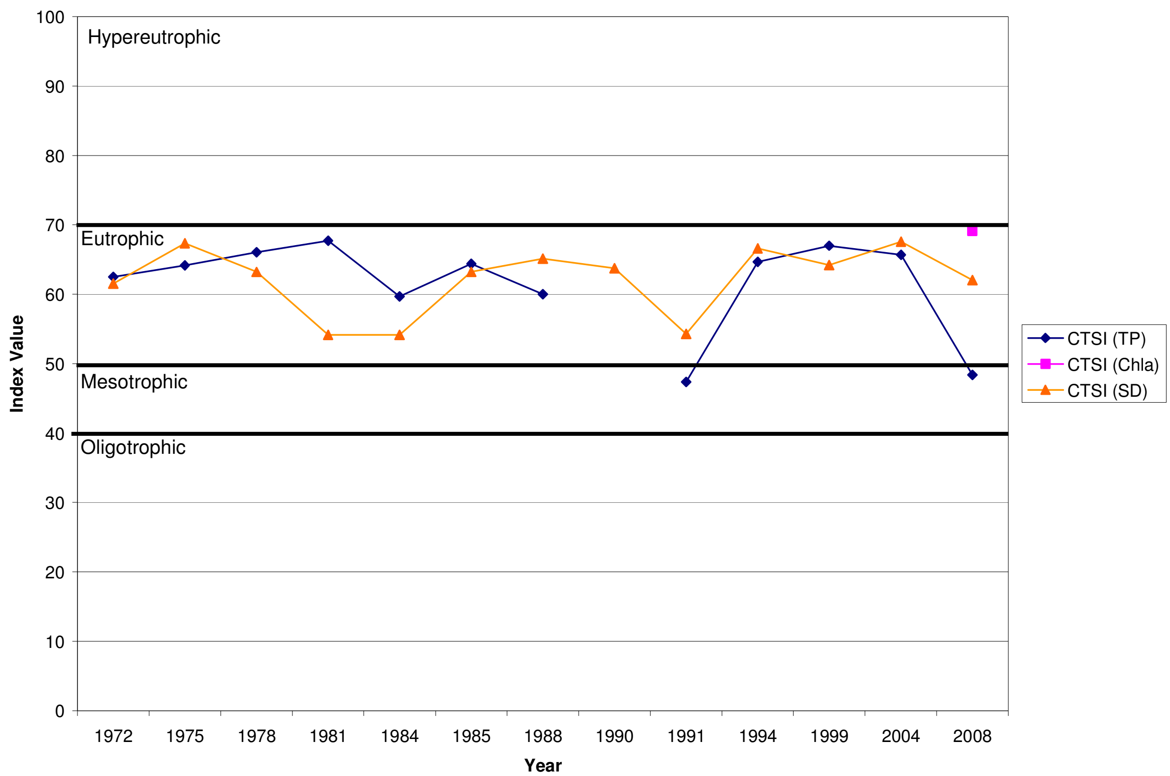


EXHIBIT 3.2-23
Results of Kendall Tau Test

Period	Parameter	2008 Median	Historical Median	Statement of Trend
July	TP (mg/L)	27	47	X
July	Chla (µg/L)	22		NA
July	SD (m)	1.3	1.3	X
August	TP (mg/L)	48.5	65	X
August	Chla (µg/L)	51.5		X
August	SD (m)	0.9	0.8	X
July–August	TP (mg/L)	27	62	X
July–August	Chla (µg/L)	44		X
July–August	SD (m)	0.9	0.8	X

X: H_0 cannot be rejected; i.e., there is insufficient evidence to prove a trend.
Y: H_0 is rejected; i.e., there is sufficient evidence to prove a trend
NA: Not applicable as the Kendall tau test could not be performed due to insufficient data.

EXHIBIT 3.2-24
Lotus Lake Historic CTSI – August Average



3.2.6 Conclusions

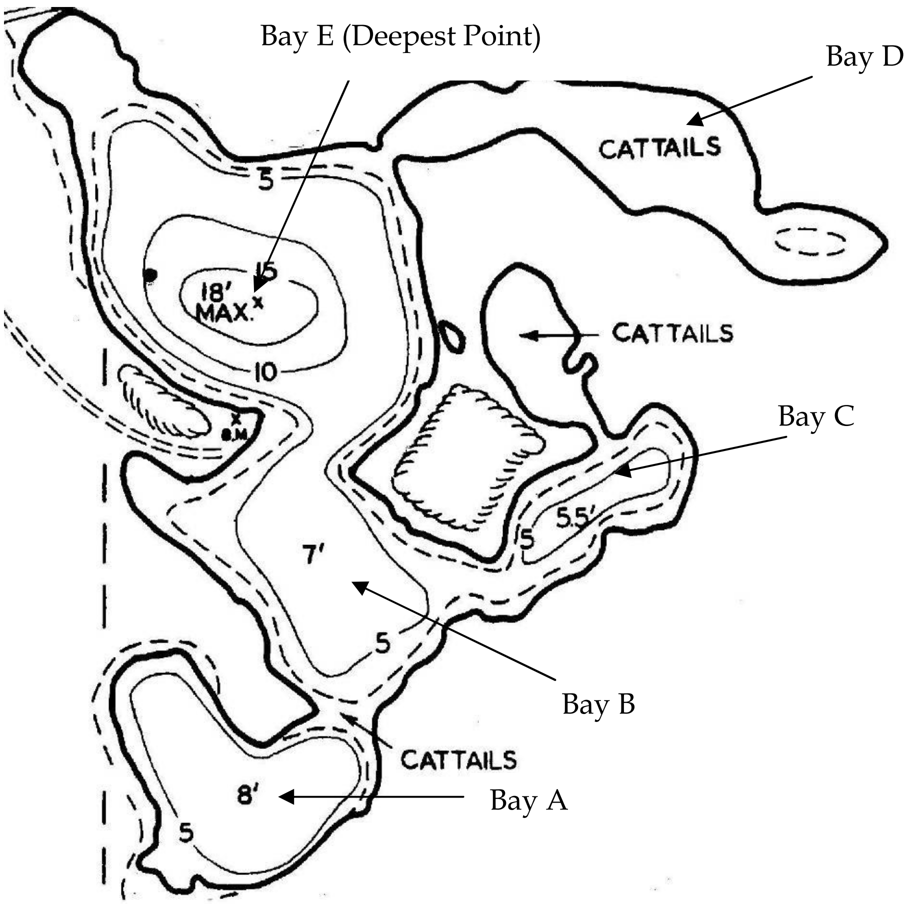
The results of the 2008 sampling season indicate that Lotus Lake is a dimictic weekly stratified eutrophic to hypereutrophic lake. The primary productivity of the lake is driven by the relative abundance of bio-available phosphorus. The lack of large bodied zooplankton to keep the algae concentration in balance allowed blooms of harmful cyanobacteria to develop. A significant source of phosphorus is internal loading from lake sediments.

3.3 Mitchell Lake

3.3.1 Introduction

In-situ water quality measurements were collected biweekly using the sonde, and water quality samples were collected monthly. Sonde measurements were taken at five locations on Mitchell Lake, and water quality samples were taken at Point E, the deepest point (Exhibit 3.3-1). Due to differing depths, fetch, and water residence times of Lake Mitchell's bays, water quality varied substantially from point to point. In Bay A (sampling point A), solar-powered mixing technology ("Solar Bees") to determine if local cyanobacteria concentrations would be suppressed by mixing of the epilimnion. The results of 2008's experiment with the Solar Bees is discussed below. Bay D's depth, vegetation (heavily dominated by *Ceratophyllum demersum* – coontail) , and position as the headwater for from coming the Round Lake watershed caused it to remain clear throughout the summer. Parts of Bay C dominated by *C. demersum* became clear half-way through the summer. Bays E, A, and B, however, had low Secchi disk depths and poor water quality throughout the sampling season.

EXHIBIT 3.3-1
Mitchell Lake 2008 Sampling Locations (Map from Minn. DNR)



Note: Bathymetry is outdated. Lake levels were raised about 3 feet after this survey was conducted. Cattail areas are now open water.

3.3.2 Point E (Deepest Point)

3.3.2.1 In-Situ Parameters

Dissolved Oxygen and Temperature. On August 6, the dissolved oxygen at the surface fell below 5 mg/L (4.72 at the surface, and 5.61 at 1 meter depth) (Exhibit 3.3-2). At all other dates in the sampling season, dissolved oxygen was at or above 8 mg/L.

The top 3.5 meters of the lake are well-mixed, as throughout the sampling period the temperature in the top layer stayed within 90 percent of the surface temperature (Exhibit 3.3-3). Below 3.5, the temperature decreased by 20 percent each meter toward the bottom of the lake. With the September 18, 2008, sampling date, temperatures stayed within 90 percent of the surface temperature down to 5 meters. Turnover occurred after the first week of September. Mitchell Lake at Point E (the deepest point) was stratified until the beginning of September, but the early September turnover showed that the thermal stratification is not strong.

Oxidation Reduction Potential. The ORP level in the bottom sediments was less than +200 mV throughout the sampling season (Exhibit 3.3-4). Values below +200 mV correspond approximately with dissolved oxygen concentrations less than 0.5 mg/L. Sulfate reduction, and accompanying sulfide production, appear to occur at ORP values of less than +100 mV. Higher TP and orthophosphate values at the bottom of the lake correspond with the low ORP values (less than +100 mV). Sulfate reducing conditions are significant, because sulfide will bind ferrous iron in insoluble ferrous sulfide complexes. Although ferrous iron [Fe(II)] is soluble and will not bind phosphorus, once ferrous iron diffuses to the mesolimnion where there are positive dissolved oxygen concentrations it oxidizes to ferric iron [Fe(III)]. Once oxidized to ferric iron it can bind orthophosphate. However, sequestration of ferrous iron in insoluble sulfide compounds greatly diminishes the iron pool and thus allows more release of orthophosphate by diffusion into the epilimnion where it increases algae growth. This effect may be seen in the increase of chlorophyll *a* concentrations. Temperature effects can be ruled out. Epilimnetic temperatures were constant or decreasing during the increase and sustained plateau of chlorophyll a concentrations, and during sustained growth of phycocyanin concentrations.

EXHIBIT 3.3-2
Mitchell Lake Point E Dissolved Oxygen 2008 Isopleth (mg/L)

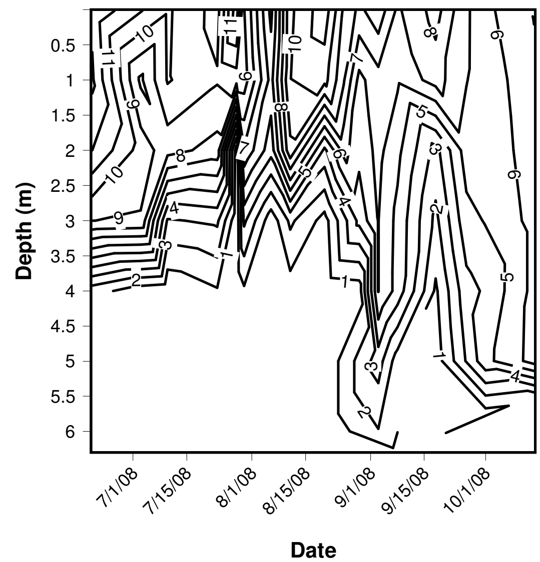


EXHIBIT 3.3-3
Mitchell Lake Point E Temperature 2008 Isopleth (°C)

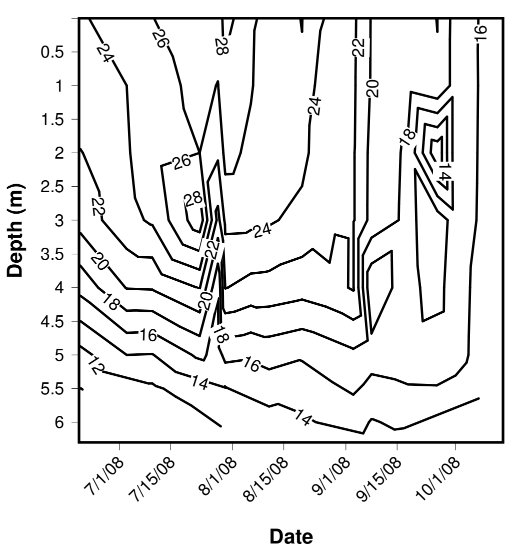
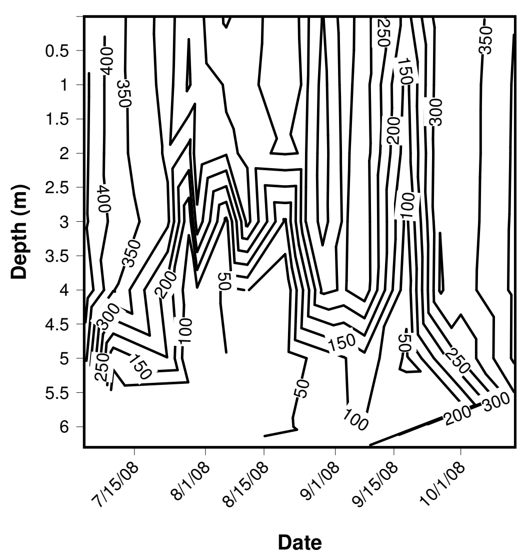


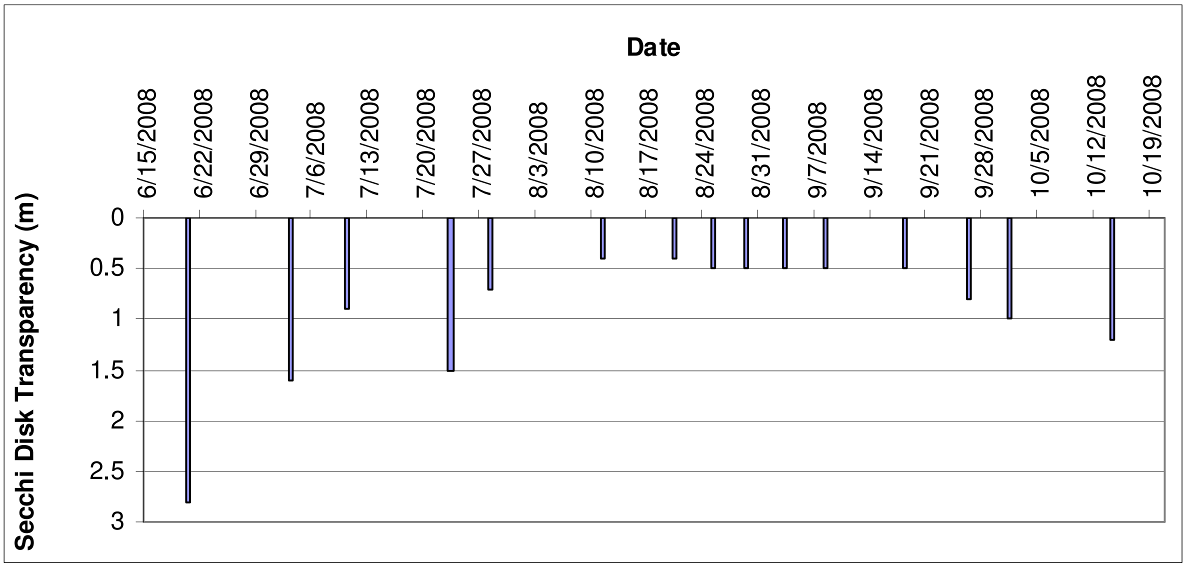
EXHIBIT 3.3-4
Mitchell Lake Point E ORP 2008 Isopleth (mV)



Between mid-June and the end of August, ORP fell below +200 mV between 2.5 meters and the bottom of the lake. During the lake's turnover, ORP also fell below +200 mV throughout the water column.

Water Clarity.
Secchi Disk. Secchi disk depths are 0.5 meter or less during late summer (Exhibit 3.3-5). The cause of the turbidity is intense algae blooms as would be expected in a hypereutrophic lake.

EXHIBIT 3.3-5
Mitchell Lake Point E 2008 Secchi Disk Data



Photosynthetic Active Radiation. The euphotic zone as measured by PAR extends down to 4 meters in the early summer, decreases to 2 meters by August, and then increases to 3 meters at the end of the season (Exhibit 3.3-6).

pH. High surface pH values (greater than 9.0) at Point E are characteristic of hypereutrophic conditions (Exhibit 3.3-7). Intense photosynthesis by algae population is responsible for the high pH values. Fish stress can occur when pH increases above 9.0–9.3, so the periods of high pH could have been a significant source of stress for fish in Mitchell Lake.

In early August, pH becomes less of an issue. Another use of pH is as an indicator for photosynthesis; an increase in pH is related to an increase in photosynthesis. The increase in pH in mid-September is well correlated to the increase in chlorophyll *a* and phycocyanin concentration.

Conductivity. Conductivity increased in the water column on the July 23, 2008 sampling date (Exhibit 3.3-8). Otherwise conductivity follows the typical pattern of being lower near the surface than in the deeper waters, as would be expected in a well stratified lake.

3.3.2.2 Nutrients—Point E

Phosphorus Species. The TP measurements show the highest values at the bottom of the lake throughout the sampling season, indicating that internal phosphorus loading is significant to the lake phosphorus budget (Exhibits 3.3-9 and 3.3-11).

EXHIBIT 3.3-6
Mitchell Lake Point E Percent Incident Light Penetration 2008 Isopleth

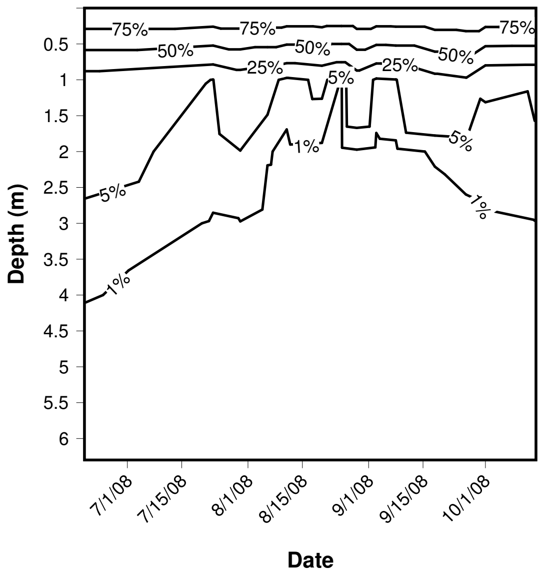


EXHIBIT 3.3-7
Mitchell lake Point E pH 2008 Isopleth

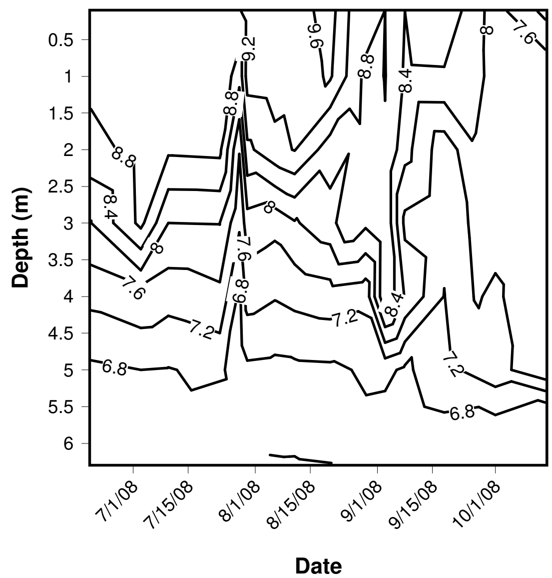


EXHIBIT 3.3-10
Mitchell Lake Point E 2008 Orthophosphate Concentrations as Function of Oxidation Reduction Potential

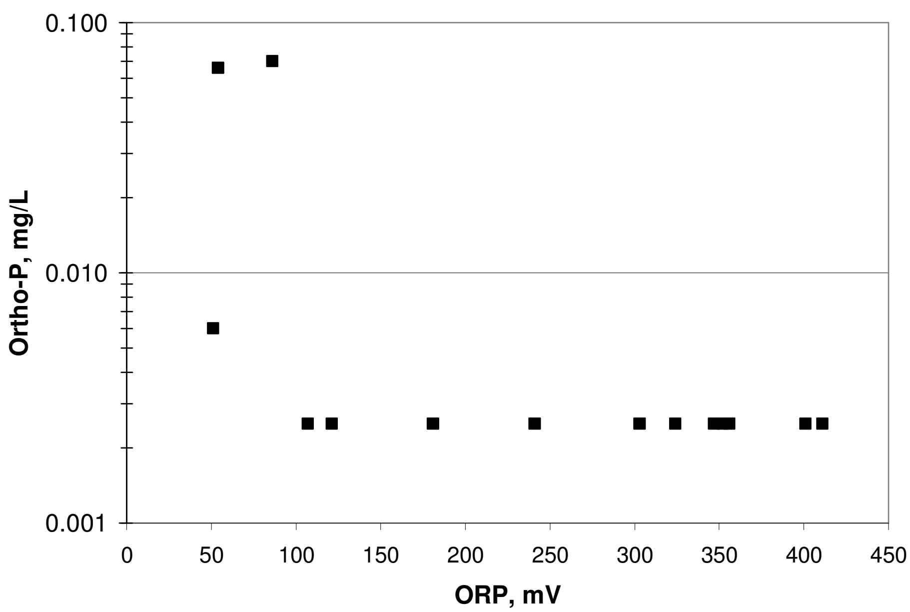


EXHIBIT 3.3-11
Mitchell Lake Point E 2008 Orthophosphate Isopleth (mg/L)

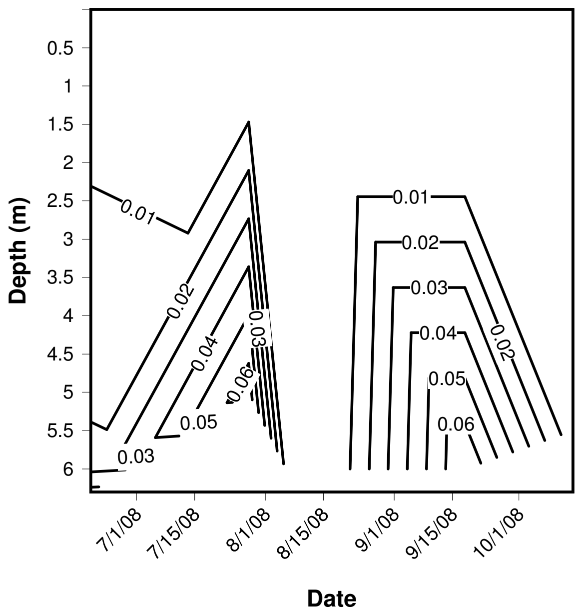
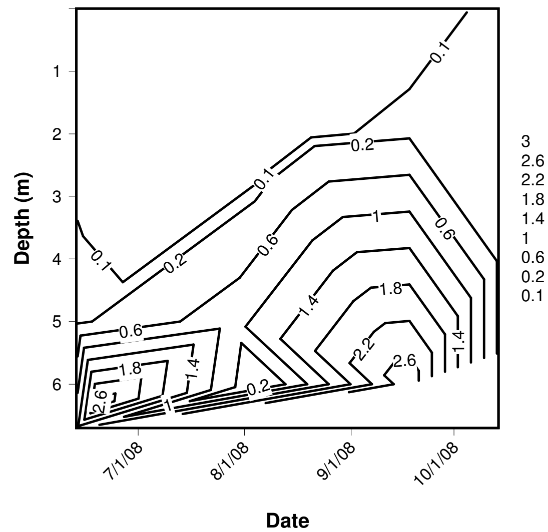


EXHIBIT 3.3-12
Mitchell Lake 2008 Ammonia Isopleth (mg/L)



The orthophosphate samples indicate most of the portion of the total phosphorus samples immediately available for algae uptake. Orthophosphate samples were below the detection limit for all samples except for the bottom measurements, and all measurements taken on June 20. When the results are considered in relation to elevated chlorophyll *a* concentrations, it is clear that algae assimilation is responsible for the low concentrations.

Both the TP and orthophosphate isopleths show that phosphorus is being released from the lake sediments. The OPR of the water at the bottom of the lake was below +200 mV from July until September (Exhibit 3.3-10). Values of ORP less than +200 mV in the lake system represent a threshold at which ferric iron (Fe[III]) is reduced to ferrous iron (Fe[II]). Phosphorus is bound by Fe(III) but not Fe(II). Release of phosphorus from sediments is thus a direct result of low ORP values. Limited data suggest that significant release of soluble phosphorus only begins at ORP values less than +100 mV, probably as result of iron sequestration in the sediments by insoluble sulfide bonds.

Nitrogen Species. The ammonia concentrations were highest at the bottom of Mitchell Lake, indicating that the internal nitrogen loading is significant to the lake nitrogen budget (Exhibit 3.3-12). Ammonia is primarily a product of protein breakdown (hydrolysis) in the sediments; some may also be from reduction of nitrate, although nitrate is low. The concentration of ammonia decreases in the lake from sediment to surface according to a typical concentration gradient due to diffusion. Ammonia could also be affected by algae uptake in the euphotic zone and nitrification in the aerobic zone. Total ammonia concentrations at associated pH and temperature values set un-ionized ammonia below the 0.02 mg/L threshold value, above which it is considered to cause acute stress in fish.

The nitrite concentration is the lake was never detected above the analytical detection limit throughout the sampling season. Nitrate was measured above the detection limit only once, on June 13 at a depth of 5 meters. The lack of nitrite and nitrate in the lake is an indication of rapid assimilation of ammonia by algae and nitrification and denitrification within the water column.

TKN concentrations peaked at the bottom depths in the lake, with its highest measurements occurring on June 20 and September 18 (Exhibit 3.3-13). However, on August 6, there was a significant rise in TKN concentration at the surface, which corresponds to a low dissolved oxygen event that occurred on that date where the dissolved oxygen at the surface dropped below 5 mg/L.

The June 13 sampling event shows a minimal concentration gradient that is likely due to the week thermal stratification that was also observed on that day.

The total nitrogen samples from Lake Mitchell show the same pattern as the TKN and ammonia samples (Exhibit 3.3-14). The most significant loading of nitrogen is internal, but an event was recorded on the August 6 sampling date where water quality was poor throughout the water column.

EXHIBIT 3.3-13
Mitchell Lake 2008 Point E TKN Isopleth (mg/L)

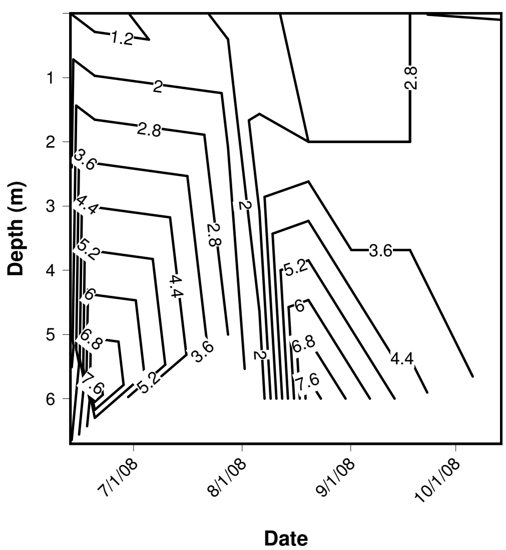
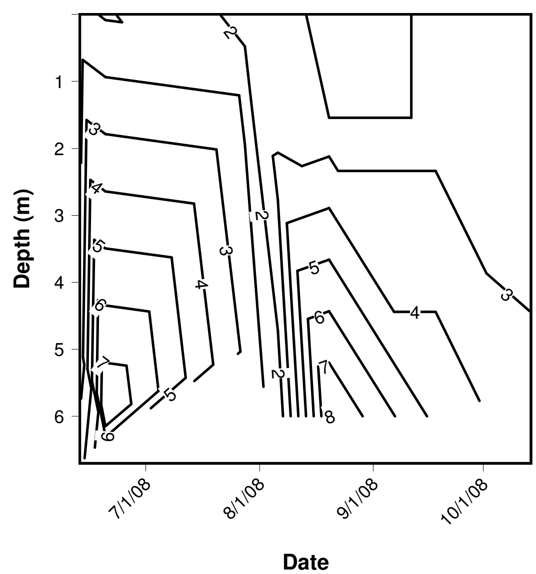


EXHIBIT 3.3-14
Mitchell Lake Point E 2008 Total Nitrogen Isopleth (mg/L)



3.3.2.3 Biological Parameters —Point E

Chlorophyll *a*. The chlorophyll *a* measurements at the surface of Mitchell Lake followed the classic rise and fall curve as the lake temperature rose through June and peaked in August (Exhibit 3.3-15). The highest chlorophyll *a* measurement was taken in late August, and the high concentration above 100 μg/L puts the lake into the hypereutrophic Carlson trophic status index.

Phycocyanin. Phycocyanin measurements peaked during the warmest part of the summer (Exhibit 3.3-16). The mid-September phycocyanin sample was corroborated with an algae enumeration and biovolume determination to be indicative of a cyanobacteria bloom. The phycocyanin measurements indicate that the lake exceeds the WHO low risk threshold for the complete sampling season. In August and September, phycocyanin levels surpassed a threshold of 8,000 cells/mL, which corresponds to the WHO moderate risk threshold of 100,000 cells/mL. Dermal contact at concentrations above this level represent a moderate risk zone for exposure to cyanotoxin.

EXHIBIT 3.3-15
Mitchell Lake Point E Chlorophyll *a* Surface Concentration (µg/L)

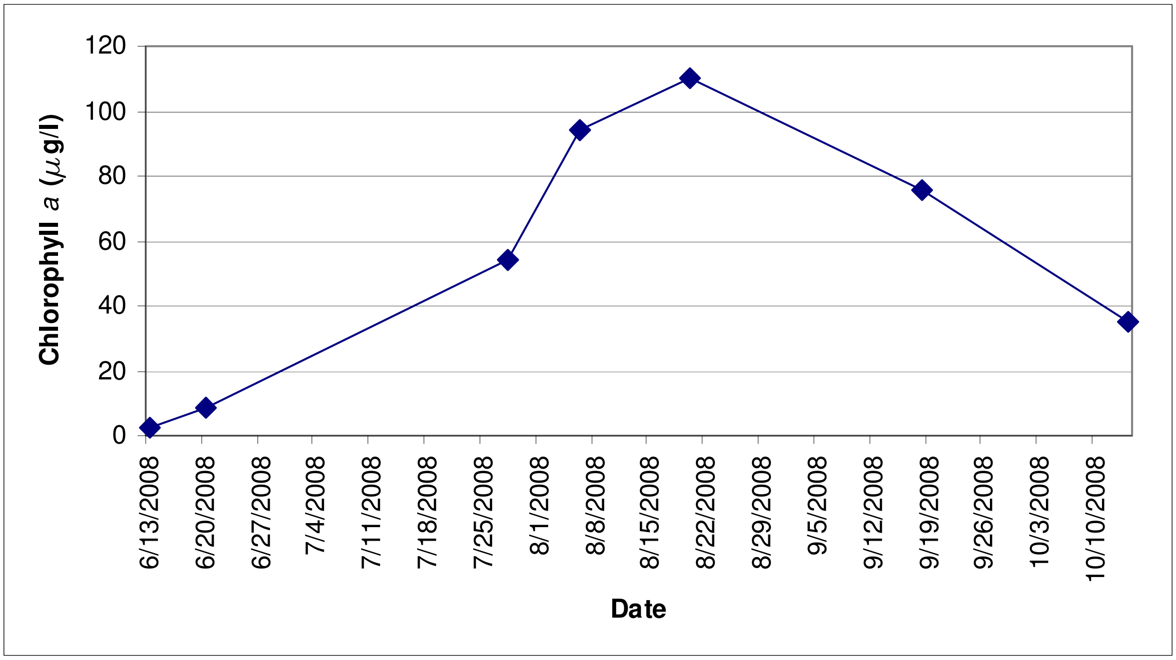
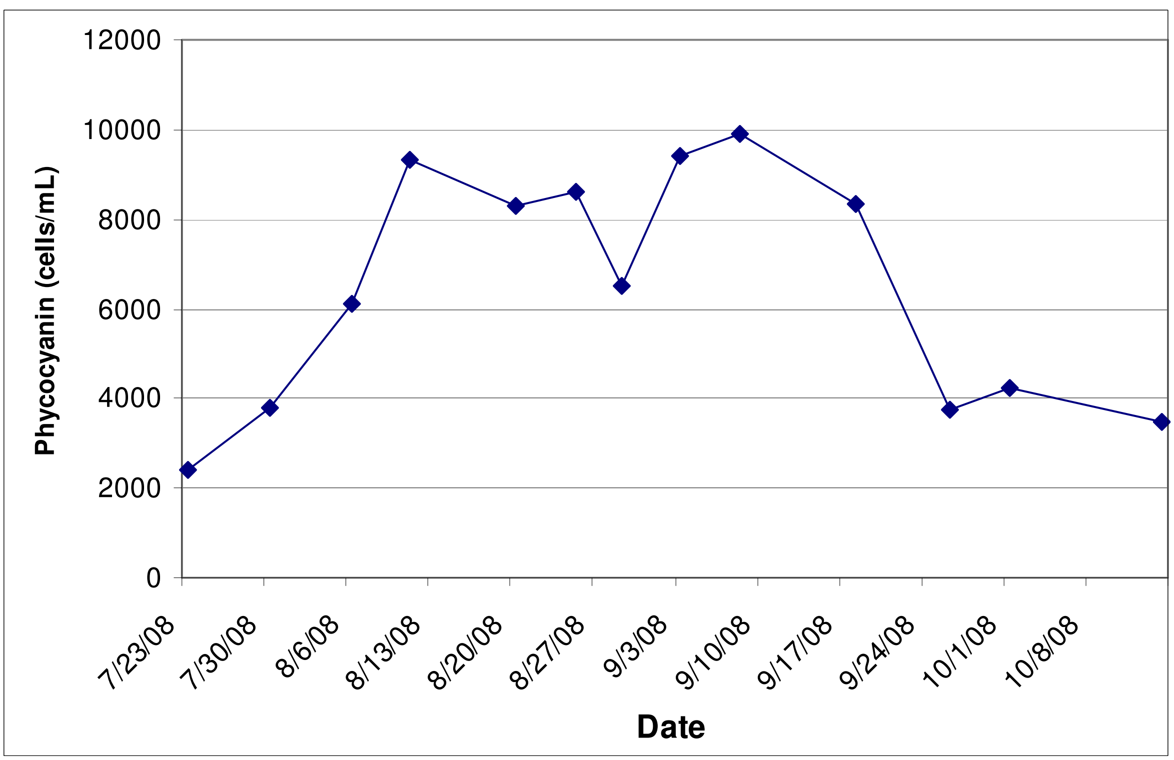


EXHIBIT 3.3-16
Mitchell Lake Point E Phycocyanin 2008 Surface Concentration (cells/mL)



The phycocyanin surface concentration follow the same pattern that was observed in the chlorophyll *a* lab samples. The cyanobacteria population begins to increase in August and peaks in early September. This surface bloom causes a spike in the dissolved oxygen at the surface of the lake and is also correlated with the decrease in the transparency of the water as measured by the Secchi disk depth.

Plankton. Phyto- and zooplankton samples were taken on August 29 and September 18, 2008, and evaluated for count and biovolume. Phytoplankton biovolume was dominated by cyanobacteria on both sampling dates, comprising nearly entirely by *Aphanizomenon flos-aquae,* a species known to produce toxins (Exhibits 3.3-17 and 3.3-18). Although it is not possible to predict cyanotoxin production, the WHO moderate risk threshold is 100,000 cells/mL. The total cyanobacteria cell density was 90,000 cells/mL on the August 29, 2008 sampling date. A value this close to the moderate risk threshold is cause for concern. It is advisable to closely monitor cyanobacteria in 2009 to further assess potential risk to public health.

EXHIBIT 3.3-17
Phytoplankton Density, August 29, 2008 (A) and September 18, 2008 (B)

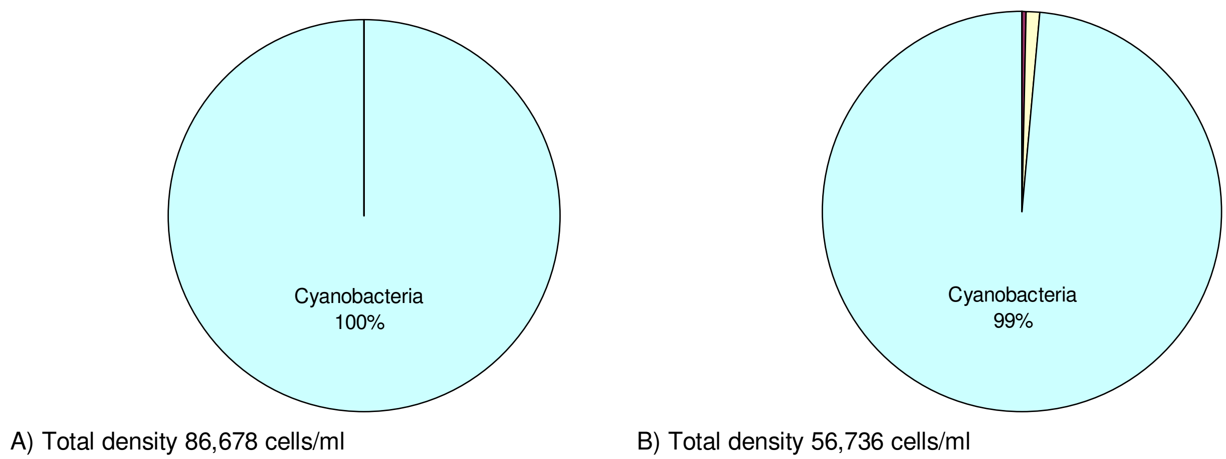
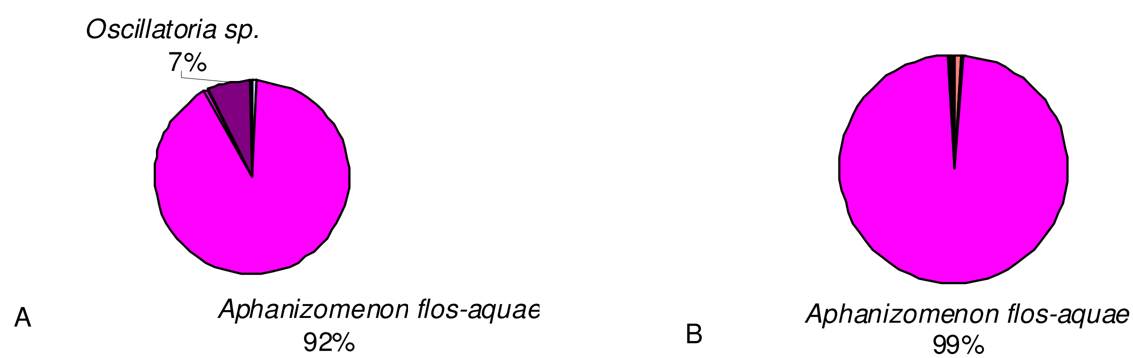


EXHIBIT 3.3-18
Dominant phytoplankton by genus or species, August 29, 2008 (A) and September 18, 2008 (B)



On the September 18 sampling event, an algae bloom of dinoflagellates and cyanobacteria was observed that caused the increase in the TKN and TN. A nitrogen-fixing species (*Aphanizomenon flos-aquae*) formed a substantial part of the algae biovolume.

The zooplankton population on the sampling dates contained a large percentage of small crustaceans that can lead to algal growth (Exhibit 3.3-19 and 3.3-20). Cladoceran zooplankton, including Daphnia, is an important element in the conditions arising for an algae bloom, were present in greater numbers on September 18 than on the August 29 sampling date.

EXHIBIT 3.3-19
Mitchell Lake Point E Zooplankton Density, August 29 and September 18, 2008

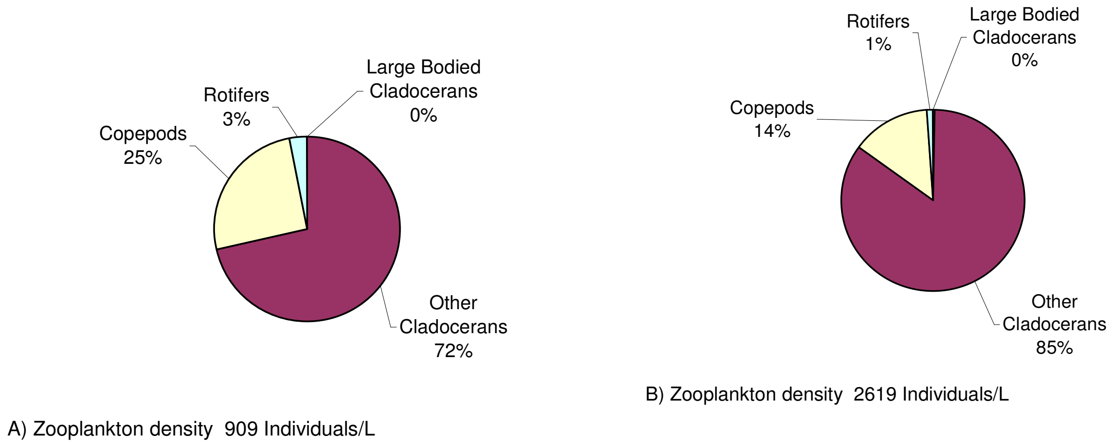
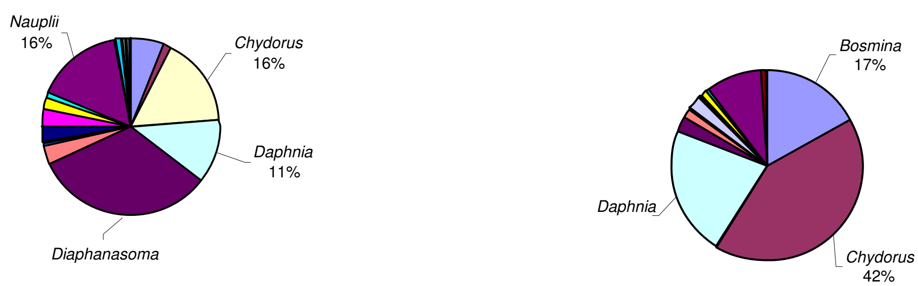


EXHIBIT 3.3-20
Mitchell Lake Point E Zooplankton Density, August 29 and September 18, 2008



3.3.2.4 Trophic Indices—Point E

Current. All three components of the CTSI show that Mitchell Lake at Point E is eutrophic through most of the sampling season. The CTSI values for the Secchi disk depth (SD) indicate that the lake is mesotrophic at the beginning and end of the sampling season (Exhibit 3.3-21). In late summer the CTSI values for chlorophyll *a* (Chla) peak at hypereutrophic levels. While there are some differences in the trophic indices, they all follow the same pattern and indicate that the lake is eutrophic to hypereutrophic.

The Indiana Trophic State Index for Mitchell Lake as measured on September 18, 2008, was 32 of 75, which classifies the lake as eutrophic. Appendix A contains the details of these calculations. The Indiana Trophic State Index and the CTSI both classify the lake as eutrophic to hypereutrophic.

The sediment oxygen demand of Mitchell Lake was measured in 2008 and is reported in is discussed in a separate technical memorandum.

Other Studies. The sediment oxygen demand of Mitchell Lake was measured in 2008 as 3.12 g oxygen/m^2/day and is discussed in a separate report.

Historic Trends. Historical Secchi disk depths for July and August indicate variable transparency with no clear trend, according to the Kendall tau analysis (Appendix B) (Exhibit 3.3-22). The lack of a clear trend indicates variability of the lake ecology.

EXHIBIT 3.3-21
Mitchell Lake Point E 2008 CTSI

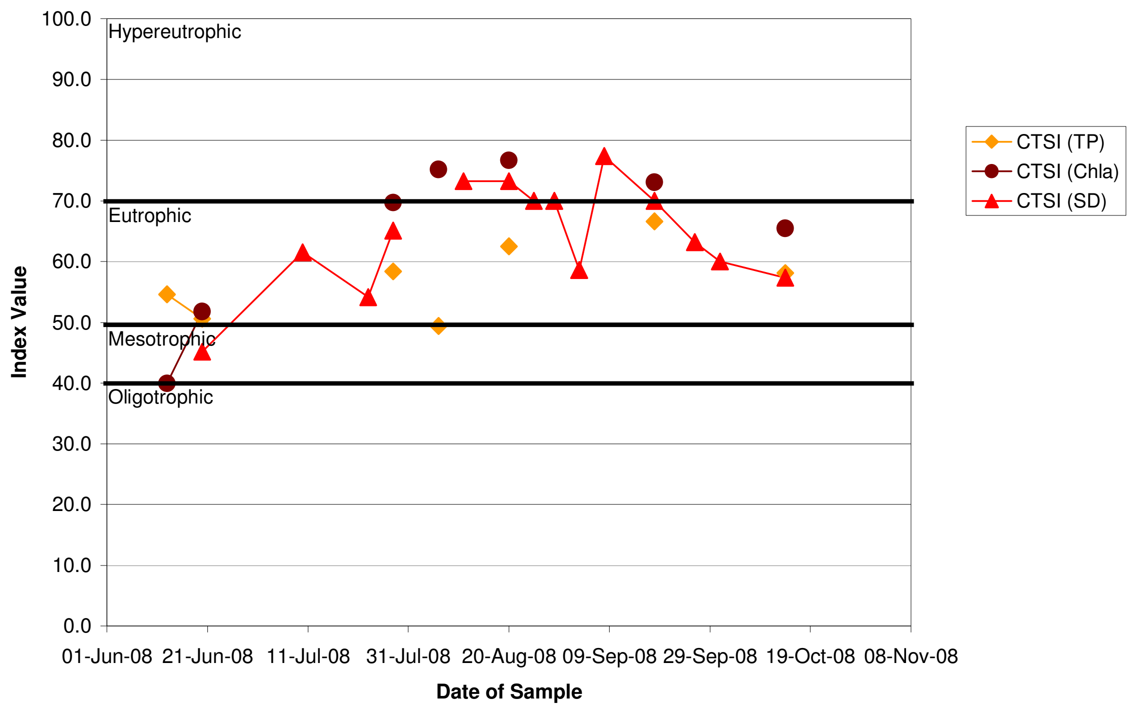
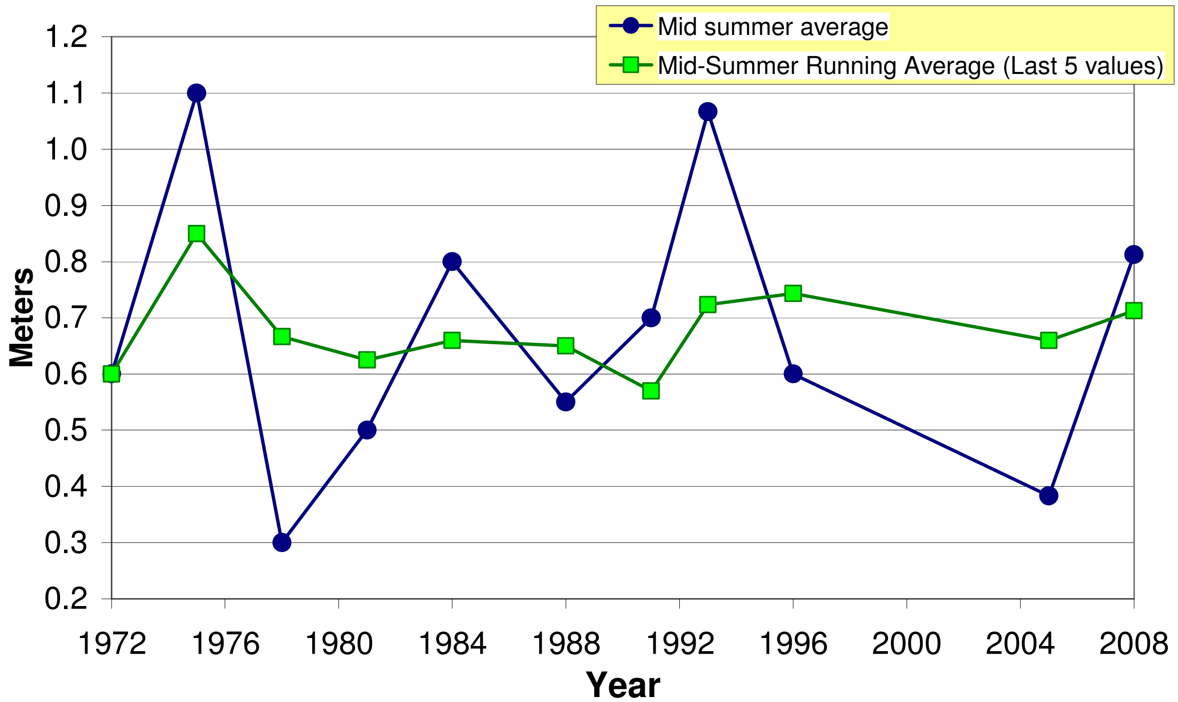
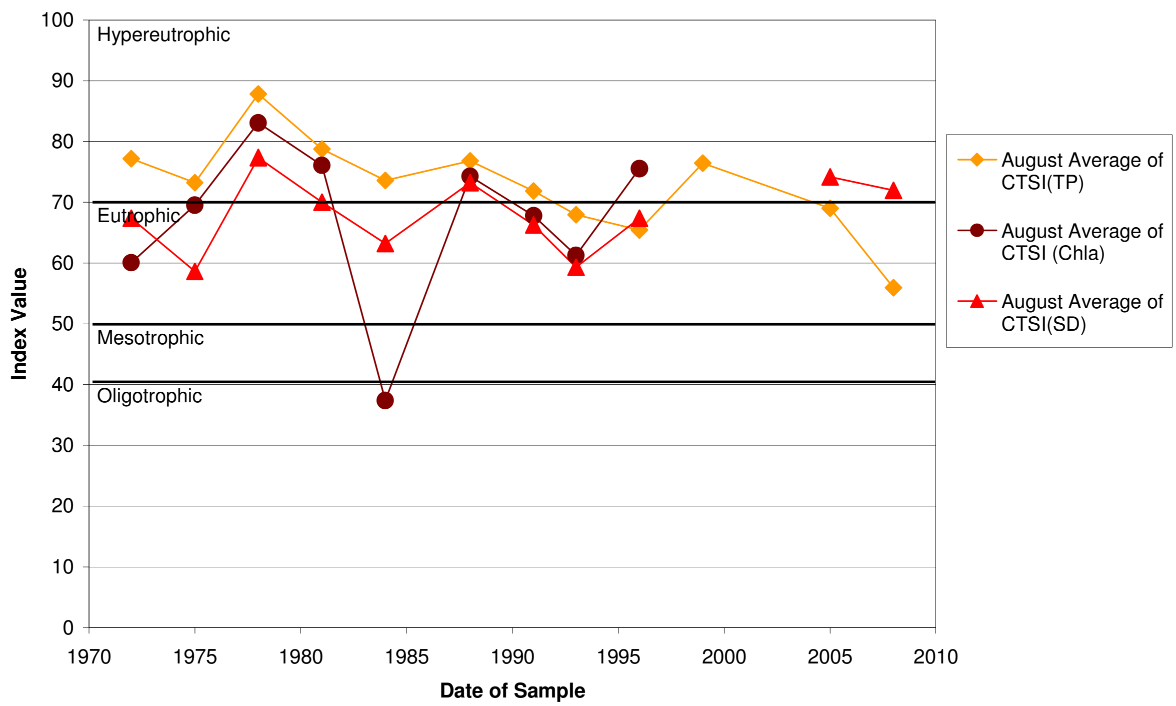


EXHIBIT 3.3-22
Historical Secchi Disk Depth Averages for July and August



Historical CTSI values have remained relatively constant during the reporting period (Exhibit 3.3-23). Furthermore the Kendall tau test indicates that there is no significant trend to the historic chlorophyll *a*, total phosphorus, or Secchi disk data.

EXHIBIT 3.3-23
Mitchell Lake Point E Historic CTSI



3.3.2.5 Conclusions—Point E

The results of the 2008 sampling season indicate that Mitchell Lake is a dimictic, weakly stratified eutrophic to hypereutrophic lake. The primary productivity of the lake is driven by the relative abundance of labile phosphorus. The lack of large bodied zooplankton to keep the algae concentration in balance allowed blooms of harmful cyanobacteria to develop. One of the sources of phosphorus release is the lake sediments. The high sediment oxygen demand (3.12 g oxygen/m^2/day) of the lake means that phosphorus is released as ferric iron is reduced to ferrous iron.

3.3.3 Point A (Bay with Solar Bee Installation)

3.3.3.1 Introduction

In-situ water quality measurements were collected biweekly using the sonde. Two Solar Bees were installed in Mitchell Lake at Point A. The machines are solar-powered mixing devices that mixed the epilimnion as a potential means of suppressing cyanobacteria formation.

3.3.3.2 In-Situ Parameters—Point A

Dissolved Oxygen and Temperature. On August 6, the dissolved oxygen at the surface fell below 6 mg/L (Exhibits 3.3-24 and 3.3-25). On that date, the dissolved oxygen concentration at Point B and Point E also fell below 6 mg/L at the surface. On August 29, the dissolved

EXHIBIT 3.3-24
Mitchell Lake Point A Dissolved Oxygen 2008 Isopleth (mg/L)

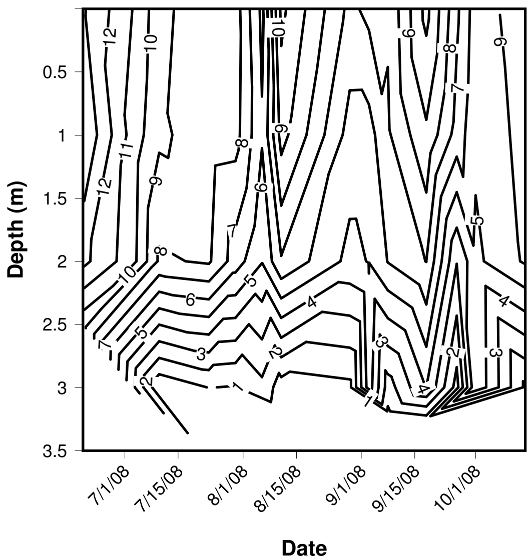
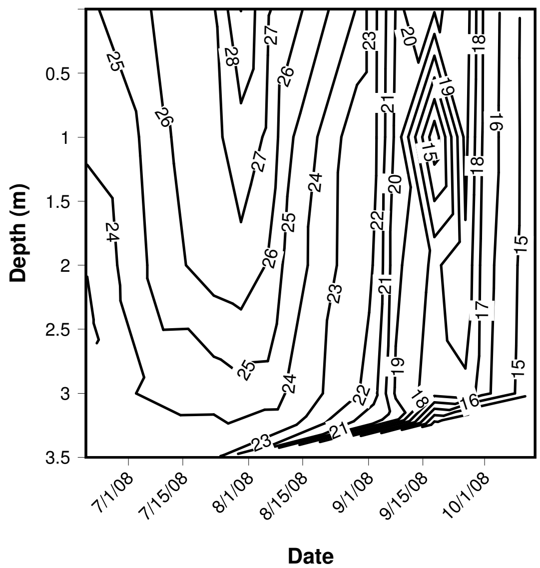


EXHIBIT 3.3-25
Mitchell Lake Point A Temperature 2008 Isopleth (°C)

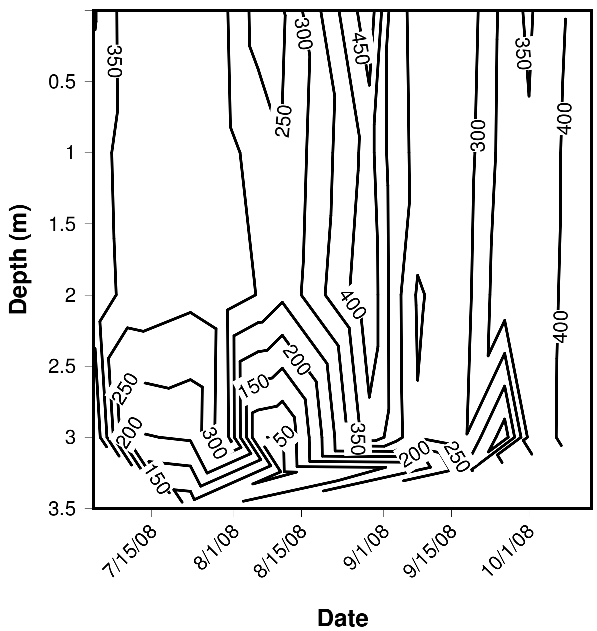


oxygen at the surface dipped below 6.75 mg/L. At all other dates in the sampling season, the dissolved oxygen was at or above 8 mg/L. Mitchell Lake is not strongly stratified at Point A. Turnover occurred in the beginning of September. Point A is weakly stratified and shallow.

Oxidation Reduction Potential. ORP was consistently low near the bottom of the lake throughout the sampling season (Exhibit 3.3-26). Between mid-June and the end of August, ORP fell below +200 mV between 3 meters and the bottom of the lake.

EXHIBIT 3.3-26

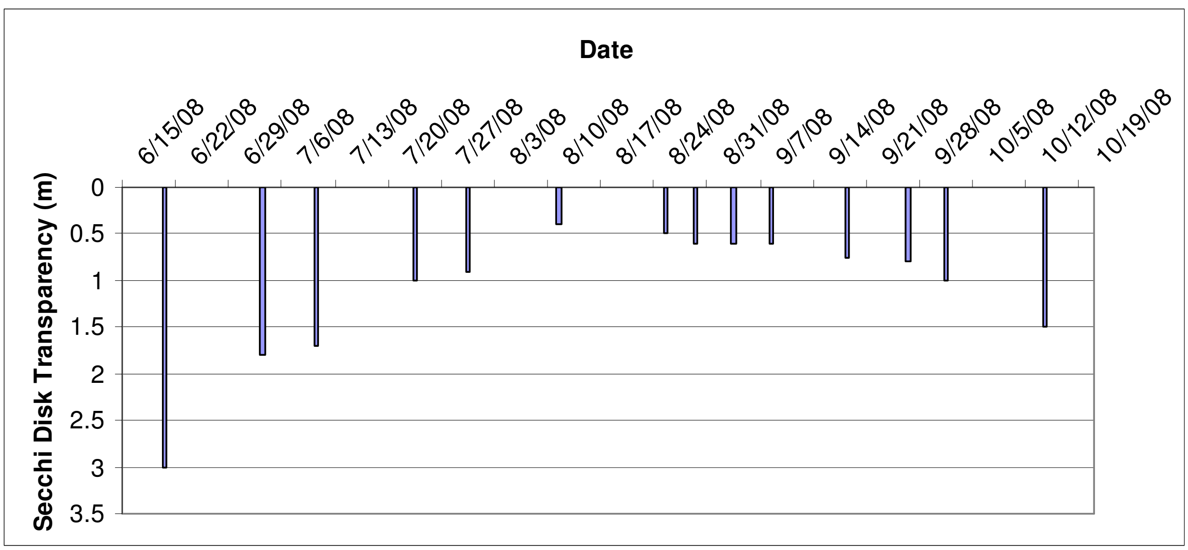
Mitchell Lake Point A ORP 2008 Isopleth (mV)



Water Clarity.

Secchi Disk. Secchi disk depths are 0.5 meters or less throughout the summer (Exhibit 3.3-27). The cause of turbidity is intense algae blooms, as would be expected in a hypereutrophic lake.

EXHIBIT 3.3-27
Mitchell Lake Point A 2008 Secchi Disk Data



Photosynthetic Active Radiation. The euphotic zone, as measured by PAR, was markedly decreased on the August 6, 2008, sampling date and also during turnover at the beginning of September (Exhibit 3.3-28).

pH. High surface pH values (greater than 9.0) at Point A are characteristic of hypereutrophic conditions (Exhibit 3.3-29). Intense photosynthesis by algae population is responsible for the high pH values. Fish stress can occur when pH increases above 9.0–9.3, so the periods of high pH could have been a significant source of stress for fish in Mitchell Lake. On August 6, the pH plot shows the evidence of an algae bloom, supported by the low dissolved oxygen values. In early August, pH becomes less of an issue. Another use of pH is as an indicator for photosynthesis; an increase in pH is related to an increase in photosynthesis. The increase in pH in mid September is well correlated to the increase in chlorophyll *a* and phycocyanin concentration.

EXHIBIT 3.3-28
Mitchell Lake Point A Percent Incident Light Penetration 2008 Isopleth

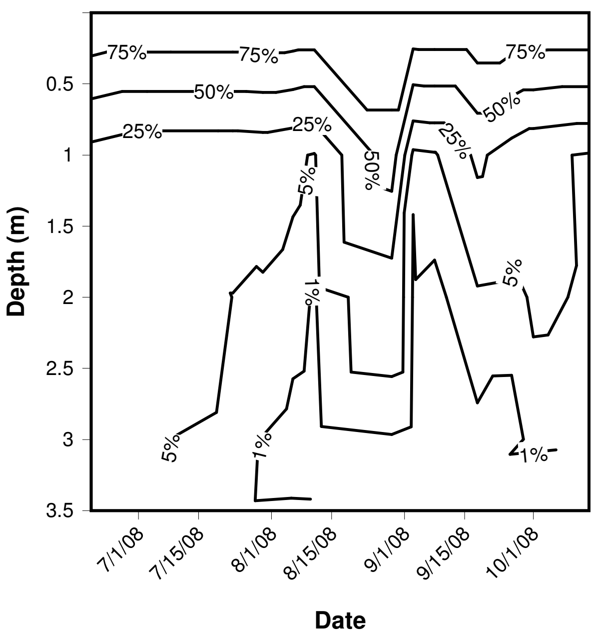


EXHIBIT 3.3-29
Mitchell Lake Point A pH 2008 Isopleth

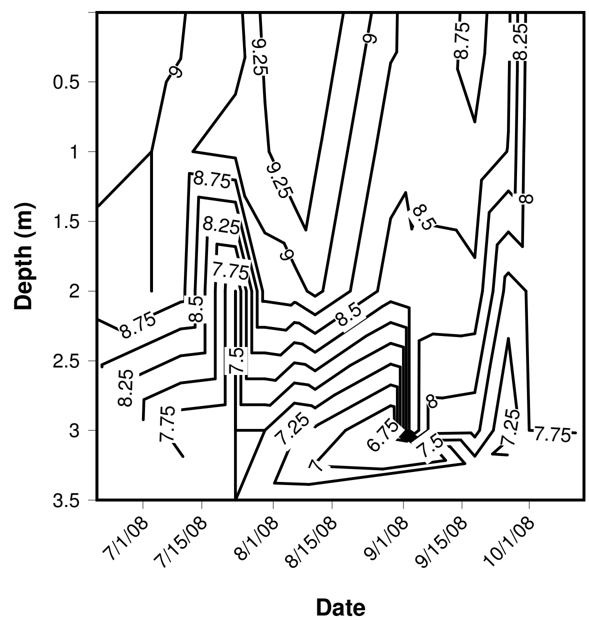
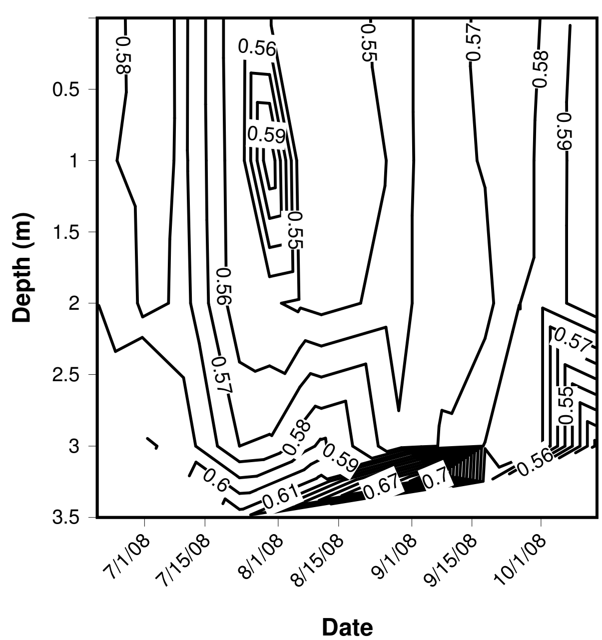


EXHIBIT 3.3-30
Mitchell Lake Point A Conductivity 2008 Isopleth

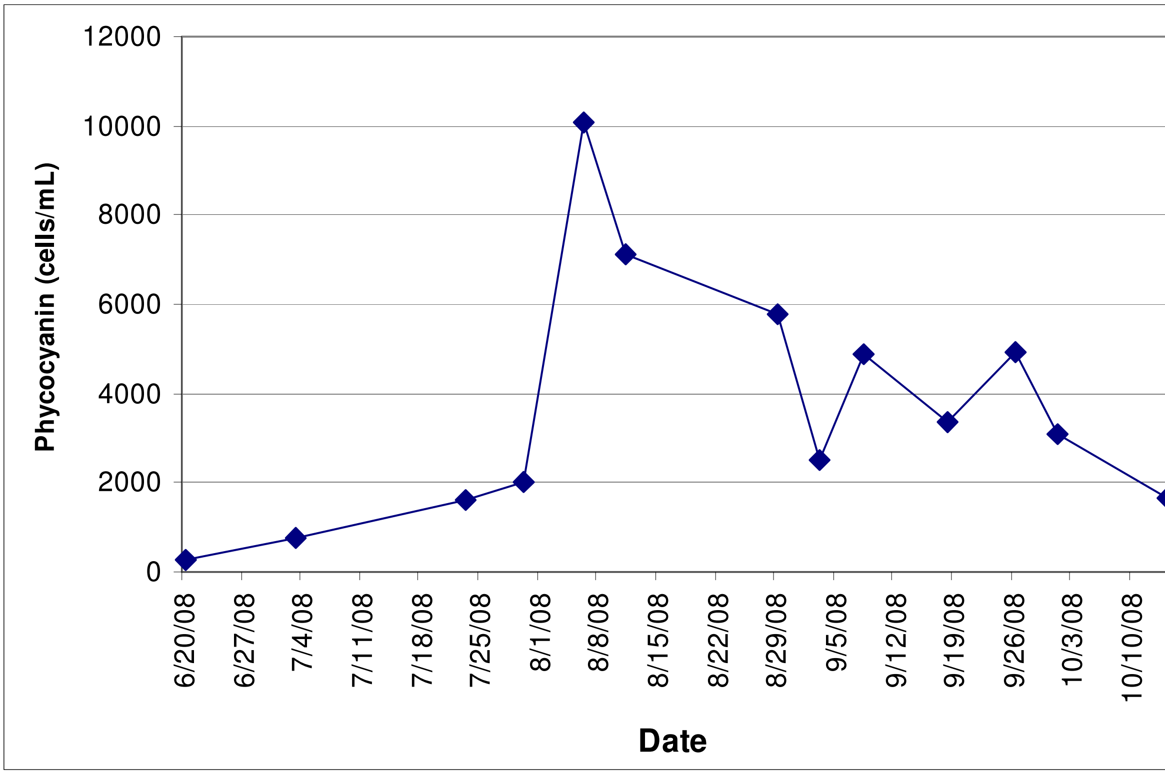


Conductivity. Conductivity was consistent throughout the sampling season, showing a minimal concentration gradient (Exhibit 3.3-30).

3.3.3.3 Biological Parameters—Point A

Phycocyanin. Phycocyanin measurements peaked during the warmest part of the summer (Exhibit 3.3-31). The mid-September phycocyanin

EXHIBIT 3.3-31
Mitchell Lake Point A Phycocyanin 2008 Surface Concentration (cells/mL)



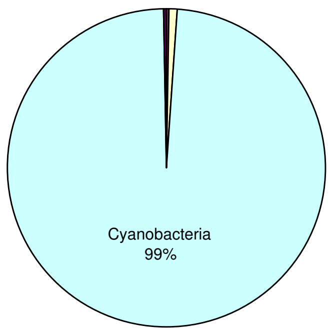
sample was correlated with an algae enumeration and biovolume determination to be indicative of a cyanobacteria bloom. The phycocyanin measurements indicate that the lake is at minimum in the WHO low risk category (1,000 to 8,000 cells/mL of phycocyanin) from June 23 to the end of the sampling season. On August 6, phycocyanin levels reached 10,000 cells/mL, well surpassing the WHO threshold of 9,000 cells/mL for dermal contact. Concentrations above this level represent a moderate risk zone for exposure to cyanotoxin.

The phycocyanin and surface concentration follow the same pattern that was observed in the dissolved oxygen concentrations—highest during the warmest part of the summer.

There was no statistically significant difference between the phycocyanin concentrations in Point A and Point B (p = 0.23). Virtually the same statistic (p = 0.25) was true for cyanobacteria concentrations between Points A and B. Therefore the SolarBee units were not effective in suppressing cyanobacteria. Surface velocity transects measured radially outward from SolarBees revealed that velocity attenuated to less than 0.001 m/s at 20 meters. Clearly, the mixing intensity was insufficient to suppress cyanobacteria.

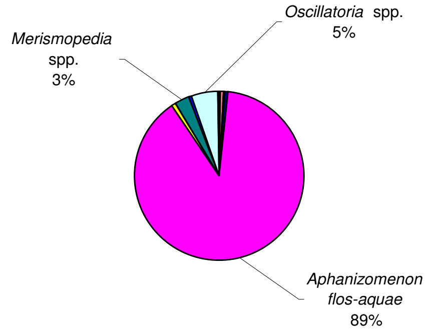
Plankton. Phyto- and zooplankton samples were taken on August 29, 2008, and evaluated for count and biovolume. Phytoplankton biovolume was dominated by cyanobacteria, comprising nearly entirely *Aphanizomenon flos-aquae,* a species known to produce toxins, (Exhibits 3.3-32 and 3.3-33). It is advisable to closely monitor cyanobacteria in 2009 to further assess potential risk to public health.

EXHIBIT 3.3-32
Mitchell Lake Point A Phytoplankton Density, August 29, 2008



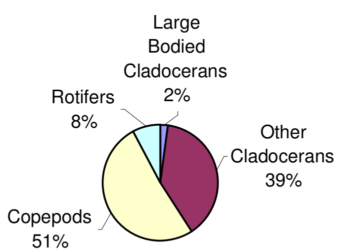
Total density 73,403 cells/ml

EXHIBIT 3.3-33
Mitchell Lake Point A Dominant Phytoplankton by Genus or Species, August 29, 2008



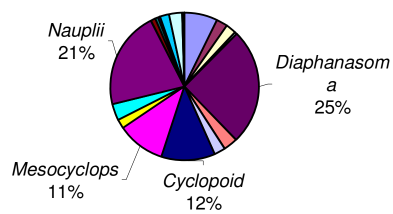
The zooplankton population was dominated by small-bodied organisms that can lead to algal growth (Exhibits 3.3-34 and 3.3-35). The absence of large-bodied Cladoceran zooplankton, is an important element in the conditions arising for an algae bloom.

EXHIBIT 3.3-34
Mitchell Lake Point A Zooplankton Density, August 29, 2008



Zooplankton density 327 Individuals/L

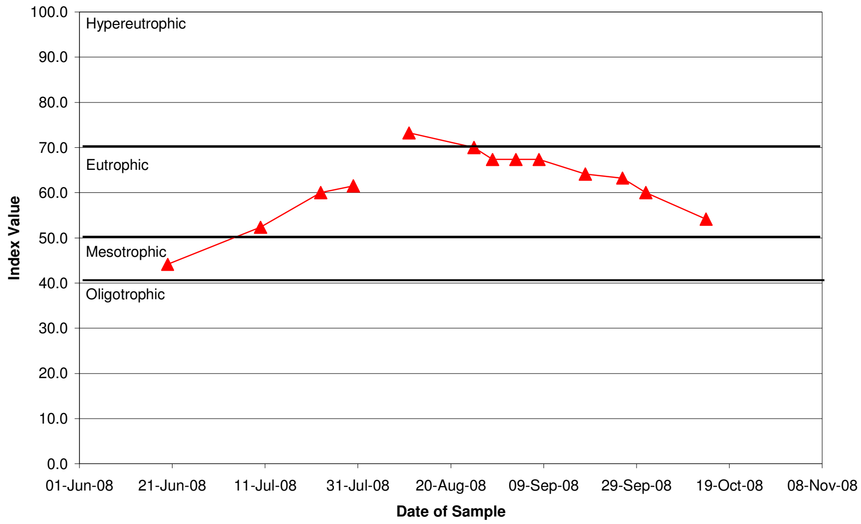
EXHIBIT 3.3-35
Mitchell Lake Point A Dominate Phytoplankton by Genus or Species, August 29, 2008



3.3.3.4 Trophic Indices—Point A

Current. The Secchi disk depth (SD) component of the CTSI was the only component able to be calculated from the data collected in 2008. The $CTSI_{SD}$ values show that Mitchell Lake at Point A is eutrophic throughout most of the sampling season, rising to hypereutrophic at the peak of summer temperatures, but mesotrophic in early summer (Exhibit 3.3-36).

EXHIBIT 3.3-36
Mitchell Lake Point A 2008 CTSI (SD)



3.3.3.5 Conclusions—Point A

The results of the 2008 sampling season indicate that Mitchell Lake at Point A experienced similar conditions to Point E, where water quality was poor. The Solar Bee technology did not prevent the cyanobacteria bloom on August 6, which also occurred at Points E and B. Similar to Point E, Point A samples reflect a dimictic, weakly stratified eutrophic to hypereutrophic lake. The primary productivity of the lake is driven by the relative abundance of bio-available phosphorus. The lack of large bodied zooplankton to keep the algae concentration in balance allowed blooms of harmful cyanobacteria to develop. One of the sources of phosphorus release is the lake sediments. The high sediment oxygen demand (3.12 g oxygen/m^2/day) of the lake means that phosphorus is released as ferric iron is reduced to ferrous iron.

3.3.4 Point B

3.3.4.1 Introduction

In-situ water quality measurements were collected biweekly using the sonde. Mitchell Lake at Point B is located between Point A, where the Solar Bees were installed, and Point E, the deepest point in the lake. Bay B is dominated by Eurasian milfoil, an invasive plant. Point B is weakly stratified and shallow.

3.3.4.2 In-Situ Parameters—Point B

Dissolved Oxygen and Temperature. Dissolved oxygen at the surface remained generally in the supersaturated range except for the sampling date at the end of August (Exhibits 3.3-37 and 3.3-38). Dissolved oxygen levels are low below 2 meters. Mitchell Lake is not strongly stratified at Point B. Turnover occurred in the beginning of September.

EXHIBIT 3.3-37
Mitchell Lake Point B Dissolved Oxygen 2008 Isopleth (mg/L)

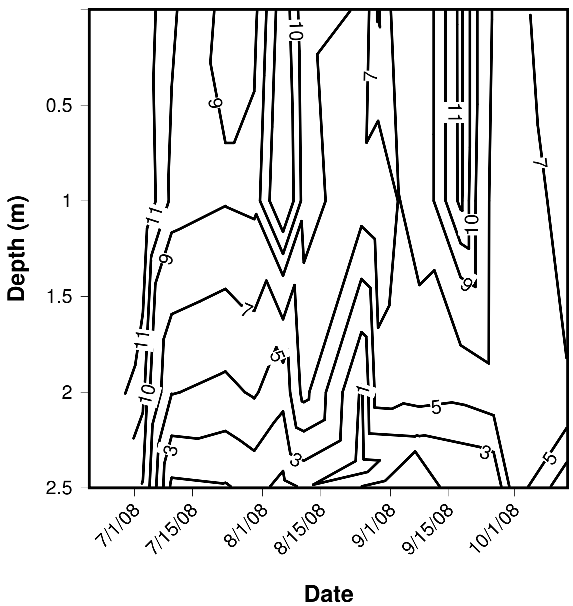
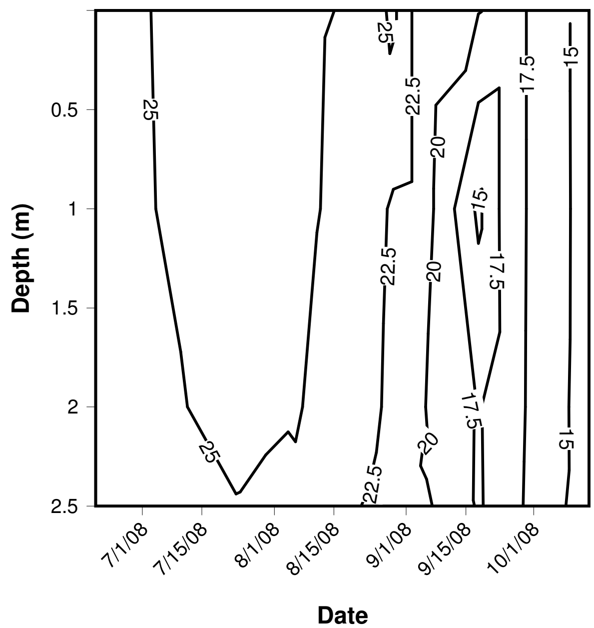


EXHIBIT 3.3-38
Mitchell Lake Point B Temperature 2008 Isopleth (°C)



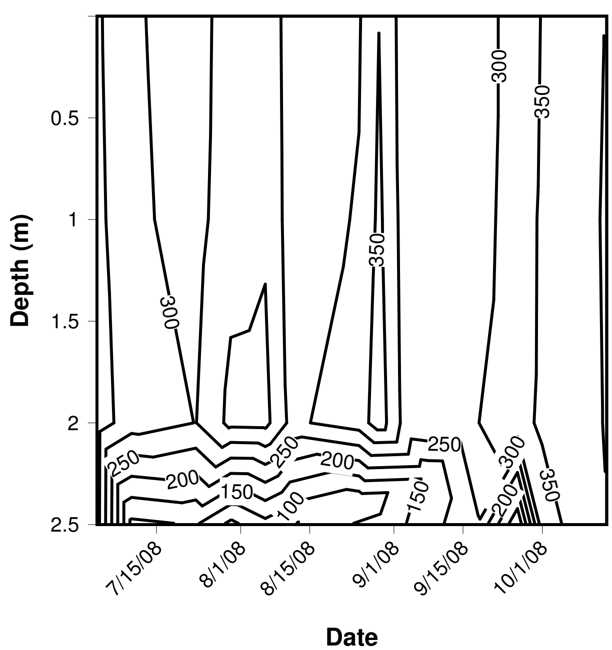
Oxidation Reduction Potential. ORP was consistently low near the bottom of the lake throughout the sampling season (Exhibit 3.3-39). ORP was +200 mV from June through late September below 2.0 meters.

Water Clarity.

Secchi Disk. Secchi disk depths are 0.5 meter or less throughout the hottest part of the summer (Exhibit 3.3-40). The cause of turbidity is intense algae blooms, as would be expected in a hypereutrophic lake.

Photosynthetic Active Radiation. The euphotic zone, as measured by PAR, extends through the entire water column or to just above the sediment for the complete sampling season (Exhibit 3.3-41).

EXHIBIT 3.3-39
Mitchell Lake Point B ORP 2008 Isopleth (mV)



pH. High surface pH values (greater than 9.0) at Point B are characteristic of hypereutrophic conditions. Intense photosynthesis by algae population is responsible for the high pH values (Exhibit 3.3-42).

EXHIBIT 3.3-40
Mitchell Lake Point B 2008 Secchi Disk Data

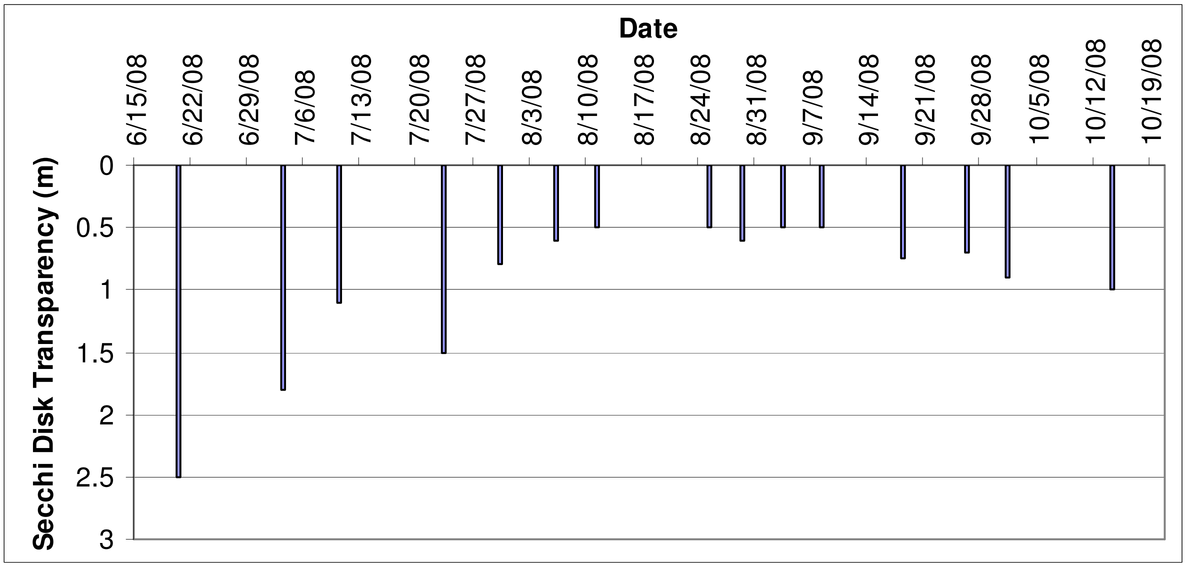


EXHIBIT 3.3-41
Mitchell Lake Point B Percent Incident Light Penetration 2008 Isopleth

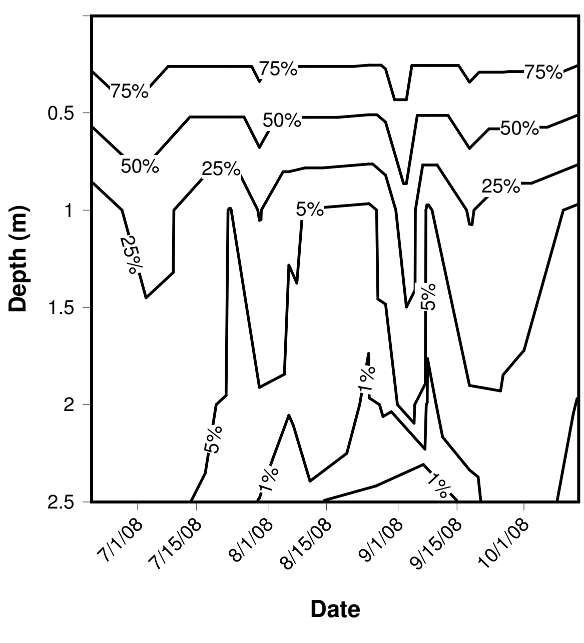
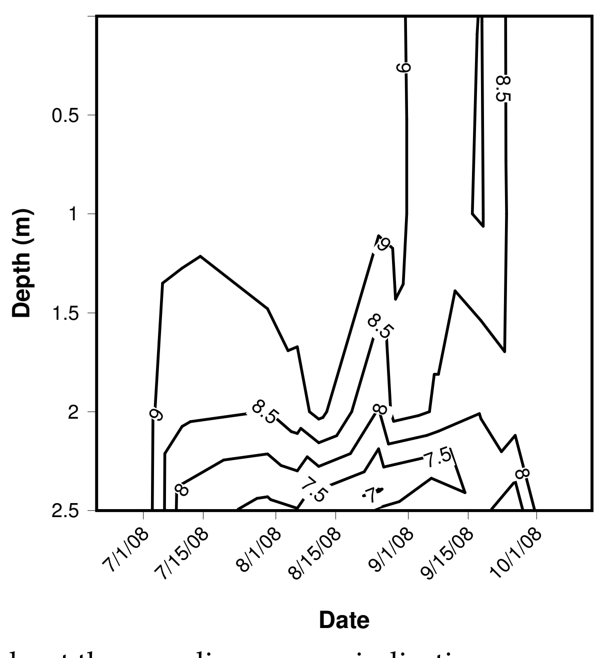


EXHIBIT 3.3-42
Mitchell Lake Point B pH 2008 Isopleth



Conductivity. Conductivity was consistent throughout the sampling season, indicating a minimal concentration gradient (Exhibit 3.3-43). It was lowest in mid-July.

3.3.4.3 Biological Parameters—Point B

Phycocyanin. Phycocyanin measurements were highest during August and September (Exhibit 3.3-44). The mid-September phycocyanin sample as well as an algae enumeration and biovolume determination were indicative of a cyanobacteria bloom. The phycocyanin measurements indicate that the lake is in the WHO low risk category (1,000 to 8,000 cells/mL of phycocyanin) for nearly the complete sampling season. On September 18, phycocyanin levels reached 8,000 cells/mL; the WHO threshold for dermal contact corresponding with moderate risk zone for exposure to cyanotoxin.

EXHIBIT 3.3-43
Mitchell Lake Point B Conductivity 2008 Isopleth

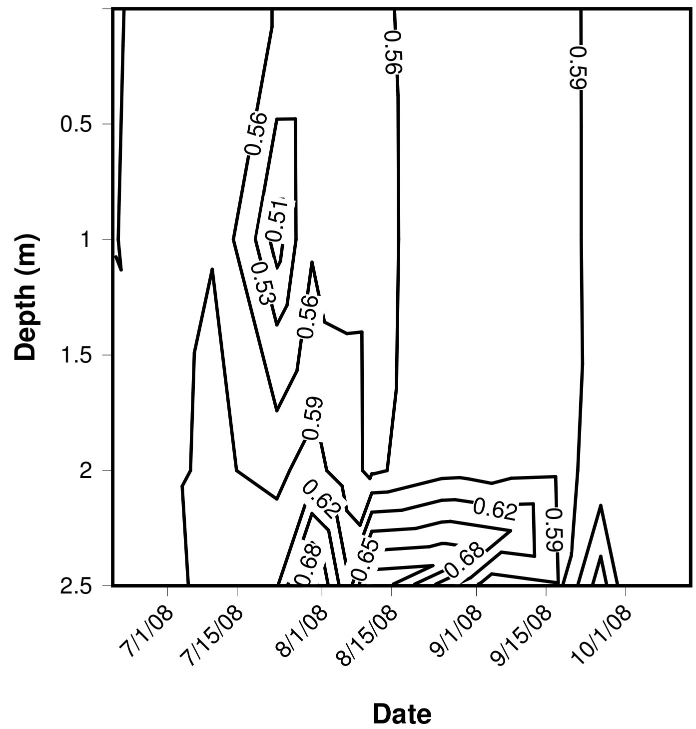
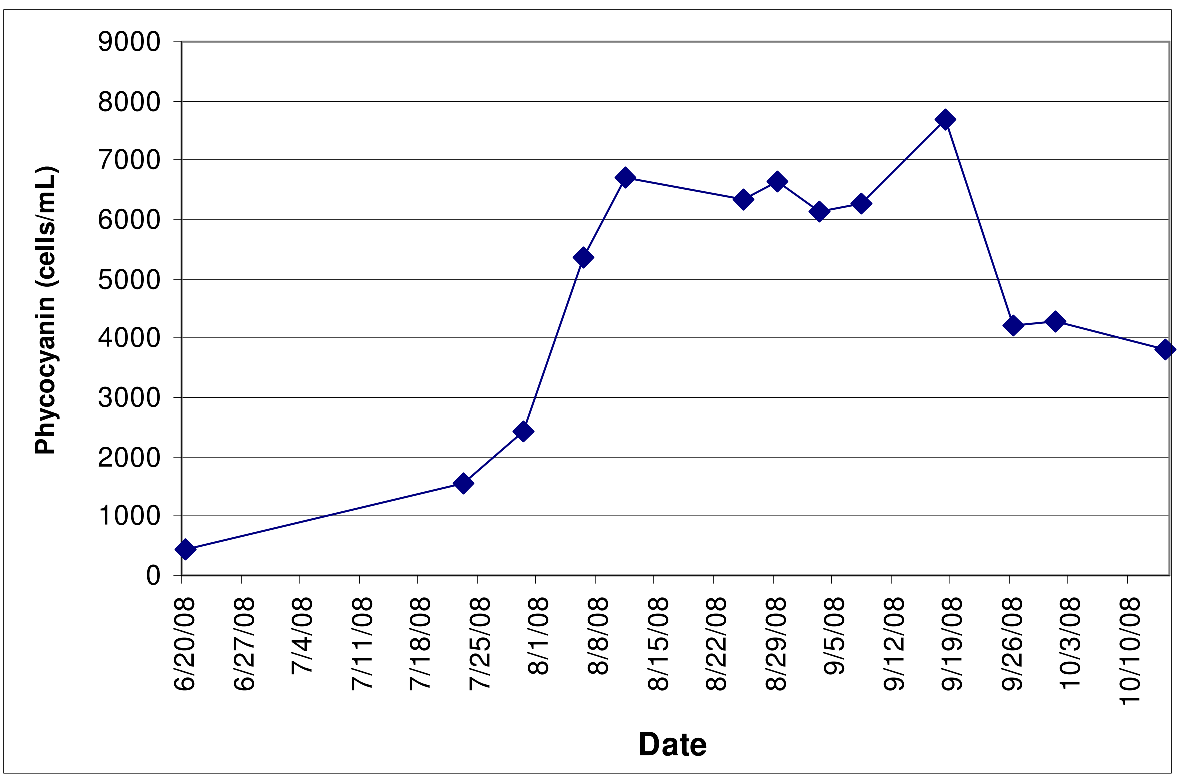


EXHIBIT 3.3-44
Mitchell Lake Point B Phycocyanin 2008 Surface Concentration (cells/mL)



Plankton. Phyto- and zooplankton samples were taken on August 29, 2008 and evaluated for count and biovolume. Phytoplankton biovolume was dominated by cyanobacteria on both sampling dates, comprising nearly entirely *Aphanizomenon flos-aquae*, a species known to produce toxins (Exhibits 3.3-45 and 3.3-46).

EXHIBIT 3.3-45
Mitchell Lake Point B Phytoplankton Density, August 29, 2008

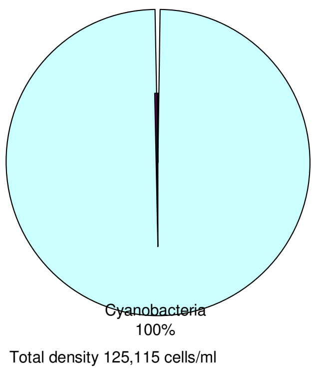
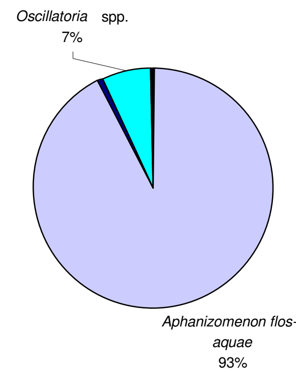


EXHIBIT 3.3-46
Mitchell Lake Point B Dominant Phytoplankton by Genus or Species, August 29, 2008



The zooplankton population was dominated by small-bodied organisms that can lead to algal growth (Exhibits 3.3-47 and 3.3-48). The absence of large-bodied Cladoceran zooplankton, is an important element in the conditions arising for an algae bloom.

EXHIBIT 3.3-47
Mitchell Lake Point B Zooplankton Density, August 29, 2008

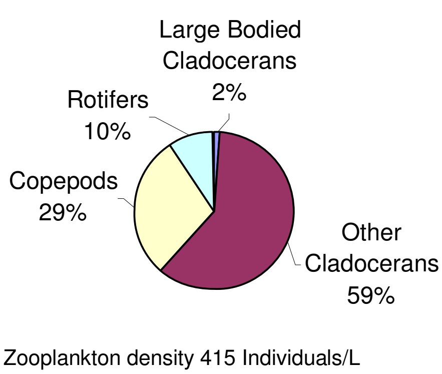
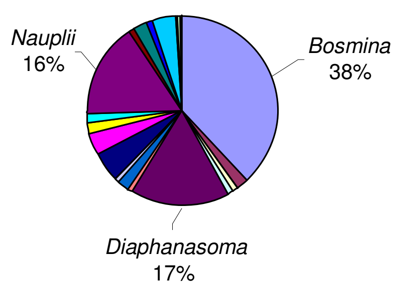


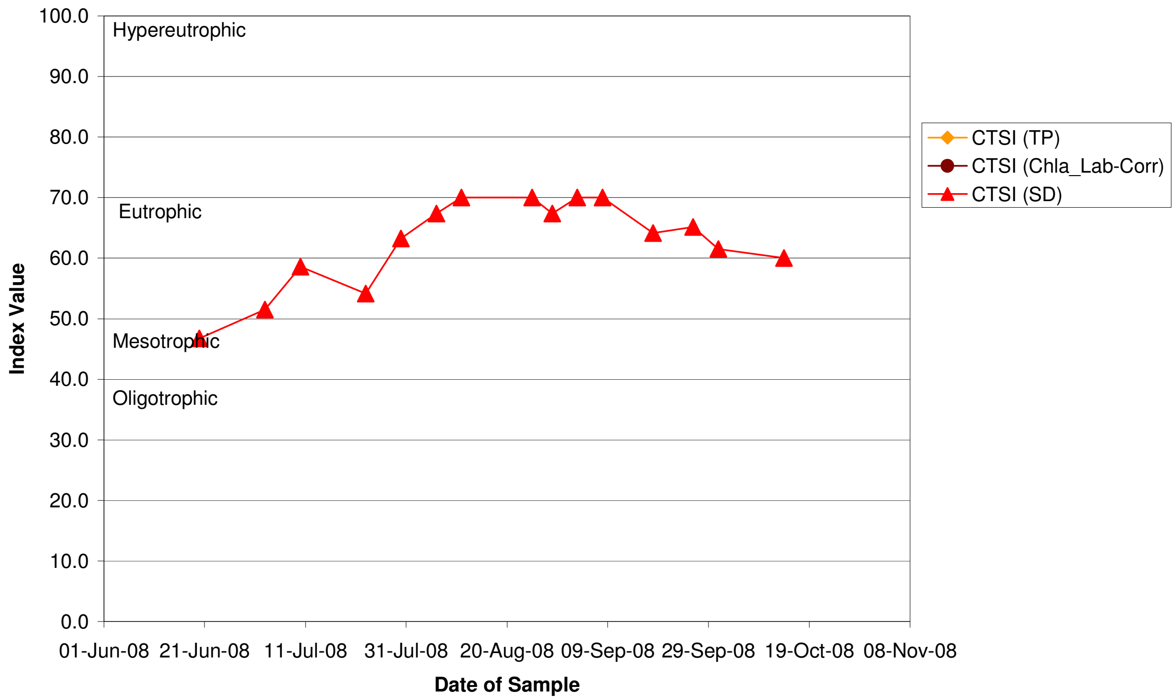
EXHIBIT 3.3-48
Mitchell Lake Point B Dominate Phytoplankton by Genus or Species, August 29, 2008



3.3.4.4 Trophic Indices—Point B

Current. The Secchi disk depth (SD) component of the CTSI indicates that Mitchell Lake at Point B is eutrophic through most of the sampling season. Values also border on hypereutrophic at the peak of the summer, but are also mesotrophic at the beginning of the sampling season (Exhibit 3.3-49).

EXHIBIT 3.3-49
Mitchell Lake Point B 2008 CTSI (SD)



3.3.4.5 Conclusions—Point B

Like Points E and A, Point B is shallow and weakly stratified, and experienced similar water quality conditions. The primary productivity of the lake is driven by the relative abundance of labile phosphorus. The lack of large bodied zooplankton to keep the algae concentration in balance allows blooms of harmful cyanobacteria to develop. One of the sources of phosphorus release is the lake sediments.

3.3.5 Point C

3.3.5.1 Introduction

In-situ water quality measurements were collected biweekly using the sonde. Mitchell Lake at Point C is located in a shallow bay off Point B that is dominated by plants, including *Ceratophyllum demersum.*

3.3.5.2 In-Situ Parameters—Point C

Dissolved Oxygen and Temperature. On August 15, dissolved oxygen at the surface fell below 7 mg/L, and during turnover in September, dissolved oxygen values at 0.5 meter in depth were as low as 3 mg/L (Exhibits 3.3-50 and 3.3-51). Mitchell Lake is not strongly stratified at Point C. Turnover occurred in the beginning of September.

Oxidation Reduction Potential. ORP was consistently low near the bottom of the lake throughout the sampling season, but this situation improved during the summer (Exhibit 3.3-52). Between June and mid-August, ORP fell below +200 mV below 1.5 to 2 meters. However, ORP values increased dramatically throughout the water column after

EXHIBIT 3.3-50
Mitchell Lake Point C Dissolved Oxygen 2008 Isopleth (mg/L)

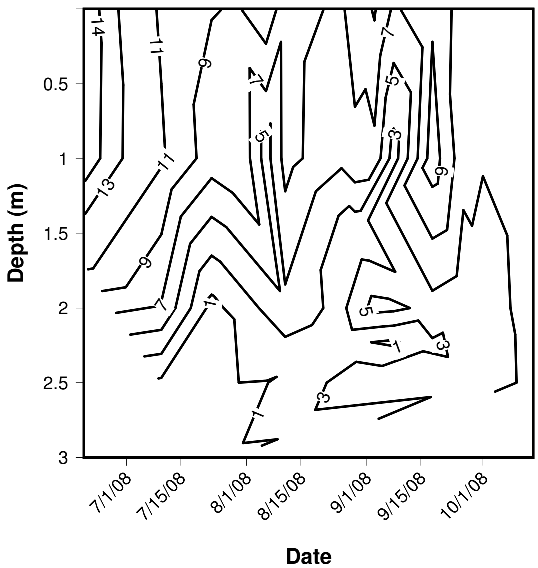
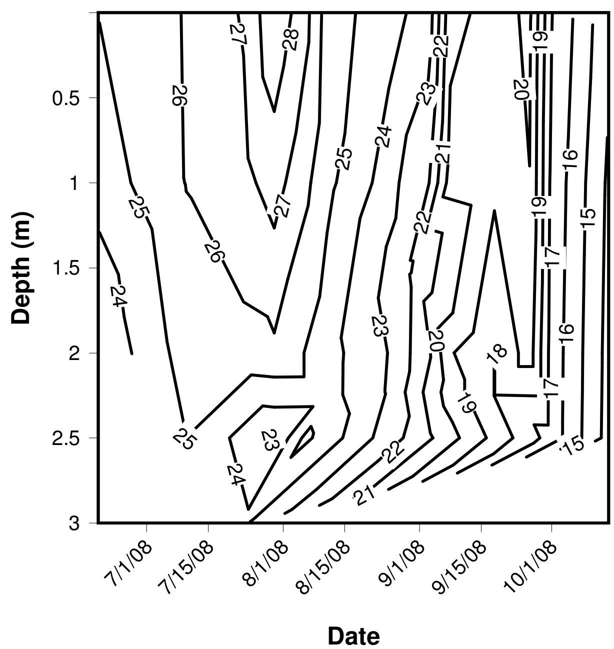


EXHIBIT 3.3-51
Mitchell Lake Point C Temperature 2008 Isopleth (°C)



mid-August. This improvement in water quality corresponds to greater Secchi disk depth measurements at Point C after mid-August.

Water Clarity.

Secchi Disk. Secchi disk depths were measured at 1.0 meter or greater except for the sampling dates on August 10 and 17 (Exhibit 3.3-53). In late August, Point C became much clearer.

EXHIBIT 3.3-52
Mitchell Lake Point C ORP 2008 Isopleth (mV)

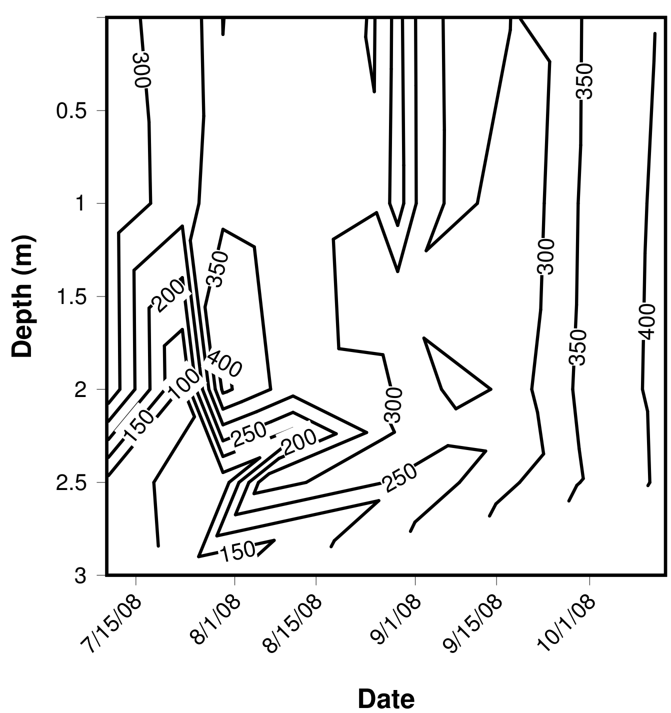
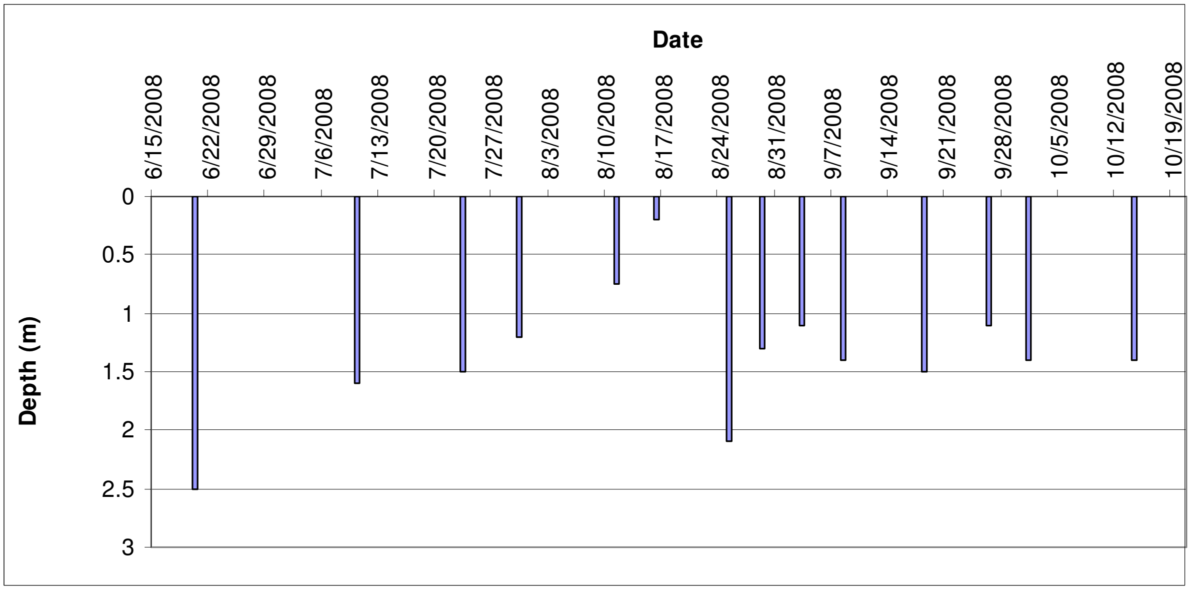


EXHIBIT 3.3-53
Mitchell Lake Point C 2008 Secchi Disk Data

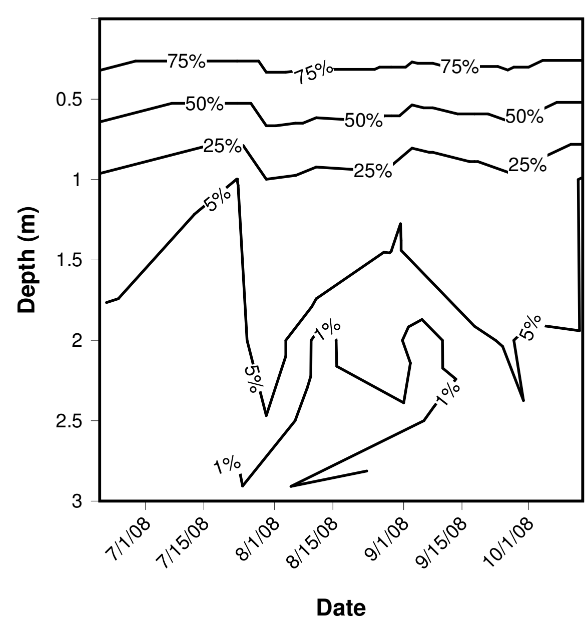


Photosynthetic Active Radiation. The euphotic zone, as measured by PAR, was relatively consistent down to 3 meters except for a period in early August (Exhibit 3.3-54).

pH. High surface pH values (greater than 9.0) at Point C are characteristic of hypereutrophic conditions (Exhibit 3.3-55). Intense photosynthesis by algae population is responsible for the high pH values. High pH values were measured through late August, and improved after that time.

Conductivity. The conductivity was consistent throughout the sampling season showing a minimal concentration gradient, and highest during late July (Exhibit 3.3-56).

EXHIBIT 3.3-54
Mitchell Lake Point C Percent Incident Light Penetration 2008 Isopleth



3.3.5.3 Biological Parameters—Point C

Phycocyanin. Phycocyanin measurements peaked at a moderate level on August 6, the date of cyanobacteria blooms at Points E, A, and B (Exhibit 3.3-57). The phycocyanin levels decreased through the second half of August through the end of the sampling season. The phycocyanin measurements indicate that the lake is in the WHO low risk category (1,000 to 8,000 cells/mL of phycocyanin) from July 23 through the end of the sampling season, except for August 25.

EXHIBIT 3.3-55
Mitchell Lake Point C pH 2008 Isopleth

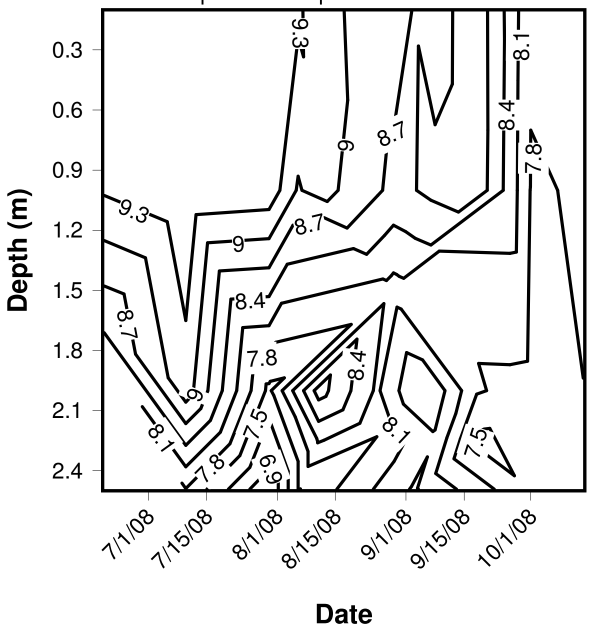


EXHIBIT 3.3-56
Mitchell Lake Point C Conductivity 2008 Isopleth

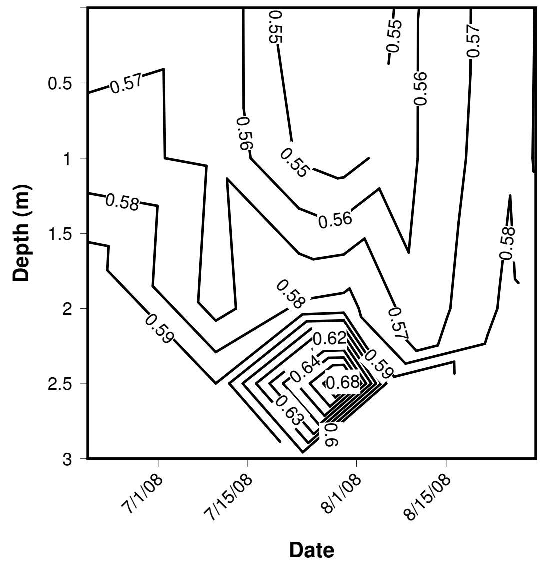
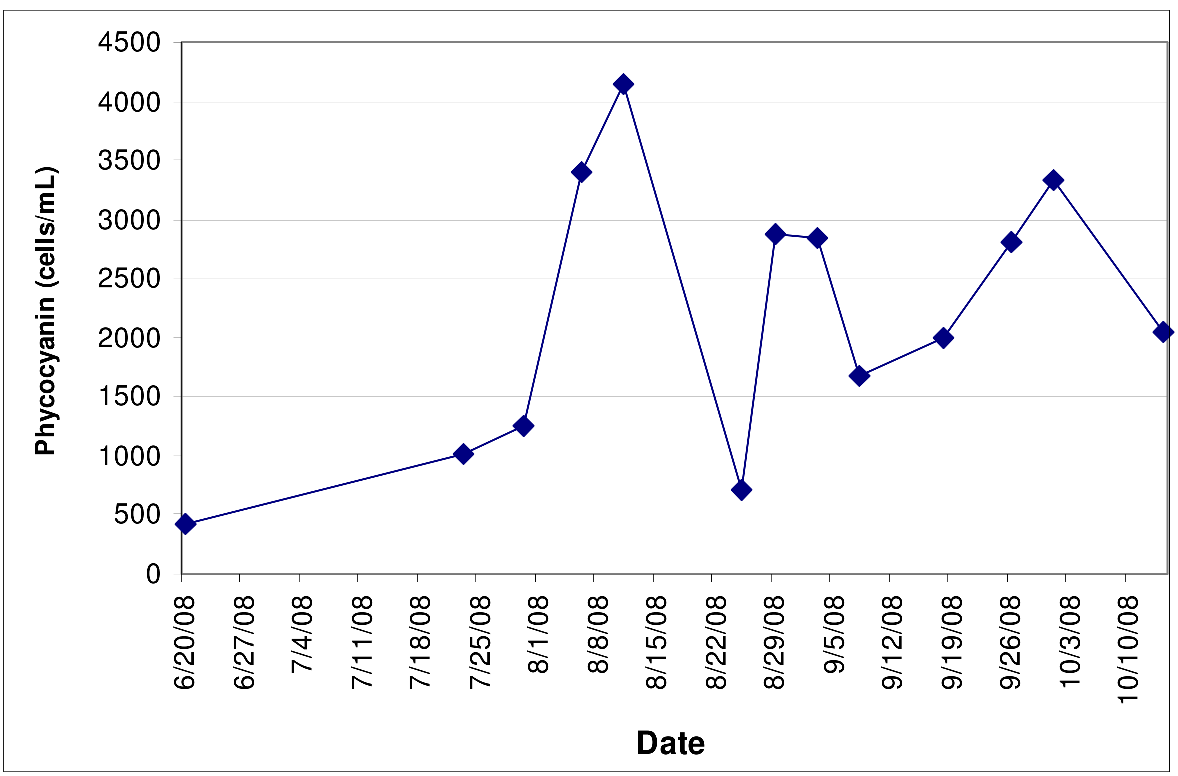


EXHIBIT 3.3-57
Mitchell Lake Point C Phycocyanin 2008 Surface Concentration (cells/mL)



Plankton. Phyto- and zooplankton samples were taken on August 29, 2008, and evaluated for count and biovolume. Phytoplankton biovolume was dominated by cyanobacteria on both sampling dates, comprising nearly entirely *Aphanizomenon flos-aquae,* a species known to produce toxins (Exhibits 3.3-58 and 3.3-59).

EXHIBIT 3.3-58
Mitchell Lake Point C Phytoplankton Density, August 29, 2008

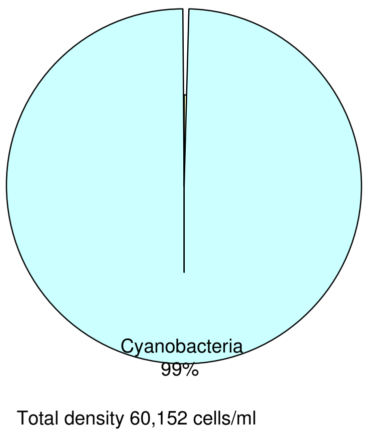
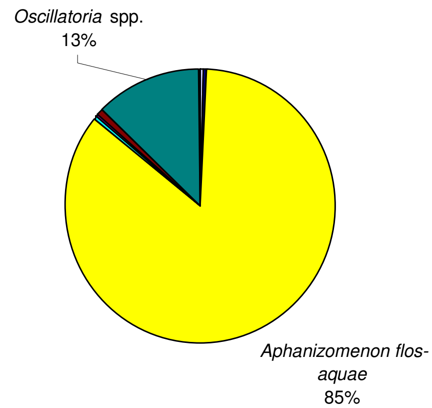


EXHIBIT 3.3-59
Mitchell Lake Point C Dominant Phytoplankton by Genus or Species, August 29, 2008



The zooplankton population was dominated by small-bodied organisms that can lead to algal growth (Exhibits 3.3-60 and 3.3-60). The absence of large-bodied Cladoceran zooplankton, is an important element in the conditions arising for an algae bloom.

EXHIBIT 3.3-60
Mitchell Lake Point C Zooplankton Density, August 29, 2008

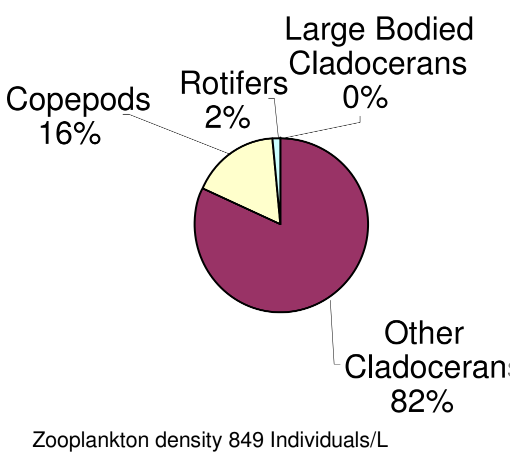
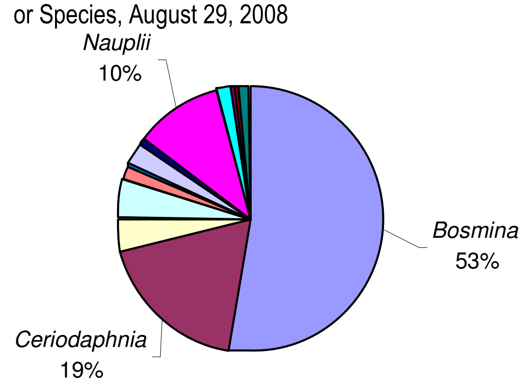


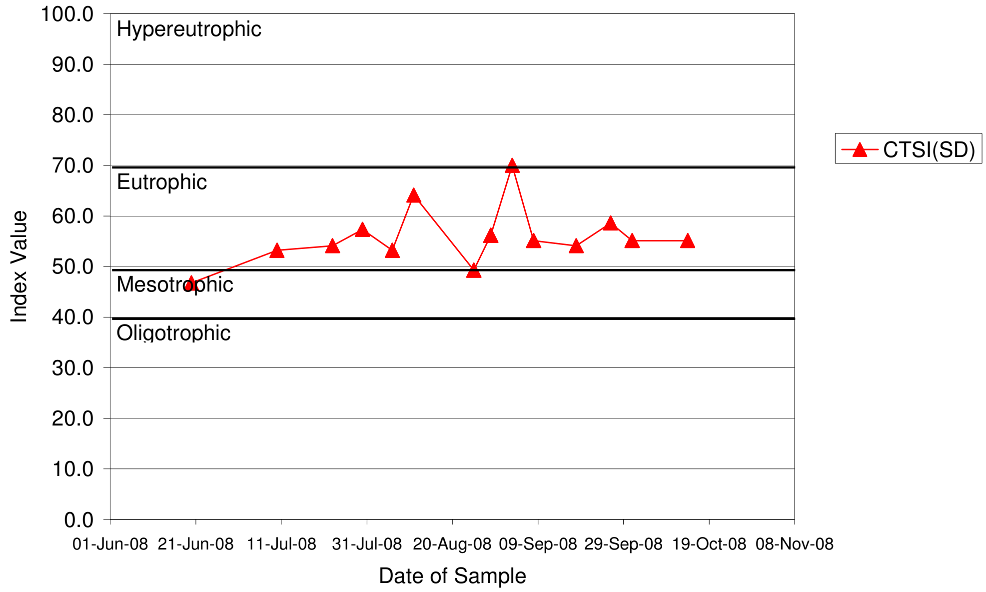
EXHIBIT 3.3-61
Mitchell Lake Point C Dominate Phytoplankton by Genus or Species, August 29, 2008



3.3.5.4 Trophic Indices—Point C

Current. The only component of the CTSI that was measured at Mitchell Lake at Point C is the secchi disk depth (SD). Measurements indicated the lake to be eutrophic through most of the sampling season (Exhibit 3.3-62). The $CTSI_{SD}$ values for the Secchi disk indicate that the lake is mesotrophic at the beginning and end of the sampling season. On the last sampling date in August, the $CTSI_{SD}$ value peaked at near hypereutrophic levels, but the $CTSI_{SD}$ value decreased quickly after that date.

EXHIBIT 3.3-62
Mitchell Lake Point C 2008 CTSI (SD)



3.3.5.5 Conclusions—Point C

Mitchell Lake at Point C is also a shallow, weakly stratified, dimictic, roughly eutrophic lake, like the other points in the lake. However, the water quality at Point C improved after

EXHIBIT 3.3-63
Mitchell Lake Point D Dissolved Oxygen 2008 Isopleth (mg/L)

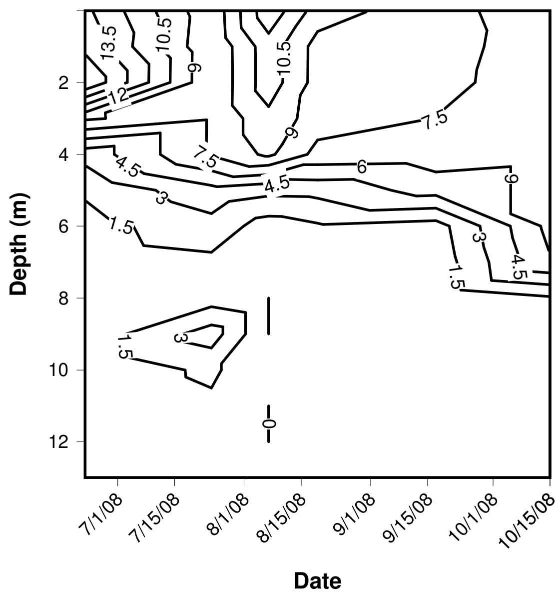
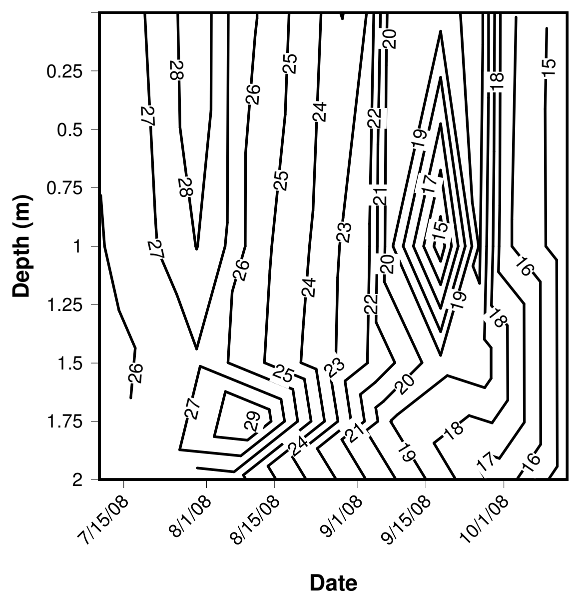


EXHIBIT 3.3-64
Mitchell Lake Point D Temperature 2008 Isopleth (°C)



the warm weather peaked. The improvement in Secchi disk depths can be correlated with the ORP conditions at the bottom of the lake, preventing phosphorus from migrating into the water column. The reason for the clear water through September and October could also be attributed to the *Ceratophyllum demersum* dominance in parts of Bay C.

3.3.6 Point D

3.3.6.1 Introduction

In-situ water quality measurements were collected biweekly using the sonde at Point D. Point D is located off the deepest bay (Point E) in Mitchell Lake. Water flows from Round Lake through Point D and then to Basin E. Basin D is heavily dominated by coontail (*Ceratophyllum demersum*).

3.3.6.2 In-Situ Parameters—Point D

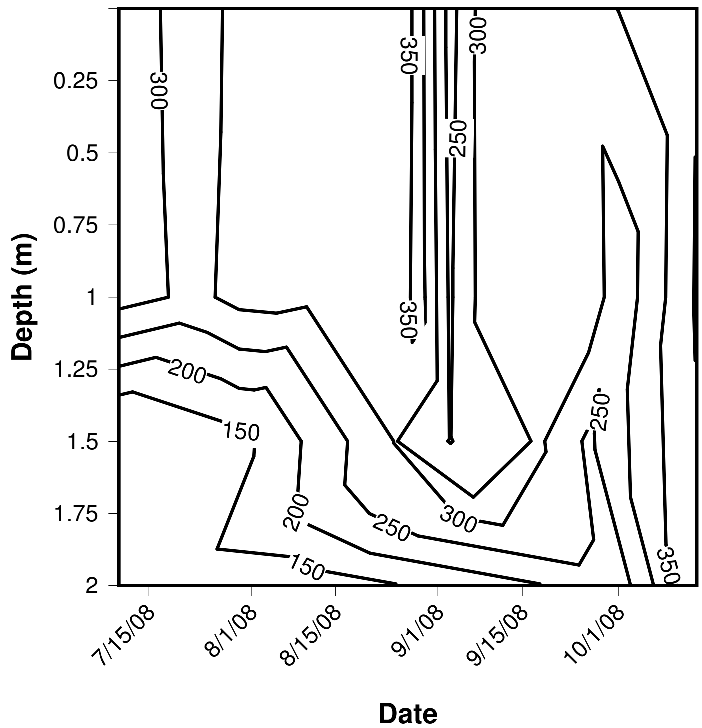
Dissolved Oxygen and Temperature. Dissolved oxygen was variable at Point D, saturated in early summer and at turnover, but below 7 mg/L throughout the water column during the entire month of August (Exhibits 3.3-63 and 3.3-64). Mitchell Lake is not stratified at Point D, where it is very shallow. Turnover occurred in the beginning of September.

Oxidation Reduction Potential. ORP fell below +200 mV on the bottom surface only in the beginning of the summer (Exhibit 3.3-65).

Water Clarity.

Secchi Disk. Secchi disk depths recorded were all in the range of 1.5 meters (Exhibit 3.3-66). The bottom was always visible, so the Secchi disk depth recorded was the depth of the bay on that date. Secchi disk depth was estimated to be 4.0 meters throughout the sampling season.

EXHIBIT 3.3-65
Mitchell Lake Point D ORP 2008 Isopleth (mV)



Photosynthetic Active Radiation. The euphotic zone as measured by PAR extended through the complete water column during the sampling season (Exhibit 3.3-67). The lake was clear with the bottom visible on all sampling dates.

pH. High surface pH values (greater than 9.0), which indicate intense photosynthesis by algae or submerged macrophytes population, are present only through early August (Exhibit 3.3-68).

Conductivity. Conductivity was consistent throughout the water column, as the lake is not strongly stratified (Exhibit 3.3-67).

EXHIBIT 3.3-66
Mitchell Lake Point D 2008 Secchi Disk Data

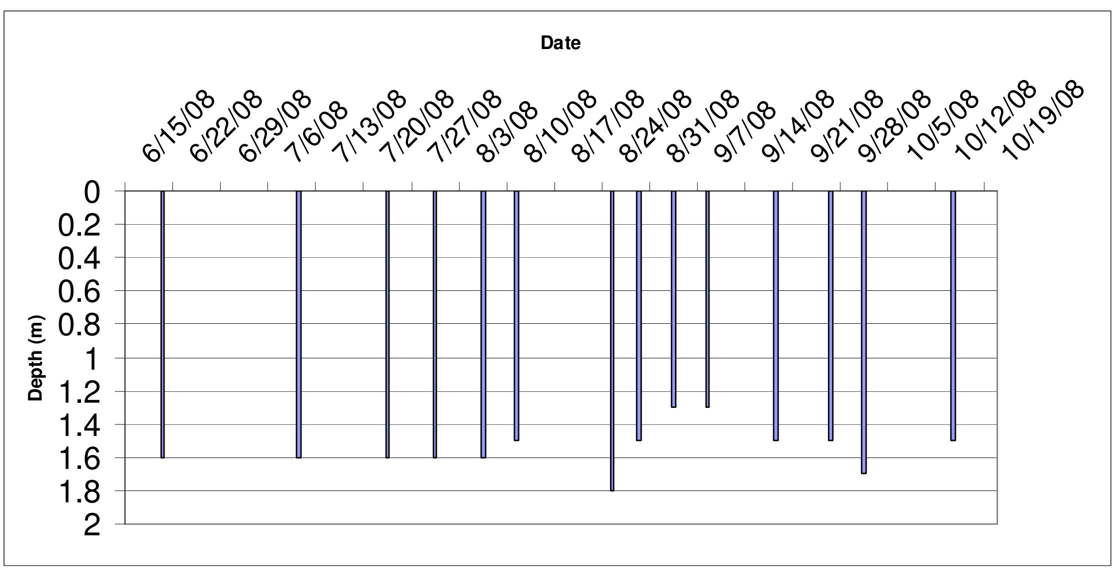


EXHIBIT 3.3-67
Mitchell Lake Point D Percent Incident Light Penetration 2008 Isopleth

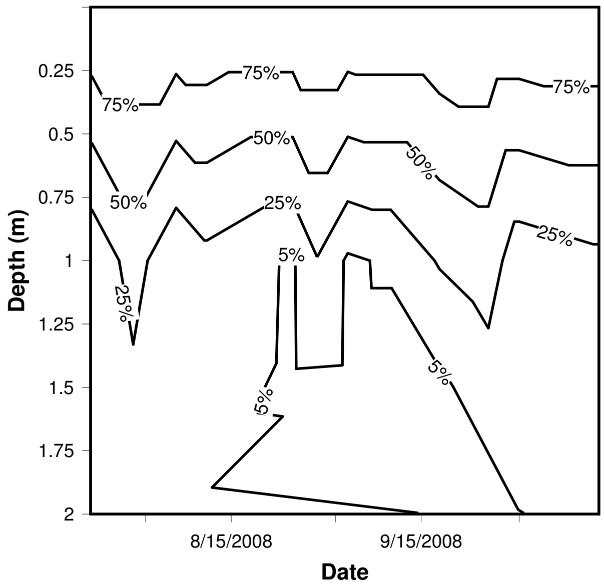
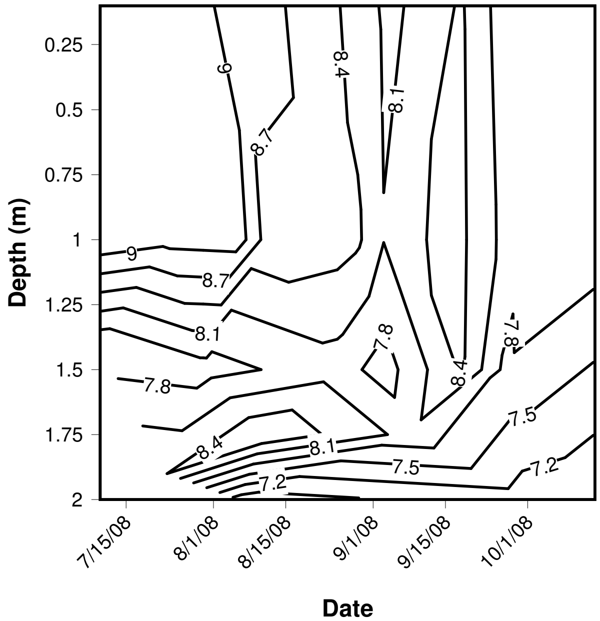


EXHIBIT 3.3-68
Mitchell Lake Point D pH 2008 Isopleth



3.3.6.3 Biological Parameters—Point D

Phycocyanin. One high measurement of phycocyanin was taken in early September, but not at a level high enough to indicate unsafe levels of cyanotoxin for dermal contact (Exhibit 3.3-68). The phycocyanin measurements indicate that the lake is in the WHO low risk category (1,000 to 8,000 cells/mL of phycocyanin) for a period in early August and early September.

EXHIBIT 3.3-67
Mitchell Lake Point D Conductivity 2008 Isopleth

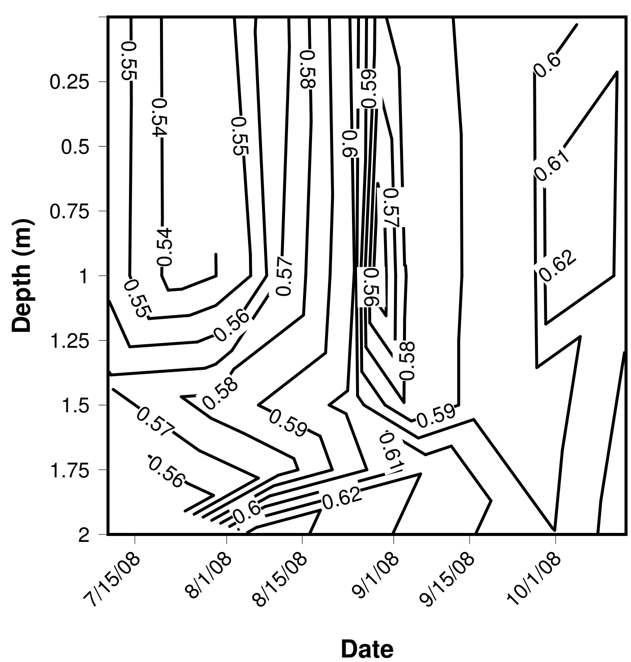
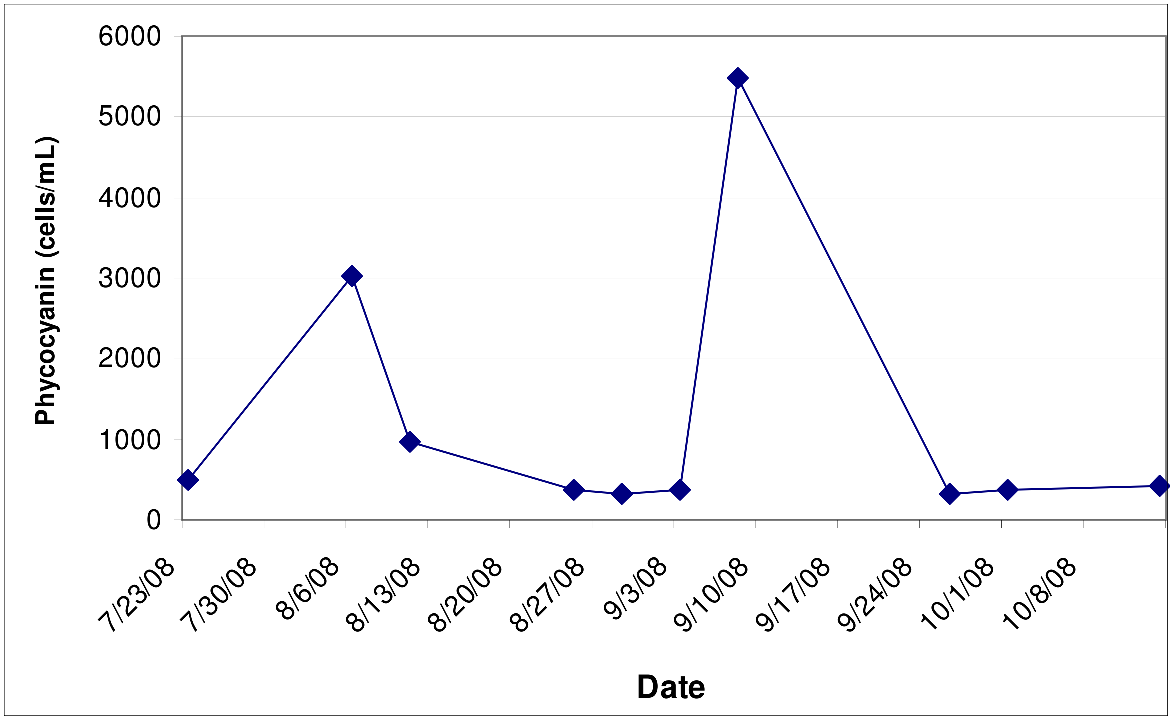


EXHIBIT 3.3-68
Mitchell Lake Point D Phycocyanin 2008 Surface Concentration (cells/mL)



Plankton. Phyto- and zooplankton samples were taken on August 29, 2008 and evaluated for count and biovolume. Phytoplankton biovolume was dominated by cyanobacteria on both sampling dates, comprising nearly entirely *Aphanizomenon flos-aquae,* a species known to produce toxins (Exhibits 3.3-69 and 3.3-70). Despite the dominance of cyanobacteria at Point D, algae blooms did not occur as the coontail in the bay did not allow enough phosphorus into the water column for the algae to take over.

EXHIBIT 3.3-69
Mitchell Lake Point D Phytoplankton Density, August 29, 2008

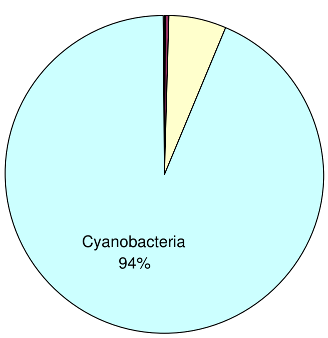
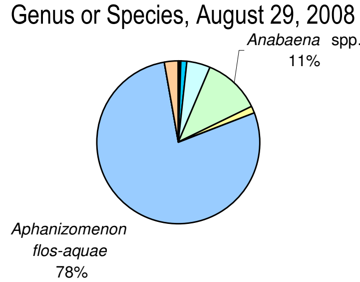
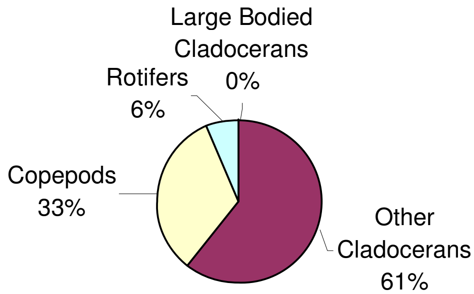


EXHIBIT 3.3-70
Mitchell Lake Point D Dominant Phytoplankton by Genus or Species, August 29, 2008



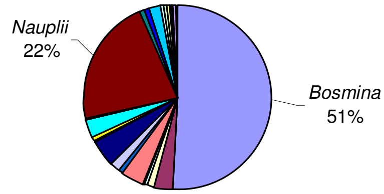
The zooplankton population was dominated by small-bodied organisms that can lead to algal growth (Exhibits 3.1-71 and 3.1-72). The absence of large-bodied Cladoceran zooplankton, is an important element in the conditions arising for an algae bloom.

EXHIBIT 3.3-71
Mitchell Lake Point D Zooplankton Density, August 29, 2008



Zooplankton density 253 Individuals/L

EXHIBIT 3.3-72
Mitchell Lake Point D Dominate Phytoplankton by Genus or Species, August 29, 2008



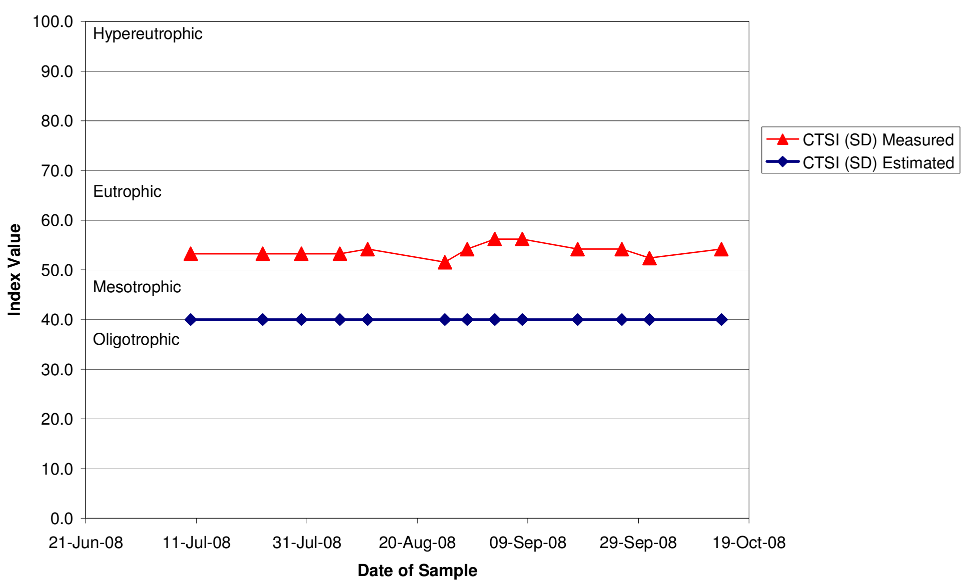
3.3.6.4 Trophic Indices—Point D

Current. CTSI values were calculated for Secchi disk depth (SD) at Point D (Exhibit 3.3-73). As the bottom of the lake was clearly visible on all sampling dates and Bay D is roughly 1.5 meters deep (with some variation as water levels rose and fell during the sampling season), the calculated $CTSI_{SD}$ was in the eutrophic range. But using an estimated Secchi disk depth of 4 meters, Bay D could be classified as borderline mesotrophic/oligotrophic.

3.3.6.5 Conclusions—Point D

Though Point D's water quality parameters showed potential for the occurrence of an algae bloom, the cyanobacteria were held in check by the domination of *Ceratophyllum demersum*. The isolation of Bay D from other points of the lake, and the other bays being downstream from Bay D, allowed it to sustain clear water throughout the sampling season.

EXHIBIT 3.3-73
Mitchell Lake Point D 2008 CTSI (SD)

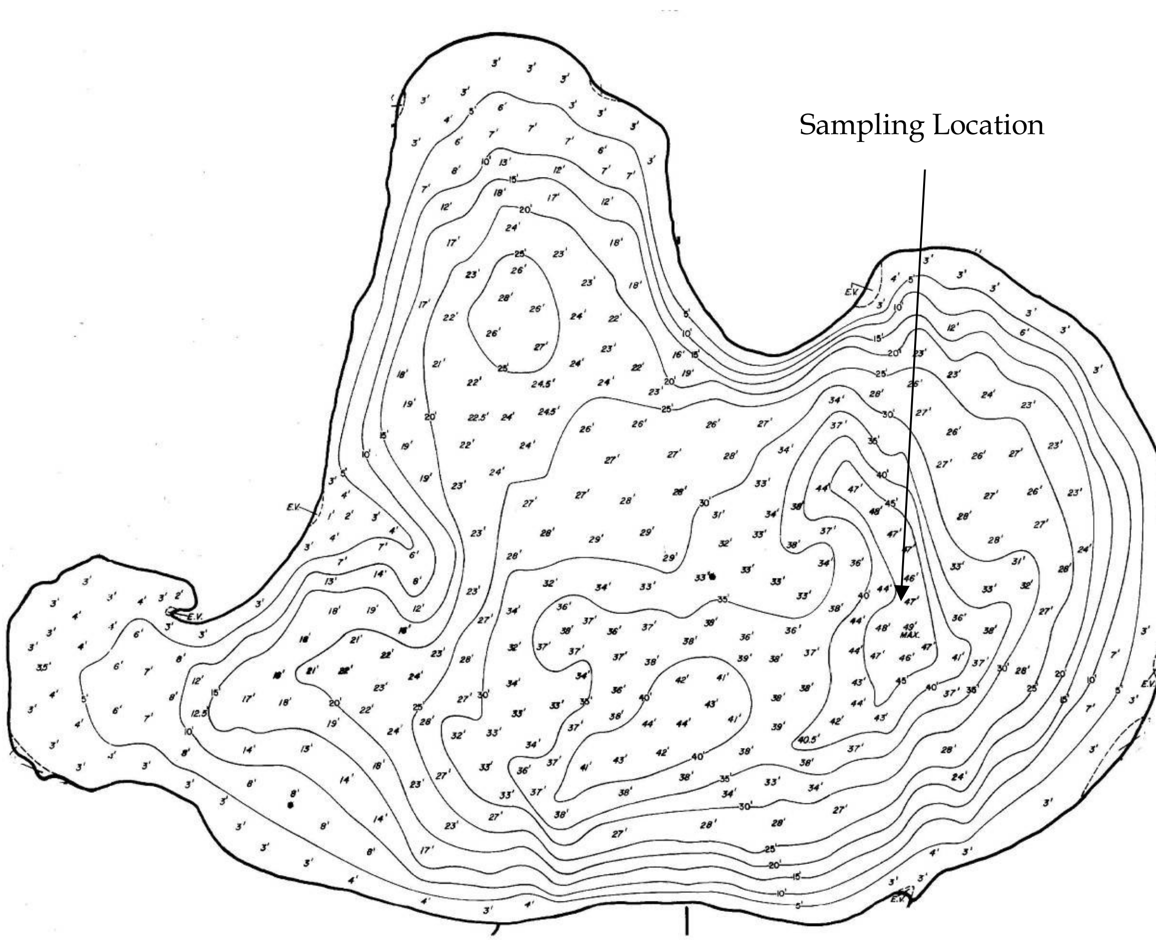


3.4 Riley Lake

3.4.1 Introduction

In-situ water quality measurements were collected biweekly using the sonde at Riley Lake. The deepest point in the lake was monitored and determined to be about 42 feet deep (Exhibit 3.4-1).

EXHIBIT 3.4-1
Riley Lake 2008 Sampling Locations (Map from Minn. DNR)



3.4.2 In-Situ Parameters

3.4.2.1 Dissolved Oxygen and Temperature

Epilimentic dissolved oxygen concentrations were consistently greater than 5.0 mg/L (Exhibit 3.4-2). The hypolimnion was anoxic throughout the sampling period. Lake Riley is a deep, well-stratified lake. It appears that turnover of the lake occurred in early November. During the hottest part of the summer, the top 4 meters of the lake were well-mixed (Exhibit 3.4-3).

3.4.2.2 Oxidation Reduction Potential

The ORP level in the bottom sediments was less than +200 mV throughout the sampling season, A value of +200 mV corresponds approximately with dissolved oxygen concentrations less than 0.5 mg/L (Exhibit 3.4-4). Sulfate reduction, and accompanying sulfide production, appear to occur at ORP values of less than + 100 mV. Higher TP and orthophosphate values at the bottom of the lake correspond with the low ORP values (less than +100 mV). Sulfate reducing conditions are significant because sulfide will bind ferrous iron in insoluble ferrous sulfide complexes. Although ferrous iron [Fe(II)] is soluble and will not bind phosphorus, once ferrous iron diffuses to the mesolimnion where there are positive dissolved oxygen concentrations it oxidizes to ferric iron [Fe(III)]. Once oxidized to ferric iron it can bind orthophosphate. However, sequestration of ferrous iron in insoluble sulfide compounds greatly diminishes the iron pool

EXHIBIT 3.4 -2
Riley Lake Dissolved Oxygen 2008 Isopleth (mg/L)

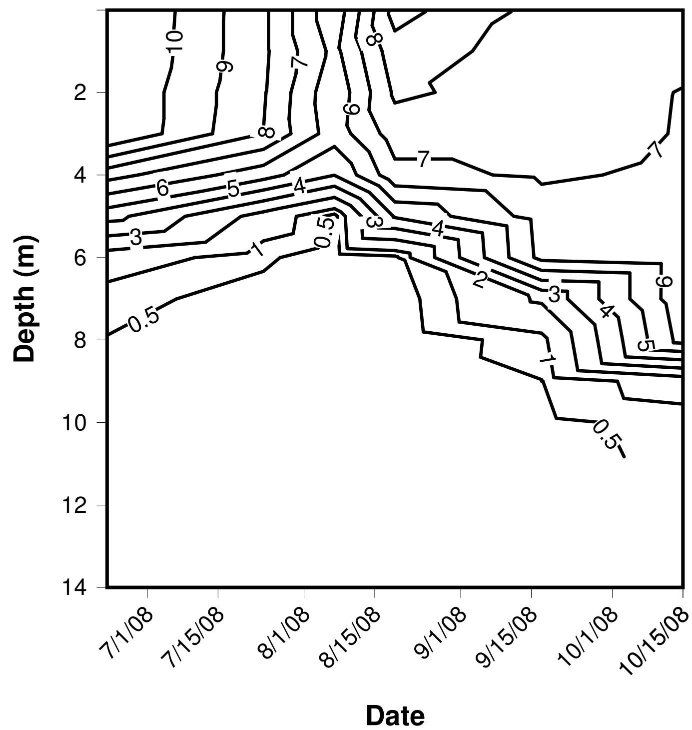
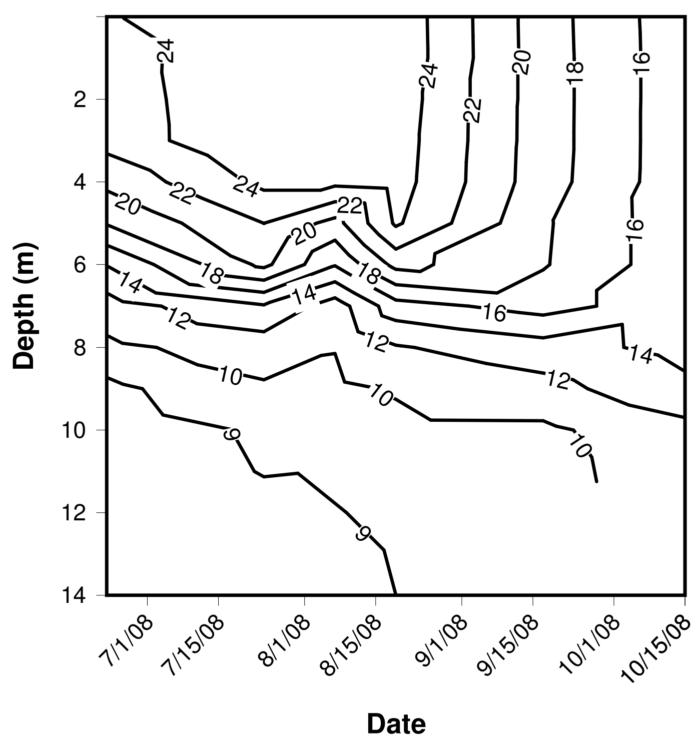


EXHIBIT 3.4-3
Riley Lake Temperature 2008 Isopleth (°C)



and thus allows more release of orthophosphate by diffusion into the epilimnion where it increases algae growth. This effect may be seen in the increase of chlorophyll *a* concentrations. Temperature effects can be ruled out. Epilimnetic temperatures were constant or decreasing during the increase and sustained plateau of chlorophyll *a* concentrations, and during sustained growth of phycocyanin concentrations.

3.4.2.3 Water Clarity

Secchi Disk. The lowest measurements of Secchi disc depth occurred in August, when values of 0.9 and 0.8 meter were measured (Exhibit 3.4-5). These values are consistent with a eutrophic lake.

EXHIBIT 3.4-4
Riley Lake ORP 2008 Isopleth (mV)

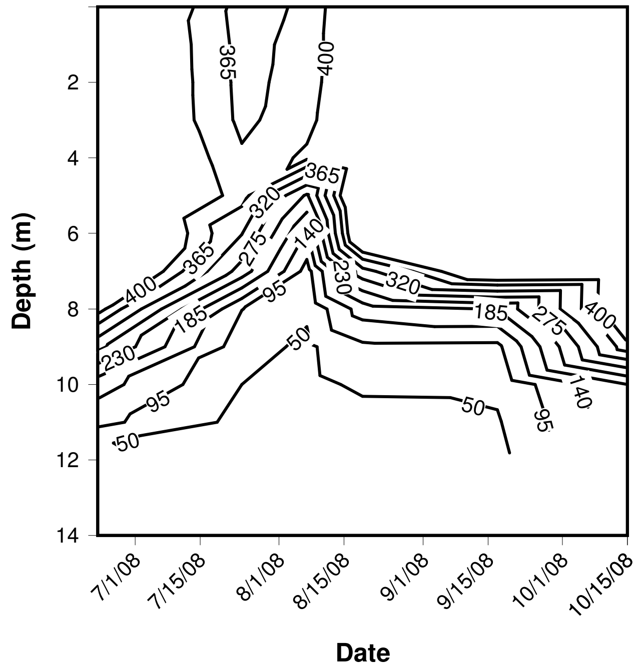
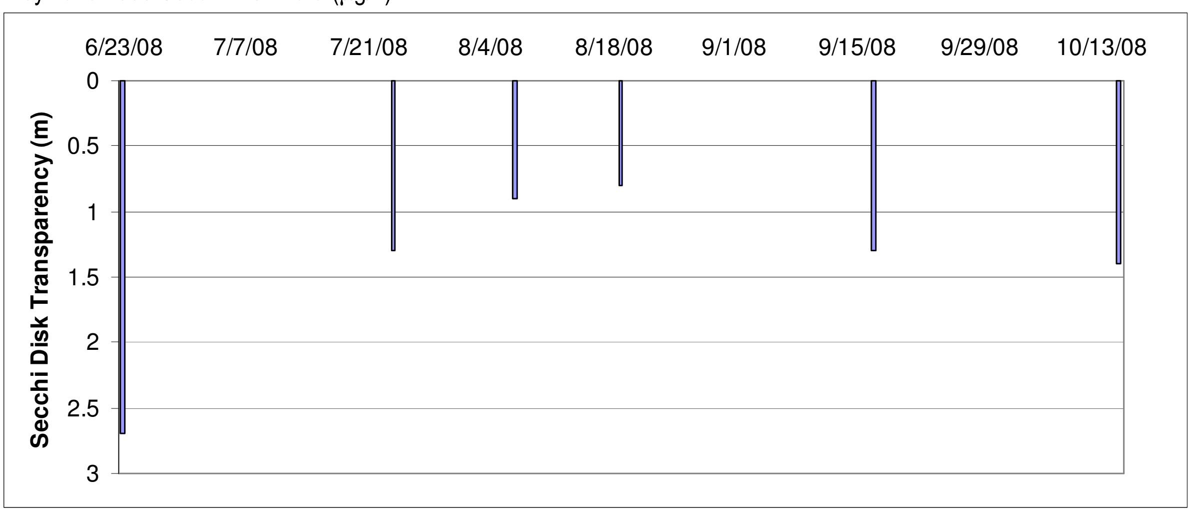


EXHIBIT 3.4-5
Riley Lake 2008 Secchi Disk Data (µg/L)



Photosynthetic Active Radiation. Penetration of light into the water column was lowest from early August to mid-September (Exhibit 3.4-6). The euphotic zone ranged from just below 5 meters in early summer to just below 3 meters in early fall.

3.4.2.4 pH

The pH in the uppermost 4 meters was above 8.5 throughout most of the sampling season (Exhibit 3.4-7). These pH values do not directly create stress conditions nor induce formation of excessive un-ionized ammonia.

3.4.2.5 Conductivity

The small difference between surface and bottom values of conductivity could indicate little influence from stormwater (Exhibit 3.4-8). If stormwater had a significant impact the surface would likely have a significantly smaller value than the bottom for conductivity.

EXHIBIT 3.4-6
Riley Lake Percent Incident Light Penetration 2008 Isopleth

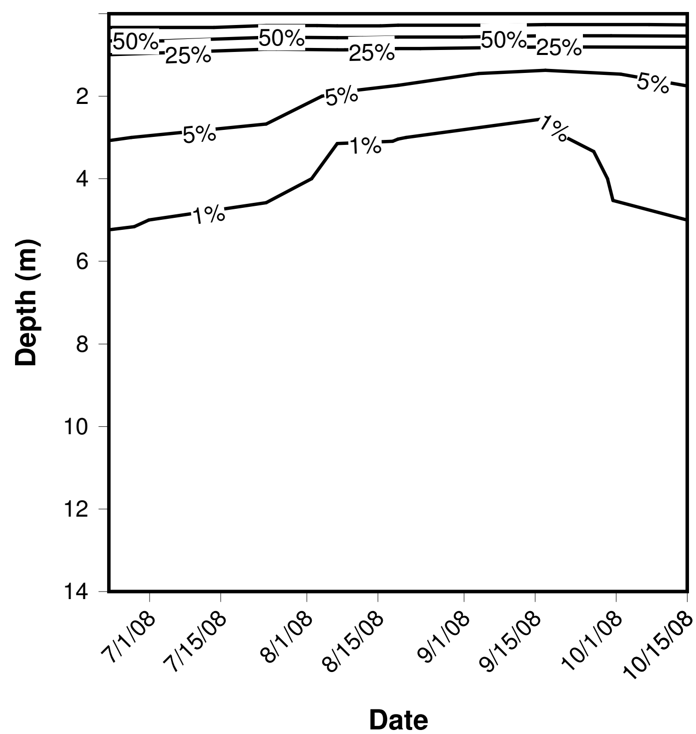


EXHIBIT 3.4-7
Riley Lake pH 2008 Isopleth (SU)

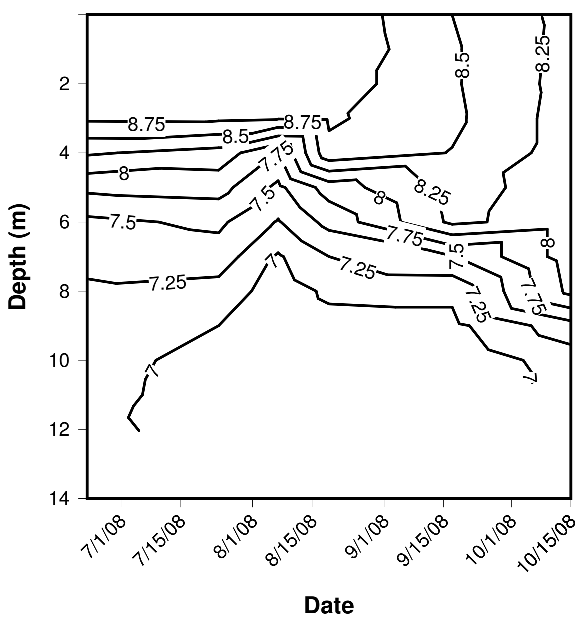
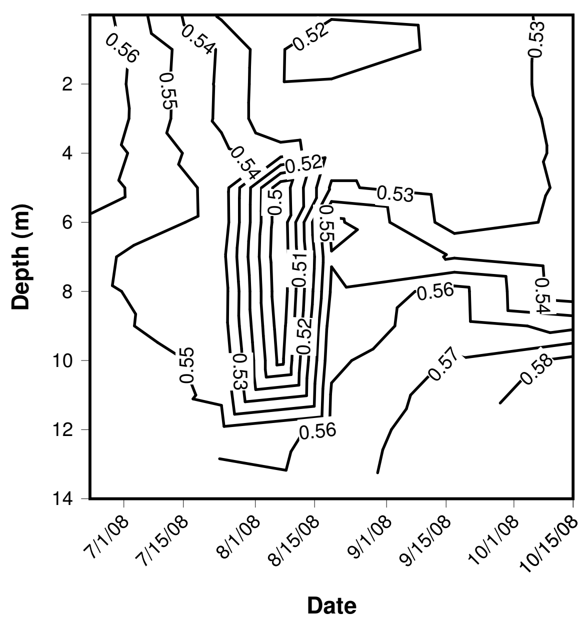


EXHIBIT 3.4-8
Riley Lake Conductivity 2008 Isopleth (mS/cm)

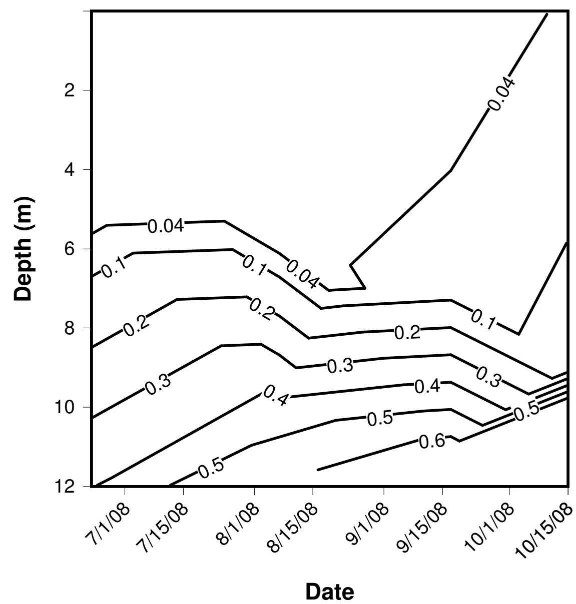


3.4.3 Nutrients

3.4.3.1 Phosphorus Species

The TP and orthophosphate concentrations are highest at the bottom of the lake throughout the sampling season, showing that internal loading is a significant, possibly dominant, contributor to the lake phosphorus budget (Exhibits 3.4-9 and 3.4-10). Orthophosphate decreases after mid-September, but TP increases dramatically towards the end of the sampling season.

EXHIBIT 3.4-9
Riley Lake 2008 Total Phosphorus Isopleth (mg/L)



3.4.3.2 Nitrogen Species

The ammonia concentration peaked with the measurement on September 17, 2008 (Exhibit 3.4-11). The ammonia/TN/TKN concentrations are highest at the bottom of the lake, showing that internal nitrogen loading is a significant, possibly dominant, part of the lake nutrient budget.

EXHIBIT 3.4-10
Riley Lake 2008 Orthophosphate Isopleth (mg/L)

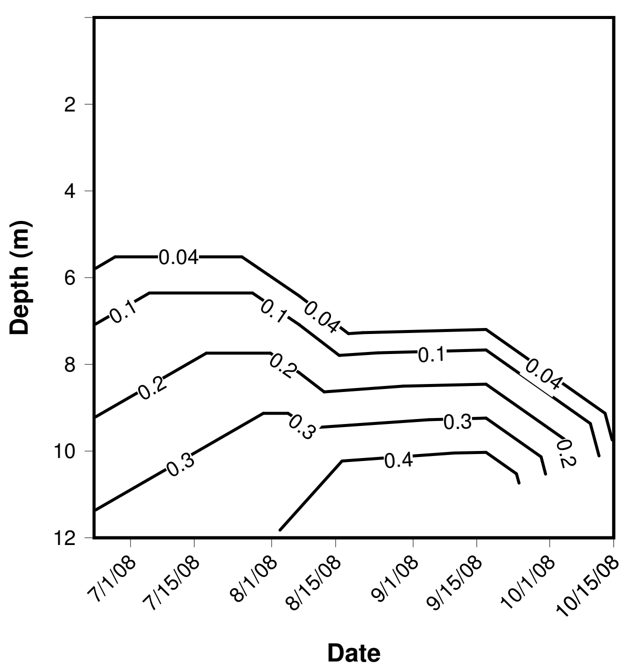
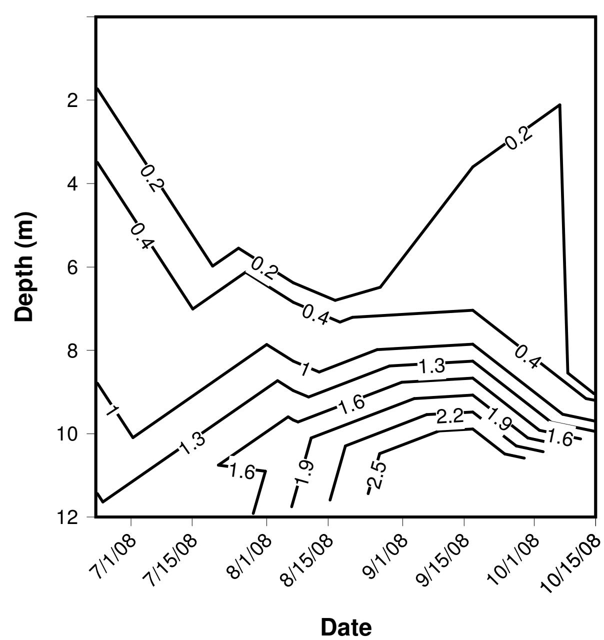


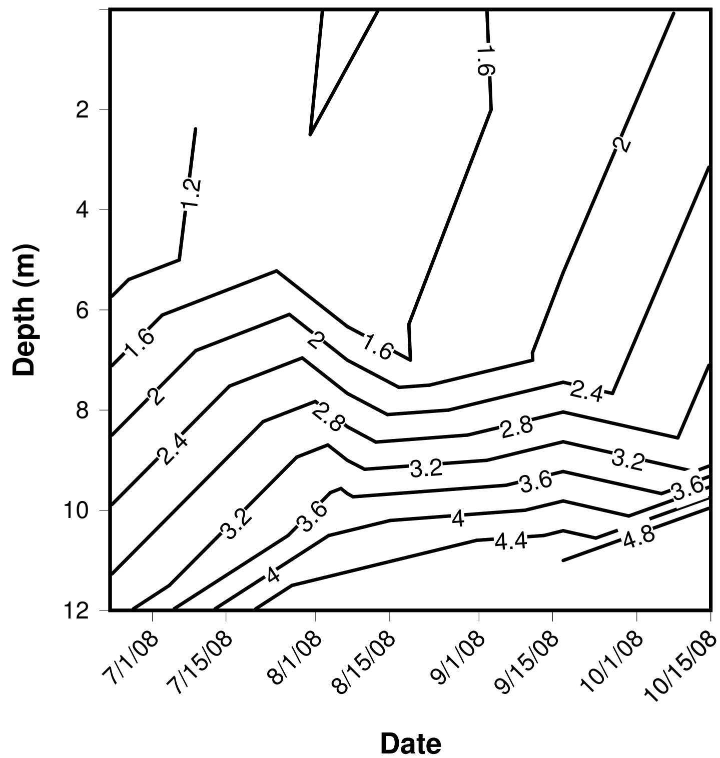
EXHIBIT 3.4-11
Riley Lake 2008 Ammonia Isopleth (mg/L)



Nitrate and nitrite were undetectable in all samples taken in the 2008 sampling season. This means that the ammonia in the water column is either taken up into algae directly or quickly nitrified and denitrified under nearly anaerobic conditions.

The TKN and TN isopleths are identical as the nitrate/nitrite concentrations were never measured above the detection limit during the 2008 sampling season (TN = TKN plus nitrate/nitrite) (Exhibit 3.4-12). The TKN concentrations continually increased each time a sample was taken over the summer. This pattern is consistent with nitrogen fixation by cyanobacteria.

EXHIBIT 3.4-12
Riley Lake 2008 TKN Isopleth (mg/L)

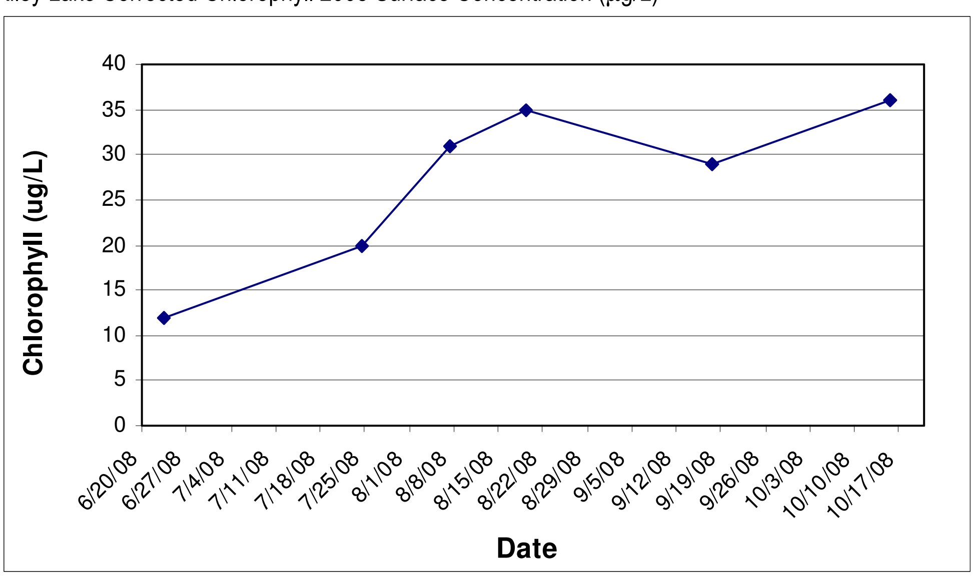


3.4.4 Biological parameters

3.4.4.1 Chlorophyll *a*

The chlorophyll *a* concentration peaked in late August and in mid-September (Exhibit 3.4-13). Algae blooms reach an apparent plateau that is sustained into early fall.

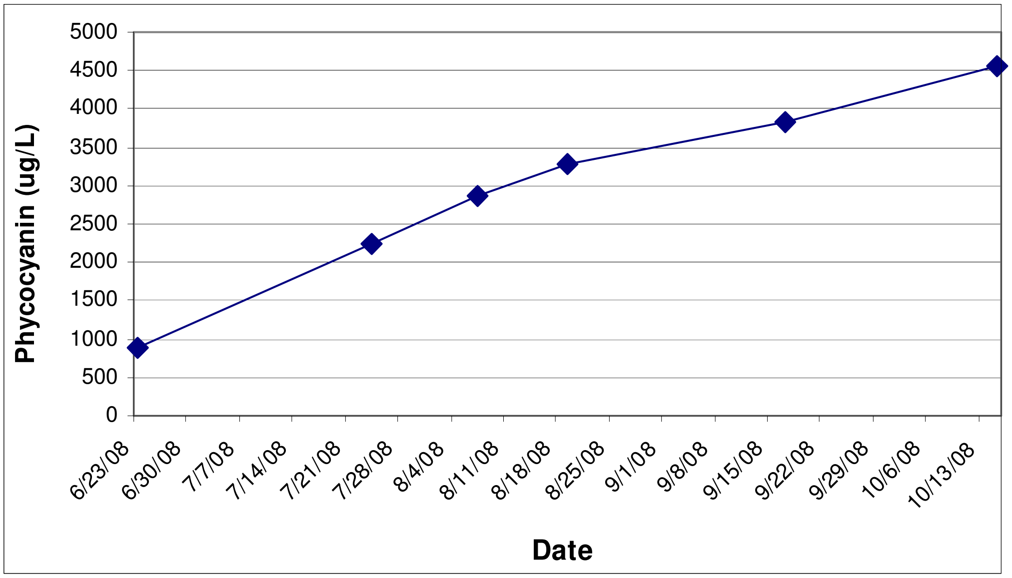
EXHIBIT 3.4-13
Riley Lake Corrected Chlorophyll 2008 Surface Concentration (μg/L)



3.4.4.2 Phycocyanin

Phycocyanin measurements increased over the sampling season, peaking at the end of the sampling season (Exhibit 3.4-14). Unlike chlorophyll *a,* there is no noted drop in level in

EXHIBIT 3.4-14
Riley Lake Phycocyanin 2008 Surface Concentration (cells/mL)



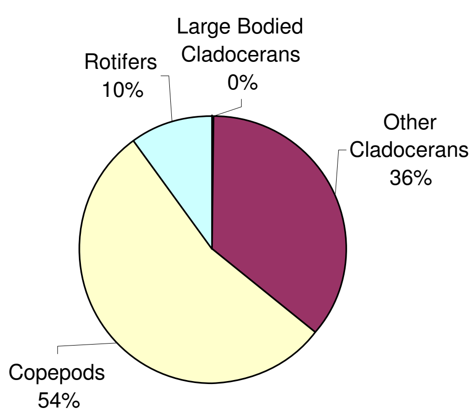
September. The phycocyanin measurements indicate that the lake is in the WHO low risk category (1,000 to 8,000 cells/mL of phycocyanin) for nearly the complete sampling season.

3.4.4.3 Plankton

Zooplankton is primarily dominated by copepods with average to small cladocerans next and then rotifers (Exhibits 3.4-15 and 3.4-16). The most present, not including the *Nauplii* which is defined as a microcrustacean, is *Daphnia*, a cladoceran, followed by *Leptodiaptomus*, a cladoceran, and then *Diaphanasom*, a copepod. Large-bodied cladocerans are consumers of algae. The lack of algae consumers is a concern.

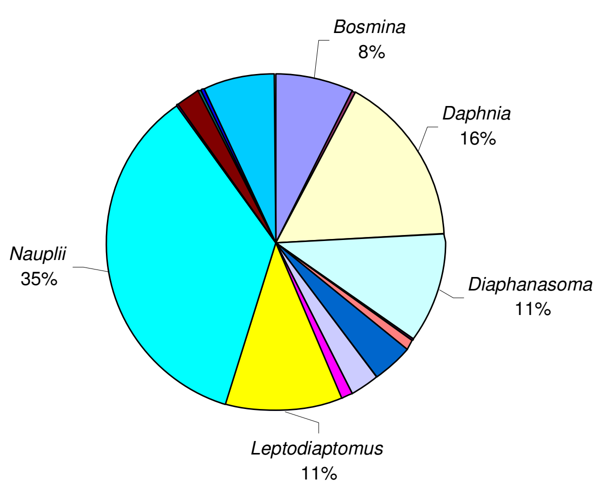
EXHIBIT 3.4-15

Riley Lake Zooplankton Density, September 18, 2008



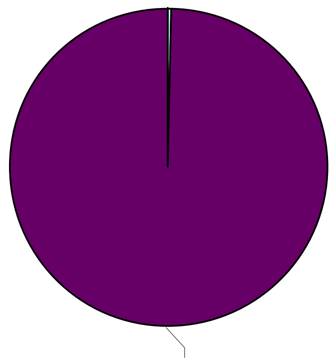
Zooplankton density 328 Individuals/L

EXHIBIT 3.4-16
Riley Lake Dominant Zooplankton by Genus or Species, September 17, 2008



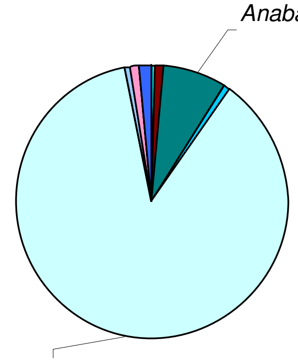
Phytoplankton is dominated by cyanobacteria (Exhibit 3.4-17). Examining the genus indicates that *Aphanizomenon flos-aquae* dominates, followed by *Anabaena* spp (Exhibit 3.4-18). Both are known toxin-producing organisms.

EXHIBIT 3.4-17
Riley Lake Phytoplankton Density, September 17, 2008



Total density 67,226 cells/ml

HIBIT 3.4-18
Riley Lake Dominant Phytoplankton by Genus or Species, September 17, 2008

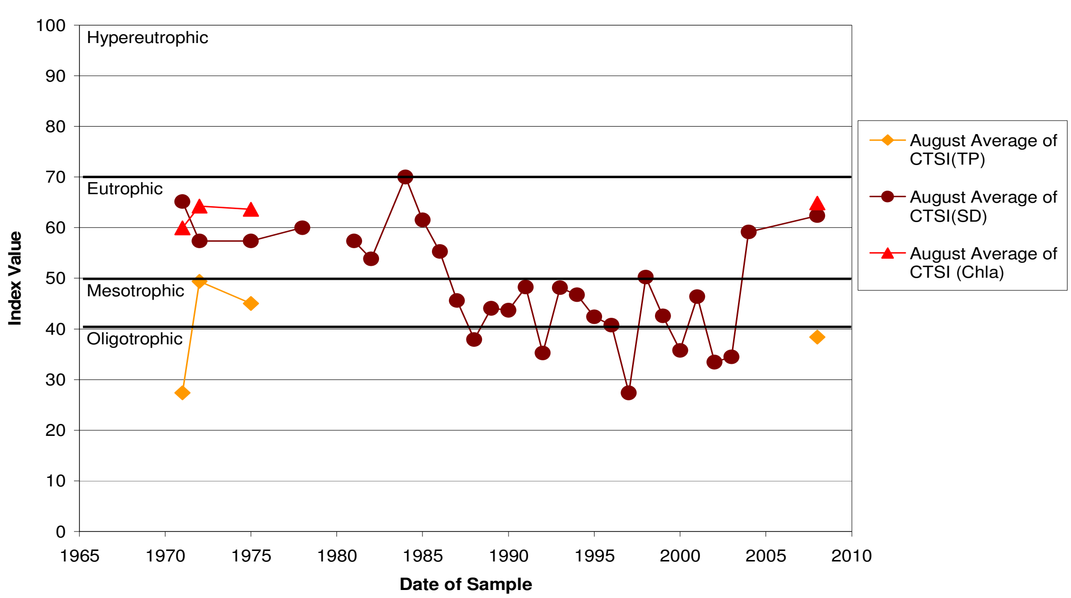


3.4.5 Trophic Indices

3.4.5.1 Current

The Carlson trophic indices (CTSI) for chlorophyll *a* (Chla) and Secchi disc depth (SD) indicate Lake Riley to be eutrophic throughout the sampling season, with CTSI values peaking in August (Exhibit 3.4-19). The CTSI values for TP indicates Lake Riley to be between mesotrophic and eutrophic for most of the summer, dipping into oligotrophic at two sampling events in mid-summer. It is evident that the lake is eutrophic by mid-summer. Closely related

EXHIBIT 3.4-19
Riley Lake 2008 CTSI



values for chlorophyll *a* and Secchi disk depth, which are also greater than TP, indicate that algae may be phosphorous limited in mid-summer. There may also be some periods early and late in the sampling season when large particulates dominate the lake.

The Indiana Trophic State Index (ITSI) level for the sampling event on September 17, 2008 indicated the lake to be eutrophic with a score of 33. ITSI scores between 32 and 46 are deemed to be eutrophic, while a measurement of 47 or higher is hypereutrophic. The CTSI and the ITSI both show Lake Riley to be eutrophic.

3.4.5.2 Historic Trends

The water quality has been stably eutrophic/mesotrophic for the past 30 years. Similar ranges of summer Secchi disk depths and CTSI measurements have been noted for the past 30 years (Exhibits 3.4-20 and 3.4-22). It is unknown if there is a recent increase in CTSI value from Secchi disk depth, a few more years of study will help to demonstrate if a trend is developing. When statistically evaluated, the data for July and August do not indicate a trend using the Kendall tau test (Exhibit 3.4-21).

3.4.6 Conclusions

Riley is a deep, well-stratified lake. During 2008 it appears the lake is low eutrophic. There is not significant difference between 2008 water quality and water quality of the past 30 years. Riley Lake becomes eutrophic throughout the summer. Internal phosphorous loading appears to be the primary producer. Lack of large bodied zooplankton to keep the algae concentration in balance allowed blooms of harmful cyanobacteria to develop.

EXHIBIT 3.4-20
Riley Lake Secchi Disk Depths (m)

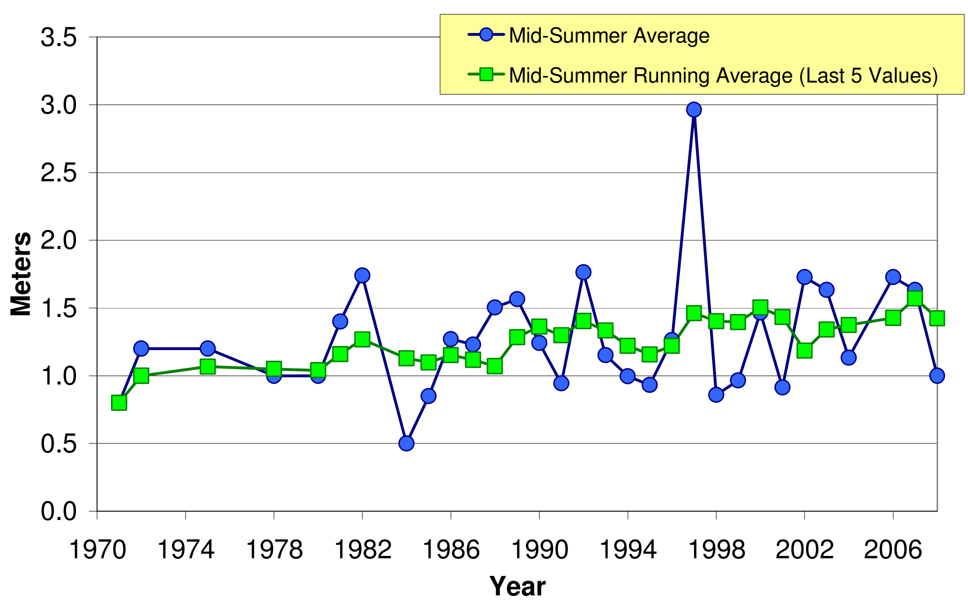
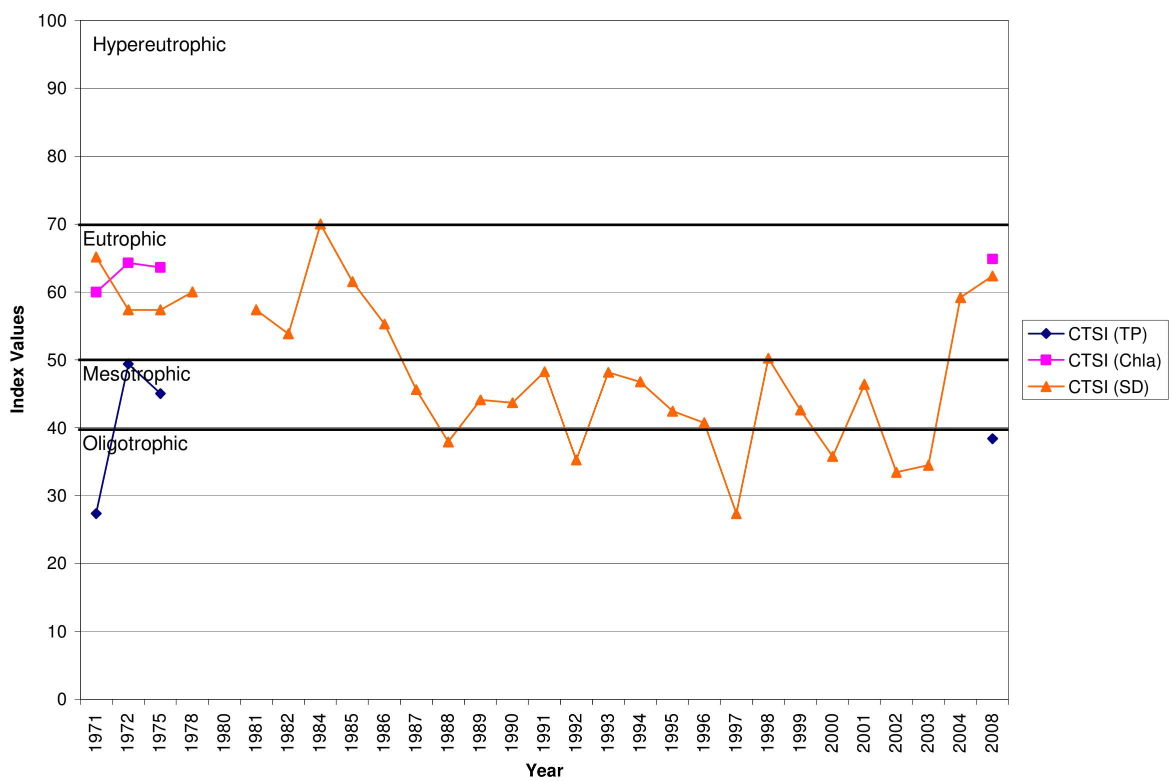


EXHIBIT 3.4-21
Results of Kendall Tau Test

Period	Parameter	2008 Median	Historical Median	Statement of Trend
July	TP (mg/L)	5	13	NA
July	Chla (µg/L)	20		NA
July	SD (m)	1.3	1.37	X
August	TP (mg/L)	14	17	X
August	Chla (µg/L)	33	29	X
August	SD (m)	0.85	1.2	X
July–August	TP (mg/L)	0.9	11.7	X
July–August	Chla (µg/L)	31	29	X
July–August	SD (m)	0.9	1.22	X

X: H_0 cannot be rejected; i.e., there is insufficient evidence to prove a trend.
Y: H_0 is rejected; i.e., there is sufficient evidence to prove a trend.
NA: Not applicable as the Kendall tau test could not be performed due to insufficient data.

EXHIBIT 3.4-22
Riley Lake Historical CTSI

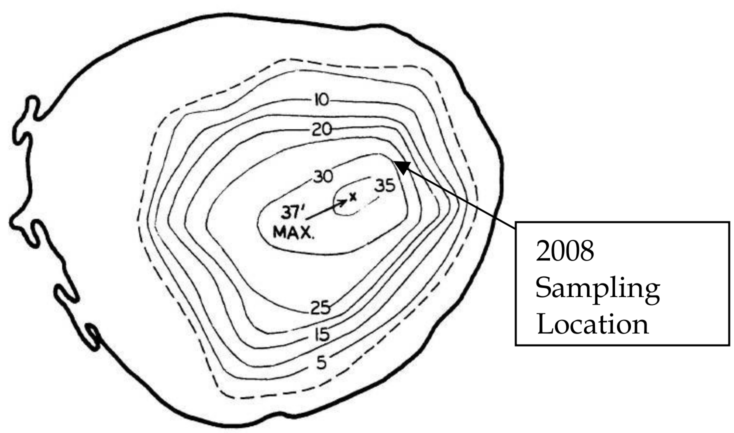


3.5 Round Lake

3.5.1 Introduction

As a priority lake, Round Lake was analyzed biweekly with the sonde, and samples were collected monthly for laboratory analysis. The sampling location is shown in Exhibit 3.5-1.
An aeration system activated on September 30, 2008.

EXHIBIT 3.5-1
Round Lake 2008 Sampling Location (Map from Minn. DNR)



3.5.2 In-Situ Parameters

3.5.2.1 Dissolved Oxygen and Temperature

The dissolved oxygen isopleth indicates a decrease in oxygen concentration throughout the summer to a minimum in early and late August (Exhibit 3.5-2). During August, dissolved oxygen is less than 1 mg/L below 3 to 4 meters. Fish will experience stress in low dissolved oxygen waters, which leaves only the top few meters for survival. Because of the depth of Round Lake, a large volume is in the anoxic state. The temperature isopleth shows that Round Lake is strongly stratified until turnover in early October (Exhibit 3.5-3). The turnover of Round Lake was assisted by the aeration of the lake.

EXHIBIT 3.5-2
Round Lake Dissolved Oxygen 2008 Isopleth (mg/L)

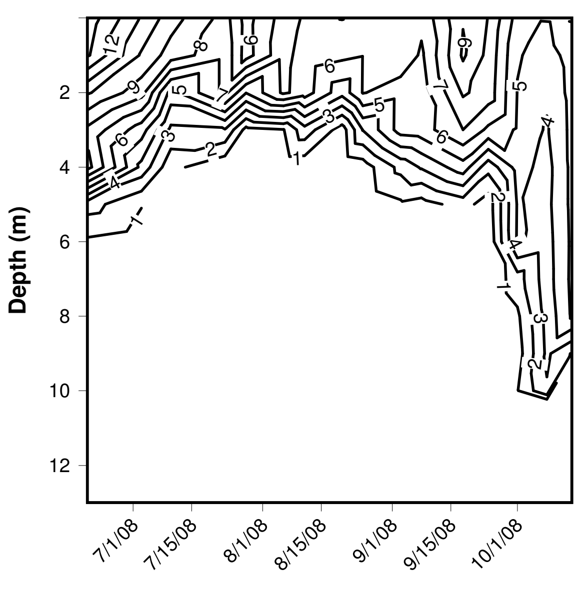
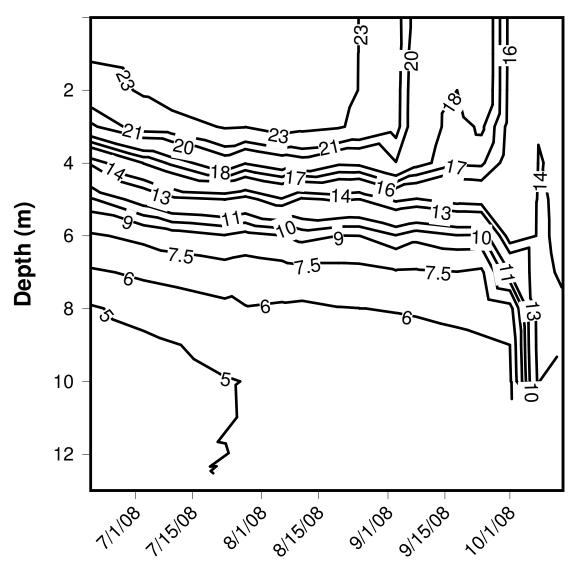


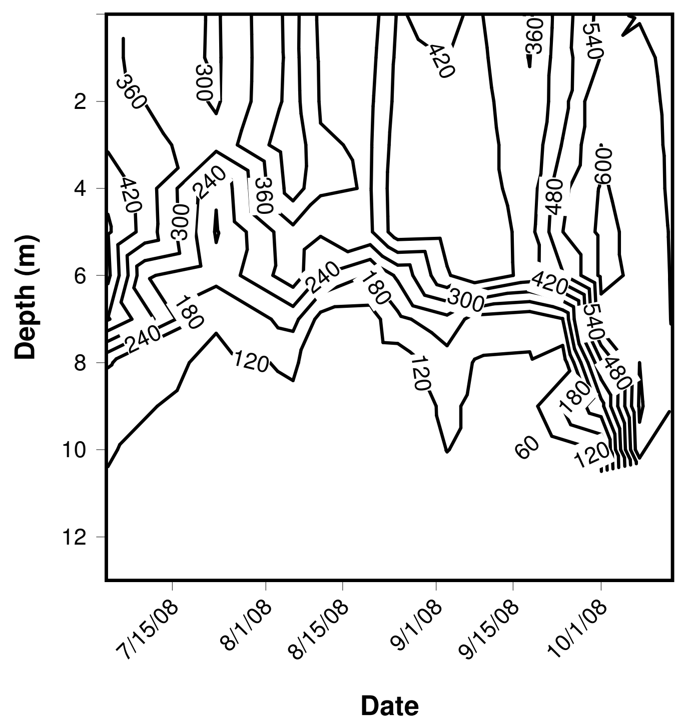
EXHIBIT 3.5-3
Round Lake Temperature 2008 Isopleth (°C)



3.5.2.2 Oxidation Reduction Potential

ORP follows a similar pattern to dissolved oxygen. Loss of oxygen corresponds approximately with the +200 mV line (Exhibit 3.5-4). Sulfate reduction occurs at values less than +100 mV.

EXHIBIT 3.5-4
Round Lake ORP 2008 Isopleth (mV)



3.5.2.3 Water Clarity

Secchi Disk. Secchi disk depth is fairly stable throughout the sampling period (Exhibit 3.5-5). A peak is noted on June 20, the first sampling event.

Photosynthetic Active Radiation. The euphotic zone, 1% light level, in Round Lake typically extends down to 4 meters (Exhibit 3.5-6).

3.5.2.4 pH

Fish stress can occur when pH increases to values above 9.0–9.3; therefore, in early summer fish prefer to live below 2 meters. In early August, pH becomes less of an issue (Figure 3.5-7). Another use of pH is as an indicator for photosynthesis; an increase in pH is related to an increase in photosynthesis.

EXHIBIT 3.5-5
Round Lake 2008 Secchi Disk Data (m)

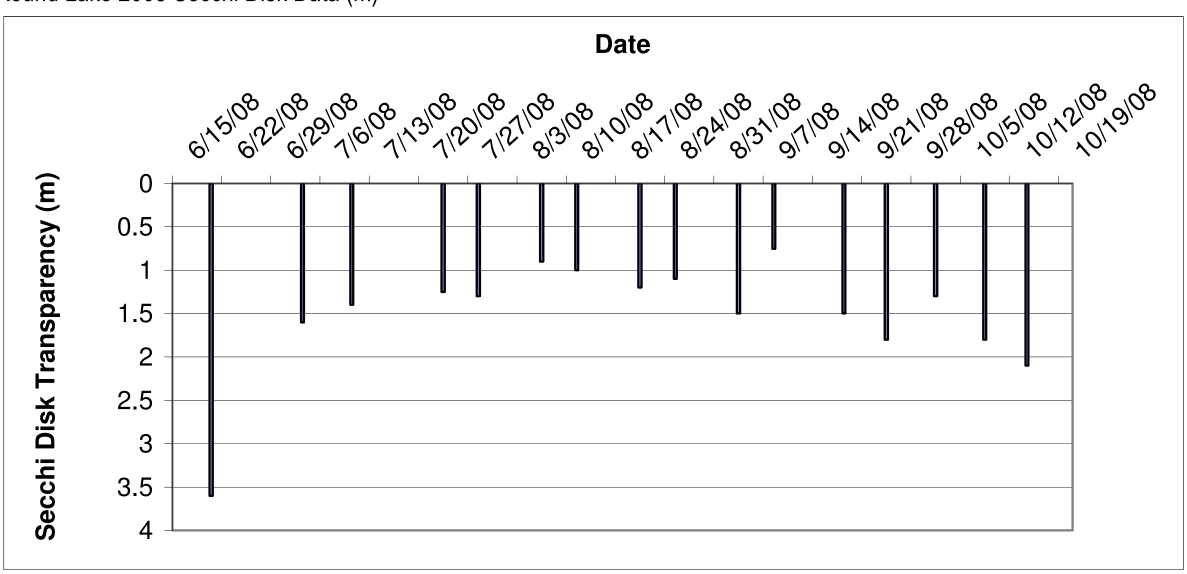


EXHIBIT 3.5-6
Round Lake PAR 2008 Isopleth (Percent of Surface Light)

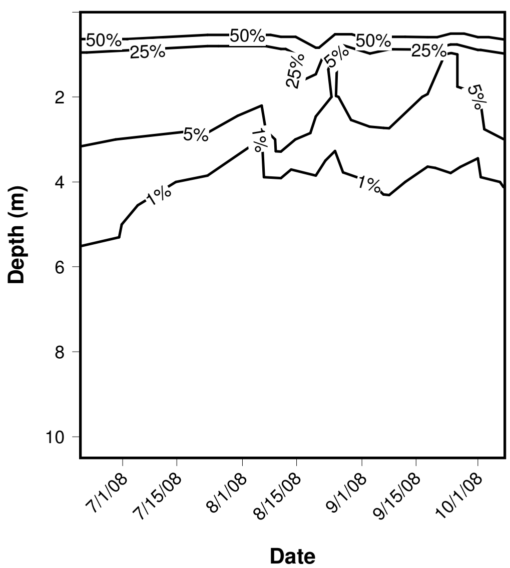
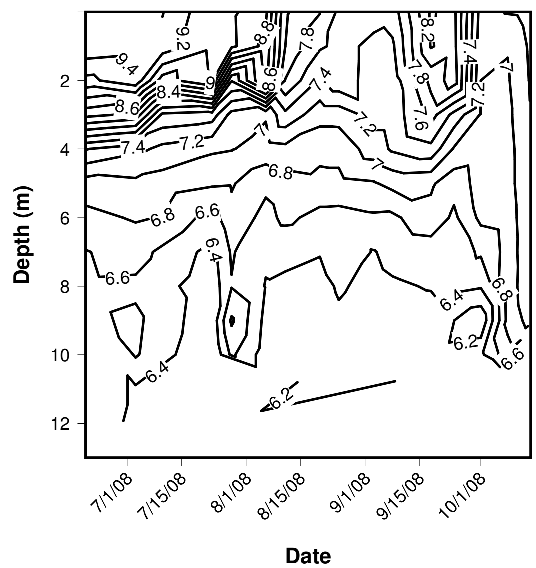


EXHIBIT 3.5-7
Round Lake pH 2008 Isopleth (SU)



3.5.2.5 Conductivity

Conductivity is consistent with a well-stratified lake. The epilimnion exhibits iso-conductivity (Exhibit 3.5-8). Diffusion of ions from the sediments sets up an increasing conductivity gradient from mesolimnion to the sediment surface.

3.5.3 Nutrients

3.5.3.1 Phosphorus Species and Chlorophyll *a*

Peak concentration of total phosphorous is noted in late July, followed by a noted decline (Exhibit 3.5-9). Orthophosphate has a similar peak to TP and the decline following peak is

EXHIBIT 3.5-8
Round Lake Conductivity 2008 Isopleth (mS/cm)

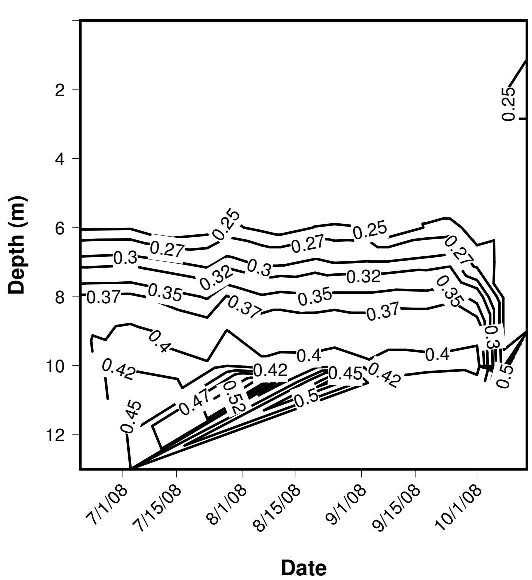
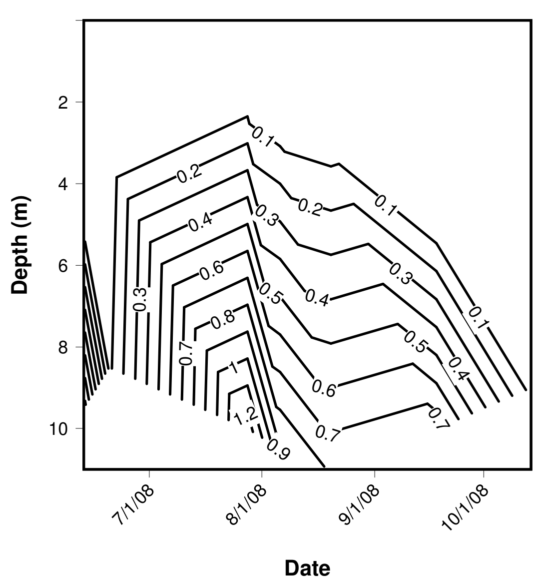


EXHIBIT 3.5-9
Round Lake 2008 Total Phosphorus Isopleth (mg/L)



much steeper (Exhibit 3.5-10). Higher concentration of TP and orthophosphate at the bottom indicates release from the bottom sediments. Hypolimnion ORP is always less than +100 mV above the sediments until turnover. Sulfate reduction (and concomitant sulfide production) occurs at ORP values less than +100 mV. At the ORP values measured near the Round Lake sediments ferric iron will be reduced to ferrous iron and release the phosphate that it had sorbed. Ferrous iron and sulfide ions form insoluble FeS, which strips iron from the hypolimnion water column. A potential outcome of this process is increased diffusion of orthophosphate from the hypolimnion to the epilimnion. A clear orthophosphate concentration gradient extending from the hypolimnion in to the epilimnion is evidence supporting this mechanism. Also the increase of chlorophyll *a* to August is corroborating evidence (Exhibit 3.5-11).

EXHIBIT 3.5-10

Round Lake 2008 Orthophosphate Isopleth(mg/L)

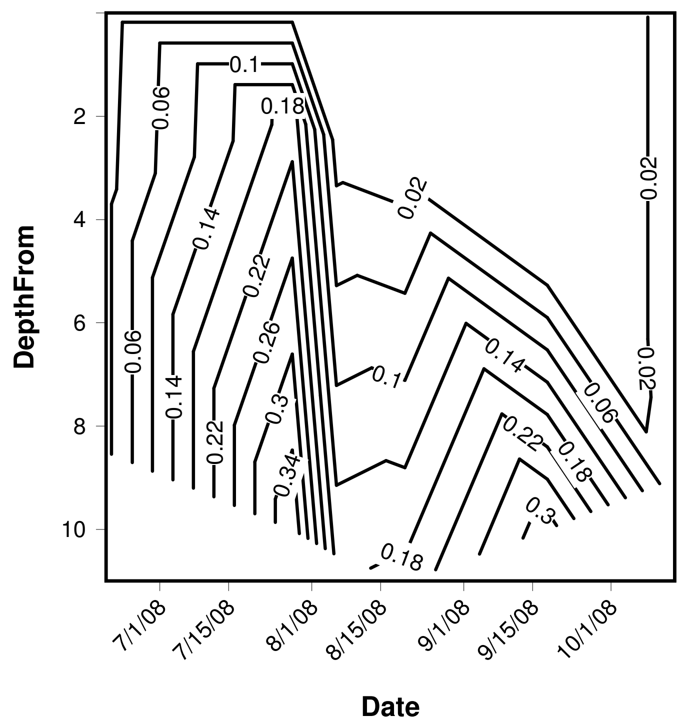
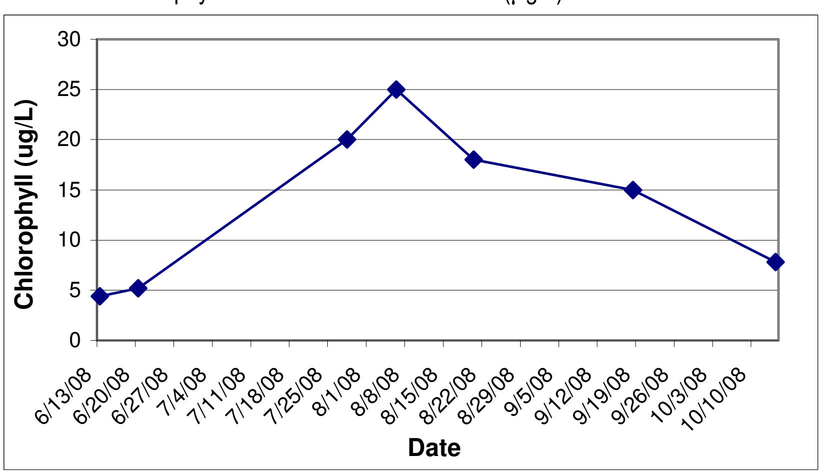


EXHIBIT 3.5-11

Round Lake Chlorophyll 2008 Surface Concentration (µg/L)

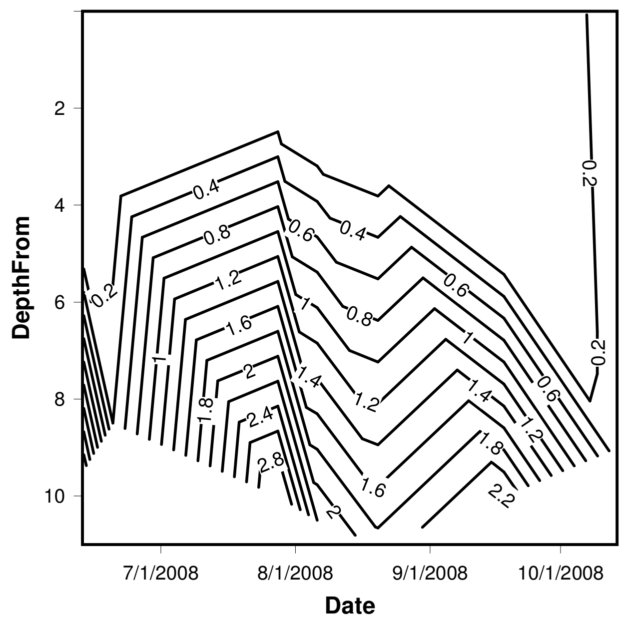


Surface chlorophyll *a* peaks slightly in mid-August and then again peaks in mid to late September. Both peaks tend to follow the high concentrations of nitrogen and phosphorous species. Peak concentrations near 25 micrograms per liter would classify the lake as eutrophic. Peaks in chlorophyll *a* are noted as peaks in the secchi disk depth. The increase in pH in mid to late September is well correlated to the increase in chlorophyll *a*. .

3.5.3.2 Nitrogen Species

Ammonia concentrations are greatest at the bottom of the lake in late summer (Exhibit 3.5-12). Another spike is noted in late September or early October. The noted horizontal line at the end of the sampling period indicate turnover. The un-ionized ammonia concentration did not exceed 0.02 mg/L (the concentration above which fish are stressed) for any samples.

EXHIBIT 3.5-12
Round Lake 2008 Ammonia Isopleth (mg/L)



Nitrate and nitrite were never measured above the detection limit. Lack of detection would indicate that nitrification and denitrification are both occurring to convert ammonia all the way to nitrogen gas. TKN and TN graphs are almost identical due to the very low levels of nitrate and nitrite (Exhibits 3.5-13 and 3.5-14). The strong diffusion gradient from bottom to surface reveals that internal nitrogen loading is a significant (possibly dominant) contributor to the lake nitrogen budget.

EXHIBIT 3.5-13
Round Lake 2008 TKN Isopleth (mg/L)

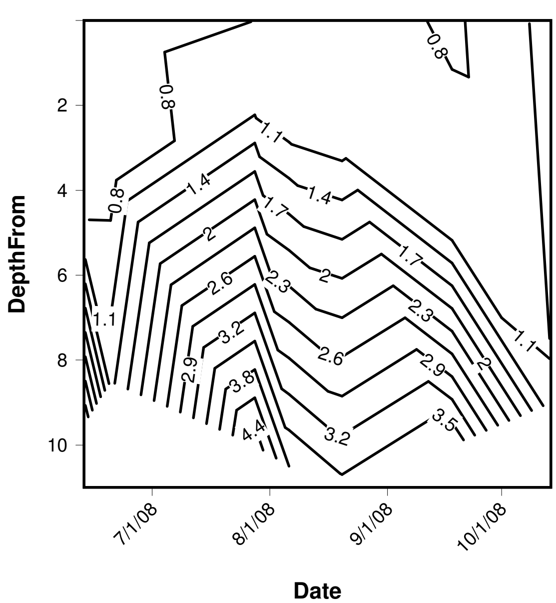
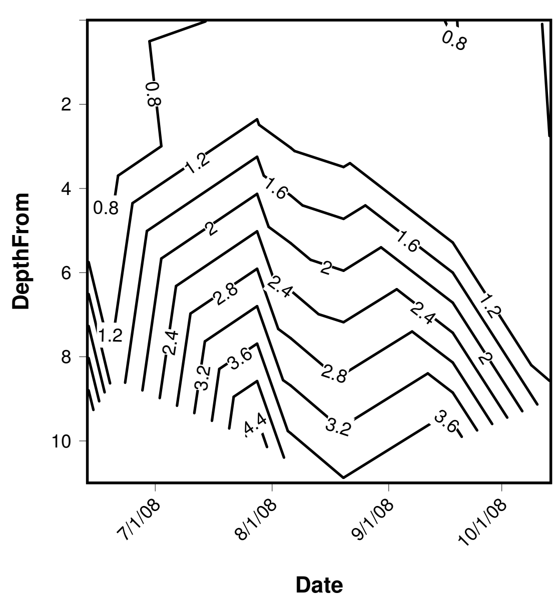


EXHIBIT 3.5-14
Round Lake 2008 Total Nitrogen Isopleth (mg/L)

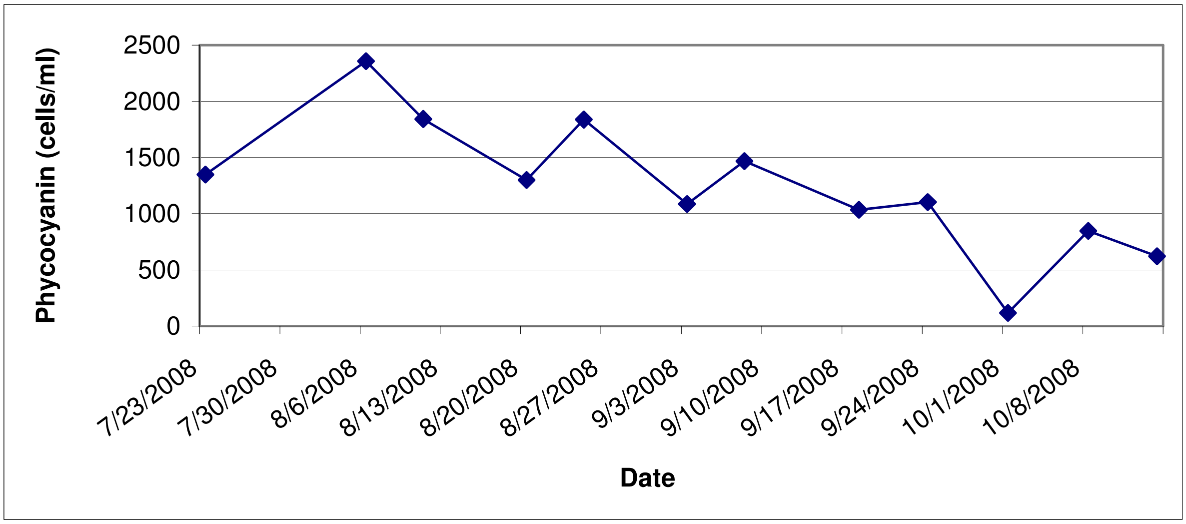


3.5.4 Biological parameters

3.5.4.1 Phycocyanin

Phycocyanin peaked in early August and continued a general trend of decreasing for the rest of the sampling period (Exhibit 3.5-15). An interesting pattern of small increase and decrease is noted throughout the decline in overall concentrations. The phycocyanin measurements indicate that Round Lake begins the sampling season in the WHO low risk category (1,000 to 8,000 cells/mL of phycocyanin) and then drops below the threshold in October.

EXHIBIT 3.5-15
Round Lake Phycocyanin 2008 Surface Concentration (cells/mL)



3.5.4.2 Plankton and Cyanotoxin Assessment

Phyto- and zooplankton samples were taken on September 18, 2008 and evaluated for count and biovolume. Phytoplankton density was dominated (91 percent) by the cyanobacteria *Aphanizomenon flos-aquae* and *Anabaena* spp., species both known to produce cyanotoxins (Exhibits 3.5-16 and 3.5-17). Although it is not possible to predict cyanotoxin production, the WHO moderate risk threshold is 100,000 cells/mL. The total cyanobacteria cell density on September 17, 2008, was about 45,000 cells/mL. The phycocyanin concentration was correlated with the cyanobacteria concentration, and it was determined that phycocyanin levels greater than 8,800 cells/mL are in the WHO moderate risk zone for exposure to cyanotoxins. The maximum Round Lake phycocyanin measured was 2,400 cells/mL, which according to the correlation would be cyanobacteria concentration of about 52,400 cells/mL. Though cyanobacteria capable of producing toxins were identified in the lake the concentration indicates that cyanotoxins are not a major concern at this point.

The zooplankton population was dominated by small-bodied organisms that can lead to algal growth (Exhibits 3.5-18 and 3.5-19). The absence of large-bodied Cladoceran zooplankton, is an important element in the conditions arising for an algae bloom.

EXHIBIT 3.5-16
Round Lake Phytoplankton Density, September 18, 2008

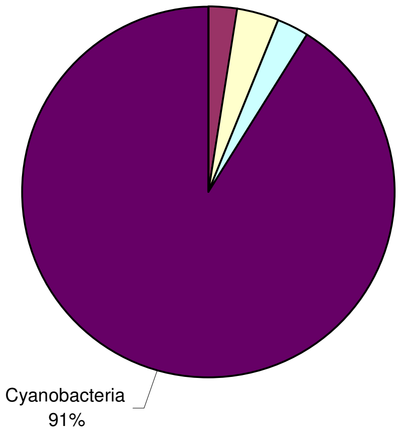


EXHIBIT 3.5-17
Round Lake Dominate phytoplankton by genus or species, September 18, 2008

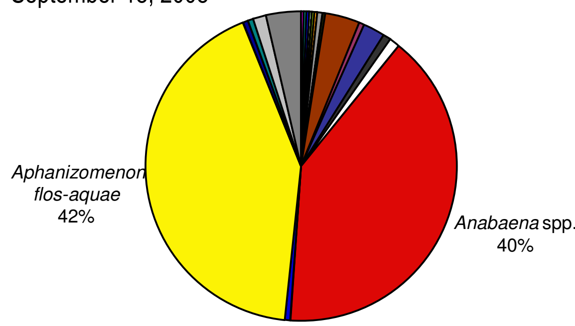
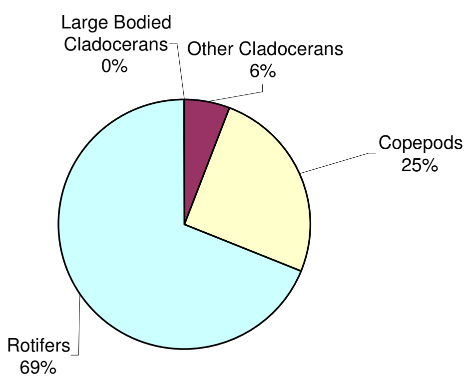
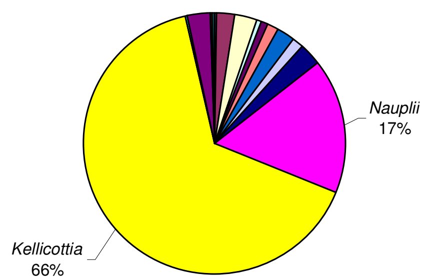


EXHIBIT 3.5-18
Round Lake Zooplankton Density, September 18, 2008



Zooplankton density 444 Individuals/L

EXHIBIT 3.5-19
Round Lake Dominate Phytoplankton by Genus or Species, September 18, 2008



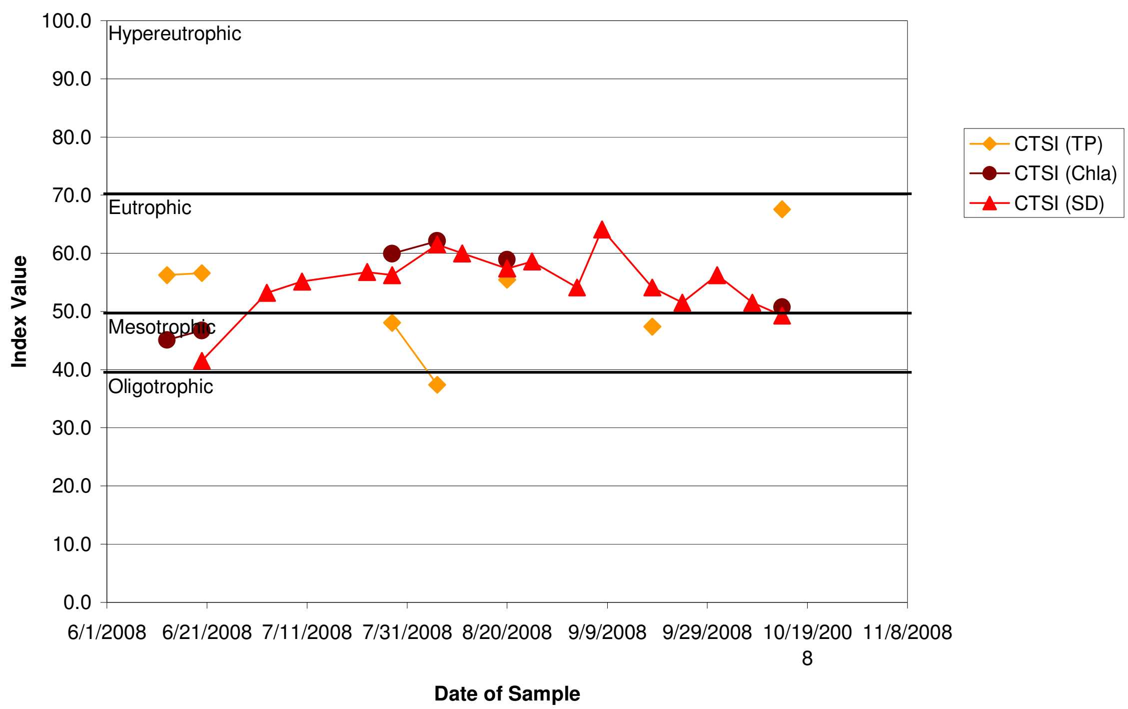
3.5.5 Trophic Indices

3.5.5.1 Current

CTSI classifies the lake as eutrophic most of the year with periods at the beginning and end of the year as mesotrophic (Exhibit 3.5-20). ITSI score of 27 indicates a mesotrophic lake on September 18, 2008.

Comparing the two indices indicates good correlation for ITSI and CTSI for TP, both indicate mesotrophic. CTSI for Secchi disk depth (SD) and ITSI indicate different trophic states; however their relative location in terms of closeness to another trophic state indicate some correlation. ITSI is 5 points from the eutrophic state while CTSI (SD) is 4.2 above the eutrophic/mesotrophic dividing line. It should also be noted that half of the weight of the ITSI comes from the total plankton and blue-green dominance.

EXHIBIT 3.5-20
Round Lake 2008 CTSI



The City of Eden Prairie has published a report on invasive plants in Round Lake (*Aquatic Plant Surveys for Round Lake, Eden Prairie, Minnesota in 2008)*. The lake has both curlyleaf pondweed and Eurasian milfoil. During the first week of August, Eurasian milfoil was harvested from the lake and the weeds were removed from the beach area.

3.5.5.2 Other Studies

The sediment oxygen demand of Round Lake was measured in 2008 as 2.16 g oxygen/m^2/ day and is discussed in a separate report.

3.5.5.3 Historic trends

Historical Secchi disk depths for July and August indicate a trend of decreasing transparency according to the Kendall tau test (Exhibits 5-21 and 5-22). This trend is a good illustration of the general water quality degradation that has occurred over the past 30 years. There is a bias in the data because of a 4-year period after 1980 in which a biomanipulation experiment produced high water transparency.

Historical CTSI values are shown in Exhibit 3.5-23. The TP and chlorophyll *a* data do not show a historical trend according to the Kendall Tau test.

3.5.6 Conclusions

The results of the 2008 sampling season indicate that Round Lake is a dimictic strongly stratified eutrophic lake. The primary productivity of the lake is driven by the relative abundance of labile phosphorus which is due to the lack of dissolved oxygen in the hypolimnion of the lake.

EXHIBIT 3.5-21
Round Lake Average Secchi Disk Depths (m)

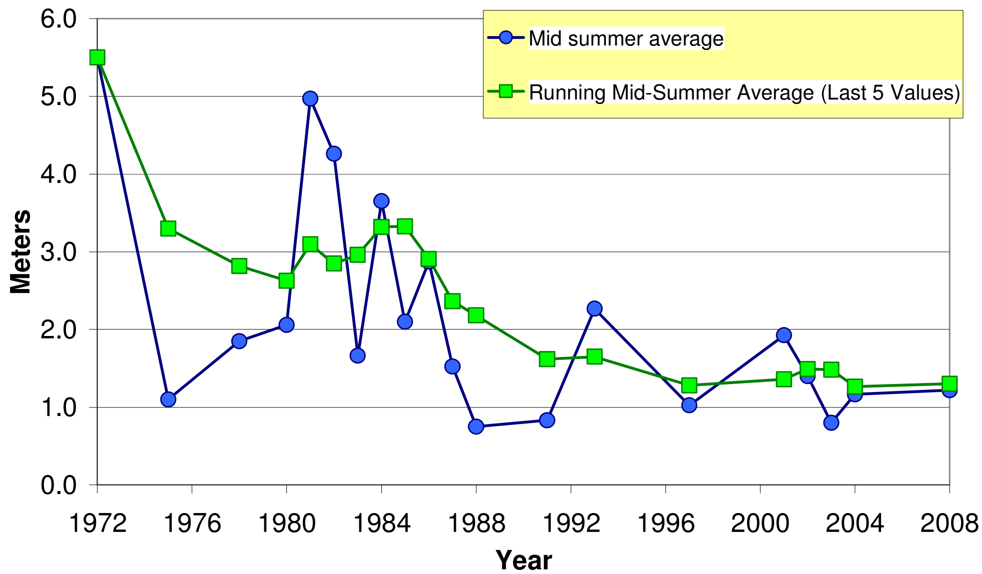
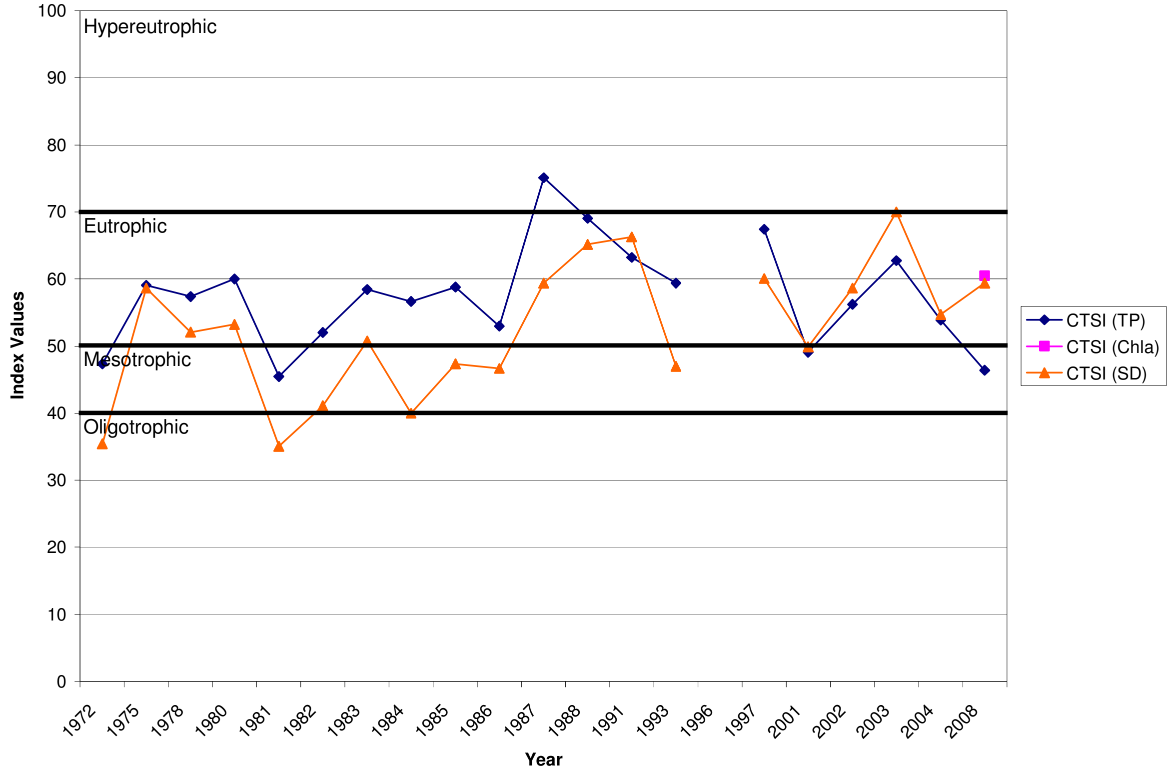


EXHIBIT 3.5-22
Results of Kendall Tau Test

Period	Parameter	2008 Median	Historical Median	Statement of Trend
July	TP (mg/L)	10.5	40.65	X
July	Chla (µg/L)		10.6	X
July	SD (m)	1.35	10.6	Y
August	TP (mg/L)	22.5	40	X
August	Chla (µg/L)		11.7	X
August	SD (m)	138	40	Y
July–August	TP (mg/L)	15.5	40	X
July–August	Chla (µg/L)		11.4	X
July–August	SD (m)	1.23	1.73	Y

X: H0 cannot be rejected; i.e., there is insufficient evidence to prove a trend.
Y: H0 is rejected; i.e., there is sufficient evidence to prove a trend.
NA: Not applicable as the Kendall tau test could not be performed due to insufficient data.

EXHIBIT 3.5-23
Round Lake Historic CTSI – August Average

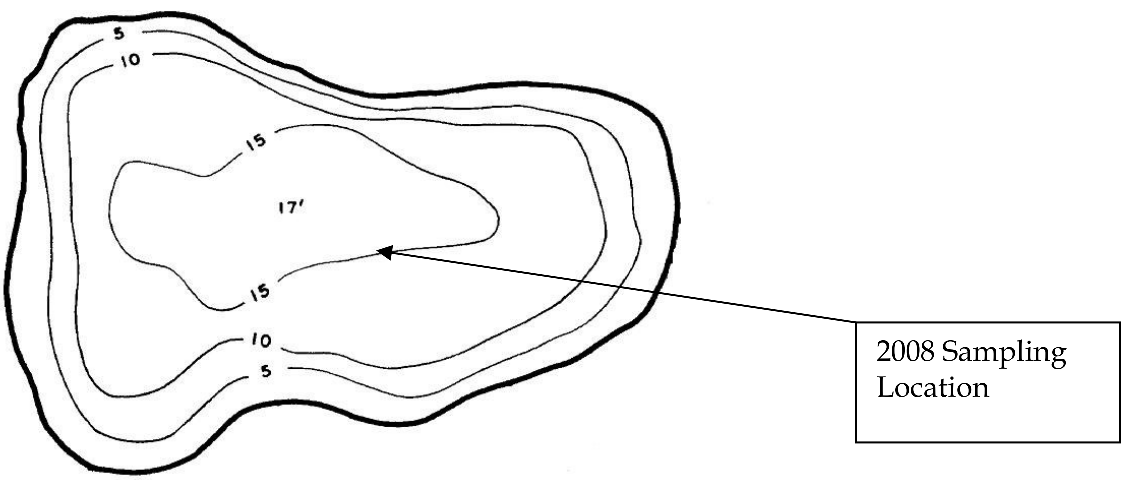


3.6 Lake Susan

3.6.1 Introduction

In-situ water quality measurements were collected biweekly using the sonde, and water quality samples were collected monthly. Susan Lake was sampled six times roughly. One other sample was collected in early August (Exhibit 3.6-1), and the University of Minnesota performed regular water quality sampling and analysis as part of the ongoing carp study.

EXHIBIT 3.6-1
Susan Lake 2008 Sampling Location (Map for Minn. DNR)

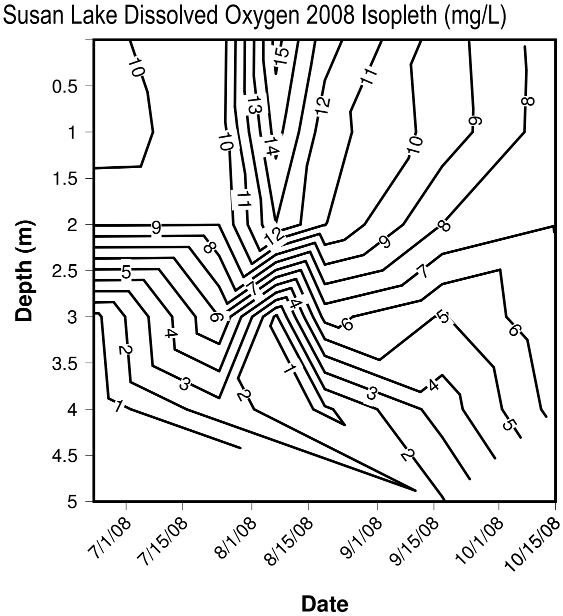


3.6.2 In-Situ Parameters

3.6.2.1 Dissolved Oxygen and Temperature

Dissolved oxygen is noted by a marked increase from the surface in mid-August, the supersaturation dissolved oxygen concentrations are indicative of intense photosynthesis in an algae bloom (Exhibit 3.6-2). Overall dissolved oxygen appears to limit fish to the top 3 meters of the lake. Temperature notes almost no stratification after roughly mid-August (Exhibit 3.6-3). For the rest of the sampling period water temperature is fairly warm, decreasing from 23 to 15 degrees Celsius.

EXHIBIT 3.6-2
Susan Lake Dissolved Oxygen 2008 Isopleth (mg/L)



3.6.2.2 Oxidation Reduction Potential

The final meter of ORP readings shows a strong gradient throughout the sampling season (Exhibit 3.6-4). The decrease in ORP indicates that the sediments are anaerobic and producing sulfides. These sulfides diffuse up from the sediments and are oxidized by the dissolved oxygen in the water. The ORP drops even when dissolved oxygen is present indicates that equilibrium has not been reached between the sulfides released from the sediments and the dissolved oxygen diffusing down from the epilimnion.

EXHIBIT 3.6-3
Susan Lake Temperature 2008 Isopleth (°C)

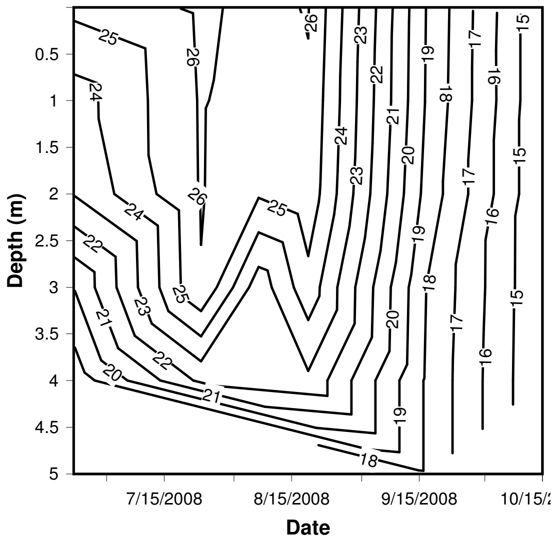
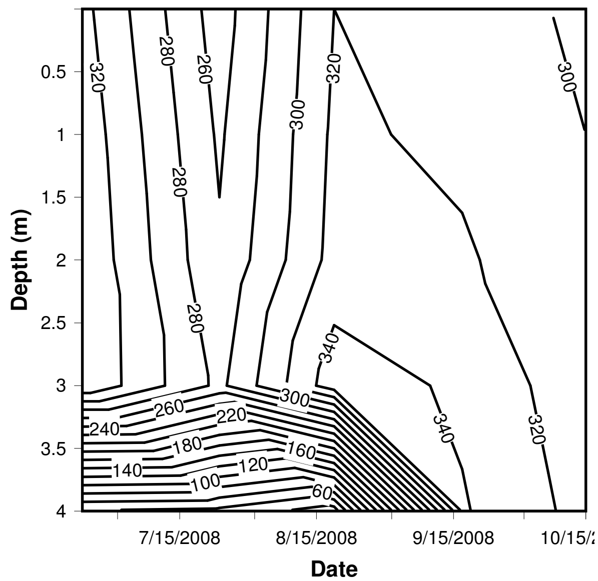


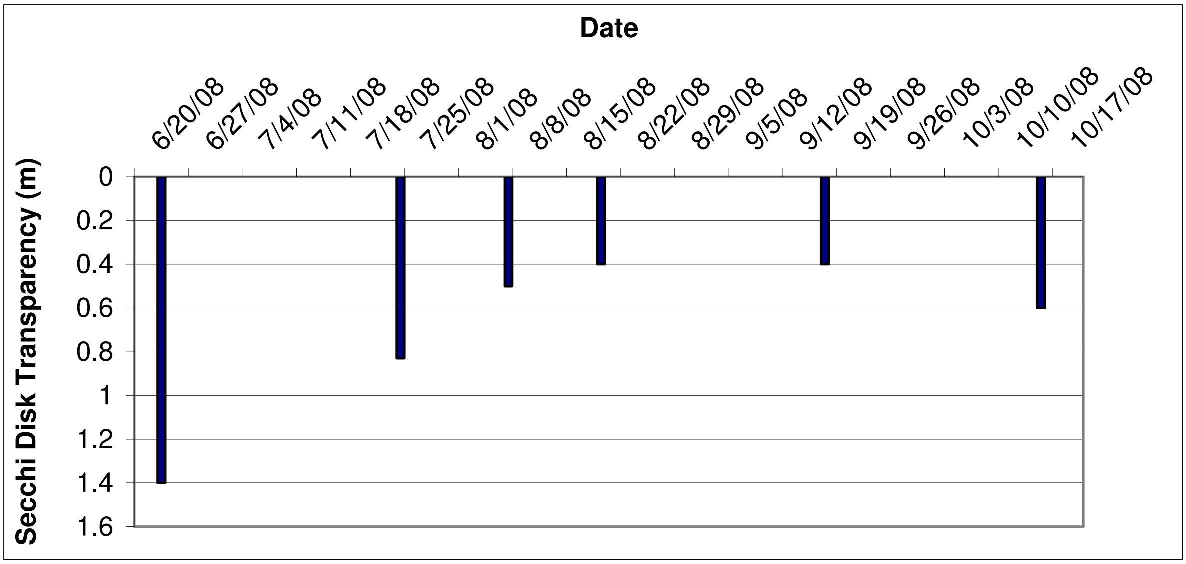
EXHIBIT 3.6-4
Susan Lake ORP 2008 Isopleth (mV)



3.6.2.3 Water Clarity

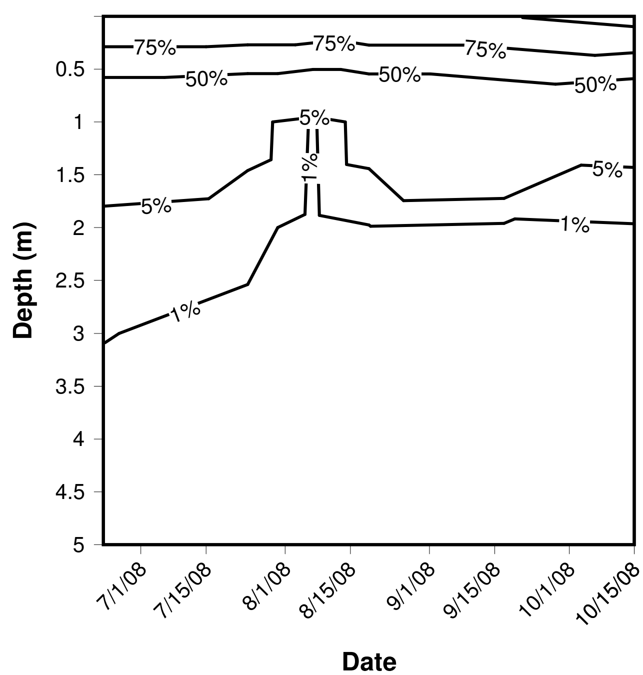
Secchi Disk. Secchi disk depth decreases throughout the summer (Exhibit 3.6-5). Late summer values are indicative of a hypereutrophic state.

EXHIBIT 3.6-5
Susan Lake 2008 Secchi Disk Data



Photosynthetic Active Radiation. The euphotic zone in Lake Susan extends down to between 2 to 3 meters (Exhibit 3.6-6).

EXHIBIT 3.6-6
Susan Lake Percent Incident Light Penetration 2008 Isopleth



3.6.2.4 pH

As a stressor to fish, pH when evaluated in combination with dissolved oxygen indicate the space in which fish can easily survive. The critical pH threshold above which fish are stressed is in the 9.0 to 9.3 range, which in late July can be as deep as 3 meters (Exhibit 3.6-7). Such a depth leaves fish with very little space to live without stress.

3.6.2.5 Conductivity

The conductivity shows a diffusion gradient from the sediments (Exhibit 3.6-8). Algae cell mass is more saline than surrounding water. Therefore the decaying mass should have a higher conductivity, which is what was observed.

EXHIBIT 3.6-7
Susan Lake pH 2008 Isopleth (SU)

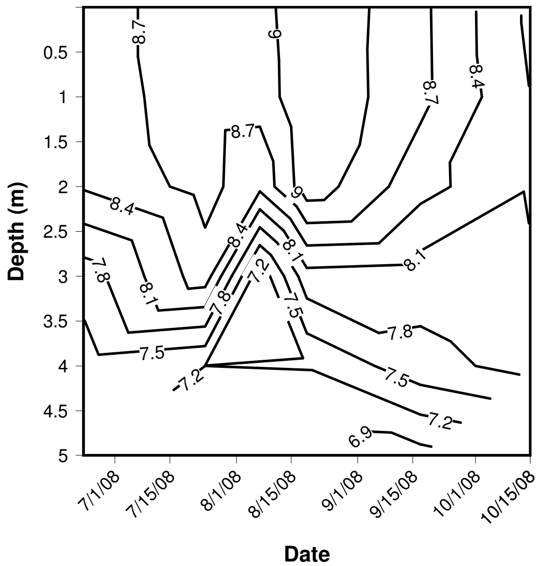
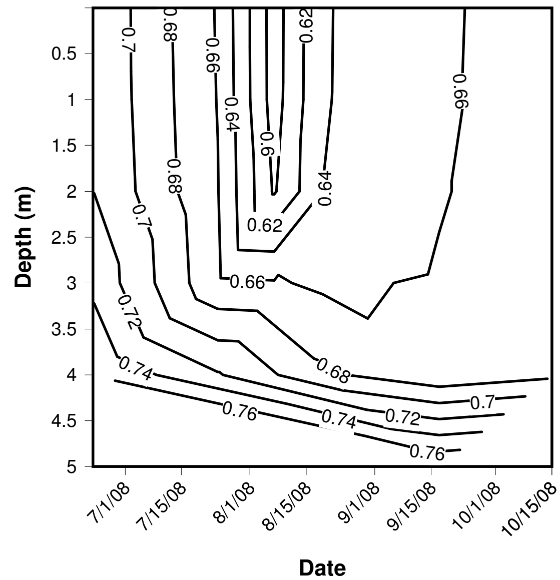


EXHIBIT 3.6-8
Susan Lake Conductivity 2008 Isopleth (mS/cm)



3.6.3 Nutrients

3.6.3.1 Phosphorus Species

Total phosphorous and orthophosphate are well distributed throughout the water column throughout most of the summer (Exhibits 6-9 and 6-10). Variable bottom depth measurements make it difficult to assess bottom concentrations.

EXHIBIT 3.6-9
Susan Lake 2008 Total Phosphorus Isopleth (mg/L)

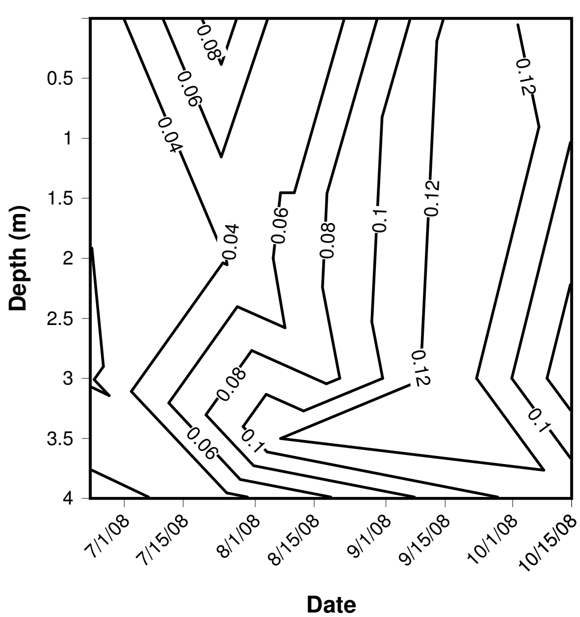
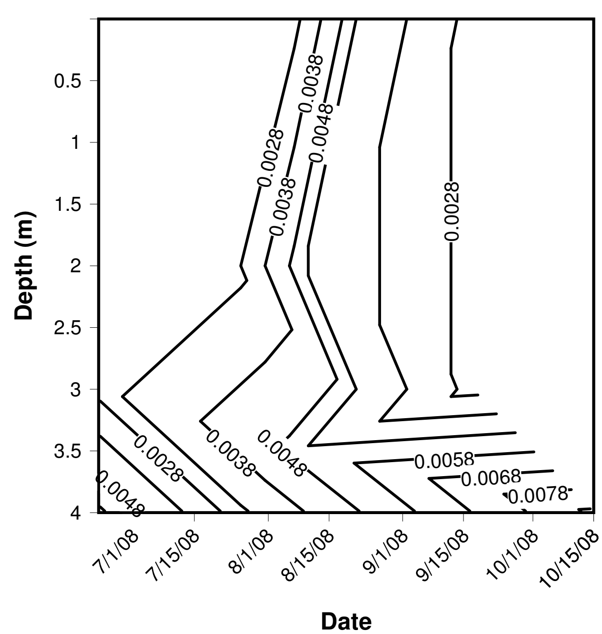
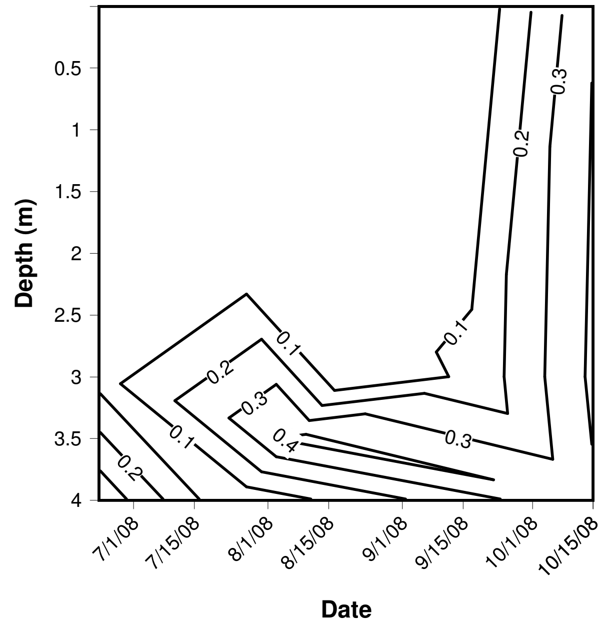


EXHIBIT 3.6-10
Susan Lake 2008 Orthophosphate Isopleth (mg/L)



3.6.3.2 Nitrogen Species

EXHIBIT 3.6-11
Susan Lake 2008 Ammonia Isopleth (mg/L)



Ammonia concentration in Susan Lake tends to follow a typical pattern of increasing concentration at the bottom and an isoconcentration profile at turnover (Exhibit 3.6-11). The ammonia concentration was recorded at the minimum detection limit for samples collected across the entire depth on July 24 and August 19, 2008.

Nitrate and nitrite were never measured above the detection limit. Lack of detection would indicate nitrification and denitrification are both occurring to convert ammonia all the way to nitrogen gas.

TKN consists of organic and ammonia nitrogen. TKN and total nitrogen are almost identical because of the very low concentrations of nitrate and nitrite (Exhibits 3.6-12 and 3.6-13). The TKN and ammonia isopleths are fundamentally different because TKN in Lake Susan is dominated by organic nitrogen. As summer progresses, fixation of nitrogen from the atmosphere by cyanobacteria causes an increasing concentration of organic N. Sedimentation of algae forces essentially constant concentration from the lake surface to the lake bottom. In contrast, ammonia, which is a product of organic N hydrolysis (decomposition), exhibits a concentration gradient because the source of ammonia is algae in the sediments.

EXHIBIT 3.6-12
Susan Lake 2008 TKN Isopleth (mg/L)

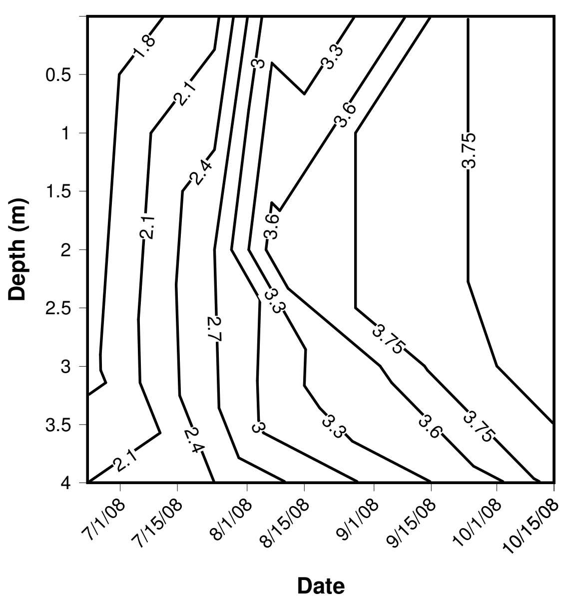
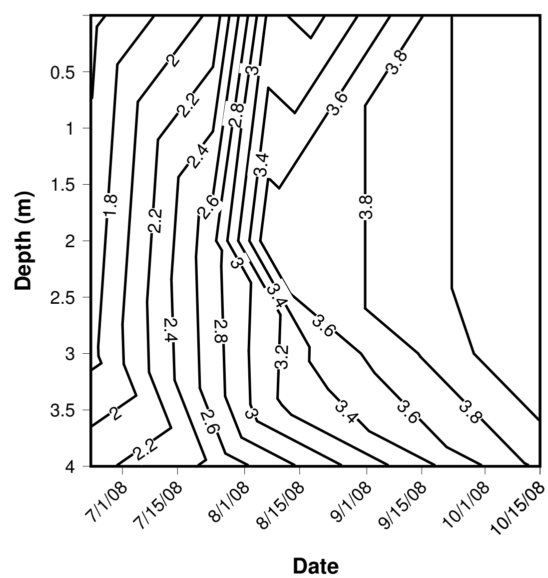


EXHIBIT 3.6-13
Susan Lake 2008 Total Nitrogen Isopleth (mg/L)



3.6.4 Biological Parameters

3.6.4.1 Chlorophyll *a*

The chlorophyll *a* measurements at the surface of Lake Susan followed the classic rise and fall curve as the lake temperature rose through June and peaked in August (Exhibit 3.6-14). The highest chlorophyll *a* measurement was taken in July and August. The chlorophyll *a* concentrations measured throughout the sampling season were very low.

3.6.4.2 Phycocyanin

Phycocyanin tends to increase as time passes, but chlorophyll *a* is more consistent (Exhibit 3.6-15). This difference indicates an increasing dominance of blue-green algae. The mid-September phycocyanin sample was corroborated with an algae enumeration and biovolume determination to be indicative of a cyanobacteria bloom. The phycocyanin measurements indicate that the lake is above the WHO low risk threshold some time in early

EXHIBIT 3.6-14
Susan Lake Chlorophyll 2008 Surface Concentration (µg/L)

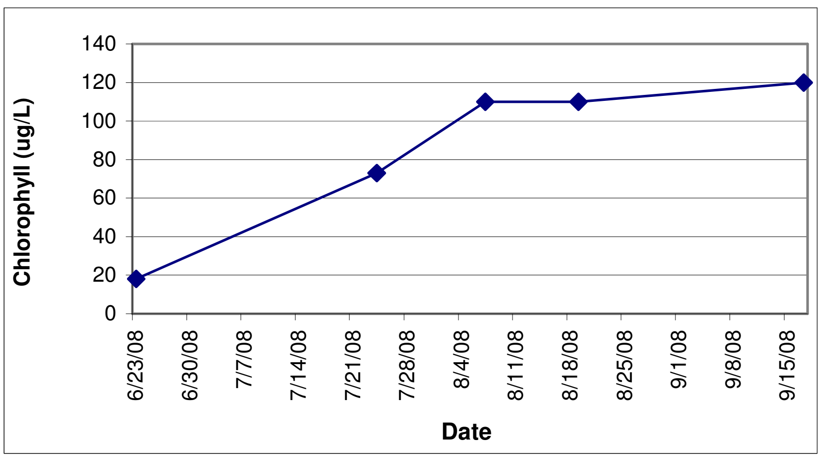
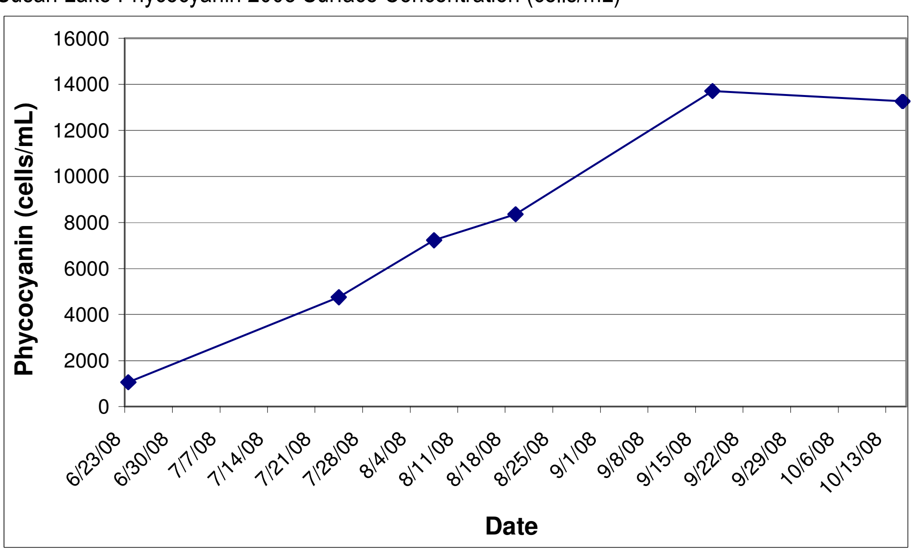


EXHIBIT 3.6-15
Susan Lake Phycocyanin 2008 Surface Concentration (cells/mL)



July. By August 7, the phycocyanin levels surpassed a threshold of 8,000 cells/mL, corresponding to the WHO moderate risk threshold of 100,000 cells/mL of cyanobacteria. This means that lake was in the moderate risk zone four of the six times it was analyzed for phycocyanin (August 7, August 19, September 17, October 15). Dermal contact at concentrations above this level represent a moderate risk zone for exposure to cyanotoxin.

3.6.4.3 Plankton and Cyanotoxin Assessment

Phyto- and zooplankton samples were taken on September 17, 2008, and evaluated for count and biovolume. Phytoplankton density was completely dominated (99 percent) by the cyanobacteria *Aphanizomenon flos-aquae*, which is known to produce toxins (Exhibits 6-16 and 6-17). Although it is not possible to predict cyanotoxin production, the WHO moderate risk threshold is 100,000 cells/mL. The total cyanobacteria cell density on September 17, 2008, was greater than 134,000 cells/mL, which is clearly cause for concern.

The zooplankton population was dominated by small-bodied organisms that can lead to algal growth (Exhibits 3.6-18 and 3.6-19). The absence of large-bodied Cladoceran zooplankton, is an important element in the conditions arising for an algae bloom.

EXHIBIT 3.6-16
Susan Lake Phytoplankton Density, September 17, 2008

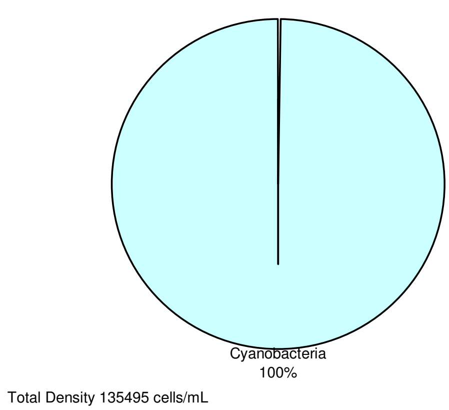


EXHIBIT 3.6-17
Susan Lake Dominate Phytoplankton by Genus or Species, September 17, 2008

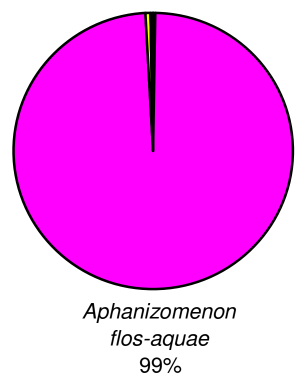


EXHIBIT 3.6-18
Susan Lake Zooplankton Density, September 17, 2008

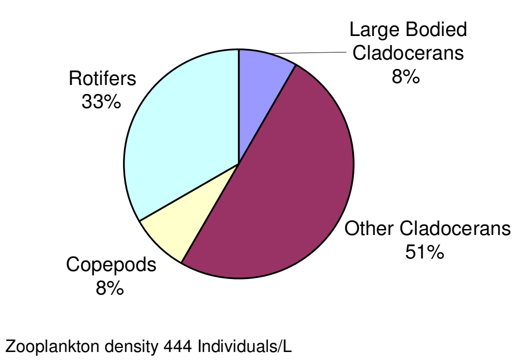
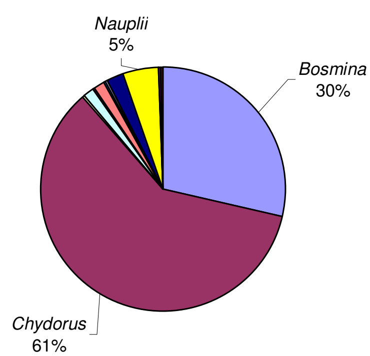


EXHIBIT 3.6-19
Susan Lake Dominate Phytoplankton by Genus or Species, September 17, 2008

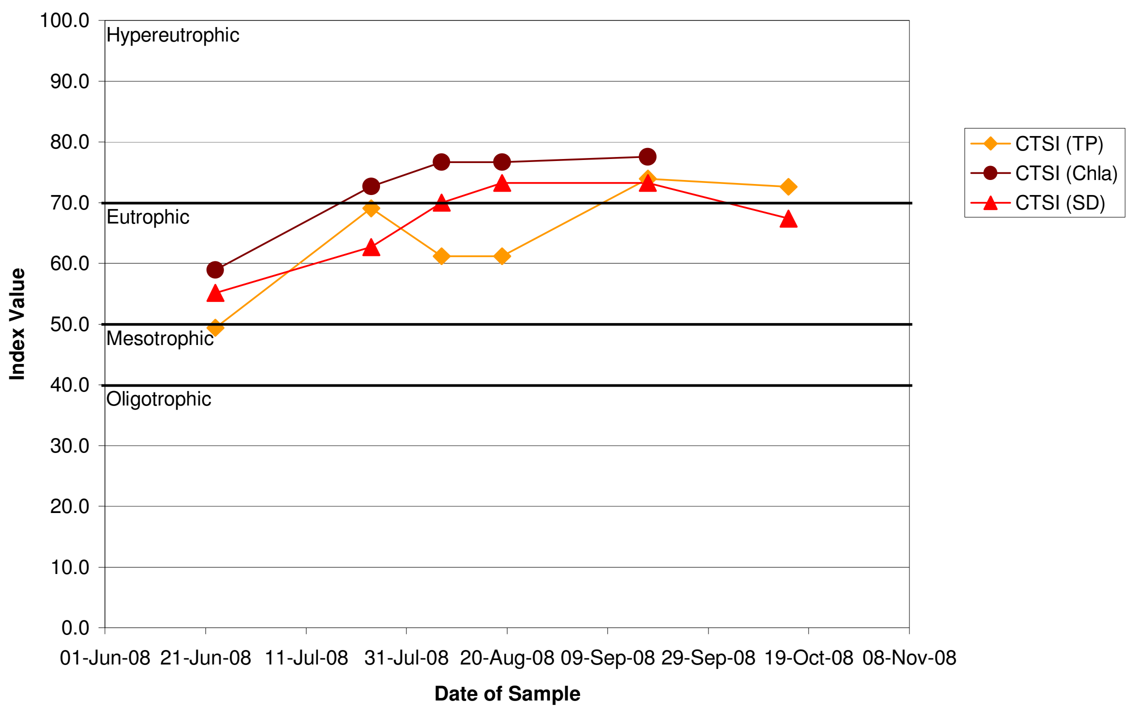


3.6.5 Trophic Indices

3.6.5.1 Current

Carlson Trophic State Index (CTSI) indicates the lake begins the summer in a eutrophic state and becomes hypereutrophic by late July (Exhibit 3.6-20). Throughout the summer CTSI values for chlorophyll *a* (Chla) greater than CTSI values for Secchi disk depth (SD), which is indicative of large particles dominating the water column. Susan Lake has a large carp population that causes substantial bioturbation of sediment. Therefore this intra-CTSI relation is consistent with a shallow lake with carp-domination of fish biomass. Indian Trophic State Index (ITSI) results in a score of 42 for September 17, 2008. The index would indicate the lake is eutrophic at this time.

EXHIBIT 3.6-20
Susan Lake 2008 CTSI



Comparison of indices results in the ITSI reading lower, indicate better lake quality, than the CTSI. The primary reasons for the difference in the scoring seems to be because of low nitrogen levels and because oxygen can reach the bottom of the lake.

3.6.5.2 Historic Trends

Historic secchi disk depths indicate a stable lake condition over the past 5 years (Exhibit 3.6-21). Overall the values are characteristic of eutrophic to hypereutrophic states. A Kendall tau test (See Appendix B) shows that there is not a significant trend to changes Secchi disk depth over the past 5 years (Exhibit 3.6-22).

EXHIBIT 3.6-21
Susan Lake Historic Secchi Disk Depth

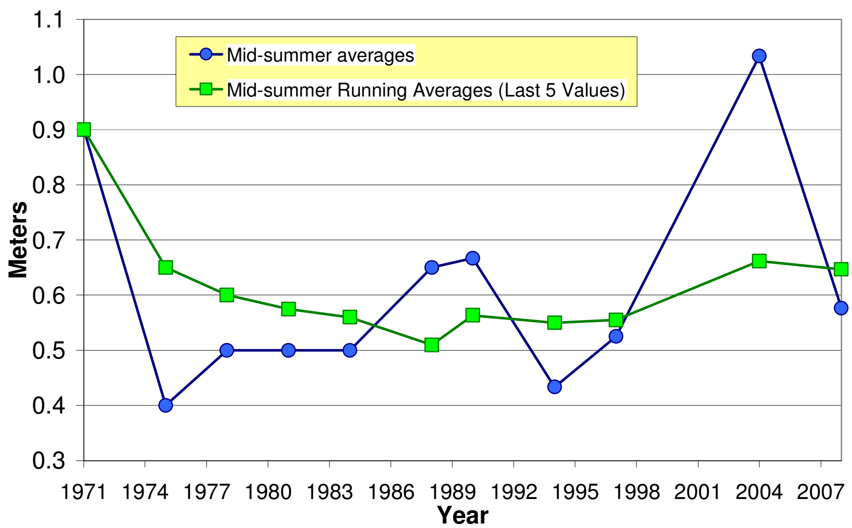


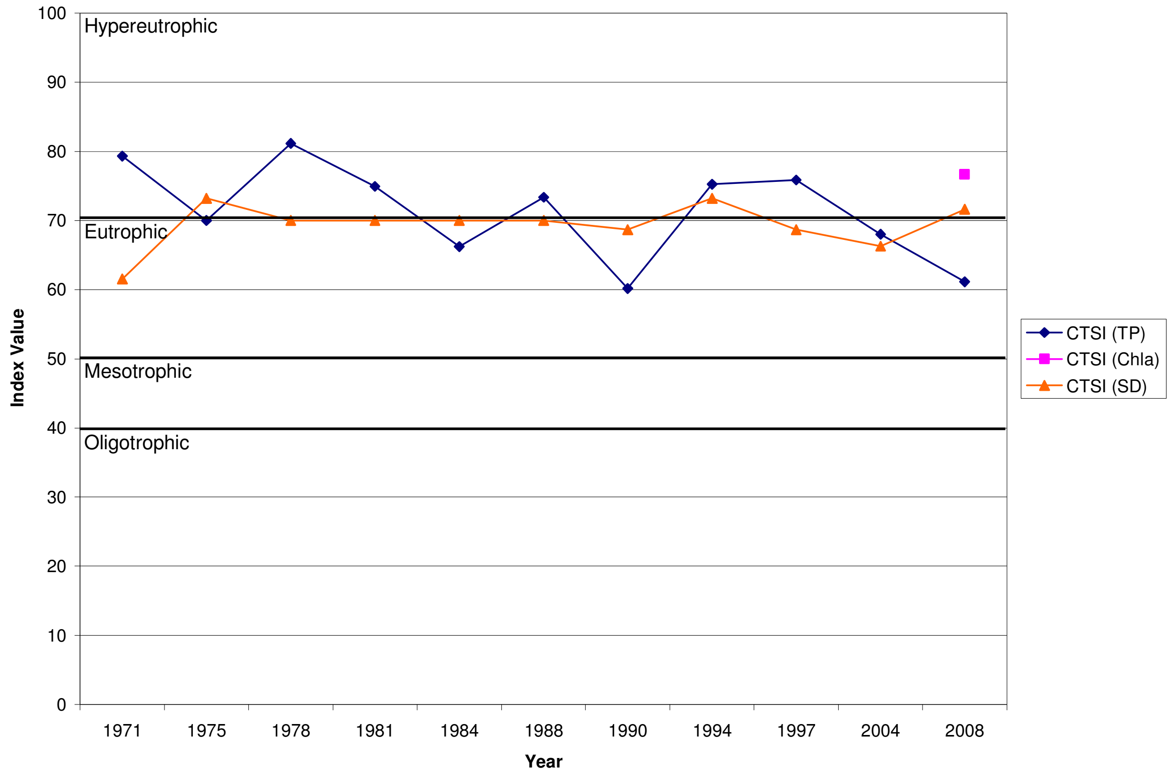
EXHIBIT 3.6-22
Results of Kendall Tau Test

Period	Parameter	2008 Median	Historical Median	Statement of Trend
July	TP (mg/L)	90	74.5	X
July	Chla (µg/L)			X
July	SD (m)	0.83	0.75	X
August	TP (mg/L)	52		X
August	Chla (µg/L)			X
August	SD (m)	0.45	0.5	X
July–August	TP (mg/L)	52	97	X
July–August	Chla (µg/L)			X
July–August	SD (m)	0.5	0.5	X

X: H0 cannot be rejected; i.e., there is insufficient evidence to prove a trend.
Y: H0 is rejected; i.e., there is sufficient evidence to prove a trend.
NA: Not applicable as the Kendall tau test could not be performed due to insufficient data.

Historic CTSI reinforce the poor lake quality noted by historic Secchi disk depth (Exhibit 3.6-23). The values do indicate a consistent quality throughout the years in late summer. A Kendall tau test confirms that there is no trend to the historic chlorophyll *a*, total phosphorus or Secchi disk values. Intertwined values for CTSI for TP and CTSI for SD indicate not a single issue but likely multiple issues contributing to the poor lake quality.

EXHIBIT 3.6-23
Susan Lake Historic CTSI – August Average



3.6.6 Conclusions

The results of the 2008 sampling season indicate that Lake Susan is a weakly stratified eutrophic to hypereutrophic lake. The lake appears to be dimictic, but stratification may be sufficiently weak to allow mixing during storms with high winds. Primary productivity of the lake is driven by the relative abundance of labile phosphorus. The lack of large bodied zooplankton to keep the algae concentration in balance allowed blooms of harmful cyanobacteria to develop. One source of phosphorus release is the lake sediments. The consequence of the apparently high sediment oxygen demand of the lake, inferred from ORP data, is that phosphorus is probably released as ferric iron is reduced to ferrous iron.

4. Summary

All of the lakes monitored during the 2008 sampling season experience substantial internal phosphorus loading from the lake sediment under anaerobic conditions at the sediment/water interface. Stimulation of algae growth as a result of phosphorus release sharply reduces water clarity in all lakes. All of the lakes monitored in 2008 cross the WHO low risk threshold for cyanobacteria at some point in the sampling season. Lake Susan and Mitchell Lake cross the WHO moderate risk threshold and Lotus Lake was just below the threshold. Low risk thresholds are crossed in Lakes Mitchell (Point E), Round and Susan throughout the summer.

Zooplankton analysis of the lakes reveals that large bodied zooplankton are absent. These large bodied zooplankton if present would help to keep the algae populations in balance. Rehabilitation of lake water clarity and mitigation of potential public health effects of cyanobacteria blooms will require control over sediment release of phosphorus. Biomanipulation of lakes to mitigate predation of large-bodied zooplankton may also be desirable.

Lake Ann is a deep, strongly stratified mesotrophic to eutrophic lake. The primary productivity of this lake is driven by the relative abundance of labile phosphorus. The 2008 total phosphorus shows a statistically significant decrease compared to the past 30 years. The lack of large bodied zooplankton to keep the algae concentration in balance allowed blooms of harmful cyanobacteria to develop. A significant source of phosphorus is internal loading from lake sediments.

Lotus Lake is a dimictic weekly stratified eutrophic to hypereutrophic lake. The primary productivity of the lake is driven by the relative abundance of labile phosphorus. There is not significant difference between 2008 water quality and water quality of the past 30 years. The lack of large bodied zooplankton to keep the algae concentration in balance allowed blooms of harmful cyanobacteria to develop. A significant source of phosphorus is internal loading from lake sediments.

Mitchell Lake, for the most part, is a dimictic, weakly stratified eutrophic to hypereutrophic lake. The primary productivity of the lake is driven by the relative abundance of labile phosphorus. The lack of large bodied zooplankton to keep the algae concentration in balance allowed blooms of harmful cyanobacteria to develop. One of the sources of phosphorus release is the lake sediments. The high sediment oxygen demand (3.12 g oxygen/m_2/day) of the lake means that phosphorus is released as ferric iron is reduced to ferrous iron. Mitchell Lake at Point A experienced similar conditions to Point E, where water quality was poor. The Solar Bee technology did not prevent the cyanobacteria bloom on August 6, which also occurred at Points E and B. Like Points E and A, Point B is shallow and weakly stratified, and experienced similar water quality conditions. Mitchell Lake at Point C is also a shallow, weakly stratified, dimictic, roughly eutrophic, like the other points in the lake. However, the water quality at Point C improved after the warm weather peaked. The improvement in Secchi disk depths can be correlated with the ORP conditions at the bottom of the lake, preventing phosphorus from migrating into the water column. The reason for the clear water through September and October could also be attributed to the *Ceratophyllum demersum* dominance in parts of Bay C. Throughout the sampling season Point D's water quality parameters showed potential for the occurrence of an algae bloom, however cyanobacteria were held in check by the domination of *Ceratophyllum demersum*. The isolation of Bay D from other points of the lake, and the other bays being downstream from Bay D, allowed it to sustain clear water throughout the sampling season.

Riley is a deep, well-stratified lake. During 2008 it appears the lake is low eutrophic. There is not significant difference between 2008 water quality and water quality of the past 30 years. Riley Lake becomes eutrophic throughout the summer. Internal phosphorous loading appears to drive primary productivity. Absence of large bodied zooplankton means the algae growth is not kept in check.

Round Lake is a dimictic strongly stratified eutrophic lake. The 2008 data show a continuation of the historical decrease in the secchi disk depth. The primary productivity of the lake is driven by the relative abundance of labile phosphorus which is due to the lack of dissolved oxygen in the hypolimnion of the lake.

Lake Susan is a weakly stratified eutrophic to hypereutrophic lake. The lake appears to be dimictic, but stratification may be sufficiently weak to allow mixing during storms with high winds. There is not significant difference between 2008 water quality and water quality of the past 30 years. Primary productivity of the lake is driven by the relative abundance of labile phosphorus from internal loading. The lack of large bodied zooplankton to keep the algae concentration in balance allowed blooms of harmful cyanobacteria to develop.

5. References

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Lund, J. W. G., C. Kipling, and E.D. LeCren. 1958. "The Inverted Microscope Method of Estimating Algal Numbers and the Statistical Basis of Estimates By Counting." *Hydrobiolgia* 11:143–70.

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`Appendix A

Monitoring and Sampling Procedures

Monitoring and Sampling Procedures

Lake Monitoring Procedures

Step 1

Unload sample bottles near the sampling location and prepare cooler, ice, *Monthly Water Sampling* form and the *Monthly Water Quality Field Measurements* form. DO NOT OPEN SAMPLE BOTTLES.

Step 2 – Deployment of boat

Place the following items in the boat:

Secchi

Hydrolab sonde and surveyor

1. Oars
2. Motor and battery
3. Boat Break (rigged and ready to deploy)
4. Depth finder
5. Water sampler. Tie end of rope to thwart.
6. Secchi disk
7. Graduated rope (1 m increments)
8. Plankton net and wash bottle (if needed)
9. Attach sonde (large multi-probe) surveyor and place in boat. Attach sonde to 20 meter lanyard for retrieval if accidently dropped in water.
10. Clipboard, ball point pen, pencil, permanent marker (sharpie fine-point)
11. Sample bottles.
12. One gallon tap water for wash bottle.

Step 3 - Measure Secchi disk depth

Check to make sure that the Secchi disk is securely attached to the measured line. Lower the Secchi disk into the water keeping your back toward the sun to block glare. Lower the disk until it disappears from view. Lower it one more foot and then slowly raise the disk until it just reappears. Move the disk up and down until the exact vanishing point is found. Mark the measurement line at the point where the line enters the water. Measure the distance from the water surface to the Secchi Disk and record this measurement on the *Water Quality Field Measurements* form. (Repeating the measurement will provide a quality control check.)

Step 4 - Deploy Sonde.

Check depth to ensure readings are taken over deepest hole. Reposition boat as necessary.

Measure water temperature, pH, dissolved oxygen, PAR, chlorophyll *a*, phycocyanin, and turbidity.

Follow the instructions on the Hydrolab Multiprobe System sampler. Check calibration according to the instructions and adjust as necessary. Hold the probe 1 m below the water surface and record readings at 1 meter intervals. Before the sonde hits the bottom (as predicted by the depth meter), take final reading approximately 0.5 meters from the lake bottom. Record the measurements on the *Water Quality Field Measurements* form. Record each measurement electronically in the surveyor per pre-designated sample labels.

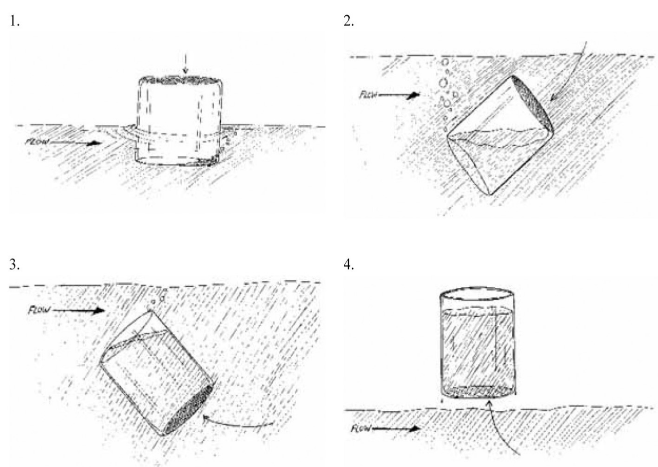
For PAR, obtain ambient reading just above water surface. This is the 0.1 meter depth on the sonde data sheet. For this reading, submerge bottom of probe to top of probe cage. The PAR sensor is in the air.

Step 5 - Collect water samples for laboratory analysis

Check depth to ensure readings are taken over deepest hole. Reposition canoe as necessary.

Collect the surface sample as depicted in the figure below. Tightly cap the bottle immediately after the sample is collected.

Do not to touch the inside of the collection bottles or collection bottle caps.



Deploy the depth sampler per instructions and figures below.

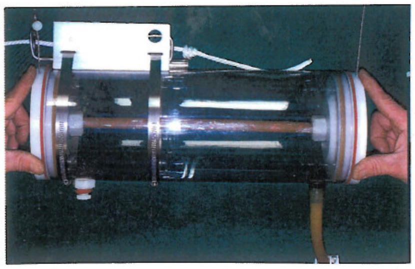


Figure 1.

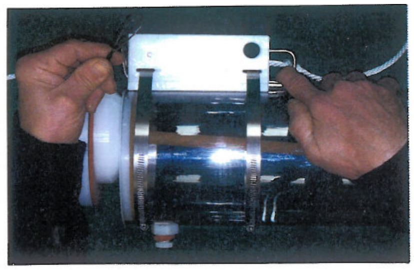


Figure 2

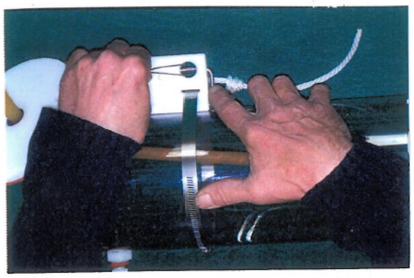


Figure 3

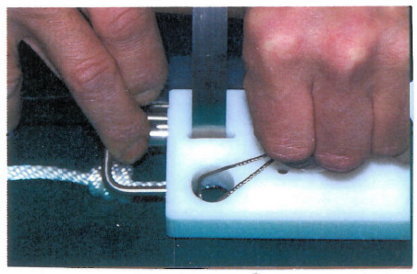


Figure 4

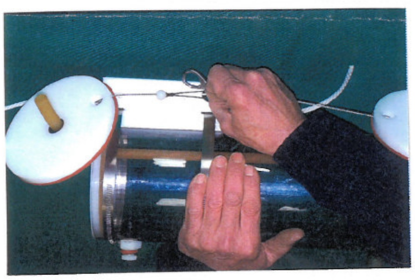


Figure 5

Figure 6

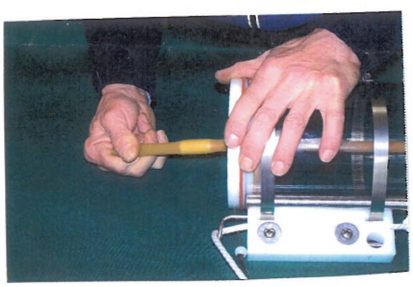


Figure 7

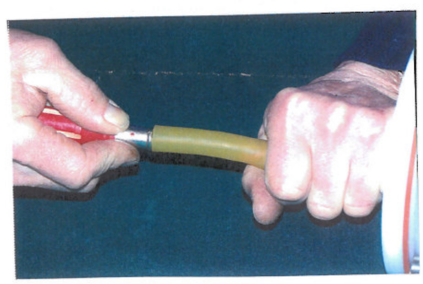


Figure 8

1. Lay sampler on its side with the rope side of the cable clamp position downward. Turn the top and bottom seal lanyards so they align with hole in the release mechanism (Figure 1)

2. Each end seal is loaded separately staring with the top seal. Use your index finger to pull the arming rod of the release mechanism downward. Pull the top seal our of the sample cylinder using the lanyard loop. Please note; you do not have to over stretch the latex internal closure during this procedure. Use the cylinder edge as a "resting point" (Figure 2). Proper arming will extend the life of the latex tubing. Insert the

lanyard "loop inside the hole in the closing mechanisms. Release the arming pin to hook the loop (Figures 3 and 4).

3. Arm the bottom seal suing the same procedure as above and clip the stainless steel clip around both the strand of the loop lanyard (Figures 5 and 6). Become familiar and inspect arming to ensure proper actuation. The sample I now ready for deployment.
4. Determine sampling depth and flake enough line onto the deck. Pass this length line through the solid messenger. Lower the sampler to depth.
5. Release the messenger to actuate the closing mechanism. Please note; it is not necessary to "throw" the messenger downward. You can generally feel the sample close at depth through the line.

For stratified lakes, the middle depth is located at the mesolimnion. The location of the mesolimnion will be seen from the temperature profile. It is the transition between the surface and bottom temperature isoclines. It is therefore necessary to have temperature profile data from the sonde prior to deploying the sampler.

If the lake is not stratified, then the middle would be half-way between the surface and the bottom.

Transfer water from the lake sampler to sample bottles. If sample bottle is not filled, collect another sample and top off.

Tightly cap bottles. Place in cooler upon return to shore.

SOD – See SOD and Sediment Sample Report

Table of Standard or EPA Methods Used

PARAMETER	STANDARD METHOD
ALKALINITY WATER	SM 2320B
AMMONIA WATER	EPA 350.1
CHLOROPHYLL *A*-PHEOPHYTIN	SM 10200H
NITRATE + NITRITE WATERS	SM4500 F
ORTHOPHOSPHATE, WATER	EPA 365.3
PHOSPHORUS, TOTAL WATER	EPA 365.3
TKN WATER AND TOTAL PHOSPHORUS	EPA 351.2

Plankton

Plankton analysis was performed once on each lake and twice on Mitchell to gather data on the zooplankton and phytoplankton community structure of the lake. Below is the materials and the method that were used in gathering the plankton data.

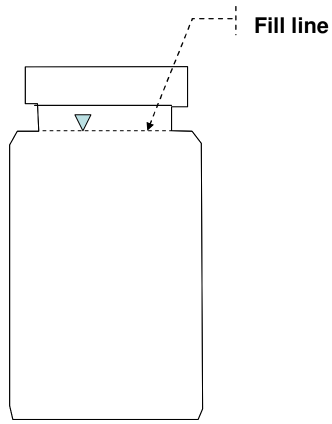
Materials

1. Plankton net
2. Rope marked at 1.0 meter intervals.
3. Hydrolab PAR sensor
4. Boat and accessories.
5. Lugol's solution
6. Squeeze bottle.
7. 1 ml auto-pipette and tips.
8. 500 ml sample bottles (one for each sample point)
9. A clean 2 to 3 gallon bucket.
10. Cooler and ice

Procedures: Phytoplankton

1. Label the outside of the sample jar using a permanent marker, such as a Sharpie, with the sample type, lake/water body, date, and time.
2. Take samples from the customary sample points used in other monitoring.
3. Take Hydrolab sonde readings from surface to the bottom at one meter intervals per normal monitoring procedures. Record data and determine the depth of 1% incident light. The day should be sunny for sample tow depths to be consistent.
4. Phytoplankton samples are taken directly from the water column because the zooplankton are small enough to pass through the plankton net.
5. Using the depth sampler, take samples at the following depths and dump them into the clean bucket. Ensure that equal volumes are taken at each depth.
    a. Surface
    b. Depth of 1% incident light
    c. Mid-depth between surface and 1% incident light

6. Fill sample bottle to the 500 ml line, which is where the bottle shoulder meets the bottle neck. Keep contents of bucket. Do not discard until zooplankton sampling is completed.



7. Using the 1 ml pipette prepare the sample with Lugol's solution. Place 5 ml of Lugol's solution in the bottle.

8. Cap bottle tightly. Mix by shaking gently.

9. Place bottle overnight in a cooler and ship to

   BSA Environmental Services, Inc.
   23400 Mercantile Rd, Suite 8
   Beachwood OH 44122

Procedures: Zooplankton

1. Label the outside of the sample jar using a permanent marker, such as a Sharpie, with the sample type, lake/water body, date, and time.

2. Take samples from the customary sample points used in other monitoring.

3. Take Hydrolab sonde readings from surface to the bottom at one meter intervals per normal monitoring procedures. Record data and determine the depth of 1% incident light. The day should be sunny for sample tow depths to be consistent.

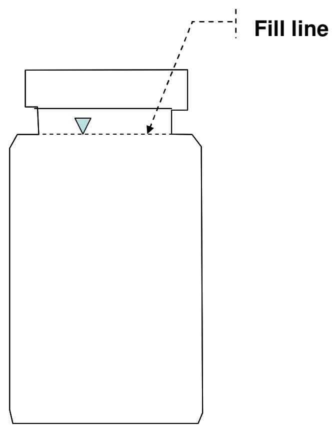
4. To perform a tow, first attach rope to the "bridle" (the rope system fixed to the mouth of the net). Gently lower the net into the water to the desired depth (1% incident light). To retrieve, pull rope back in a steady, unhurried, hand-over-hand motion. **Note**: *Do not pull faster than 0.5 m*/s (e.g., if the tow distance is 20 m, retrieval should take 40 seconds). Pulling too fast will cause a pressure wave in front of the net that pushes water and plankton away from the mouth of the net, and as such, does not effectively sample the desired volume of water. Record the distance of each tow on the Plankton Sample Datasheet (Use the monitoring sheet on which you have recorded vertical profiles). Rinse net contents into sample bottle (described

below) between each tow.

5. At the end of each tow, lift the net so that the net opening is above the water surface. Next, lower the net back into the water (keeping the opening above the water surface) and then quickly pull the net straight up; this action will move the collected plankton into the cod-end piece. Repeat this procedure as needed.

6. Carefully transfer the net contents to the labeled sample jar. Use the wash bottle (filled with water from bucket) to gently rinse down any remaining contents into the jar.

7. Using water from the phytoplankton composite sample bucket, fill sample bottle to the 500 ml line, which is where the bottle shoulder meets the bottle neck.



8. Using the 1 ml pipette prepare the sample with Lugol's solution. Place 5 ml of Lugol's solution in the bottle.

9. Cap bottle tightly. Mix by shaking gently.

10. Rinse the net free of debris visible to the eye.

11. Place bottle in a cooler and ship overnight to

    BSA Environmental Services, Inc.
    23400 Mercantile Rd, Suite 8
    Beachwood OH 44122

Appendix B
Water Quality Trend Analysis

Water Quality Trend Analysis

TO: Riley Purgatory Bluff Creek Watershed District

FROM: CH2M HILL

DATE: December 02, 2008

PROJECT NUMBER: 365812.09.UA.DR

Introduction

The objective of this Technical Memorandum is to perform Kendall tau test to determine existence of trend over time in three parameters: total phosphorus (mg/m3), Chlorophyll a (mg/l) and Secchi disk depth (m). In particular, one would like to see if there is a trend over time by analyzing July and August measurements separately. The Kendall tau test is a non-parametric statistic that measures the correlation between two rankings and assesses the significance of that correlation.

Calculation of Kendall Tau

A two-sided test for correlation is conducted to evaluate the following equivalent statements for the null hypothesis H_0, as compared to the alternate hypothesis H_1:

H_0: i) there is no correlation between the two variables x and y (i.e., $\tau = 0$), or
ii) x and y are independent.

H_1: i) the two variables x and y are correlated (i.e., $\tau \neq 0$), or
ii) x and y are dependent.

In order to calculate the test statistic, comparisons among the bivariate sample population (x_i, y_i where x is time and y is a measure of water quality) are made to determine the existence of a trend. Calculation is performed to determine the number of concordant observations P (both x and y increase) and discordant observations M (x and y change in opposite directions). Based on this calculation, the test statistic S is determined that measures the monotonic dependence of y on x. The static S is given as (Maidment, 1993):

$$S = P - M \qquad (1)$$

where,
P = "number of concordant pairs", i.e., the number of $y_i < y_j$ for all $i < j$,
M = "number of discordant pairs," i.e., the number of $y_i > y_j$ for $i < j$.
for all i = 1,....(n − 1) and j = (i+1),.....n.

The Kendall's correlation coefficient τ that measures the strength of the monotonic association between two variables is defined as (Maidment, 1993):

$$\tau = \frac{S}{n(n-1)/2} \qquad (2)$$

From Equation (2), it is clear that the Kendall correlation statistic τ represents a probability. To test for significance of τ, S is compared to what would be expected when the null hypothesis is true. For n ≤ 10 an exact test is computed using critical values given in Statistics Textbooks. For n > 10 the test statistic can be approximated to follow a normal distribution. The standardized test statistic Z is computed as (Maidment, 1993):

$$\tau = \frac{S-1}{\sqrt{Var(S)}} \;\; if \; S > 0; \;\; 0 \;\; if \; S = 0; \;\; \frac{S+1}{\sqrt{Var(S)}} \;\; if \; S < 0; \qquad (3)$$

The Var(S) is calculated as:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{1}^{n} t_i i(i-1)(2i+5)}{18} \qquad (4)$$

where t_i is the number of ties of extent i. Using the calculated values of Z, the P value is calculated and compared with the assumed level of significance, typically 0.05. The P value is the probability that gives the measure of observed significance level. In other words, it is the estimated probability of rejecting the null hypothesis (H_0) of a study question when that hypothesis is true.

Results

Using the above procedure, Kendall Tau tests were conducted on both individual month data sets and the combined data set. Results for all three parameters TP. Chla, and Secchi depth are presented in Tables 1, 2, and 3 for the month of July, August, and July-August combined together. Based on this preliminary analysis following conclusions can be made:

- Strong evidence (indicated by a very small P-value) of a moderate (magnitude of τ = 0.38) decreasing trend (indicated by "-ve" sign of τ) were found in Lake Round Secchi depth data for both the months of July and August analyzing them either separately or combindly.
- Most correlations are weak correlations.
- TP data for the month of August for Lake Ann indicates a decreasing trend whereas July data doesn't.
- In all other cases (except the above cases), there is insufficient evidence to prove a trend in TP, Chla, and Secchi depth for all lakes.
- There are few cases in which no test could be conducted due to insufficient data.

References

Maidment, D.R. (1993). Handbook of Hydrology, McGraw-Hill.

TABLE 1
Kendall Tau test for the July Data
Water Quality Trend Analysis

Lake	n	P	M	S = P-M	Tau, τ	P-value (Small sample)	$\sqrt{Var(S)}$	Abs(Z)	P-value (large sample)	Remarks
					TP					
Ann	10	16	28	-12	-0.267	0.34	11.136	0.988	0.323	X
Lotus	8	18	10	8	0.286	0.398	8.083	0.866	0.386	X
Mitchell	7	6	15	-9	-0.429	0.238	6.658	1.202	0.230	X
Riley	2									NA
Round	28	202	175	27	0.071		50.596	0.514	0.607	X
Susan	7	10	11	-1	-0.048	0.886	6.658	0.000	1.000	X
					Chla					
Ann	1	-								NA
Lotus	1									NA
Mitchell	4	1	5	-4	-0.667	0.334	2.944	1.019	0.308	X
Riley	2									
Round	17	86	50	36	0.265		24.276	1.442	0.149	X
Susan	7	13	8	5	0.238	0.562	6.658	0.601	0.548	X
					Secchi_Depth					
Ann	10	20	22	-2	-0.044	0.862	11.045	0.091	0.928	X
Lotus	12	33	28	5	0.076		14.387	0.278	0.781	X
Mitchell	6	8	6	2	0.133	0.86	5.132	0.195	0.845	X
Riley	125	3398	3778	-380	-0.049		468.395	0.809	0.418	X
Round	30	129	297	-168	-0.386		55.964	2.984	0.003	Y
Susan	7	12	9	3	0.143	0.772	6.658	0.300	0.764	X

Note:

X: H_0 can't be rejected, i.e., there is insufficient evidence to prove a trend
Y: H_0 is rejected, .e., there is sufficient evidence to prove a trend
NA: Not applicable as the Kendall Tau test couldn't be performed due to insufficient data.

TABLE 2

Kendall Tau test for the August Data

Water Quality Trend Analysis

Lake	n	P	M	S = P-M	Tau, τ	P-value (Small sample)	$\sqrt{Var(S)}$	Abs(Z)	P-value (large sample)	Remarks
TP										
Ann	19	45	120	-75	-0.439		28.449	2.601	0.009	Y
Lotus	17	77	58	19	0.140		24.256	0.742	0.458	X
Mitchell	17	31	104	-73	-0.537		24.256	2.968	0.003	Y
Riley	5	4	4	0	0.000	1	3.697	0	1	X
Round	35	306	282	24	0.040		70.347	0.327	0.744	X
Susan	16	38	79	-41	-0.342		22.121	1.808	0.071	X
Chla										
Ann	2				0.209		18.267	0.985	0.324	X
Lotus	2				0.700	0.159	3.958	1.516	0.130	X
Mitchell	14	55	36	19	0.135		45.358	0.948	0.343	X
Riley	5	8	1	7	0.050		22.166	0.226	0.822	X
Round	26	184	140	44	0.209		18.267	0.985	0.324	X
Susan	16	62	56	6	0.700	0.159	3.958	1.516	0.130	X
Secchi_Depth										
Ann	19	90	72	18	0.105		28.337	0.600	0.549	X
Lotus	21	85	104	-19	-0.090		32.588	0.552	0.581	X
Mitchell	18	52	84	-32	-0.209		25.852	1.199	0.230	X
Riley	134	4419	3849	570	0.064		518.628	1.097	0.273	X
Round	38	210	477	-267	-0.380		79.415	3.350	0.001	Y
Susan	16	46	44	2	0.017		20.897	0.048	0.962	X

Note:

X: H_0 can't be rejected

Y: H_0 is rejected

TABLE 3

Kendall Tau test for the Combined July and August Data

Water Quality Trend Analysis

Lake	n	P	M	S = P-M	Tau, τ	P-value (Small sample)	$\sqrt{Var(S)}$	Abs(Z)	P-value (large sample)	Remarks
TP										
Ann	29	121	265	-144	-0.35		53.05	2.70	0.01	Y
Lotus	25	161	135	26	0.09		42.77	0.58	0.56	X
Mitchell	24	74	201	-127	-0.46		40.30	3.13	0.00	Y
Riley	7	8	9	-1	-0.05	1.00	6.30	0.00	1.00	X
Round	63	1019	919	100	0.05		168.56	0.59	0.56	X
Susan	23	88	160	-72	-0.28		37.80	1.88	0.06	X
Chla										
Ann	3	3	0	3	1.00	0.33	1.91	1.04	0.30	X
Lotus	3	3	0	3	1.00	0.33	1.91	1.04	0.30	X
Mitchell	18	83	70	13	0.08		26.40	0.45	0.65	X
Riley	7	16	3	13	0.62	0.07	6.51	1.84	0.07	X
Round	43	529	371	158	0.17		95.54	1.64	0.10	X
Susan	23	129	122	7	0.03		37.84	0.16	0.87	X
Secchi_Depth										
Ann	29	211	180	31	0.08		53.14	0.56	0.57	X
Lotus	33	233	261	-28	-0.05		64.15	0.42	0.67	X
Mitchell	24	102	146	-44	-0.16		39.77	1.08	0.28	X
Riley	259			347	0.01		1393	0.25	0.80	X
Round	68	680	1540	-860	-0.38		188.69	4.55	0.00	Y
Susan	23	111	103	8	0.03		36.80	0.19	0.85	X

Note:

X: H_0 can't be rejected

Y: H_0 is rejected

Appendix C

Trophic State Index Calculations

Trophic State Index Calculations

Carlson Trophic State Index

The Carlson Trophic State Index (CTSI) was developed by Robert E. Carlson at the University of Minnesota and published in a 1977 paper in Limnology and Oceanography. Three equations were developed by Carlson that yield three trophic state index values. Each equation references a different water quality parameter. As the process name implies these values are only indicies of the trophic state and do not define the trophic status. Lakes vary widely and one parameter cannot define all lakes. All three values are presented and discussed.

The first water quality parameter is total phosphorous (TP) on the surface of the lake as reported in milligrams per cubic meter of lake water, Equation 1.

$$CTSI(TP) = 10 * \left(6 - \frac{\ln \frac{48}{TP}}{\ln 2} \right) \qquad \text{Equation 1}$$

The second water quality parameter is chlorophyll (Chla) at the surface of the lake in milligrams per cubic meter. Chlorophyll's CTSI is found by Equation 2.

$$CTSI(Chla) = 10 * \left(6 - \frac{2.04 - 0.68 * \ln Chl}{\ln 2} \right) \qquad \text{Equation 2}$$

The final water quality parameter is secchi disk (SD) depth, in meters, which can be found by Equation 3.

$$CTSI(SD) = 10 * \left(6 - \frac{\ln SD}{\ln 2} \right) \qquad \text{Equation 3}$$

Water quality parameters were collected throughout the summer and fall of 2008 for six lakes within the Riley Purgatory Bluff Creek Watershed District. Total phosphorous was reported in terms of milligrams per liter and converted into milligrams per cubic meter. Chlorophyll was reported in micrograms per liter which is equivalent to milligrams per cubic meter. Results for chlorophyll are the chlorophyll-a species and include field values and lab corrected values, as specified in legends on each plot. Seechi disk depth was reported in meters.

Indiana Trophic State Index

The Indiana Trophic State Index (ITSI) was developed by the State of Indiana as a modified version of the BonHomme Index from 1972. A four page synopsis titled 'Use of the Indiana Trophic State Index (ITSI) to Guide Lake Management,' dated December 18, 2007 was used for reference. Physical, chemical, and biological parameters are combined to determine ITSI values. Direct water quality parameters as well as calculations are computed and from these results eleven eutrophy point values are determined and summed. The sum is the ITSI value and then related to U.S.E.P.A. Trophic Classes.

A spreadsheet was developed to allow the user to input water quality parameters and have the software calculate parameters, if needed, and then assign eutrophy points, sum the points, and determine U.S.E.P.A. Trophic Classes. In order to do this multiple assumptions were required; however these assumptions should not impact the integrity of the results. Specified ranges were not necessarily all encompassing and left some room for interpretation. The software ranges were developed by adding another significant digit than specified in the ranges and applying standard rounding practice (values of five and greater are rounded up and values four and less are rounded down). The term below, included in many of the ranges, was interpreted to mean less than. It is important to note the index was developed with length and depth measurements in English units while concentrations are represented by SI units. The user should take great care to assure input values are in the correct units, units are specified for each input field.

Total phosphorus, in milligrams per liter, is the first value to be determined. Six categories are specified for varying eutrophy points, zero to five, with the divisions between 0.03 and 1.0, values greater than or less than are assigned the extreme values. Soluble phosphorus, in milligrams per liter, is the second parameter and is determined based on the same range as total phosphorous. The next three parameters are nitrogen species. Nitrate, in milligrams per liter, includes five different ranges for eutrophy points, zero to four, with the divisions between 0.3 to 2.0. Ammonia, in milligrams per liter, includes five classes ranging from 0.3 to 1.0. Organic nitrogen, in milligrams per liter, includes five divisions from 0.5 to 2.0. Organic nitrogen is assumed to be the difference between Total Kjeldahl Nitrogen (TKN) and ammonia; therefore the user is asked to input TKN and the value for organic nitrogen is calculated. The previously input value for ammonia is also used for this calculation.

To calculate the percent saturation of dissolved oxygen (D.O.) at a depth of five feet, the user is asked to input three parameters and the software will then calculate the percentage. Inputs are elevation (km), water temperature (°C), and measured D.O. (mg/L). The calculation is based on three equations that determine atmospheric pressure based on elevation, oxygen concentration at nonstandard pressure, and finally the percentage of saturation of the measured D.O. Pressure calculation is completed by Equation 4, where the variables elevation (h) in kilometers and results in a pressure (P) in terms of atmospheres (atm).

$$\ln P = 5.25 * \ln\left(1 - \frac{h}{44.3}\right) \qquad \text{Equation 4}$$

Next, equilibrium oxygen concentration at the nonstandard pressure (C_p) in milligrams per liter is calculated, Equation 5. The user input water temperature (t) is used in this calculation as well as previously calculated pressure.

$$C_p = C^* * P * \left[\frac{(1 - P_{wv} / P) * (1 - \Theta * P)}{(1 - P_{wv}) * (1 - \Theta)} \right] \qquad \text{Equation 5}$$

In Equation 5, C^* represents the equilibrium D.O. concentration, in mg/L, at standard pressure of 1 atm and is calculated by Equation 6.

$$\ln C^* = 7.7117 - 1.31403 * \ln(t + 45.93) \qquad \text{Equation 6}$$

In Equation 5, P_{wv} represents the partial pressure of water vapor in atm and is calculated by Equation 7.

$$\ln P_{wv} = 11.8571 - \left(\frac{3840.70}{t + 273.15} \right) - \left(\frac{216{,}961}{(t + 273.15)^2} \right) \qquad \text{Equation 7}$$

In Equation 5, Θ is calculated by Equation 8.

$$\Theta = 0.000975 - \left(1.426 * 10^{-5} * t^2\right) + \left(6.436 * 10^{-8} * t^2\right) \qquad \text{Equation 8}$$

With the results from Equation 5, the percent of D.O. saturation is calculated, Equation 9. The user must input the measured D.O. in milligrams per liter.

$$D.O.PercentSaturation = \frac{(100 * D.O.)}{C_p} \qquad \text{Equation 9}$$

From this result a eutrophy value can be assigned for this parameter.

The next parameter is the percentage of the water column with at least 0.1 ppm (0.1 mg/L) of D.O. For this parameter the user must calculate the percent and input it into the correct field. The calculation can be completed by dividing the depth of water with at least 0.1 ppm of D.O. by the total depth of the water measured. A eutrophy point will then be assigned by the software.

Light is the basis for the next two parameters. Light penetration by means of secchi disk depth measurement is the first parameter. The user inputs the measured depth and the software assigns the eutrophy points. Photocell measurements are the second light parameter. The user is asked to input the percentage of light transmitted at a depth of three feet. This is computed by the user by dividing the PAR value at three feet by the PAR value at the surface.

Plankton is the final parameter included in the ITSI. The user inputs a density of plankton in terms of organisms per liter of water. Index specifications call for the measurement to come from a single vertical tow between the 1% light level and the surface.

Once all the user input data has been completed the software is able to assign eutrophy points and sum the points for a final ITSI score. Based on a table presented by the State of Indiana, the score can be related to U.S.E.P.A. Trophic Classes. The software will display the related U.S.E.P.A. Trophic Class and provide a background color arbitrarily related to lake conditions (blue is presumed better than dark green).

Assumptions made based on the data available for 2008; however these do not effect the development of the software, but do impact the results presented. Results are presented in SI units, while many of the parameters specify depths in English units. It was assumed three feet would be approximately equal to one meter and five feet would be equal to 1.5 meters. To obtain water quality values at depths not reported, a linear interpolation was completed based on the nearest values above and below the depth of interest. Soluble phosphorous is assumed to be equivalent to ortho-phosphate. In order to calculate percent saturation of dissolved oxygen, it was assumed the elevation of the lakes was 886 feet (0.27 kilometers); which is a standard elevation value given for Eden Prairie, Minnesota. Total Plankton was assumed to be only phytoplankton. Values presented as “Density (mL)” in the tabulated results are assumed to be equivalent to organisms per liter and the sum of the different species is used as the value for total plankton.

Duck Lake

August 2008

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Duck Lake

1.1 Lake Watershed Goals

The approved Riley-Purgatory-Bluff Creek Watershed District Water Management Plan, 1996, (Water Management Plan) inventoried and assessed Duck Lake. The plan articulated five specific goals for Duck Lake. These goals address recreation, aquatic communities, water quality, water quantity, and wildlife. The approved Duck Lake Use Attainability Analysis (UAA), 2005 further expanded the characterization of Duck Lake by evaluating the intended five goals.

1.2 Watershed Goals

1.2.1 Water Quantity

The water quantity goal for Duck Lake is to provide sufficient water storage during a regional flood (100-yr, 24-hr storm event). According to the UAA, the water quantity goal has been achieved and no action is required.

1.2.2 Water Quality

The water quality goal of Duck Lake is predicated on the lake's recreational goal. The goal is to achieve a water quality that will fully support the lake's use as a fishery (2005 UAA). The 1996 Plan states that the MPCA has classified Duck Lake as "non-support of swimmable use", which allows TSI_{SD} to be greater than the current water quality. Therefore, the water quality goal for Duck Lake is at the aquatic communities goal – TSI_{SD} of 65 or lower. Duck Lake's water quality reported in the 1996 Plan (TSI_{SD} = 65) did not meet this goal.

The 2005 UAA cites a Riley-Purgatory-Bluff Creek Watershed District (District) water quality goal of TSISD ≤ 54.5, based on the MDNR average water quality recommendation for the ecological class (Class 40) of Duck Lake. The water quality conditions according to 1996 data (TSISD = 60) did not meet the MDNR recommendation.

1.2.3 Recreation

The recreation goal is to maintain the lake for full support of designated fishing activities and waterfowl habitat, as well as for aesthetic viewing. Because Duck Lake has not been designated a swimming lake by the RPBCWD, the recreational goal is to fully support the lake's fishery and maintain a $TSI_{SD} \leq 54.5$. Based on water quality data in the 1996 Plan, 2004 UAA and 2005 monitoring period, this goal is not being achieved.

1.2.4 Aquatic Communities

The aquatic communities goal for Duck Lake is the achievement and maintenance of a water quality that fully supports the lake's fisheries-use classification as determined by the MDNR (Schupp 1992). This means maintaining a MDNR ecological class 40 rating, with $TSI_{SD} \leq 54.5$.

1.2.5 Wildlife

The wildlife goal for Duck Lake is to protect existing, beneficial wildlife uses. Achieve this goal supports the recreational goal, as described above. According to the 2005 UAA, the wildlife goal has been achieved.

1.2.6 Public Participation

The goal is to encourage public participation in reaching achievable outcomes for Lake Ann.

1.3 Existing Watershed Conditions

Duck Lake is located in the City of Eden Prairie in the central part of the Riley-Purgatory-Bluff Creek watershed. It drains to Purgatory Creek.

1.4 Watershed Description

1.4.1 Land Use

The land use for the Duck Lake watershed is summarized in Table 1. The total watershed area is fairly consistent between the 2005 and 2020 land use survey and the areas reported in the 1996 Plan from a 1991 survey and areas reported in the UAA in a 2000 survey. The exception is the water land use which was not reported in the 1991 data. Based on the data, it appears that, overall, the land use categories have remained fairly unchanged. The 2020 projections indicate that there will be a decrease in residential and parks and open areas land use.

TABLE 1
Summary of Past and Projected Land Use Acreage – Duck Lake

Land Use Category	1991 [1]	1997 [2]	2005 [3]	2020 [3]
Single Family & Low Density Residential	197	144	146.09	122.13
Commercial	2	*	*	*
Parks + Open Areas	12	21	20.10	6.19
Highway/Roads	*	*	*	34.14
Water	*	50	49.08	49.99
Institutional (School, etc)	*	13	12.49	15.31
TOTAL	211	228	227.75	227.75

* Land use category not reported
1. Data from 1996 Watershed Plan.
2. Data from 2005 Duck Lake UAA.
3. Metropolitan Council, Generalized Land Use 2005 for the Twin Cities Metropolitan Area and Regional Planned Land Use - Twin Cities Metropolitan Area.

1.4.2 Major Hydrologic Characteristics

Duck Lake has a 228-acre watershed, a surface area of 38 acres, a maximum depth of approximately 10 feet, and a mean depth of 4 feet. Duck Lake is the smallest District-monitored lake by volume. Per the 2005 UAA, Duck Lake's entire lake surface is considered littoral, meaning the entire lake is shallow enough to support aquatic plant growth. Water enters the lake by either direct precipitation or by stormwater inflows from yards and green space directly adjacent to the lake. Water exits the lake by ground water infiltration and through a piped outlet Located on the south east side of the lake. The UAA determined that the lake's volumes, outflow volumes, and hydrologic residence times vary with climatic conditions (Table 2).

TABLE 2
Duck Lake Estimated Volumes, Outflow Volumes and Hydrologic Residence Times

Climatic Condition (Water Year, Inches of Precipitation)	Average Lake Volume (m^3 / ac-ft)	Estimated Annual Lake Ouflow through Outlet* (m^3/ac-ft)	Estimated Annual Lake Ouflow by Infiltration* (m^3/ac-ft)	Hydraulic Residence Time (years)
[1]Wet Year (2002, 41 Inches)	173,944 / 141	25,907 / 21	28,374 / 23	3.2
Average Year (1999, 34 Inches)	203,297 / 164	32,075 / 26	24,673 / 20	3.6
Dry Year (2000, 24 Inches)	162,841 / 132	69,084 / 56	0 / 0	2.4

i
[1]Model calibration performed using the wet year data.
Source: Duck Lake UAA (Barr Engineering, May 2005)

1.4.3 Duck Lake Water Quality

The water quality of a lake provides an indication of how a lake functions. A standardized lake rating system is often used to classify the ecological conditions of a lake. The rating system uses phosphorus, chlorophyll *a*, and Secchi disc transparency values to classify a lake into four categories: Oligotrophic (clear, low productivity lakes with excellent water quality), Mesotrophic (intermediate productivity lakes with good water quality), Eutrophic (high productivity lakes with poor water quality) and Hypereutrophic (extremely productive lakes with poor water quality).

1.4.4 Data Collection

Data for the previous watershed management plan was collected from 1971 through 1993. Additional data was collected in 1996 and 2002 to support the Duck Lake UAA. An additional sampling year was accomplished in 2005.

1.4.5 Baseline/Current Water Quality

In general, Duck Lake water quality remained very poor throughout the more recent monitoring period (1996 – 2005). The lake can still be classified as hypereutrophic.

Total phosphorus concentrations in 2005 were in the hypereutrophic category for the monitoring season, similar to 1996 and 2002 (Figure DL-1). Concentrations appear to be slightly lower than in previous monitoring years. Chlorophyll *a* concentrations follow the same trend (Figure DL-2). Secchi disc transparency decreased over the recent monitoring period, and is in the hypereutrophic category for the entire monitoring season (Figure DL-3). In 1996, secchi disk transparency began in the eutrophic range in the spring, peaked in the mesotrophic category in the early summer, then decreased into the hypereutrophic range in mid-summer.

FIGURE DL-1
Duck Lake Total Phosphorus.

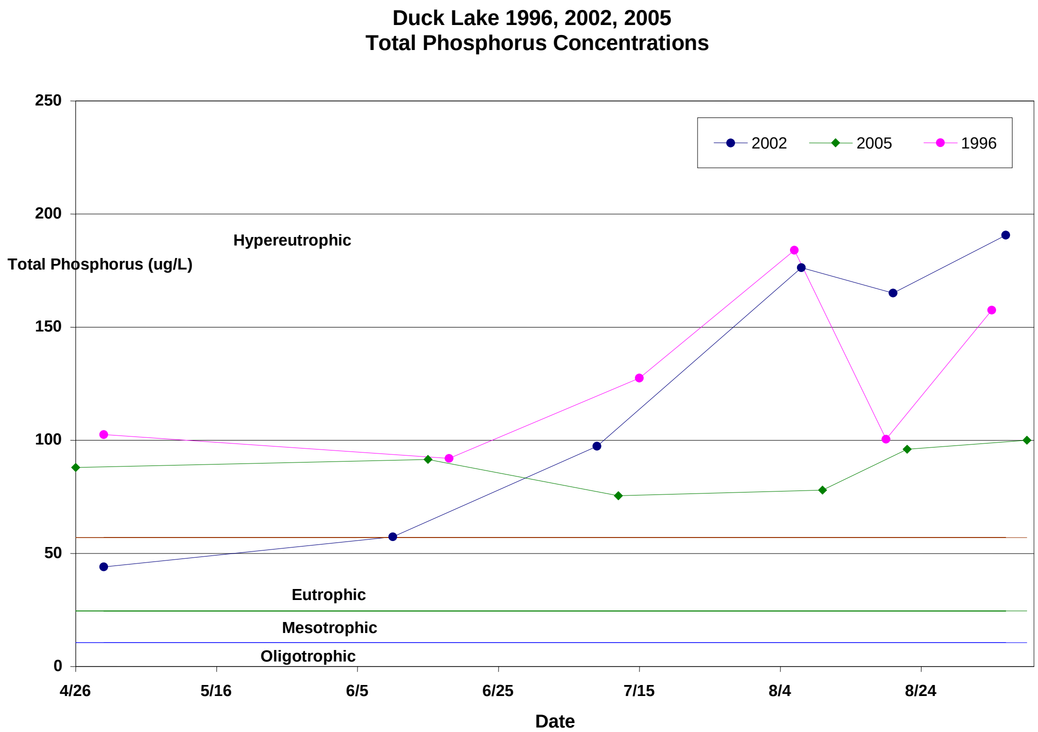


FIGURE DL-2
Duck Lake Chlorophyll *a*.

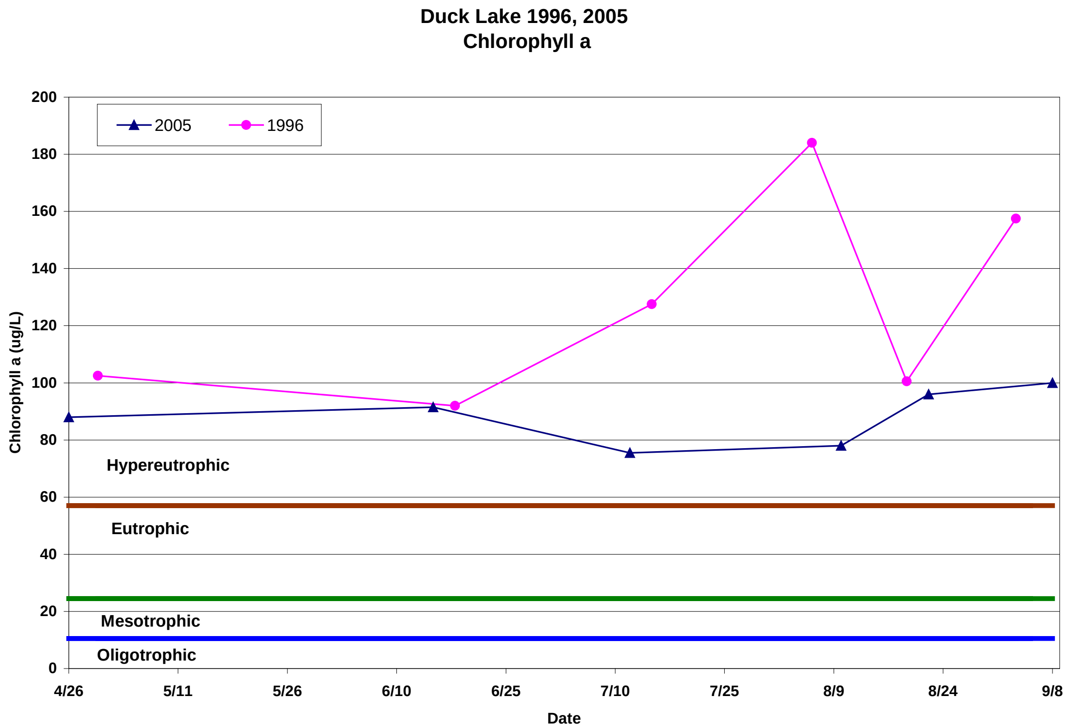
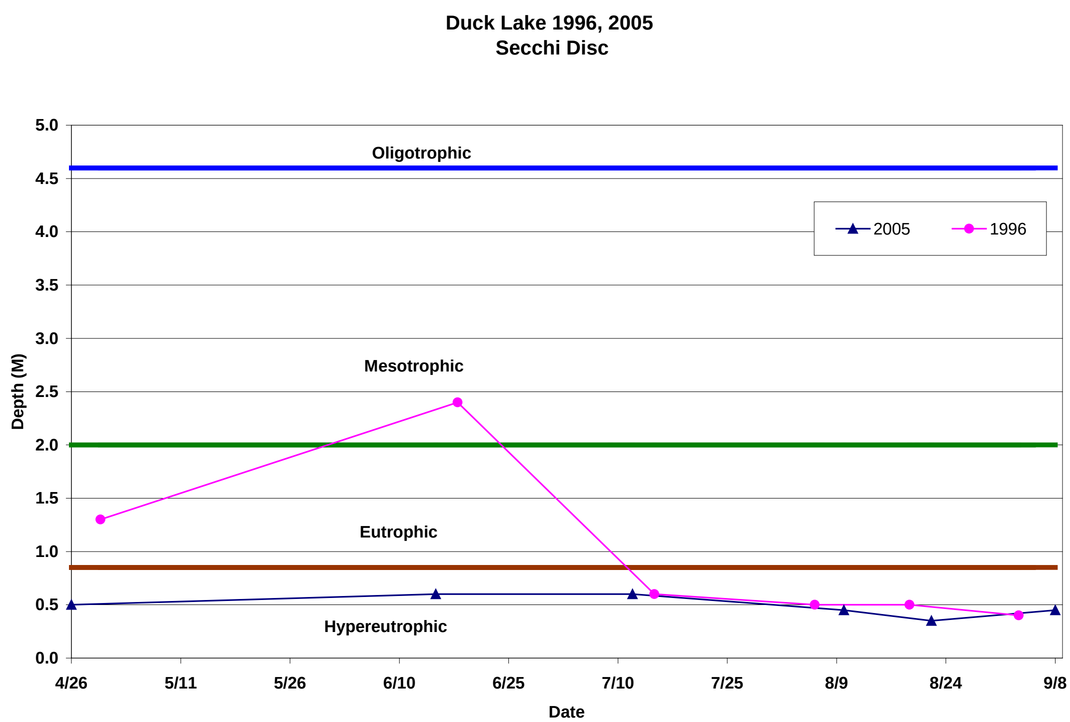


FIGURE DL-3
Duck Lake Secchi Disc



According to the UAA, modeling results, sediment sampling and aquatic plant data suggest that release phosphorus from the lake's bottom sediments are primarily responsible for the observed seasonal change in phosphorus concentrations. Stormwater runoff and curlyleaf pondweed decay both contribute to the lake's phosphorus content, but play a lesser role than the lake's bottom sediments.

1.5 Ecosystem Data

Duck Lake is a Class 40 lake. Class 40 lakes are typically shallow and productive lakes. Average water quality for the ecological class is a TSI_{SD} of 54.5 or lower. The lake's water quality in 1996 corresponded to a TSI_{SD} = 60.0. The lake's current water quality (2005 data) corresponds to a TSI_{SD} = 70.0, indicating that its water quality is still very poor compared to the average lake in its ecological class.

1.5.1 Aquatic Ecosystems

According to the 1996 Plan, Duck Lake's ecosystem is typical for a temperate lake. Its plants and animal communities have no unusual characteristics, although zooplankton species abundance was relatively low at the time for lakes in the District.

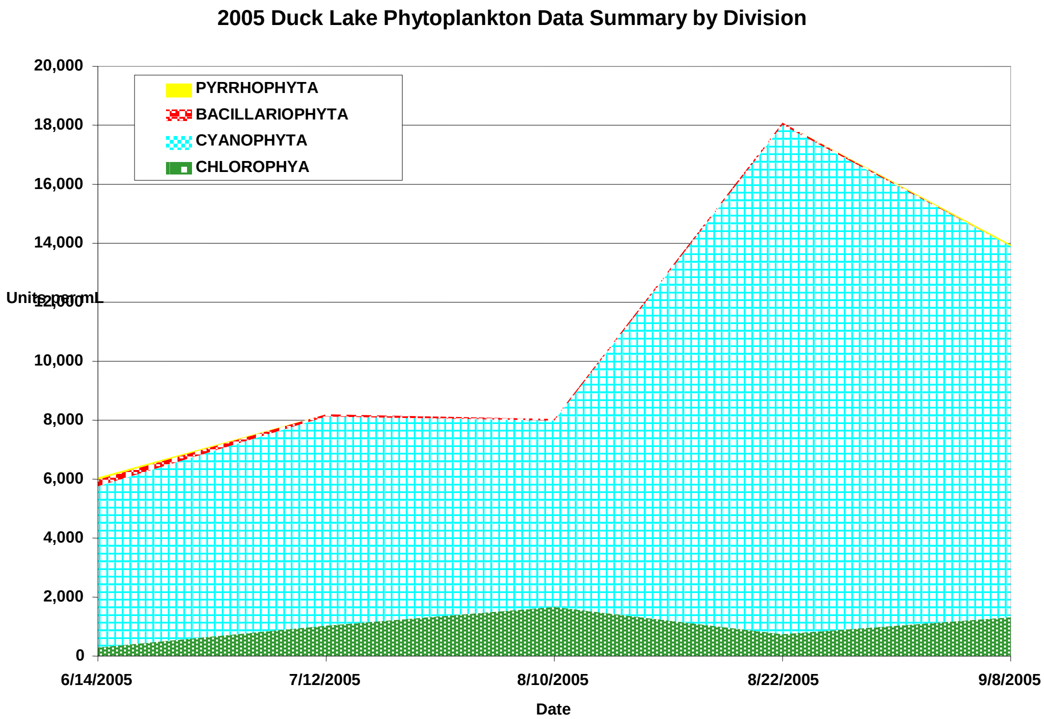
The UAA states that the interactions of the physical, chemical and biological components of the Duck Lake aquatic ecosystem have a large effect on the capacity of Duck Lake to achieve the recreation, aquatic communities, and water quality goals that have been established for the lake. The aquatic ecosystem of Duck Lake is a good example of how the biological community of a lake (i.e. zooplankton, algae, and aquatic plants) can affect the chemical environment of a lake (i.e. pH, phosphorus levels, and dissolved oxygen) which can then also affect the biological community.

1.5.2 Phytoplankton

According to the 1996 Plan, Duck Lake's phytoplankton in 1993 was dominated by green algae (Chlorophyta) until late August, when blue-green algae becomes the dominant phytoplankton. Per the 2005 UAA, the 2002 population of phytoplankton in Duck Lake goes through a seasonal transformation where green algae and cryptomonads are dominant in the spring but decline in the summer, while blue-green algae populations are low in spring and dominate in the summer. Algal blooms are observed in Duck Lake from July through September. The blooms primarily consist of blue-green algae which are large and visible and are often noted to be floating on the surface during periods of severe blooms. Large populations of blue-green algae are most often associated with high levels of phosphorus. Hence, phosphorus levels will need to be reduced to decrease the blue-green algae populations in Duck Lake.

The 2005 data shows that the phytoplankton population is now dominated by blue-green algae throughout the entire monitoring season (Figure DL-4). Green algae is also present throughout the monitoring season.

FIGURE HL-4
Duck Lake Phytoplankton Data Summary (2005)



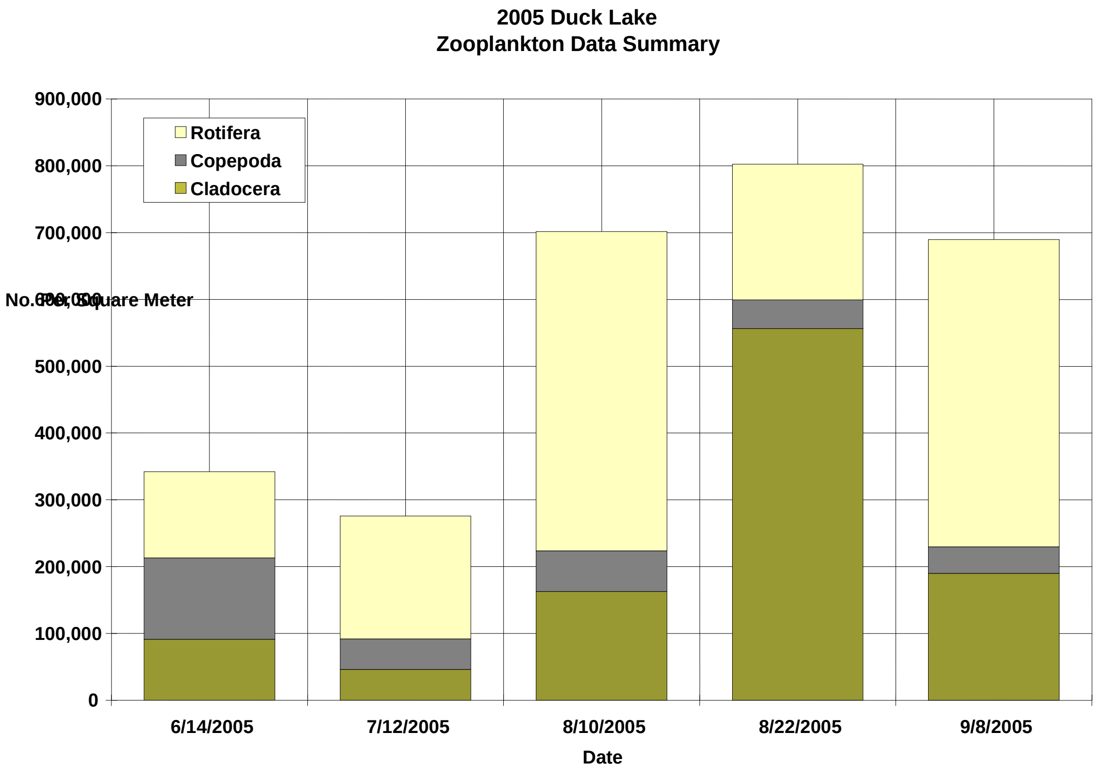
1.5.3 Zooplankton

According to the 1996 Plan, in 1993, cladocera dominated the zooplankton community in the first half of the growing season, but began to decline as the edible green algae were replaced by inedible blue-green algae. Zooplankton species diversity was relatively low in Duck Lake compared with other lakes in the watershed district.

The 2005 UAA reports that all three groups of zooplankton are well represented in Duck Lake during 2002. The data showed that the community structure changed, however, during June through early August when larger-bodied cladocera decreased significantly and small bodied cladocera increased. This observed drop in the large-bodied cladocera population is typically caused by predation by newly hatched fish. Changes in the number of large-bodied cladocera affect a lake's water quality because large-bodied cladocera have the capacity to biologically control algal growth through daily grazing. Daily zooplankton grazing rates of Duck Lake were estimated to range from 4 to 19 percent in 2002. Grazing rates decreased from 17 percent during June to 4 percent during early August. However, 2002 data showed that zooplankters were unable to exert control over the algae during August through September, due to the concurrent changes in the phytoplankton and zooplankton communities (i.e. an increase in size of phytoplankton with decrease in size of zooplankton) in the season prevented biological control of the lake's algal community during July through August.

The 2005 data shows that all three groups of zooplankton are well represented (Figure DL-5) with Rotifera and cladocera being the dominant species.

FIGURE DL-5
Duck Lake Zooplankton Data Summary (2005)



1.5.4 Macrophytes

Per the 1996 Plan, Duck Lake's macrophytes were surveyed in June and August 1993. As a very shallow lake with high nutrient levels, Duck Lake provides an excellent environment for macrophyte growth. Curlyleaf pondweed virtually covered the lake in the June survey, with some coontail and sago pondweed present. By August the curlyleaf pondweed had died back, leaving more open water in the center of the lake and coontail dominated the macrophytes in water less than 5 feet deep.

According to the 2005 UAA, the June and August 2002 macrophytes surveys showed a plant community consisting of eight submerged species and three emergent species which are common to Minnesota lakes, with most providing good habitat for the fish and aquatic animals living within the lake. However, the community included one non-native submerged species, curlyleaf pondweed and one non-native emergent species, purple loosestrife. The growth of these exotic and non-native species in Duck Lake is of concern.

The 2005 macrophyte surveys showed that in June, leafy pondweed and elodea were the dominant species in June with light to heavy densities in some areas. In August, coontail is the dominant species with light to heavy densities in some areas. Curlyleaf pondweed is present in June in light to moderate densities in some areas as well as in August, but with only one light density cluster. The 1996, 2002 and 2005 surveys are summarized in Table 4. Management of curlyleaf pondweed is recommended to protect the lake's water quality and native plant community and to improve the lake's fishery.

TABLE 4
Duck Lake Aquatic Plants (1996, 2002, and 2005)

Common Name	Scientific Name	1996 Density	2002 Density	2005 Density
Submerged Aquatics				
Curlyleaf pondweed	***P. crispus***	**1-3**	**1-3**	**1-2**
Flatstem pondweed	***P. zosteriformis***	**2-3**	**1-2**	**1**
Sago pondweed	***P. pectinatus***	**1-3**	**1-2**	**1**
Leafy pondweed	***P. foliosus***	**1-2**	**1-3**	**1-3**
Coontail	***Ceratophyllum demersum***	**1-3**	**1-3**	**1-3**
Elodea	***Elodea Canadensis***	**1-3**	**1**	**1-3**
Water stargrass	***Zosterella dubia***	**1**	**--**	**1**
Stonewort	***Nitella spp.***	**--**	**1**	**--**
Muskgrass	***Chara sp.***	**--**	**1**	**--**
Bushy pondweed	***Najas sp.***	**--**	**--**	**1**
Floating Leaf Plants				
White waterlily	***Nymphaea turberosa***	**--**	**--**	**--**
Greater duckweed	***Spirodela polyrhiza***	**--**	**--**	**--**
Lesser duckweed	***Lemna minor***	**--**	**--**	**--**
Emergent Plants				
Bulrush	***Scirpus spp.***	**--**	**--**	**--**
Cattail	***Typha spp***	**--**	**--**	**--**
Purple loosestrife	***Lythrum salicaria***	**--**	**--**	**--**

1.6 Water-Based Recreation

The 1996 Plan states that Duck Lake is used by neighborhood residents for canoeing and sailing. The 2005 UAA also cites fishing and aesthetic viewing as additional primary uses. According to the UAA, the City of Eden Prairie installed five parking spaces along Duck Lake Trail on the north side of the lake and placed a no motor restriction on the lake in 1996. The paved trail to the lake shore limits boats to carry-on access. The trail provides handicap accessibility to the waters edge. Presently, kids fish on a narrow strip of land between the lake and Duck Lake Road (MDNR, 1998).

1.7 Fish and Wildlife Habitat

The 1996 Plan states that according to its ecological classification, Duck Lake is a Class 40 lake, with primary fish species being northern pike, carp and black bullhead. The MDNR has indicated that the ideal water quality for its ecological class is a TSI_{SD} of 54.5 or lower (i.e. a summer average Secchi disc transparency of about 4.8 feet or greater). The recommendation is based upon the water quality needs of the fishery found in a Class 40 lake. Duck's water quality does not meet this criteria based upon the data from the recent monitoring period (1996-2005). The lake's water quality for 1996 and 2005 corresponds to a TSI_{SD} of 60.0 and 70.0, respectively.

According to the UAA, Duck Lake's fishery, based on the 1996 MDNR fish survey, consists of panfish (black crappie and bluegill) and rough fish (black bullhead). Black bullheads dominated the lake's fish community. Area residents have indicated periodic winterkills have severely limited the lake's fishery (UAA).

The UAA states that the MDNR had prepared a fisheries management plan for Duck Lake. According to the plan, the MDNR will:

1. Monitor winter oxygen levels in cooperation with Eden Prairie Parks and Recreation,
2. Stock 10 largemouth bass, 10 black crappie, and 10 bluegill adults following a severe winterkill that is expected to occur on average once in 10 to 20 years. The stocking will occur in spring and will provide brood stock.
3. Issue a stocking permit to the lake association to purchase these species if they prefer fish to be stocked more frequently.

According to the UAA, the MDNR long range goal for the lake is to employ winterkill and periodic stocking as tools to produce occasional good fishing capable of supporting 0 to 50 angler hours per acre. The mid-range objective is to maintain the present level of fishing pressure. The MDNR has recommended installation of a fishing pier on Duck Lake.

Duck Lake provides good habitat for seasonal waterfowl such as ducks and geese. MDNR staff reported that a considerable number of waterfowl were seen during the lake's 1996 fish survey (MDNR 1996).

1.8 Natural and Urban Drainage Systems

1.8.1 Natural Conveyance Systems

Duck Lake's natural source of water is direct runoff from the land surrounding the lake and groundwater discharge. All other discharges to the lake are through piped inlets.

1.8.2 Stormwater Conveyance Systems

Stormwater conveyances to Duck Lake were investigated in the 2005 UAA. Stormwater is conveyed from residential neighborhoods surrounding Duck Lake. Figure 1 shows the stormwater conveyance systems. Although most stormwater enters the lake untreated, stormwater in one particular subwatershed is treated by a pond before it is conveyed to Duck Lake. A second stormwater detention pond located in another subwatershed does not contribute runoff to Duck Lake. The pond does not have an outlet and all the stormwater is infiltrated or evaporated.

1.8.3 Public Ditch Systems

There are no public ditch systems that affect Duck Lake.

1.9 Water Appropriations

There are no known water appropriations from Duck Lake.

Hyland Lake

August 2008

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Hyland Lake

The Hyland Lake lies entirely within the borders of the Three Rivers Park District. According to the 2004 UAA, the Park District planned to initiate a 3-year aquatic plant harvesting program starting in 2004 to control the growth of curlyleaf pondweed in Hyland Lake. The Park District also intended to draw down the lake to a level such that a new outlet from Hyland Lake could be constructed in 2004. The management alternatives discussed in the UAA were developed with consideration of the Three Rivers Park District's 1999 Water Quality Management Plan and the intended efforts by the Three Rivers Park District to improve water quality of Hyland Lake. The 2004 UAA has incorporated some of the intended plans by the Park District. Management recommendations provided in the UAA included efforts that are intended to assist the Park District in reaching their goals for Hyland Lake. The UAA designed the management alternatives recommended in this study so that there will be time to evaluate the effectiveness of management efforts such as harvesting and herbicide treatment and discuss the appropriate timing for additional management efforts such as an alum-lime treatment.

A TMDL for Hyland Lake has been identified by the MPCA. The impairment is for nutrients, affecting aquatic recreation. The TMDL process is scheduled to begin in 2010. Three Rivers Park District will be providing leadership for the assessment and planning related to the TMDL process.

1.1 Hyland Lake Watershed Goals

The approved Riley-Purgatory-Bluff Creek Watershed District Water Management Plan, 1996, (Water Management Plan) inventoried and assessed Hyland Lake. The plan articulated five specific goals for Hyland Lake. These goals address recreation, aquatic communities, water quality, water quantity, and wildlife. The approved Hyland Lake Use Attainability Analysis (UAA), 2004 further expanded the characterization of Hyland Lake by evaluating the intended five goals.

1.1.1 Water Quantity

The water quantity goal for Hyland Lake is to maintain a flood envelope that is reasonably capable of providing water storage during regional flood (100-yr, 24-hr storm event). According to the 2004 UAA, the water quantity goal has been achieved and no action is required.

1.1.2 Water Quality

The water quality goal of Hyland Lake is predicated on the lake's recreational goal. The goal is to achieve a water quality that will fully support the lake's use as a fishery (2004 UAA). The MPCA has classified Hyland Lake as non-supporting of aquatic recreation. In order to be considered partially supporting, the lake must have a range of TSI_{SD}, less than 57 and greater than 53. Hyland Lake's water quality reported in the 1996 Plan (TSI_{SD}=73). The water quality goal for Hyland Lake that meets all criteria is the upper limit of the desired swimmable use goal - TSI_{SD} of 63 or lower.

The 2004 UAA cites a Riley-Purgatory-Bluff Creek Watershed District water quality goal of $TSI_{SD} \leq 54.5$, based on the MDNR average water quality recommendation for the ecological class (Class 40) of Hyland Lake. The recommendation is based on the water quality needs of the fishery found in a Class 40 lake. The 2000 water quality conditions reported in the UAA (TSI_{SD}=58.6) did not meet the MDNR recommendation.

1.1.3 Recreation

The recreation goal is to maintain the lake for aesthetic viewing and allow partial support of swimmable use. Because Hyland Lake has not been designated a swimming lake by the RPBCWD or the Three Rivers Park District, the recreational goal is to fully support the lake's fishery and maintain a $TSI_{SD} \leq 54.5$. Based on water quality data in the 1996 Plan, 2004 UAA and 2005 monitoring period, this goal is not being achieved. The two alternatives presented in the water quality section above will allow Hyland Lake to achieve or exceed the District recreation goal.

1.1.4 Aquatic Communities

The aquatic communities goal for Hyland Lake is to fully support the lake's fisheries-use classification as determined by the MDNR (Schupp 1992). This means maintaining a MDNR ecological class 40 rating, with a $TSI_{SD} \leq 54.5$. Based on water quality data in the 1996 Plan, 2004 UAA and 2005 monitoring period, Hyland Lake's conditions do not meet the goals stated in the UAA. The two alternatives presented in the water quality section above will allow Hyland Lake to achieve or exceed the District aquatic communities goal.

1.1.5 Wildlife

The wildlife goal for Hyland Lake is to protect existing, beneficial wildlife uses. Achieving this goal supports the recreational goal, as described above. According to the 2004 UAA, the wildlife goal has been achieved.

1.1.6 Public Participation

The goal is to encourage public participation in reaching achievable outcomes for Hyland Lake.

1.2 Existing Watershed Conditions

Hyland Lake is located in the City of Bloomington in the southeastern part of the Riley-Purgatory-Bluff Creek watershed. It drains to Purgatory Creek.

1.2.1 Watershed Description

1.2.1.1 Land Use

The land use for the Hyland Lake watershed is summarized in Table X. The total watershed area is fairly consistent between the 2005 and 2020 land use survey and the areas reported in the UAA in a 2000 survey. The exception is the water land use. Based on the data, it appears that, overall, the land use categories have remained fairly unchanged. The 2020 projections indicate that there will be a decrease in residential land use.

TABLE 1
Summary of Past and Projected Land Use Acreage – Hyland Lake

	2000 [1]	2005 [2]	2020 [2]
Single Family/Low Density Residential	369	371.65	293.15
Medium Density Residential	50	51.76	37.88
Multifamily/High Density Residential	53	55.56	51.87
Parks & Open Areas	423	430.31	416.16
Retail/Commercial	9	8.60	6.80
Industrial	*	0.22	0.83
Institutional	24	23.71	14.34
Highway/Roads/Right of Way	*	*	117.96
Water	29	98.16	100.98
TOTAL	957	1039.96	1039.96

* Land use category not reported
[1] Hyland Lake UAA, 2002
[2] Metropolitan Council, Generalized Land Use 2005 for the Twin Cities Metropolitan Area and Regional Planned Land Use - Twin Cities Metropolitan Area.

1.2.1.2 Major Hydrologic Characteristics

Hyland Lake has a 1,040-acre watershed, a surface area of 83 acres, a maximum depth of approximately 10 feet, and a mean depth of 7.5 feet. Per the 1999 UAA, Hyland Lake's entire lake surface is considered littoral, meaning the entire lake is shallow enough to support aquatic plant growth. Water enters the lake by either direct precipitation, runoff from surrounding park land, or stormwater conveyances from areas to the east. Water exits the lake by ground water infiltration or through a piped outlet and weir structure at the south end of the lake. The crest of the weir is currently at an elevation of 818.21 feet and hence water discharges from Hyland Lake through this outlet only when the surface elevation of the lake exceeds this elevation. Discharge through the outlet occurs only during very wet conditions. The UAA determined that the lake's volumes, outflow volumes, and hydrologic residence times vary with climatic conditions (Table 2).

TABLE 2
Hyland Lake Estimated Volumes, Outflow Volumes and Hydrologic Residence Times

Climatic Condition (Water Year, Inches of Precipitation)	Average Lake Volume (m^3 / ac-ft)	Estimated Annual Lake Ouflow through Outlet* (m^3/ac-ft)	Estimated Annual Lake Ouflow by Infiltration* (m^3/ac-ft)	Hydraulic Residence Time (years)
Wet Year (2002, 38 Inches)	826,682 / 670	29,443 / 24	218,417 / 177	3.8
Average Year (1998, 30 Inches)	894,646 / 725	0 / 0	181,397 / 147	4.9
[1]Dry Year (2000, 25 Inches)	826,682 / 670	0 / 0	231,991 / 188	3.4

*Outflows are based on the Hyland Lake WATBUD model results.

TABLE 2
Hyland Lake Estimated Volumes, Outflow Volumes and Hydrologic Residence Times

[1]Model calibration performed for the dry year.

Source: Hyland Lake UAA (Barr Engineering, July 2004)

The UAA states that the Three Rivers Park District planned to construct a new outlet from Hyland Lake in 2004 with the intent of lowering the lake elevation by one foot. According to the UAA, the effect of this new outlet on outflows through the outlet and by groundwater exfiltration was difficult to predict in the UAA analysis given the dynamic relationship between ground water outflows/inflows and the normal water elevation of Hyland Lake. It was also difficult to predict by how much the long run normal water elevation would eventually change.

1.2.2 Hyland Lake Water Quality

The water quality of a lake provides an indication of how a lake functions. A standardized lake rating system is often used to classify the ecological conditions of a lake. The rating system uses phosphorus, chlorophyll *a*, and Secchi disc transparency values to classify a lake into four categories: Oligotrophic (clear, low productivity lakes with excellent water quality), Mesotrophic (intermediate productivity lakes with good water quality), Eutrophic (high productivity lakes with poor water quality) and Hypereutrophic (extremely productive lakes with poor water quality).

1.2.2.1 Data Collection

Data for the previous watershed management plan was collected from 1972 through 1994. Additional data was collected in 1996 and 2000 to support the Hyland Lake UAA. Lake monitoring data was also received from the Three Rivers Park District for 1971-2002. An additional sampling year was accomplished in 2005.

1.2.2.2 Baseline/Current Water Quality

In general, Hyland Lake water quality remained poor throughout the more recent monitoring period (1996 – 2005), and perhaps slightly worsened. The lake can still be classified as eutrophic to hypereutrophic.

Total phosphorus concentrations were typically in the eutrophic category in the spring and early summer, and increased to a peak in the hypereutrophic category in the mid to late summer (Figure HL-1). Total phosphorus concentrations were generally higher in 2005 than in 1996 and 2000, throughout the monitoring season. Chlorophyll *a* concentrations were typically in the mesotrophic category in the spring, and increased to the eutrophic category by early summer, and peaked in the hypereutrophic category in mid-summer (Figure HL-2). Secchi disc depths generally start in the eutrophic category in the spring through mid-summer, with a quick peak into the mesotrophic category for a couple of weeks in mid-summer, then decrease into the hypereutrophic category for the remainder of the summer (Figure HL-3).

According to the UAA, the poor water quality condition of Hyland Lake is largely the result of historical inputs of sediment and phosphorus and the current influence of invasive and native aquatic plans on the mobilization of phosphorus from lake sediments. The UAA reports that there was a lake restoration effort in 1978. This restoration effort involved the draining of the lake to expose the bottom sediments, construction of storm water detention ponds, construction of an outlet, and the construction of an augmentation well and an aeration system. The lake was also restocked with bass. The result of the restoration effort was that for a few years following the restoration there were reduced phosphorus levels and significantly reduced chlorophyll *a* levels and improved Secchi disc transparency. The benefits of the restoration began to diminish significantly by 1984. From the water quality data, it was inferred that phosphorus release from the lake sediments was reduced as a result of "aerating" the lake sediments during the lake draw down. However, it appears that the lake sediments became anaerobic sometime after the restoration effort, phosphorus again began to be released from sediments, and phosphorus levels were once again very high in Hyland Lake.

FIGURE HL-1
Hyland Lake Total Phosphorus.

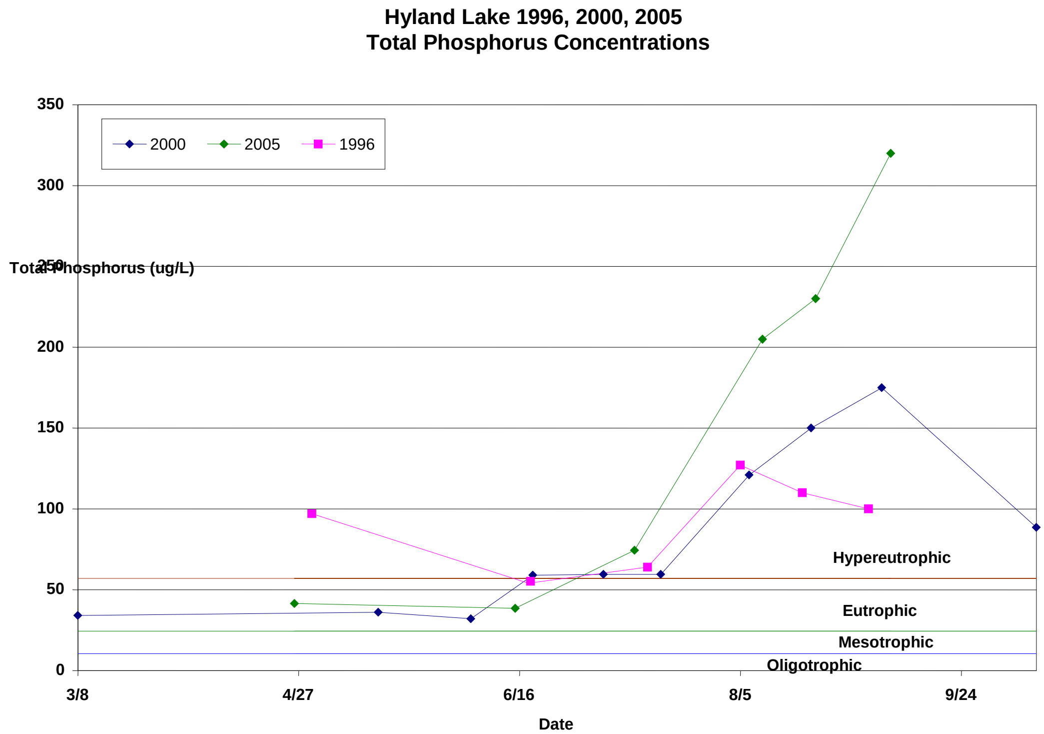


FIGURE HL-2
Hyland Lake Chlorophyll *a*.

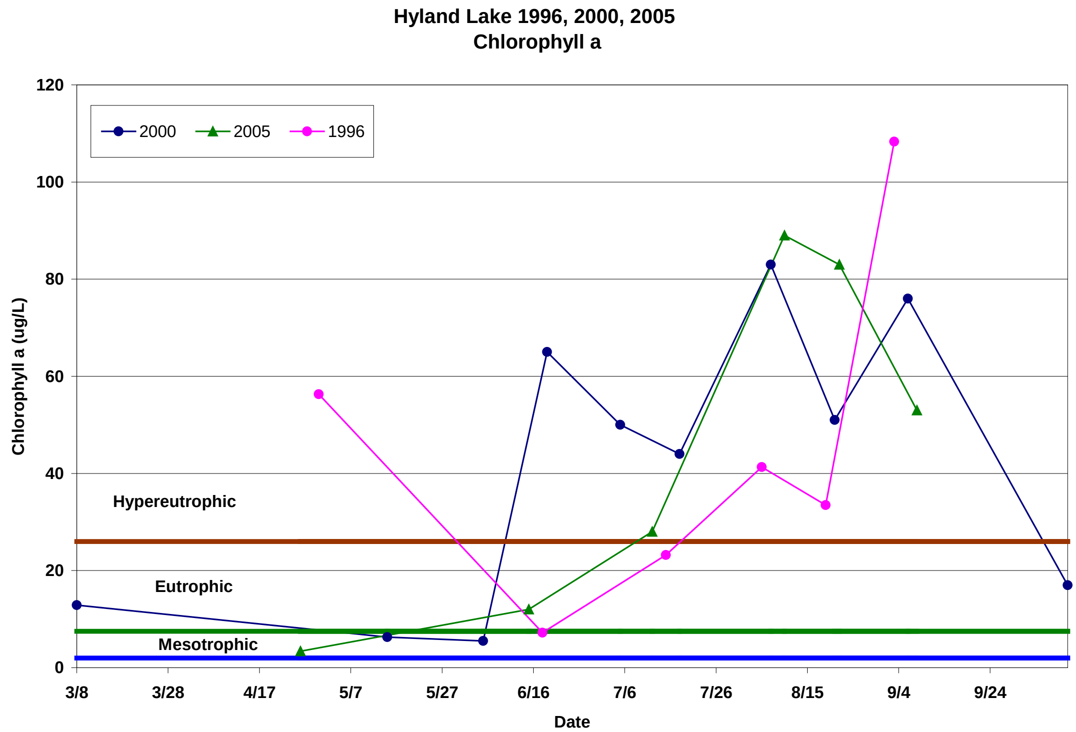
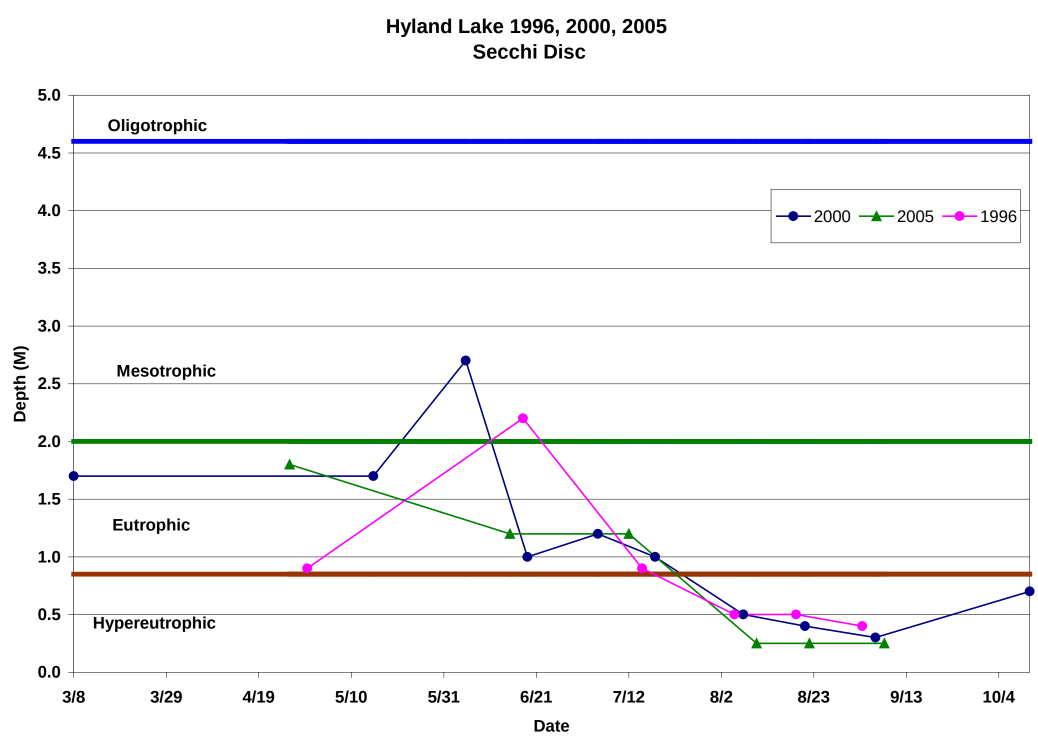


FIGURE HL-3
Hyland Lake Secchi Disc



1.2.3 Ecosystem Data

Hyland Lake is a Class 40 lake. Class 40 lakes are typically shallow and productive lakes. Average water quality for the ecological class is a TSI_{SD} of 54.5 or lower. The lake's water quality in 1996 and 2000 corresponded to a TSI_{SD} of 59.6 and 58.2 respectively. The lake's current water quality (2005 data) corresponds to a TSI_{SD} of 64.6, indicating that its water quality is still poor compared to the average lake in its ecological class.

1.2.3.1 Aquatic Ecosystems

According to the 1996 Plan, Hyland Lake's ecosystem is typical for a temperate lake. Its plants and animal communities have no unusual characteristics, although species abundance was relatively low at the time.

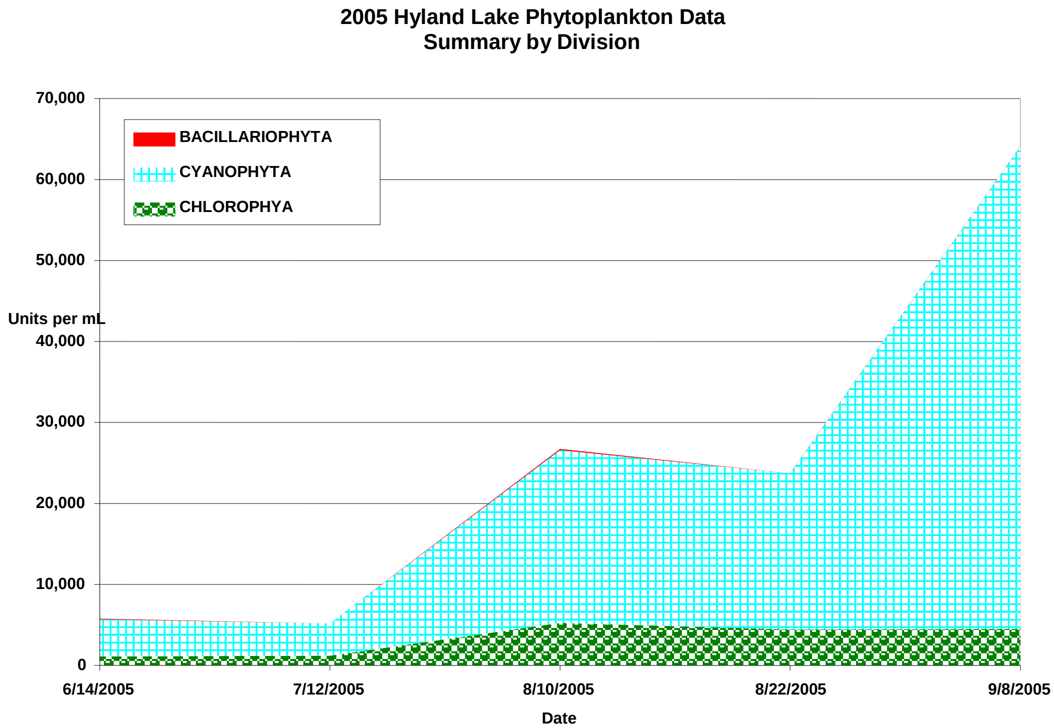
The UAA states that the interactions of the physical, chemical and biological components of the Hyland Lake aquatic ecosystem have a large effect on the capacity of Hyland Lake to achieve the recreation, aquatic communities, and water quality goals that have been established for the lake. The aquatic ecosystem of Hyland Lake is a good example of how the biological community of a lake (i.e. zooplankton, algae, and aquatic plants) can affect the chemical environment of a lake (i.e. pH, phosphorus levels, and dissolved oxygen) which can then also affect the biological community.

1.2.3.2 Phytoplankton

According to the 1996 Plan, Hyland Lake's phytoplankton in 1993 were dominated by blue-green algae (Cyanophyta) as they had been in all years previous to the Plan. Per the UAA, the 2000 phytoplankton population in Hyland Lake is diverse and goes through a seasonal transformation where green algae and diatoms are dominant in the spring but decline in the summer, while blue-green algae populations are low in spring and dominate in the summer and fall. Algal blooms are observed in Hyland Lake from late-June through September. The blooms primarily consist of blue-green algae which are large and visible and are often noted to be floating on the surface during periods of severe blooms. Large populations of blue-green algae are most often associated with high levels of phosphorus. Hence, phosphorus levels will need to be reduced to decrease blue-green algae populations in Hyland Lake.

The 2005 data shows that the phytoplankton population is still dominated by blue-green algae (Figure HL-4). Green algae is also present throughout the monitoring season.

FIGURE HL-4
Hyland Lake Phytoplankton Data Summary (2004)



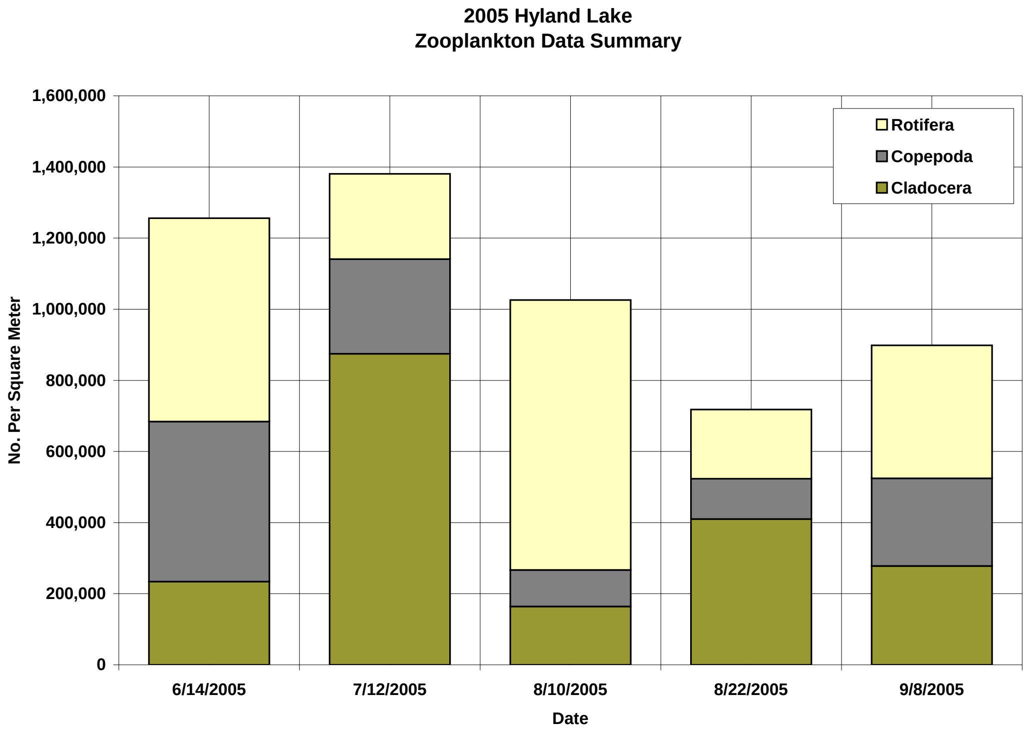
1.2.3.3 Zooplankton

According to the 1996 Plan, in 1993, cladocera dominated the zooplankton community in June. Rotifers dominated the zooplankton community mid-summer and copepods dominated in late August. Zooplankton species diversity was low in Hyland Lake compared with other lakes in the watershed district.

The 2004 UAA reports that all three groups of zooplankton are well represented in Hyland Lake. The 2000 data showed that there was a large population of rotifers and copepods, as well as cladocera which is good because they have the capacity to biologically control algal growth. The data also showed that cladocera decreased significantly in early June 2000 and did not recover until mid-July. This observed drop is typically caused by predation by newly hatched fish. According to the 2002 MDNR fish survey, the 2000 year-class is large, meaning there was an abundant population of small, newly hatched fish in Hyland Lake in 2000, and to a limited degree this fish population may be affecting the abundance of the cladocera population in Hyland Lake.

The 2005 data shows that all three groups of zooplankton are still well represented (Figure HL-5).

FIGURE HL-5
Hyland Lake Zooplankton Data Summary (2004)



1.2.3.4 Macrophytes

Per the 1996 Plan, Hyland Lake's macrophytes were surveyed in June and August 1993 which showed that the littoral area was dominated by the nuisance submerged plant, curlyleaf pondweed (*Potamogeton crispus*), which had died by the August survey. Hyland Lake had not become infested with Eurasian watermilfoil (*Myriophyllum spicatum*).

According to the 2004 UAA, the June and August 2000 macrophyte surveys showed a plant community consisting of six individual species which are common to Minnesota lakes. However, the presence and growth of exotic (nonnative) species, curlyleaf pondweed was still a concern.

The 2005 macrophyte surveys showed that in June, curlyleaf pondweed significantly dominated the macrophyte population in several areas. Also present were narrowleaf pondweed, sago pondweed, and floating leaf pondweed in light densities. In August, the curlyleaf pondweed had died off. The 1996, 2000 and 2005 surveys are summarized in Table 4. Management of curlyleaf pondweed is recommended to protect the lake's water quality and native plant community and to improve the lake's fishery.

TABLE 4
Hyland Lake Aquatic Plants (1996, 2000, and 2005)

Common Name	Scientific Name	1996 Density	2000 Density	2005 Density
Submerged Aquatics				
Curlyleaf pondweed	***P. crispus***	**1-3**	**1-3**	**2-3**
Flatstem pondweed	***P. zosteriformis***	**1-3**	**1**	

TABLE 4
Hyland Lake Aquatic Plants (1996, 2000, and 2005)

Common Name	Scientific Name	1996 Density	2000 Density	2005 Density
Sago pondweed	***P. pectinatus***	**1-3**	**1-3**	**1**
Narrowleaf pondweed	***P. spp.***		**1-2**	**1-2**
Floating leaf pondweed	***P. natans***	**1**	**1**	**1**
Leafy pondweed	***P. foliosus***	**1**		
Coontail	***Ceratophyllum demersum***		**1**	
Elodea	***Elodea Canadensis***	**1-3**	**1-3**	
Floating Leaf Plants				
White waterlily	***Nymphaea turberosa***	**--**	**--**	**--**
Greater duckweed	***Spirodela polyrhiza***	**--**	**--**	**--**
Lesser duckweed	***Lemna minor***	**--**	**--**	**--**
Emergent Plants				
Bulrush	***Scirpus spp.***	**--**	**--**	**--**
Cattail	***Typha spp***	**--**	**--**	**--**
Purple loosestrife	***Lythrum salicaria***	**--**	**--**	**--**

1.2.4 Water-Based Recreation

The 1996 Plan and 2004 UAA describe the water-based recreation for Hyland Lake as follows. The lake is located in the Three Rivers Park District (formerly Hennepin Parks). Park visitors use the lake for fishing, swimming, and boating, as well as hiking and picnicking. There is a swimming beach and fish pier that is owned and operated by the Thee Rivers Park District. There is a public boat access within the park in the southwest corner of the lake. The Three Rivers Park District has categorized Hyland Lake as a Class II lake (Suburban Hennepin Regional Park District, 1999), meaning the primary existing use of the lake is fishing, and swimming is not a desirable use. A creel survey by the MDNR in 1990 indicates that fishing is a popular activity at Highland Lake and fishing pressure is considered to be high.

1.2.5 Fish and Wildlife Habitat

The 1996 Plan states that according to its ecological classification, Hyland Lake is a Class 40 lake, with primary fish species being northern pike, carp, and black bullhead. Per the 2004 UAA, the MDNR has indicated that the ideal water quality for its ecological class is a TSISD of approximately 54.5 or lower (i.e. a summer average Secchi disc transparency of about 4.8 feet or greater). This recommendation is based upon water quality needs of the fishery found in a Class 40 lake. Hyland Lake's current (2005) water quality (TSISD = 64.6 which corresponds to a summer average Secchi disc transparency of 2.39 feet) does not meet this recommendation.

The 2004 UAA states that the 2002 MDNR fish survey for Hyland Lake showed that black crappie, bluegill, hybrid sunfish, largemouth bass, yellow perch, black bullhead, and golden shiner are present in the lake. There has been a history of stocking gamefish (largemouth bass and yellow perch) in Hyland Lake. The experimental slot size regulation, meaning fish of a certain size that have been caught must be released, that was established for largemouth bass in Hyland Lake in 1981 expired in 1999. The fish survey shows that bluegill, black crappie and black bullhead are the primary species based on quantity.

Hyland Lake provides good habitat for waterfowl such as ducks and geese. There is an island in the middle of the lake that provides potential nesting sites.

1.2.6 Natural and Urban Drainage Systems

1.2.6.1 Natural Conveyance Systems

Hyland Lake's natural inflow consists of direct runoff from parkland surrounding the lake and groundwater inflows. All other discharges to the lake are through piped inlets.

1.2.6.2 Stormwater Conveyance Systems

Stormwater conveyances to Hyland Lake were investigated in the 2004 UAA. Stormwater is conveyed primarily from residential neighborhoods directly east of Hyland Lake. This stormwater is routed through five wet detention ponds and a wetland. In 2004 the Three Rivers Parks District intended to upgrade the wetland that is located directly north of Hyland Lake.

1.2.6.3 Public Ditch Systems

There are no public ditch systems that affect Hyland Lake.

1.2.7 Water Appropriations

There are no known water appropriations from Hyland Lake.

Lake Ann

August 2008

Contents

Lake Ann

1.1 Lake Ann Watershed Goals

The approved Riley-Purgatory-Bluff Creek Watershed District Water Management Plan, 1996, (Water Management Plan) inventoried and assessed Lake Ann. The plan articulated five specific goals for Lake Ann. These goals address recreation, aquatic communities, water quality, water quantity, and wildlife. The approved Lake Lucy and Lake Ann Use Attainability Analysis (UAA), 1999 further expanded the characterization of Lake Ann by evaluating the intended five goals.

1.1.1 Water Quantity

The water quantity goal for Lake Ann is to provide sufficient water storage during a regional flood (100-yr, 24-hr storm event). This goal is attainable with no action. (UAA, 1999)

1.1.2 Water Quality

Lake Ann's 1996 water quality (TSI_{SD}=49) exceeded the MPCA swimmable use goal (TSI_{SD}≤57) and the aquatic communities goal (TSI_{SD}≤50.4). Therefore, in keeping with the District's policy of non-degradation of current lake water quality conditions, the water quality goal for Lake Ann is TSI_{SD}=49 or lower. Per the 1999 UAA, this goal is attainable, but only with recommended BMPs throughout the Lake Ann watershed.

1.1.3 Recreation

The recreation goal for Lake Ann is to achieve a fully supporting use classification in accordance with the "MPCA Use Support Classification for Swimming Relative to Carlson's Trophic State Index by Ecoregion" (MPCA, 1997), with a Trophic State Index of less than or equal to 53. Per the 1999 UAA, this goal is attainable through the implementation of recommended BMPs throughout the Lake Ann and Lake Lucy (upstream) watersheds.

1.1.4 Aquatic Communities

The fisheries goal for Lake Ann is to maintain a MDNR ecological class 24 rating, with TSI_{SD} of approximately 50. It would take a large change in water clarity to move a lake into a different lake class (Schupp, 1999). The UAA states that therefore, this part of the goal can be achieved with no action. A TSI of 50 corresponds to a Secchi disk transparency of 1.6m, the average of the Class 24 lakes studied by the MDNR. Per the UAA, Lake Ann summer average Secchi disk transparency in 1997 was 3.2m, greater than the MDNR average. Based on 2004 data, Lake Ann summer average Secchi disk transparency was 2.25m and still exceeded the MDNR average.

1.1.5 Wildlife

The wildlife goal for Lake Ann is to protect existing, beneficial wildlife uses. The wildlife goal can be achieved with no action, especially if the wetlands and park land surrounding the lakes in the City of Chanhassen's future land use plan stays intact. (UAA)

1.1.6 Public Participation

The goal is to encourage public participation in reaching achievable outcomes for Lake Ann.

1.2 Existing Watershed Conditions

Lake Ann is located in City of Chanhassen in the western part of the Riley-Purgatory-Bluff Creek watershed. It is downstream of Lake Lucy and drains to Riley Creek.

1.2.1 Watershed Description

1.2.1.1 Land Use

Land use is an important watershed characteristic that has a direct impact on a lake and its water quality. Increasingly intensive land use will increase both sediment and phosphorus loads, as well as, alter the routine hydrology of a lake and its tributaries. Urbanization can also lead to thermal impacts which in turn can play a role in fisheries habitat. Sound watershed planning needs to consider both existing and future land use.

The land use for the Lake Ann watershed is summarized in Table 2. The total watershed area is relatively consistent between the 2005 and 2020 land use survey and the areas reported in the 1996 Watershed Management Plan from a 1991 survey and areas reported in the UAA in a 1997 survey. Based on a comparison of this data, it appears that residential land use has significantly decreased over the past 14 years and that by 2020, it is expected to increase. Conversely, it appears that parks and open space have increased significantly over time, but by 2020, this land use category is expected to decrease to 1991 levels.

TABLE 2
Summary of Past and Projected Land Use Acreage – Lake Ann

Land Use Category	1991 [1]	1997 [2]	2005 [3]	2020 [3]
Single Family & Low Density Residential	88	6	3.80	23.83
Medium Density Residential	*	*	0.00	12.54
Commercial	1	*	0.00	0.00
Agricultural	*	*	17.01	*
Parks + Open	59	119	119.90	58.87
Wetlands	*	8	*	*
Water	*	117	116.29	125.96
Institutional (School, etc)	*	5	0.12	35.91
TOTAL	148	255	257.11	257.11

* Land use category not reported
1. Data from 1996 Watershed Plan.
2. Data from 1999 Lake Lucy and Lake Ann UAA.
3. Metropolitan Council, Generalized Land Use 2005 for the Twin Cities Metropolitan Area and Regional Planned Land Use - Twin Cities Metropolitan Area.

1.2.1.2 Major Hydrologic Characteristics

Lake Ann has a 257-acre watershed, a surface area of 116 acres, a maximum depth of approximately 40 feet, and a mean depth of approximately 16.9 feet. The lake's volumes, outflow volumes, and hydrologic residence times vary with climatic conditions, according to the 1999 UAA (Table 3).

TABLE 3
Lake Ann Estimated Volumes, Outflow Volumes and Hydrologic Residence Times

Climatic Condition (Water Year, Inches of Precipitation)	Estimated Lake Volume (m^3 / ac-ft)	Estimated Annual Lake Ouflow* (m^3/ac-ft)	Estimated Hydraulic Residence Time (years)
Wet Year (1983, 41 Inches)	2,472,000 / 2004.3	996,000 / 807.6	2.5
Average Year (1995, 27 Inches)	2,426,000 / 1966.8	362,000 / 293.5	6.7
Model Calibration Year (1997, 34 Inches	2,428,000 / 1969.1	766,000 / 621.1	3.2
Dry Year (1988, 19 Inches)	2,472,000 / 2004.3	996,000 / 807.6	2.5

*Outflows are based on the Mitchell Lake WATBUD model results.
Source: Lake Lucy and Lake Ann Use Attainability Analysis (Barr Engineering, July 1999)

Lake Ann overflows to form the headwaters of Riley Creek when its surface elevation exceeds 954.7 feet MSL.

1.2.2 Lake Ann Water Quality

The water quality of a lake provides an indication of how a lake functions. A standardized lake rating system is often used to classify the ecological conditions of a lake. The rating system uses phosphorus, chlorophyll *a*, and Secchi disc transparency values to classify a lake into four categories: Oligotrophic (clear, low productivity lakes with excellent water quality), Mesotrophic (intermediate productivity lakes with good water quality), Eutrophic (high productivity lakes with poor water quality) and Hypereutrophic (extremely productive lakes with poor water quality).

1.2.2.1 Data Collection

Data for the previous watershed management plan was collected from 1972 to 1994. Additional data was collected in 1996-1997 to support the Lake Ann UAA. An additional sampling year was accomplished in 2004.

1.2.2.2 Baseline/Current Water Quality

In general, Lake Ann water quality has not changed significantly throughout the more recent monitoring (1997 – 2004).

Total phosphorus concentrations were typically in the eutrophic category throughout the spring and summer (Figure LA-1). In 1997, there were a few days in mid-summer when concentrations decreased into the mesotrophic category. Chlorophyll *a* concentrations typically start in the eutrophic category in the spring, and then in mid-summer decreased significantly into the mesotrophic zone for the rest of the season (Figure LA-2). In 1997, the transition from eutrophic to mesotrophic zones occurred earlier, in late spring. Secchi disc depths start within the eutrophic category and increase into the mesotrophic category in mid-summer (Figure LA-3). In 1997, the transition from eutrophic to mesotrophic zones occurred earlier, in late spring.

FIGURE LA-1
Lake Ann Total Phosphorus.

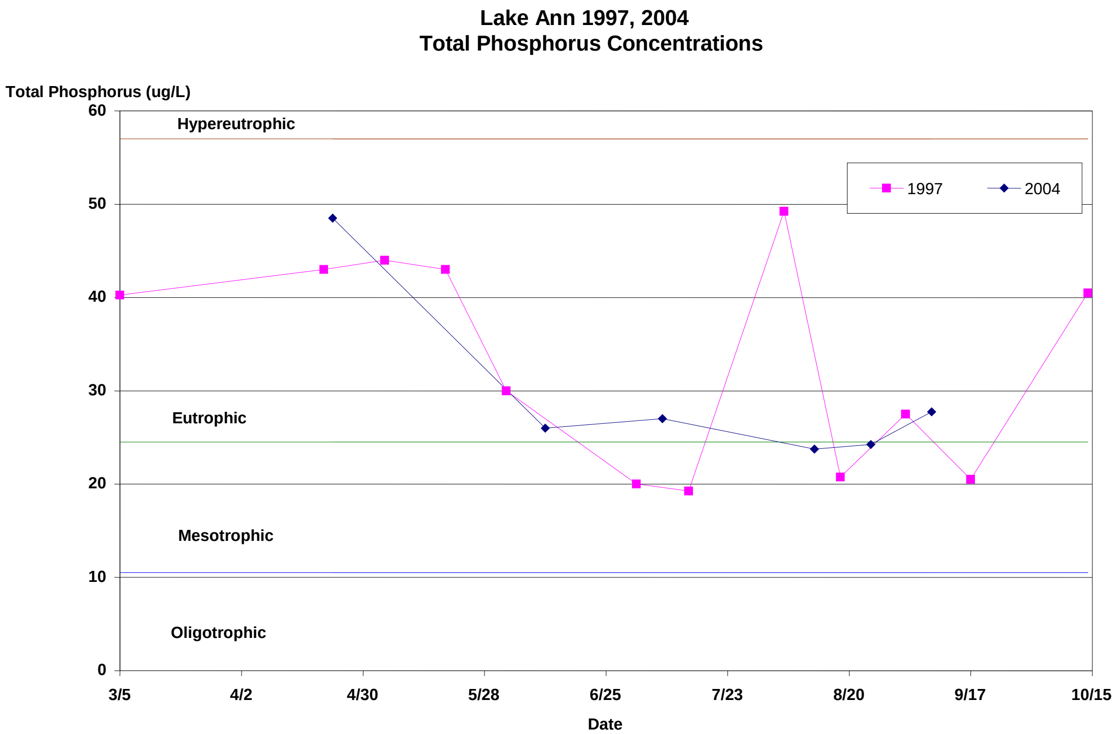


FIGURE LA-2
Lake Ann Chlorophyll *a*.

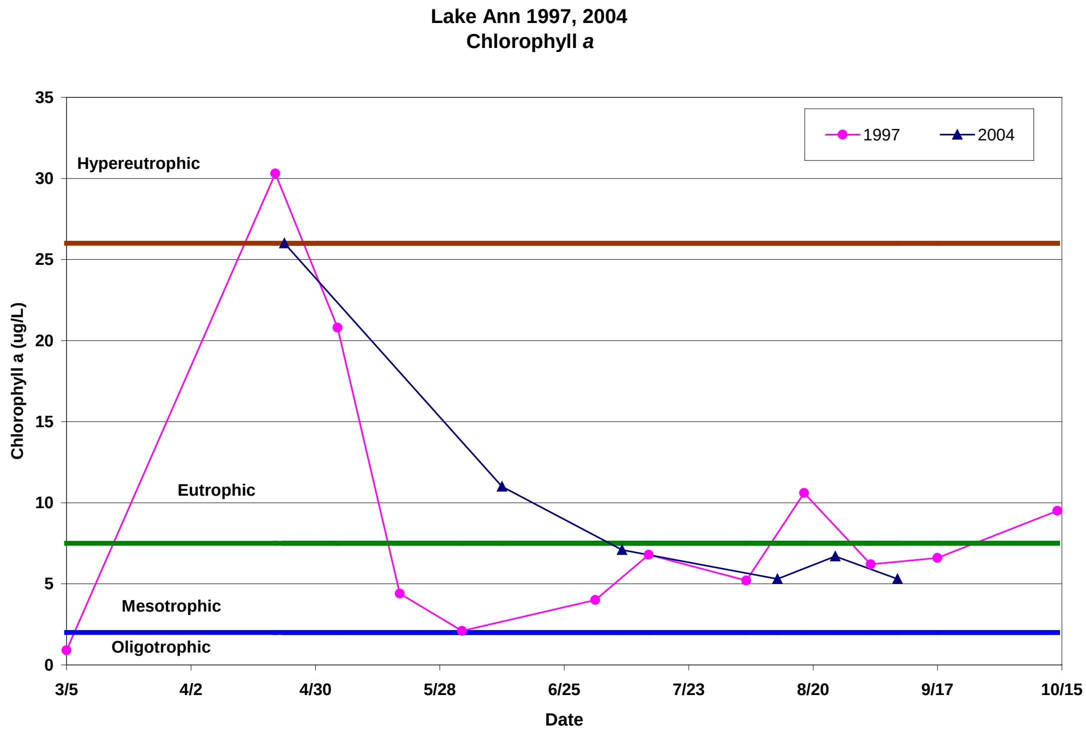
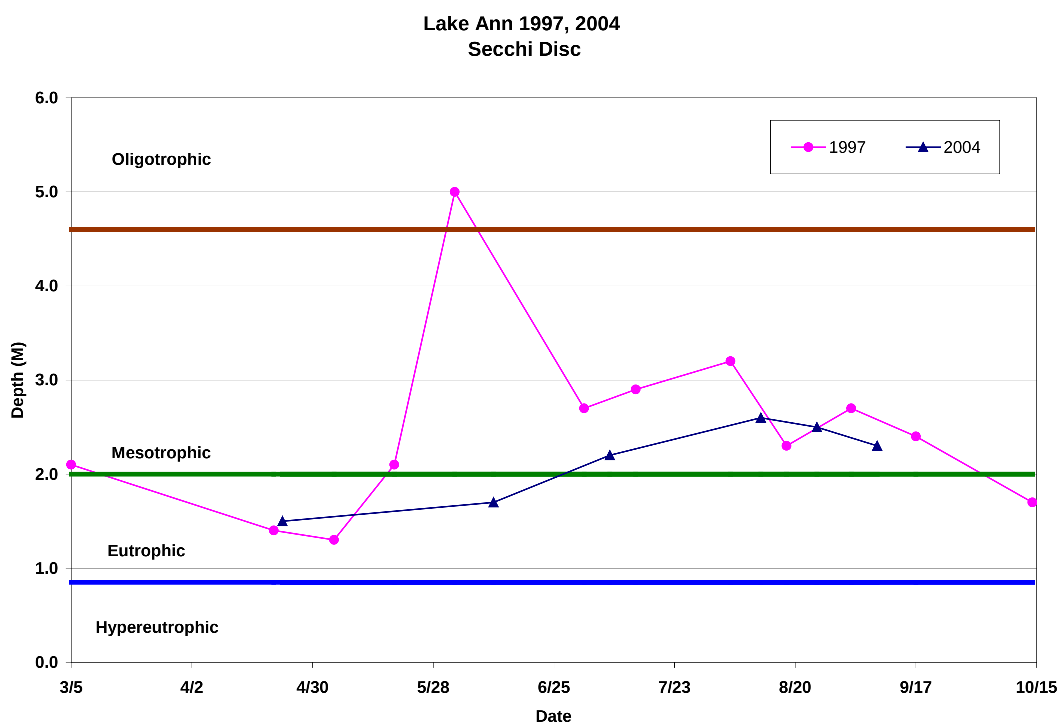


FIGURE LA-3
Lake Ann Secchi Disc



1.2.3 Ecosystem Data

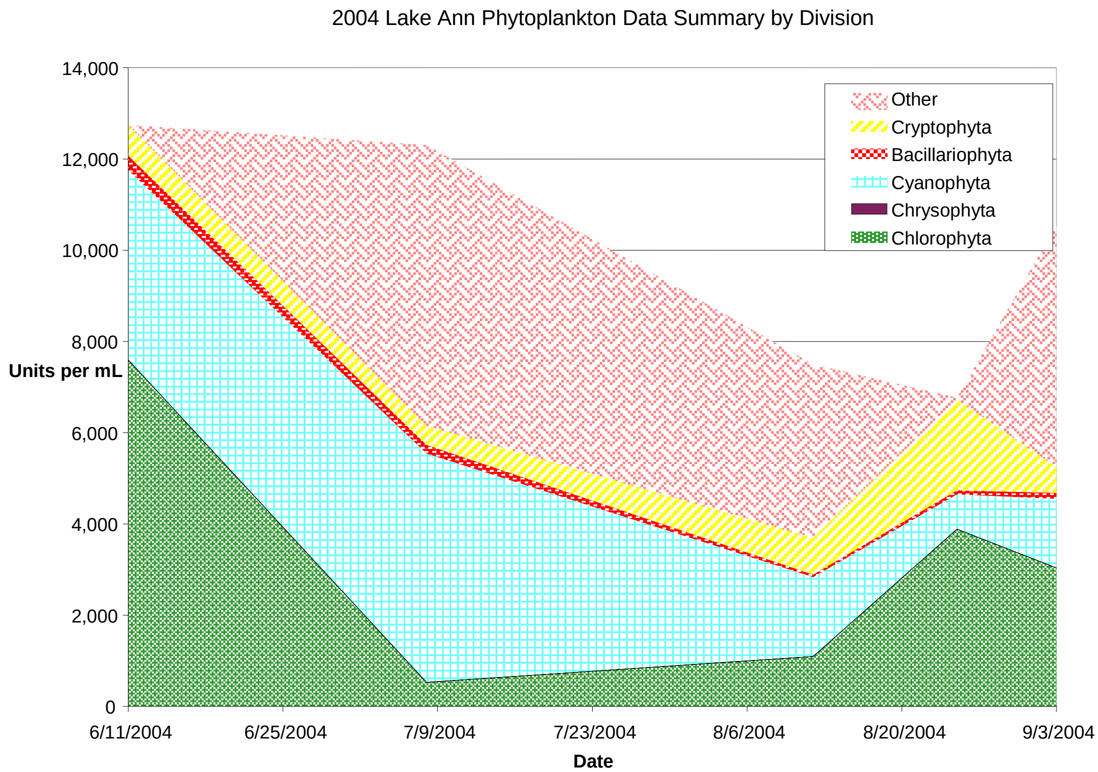
Lake Ann is a Class 24 lake. Class 24 lakes typically have a good permanent fishery. The MDNR has assigned an ecological rating (TSI_{SD}) of 50.4 or lower. The lake's current water quality (2004 data) corresponds to a TSI_{SD} of 48.3, indicating that its condition is considered better than the average lake in its ecological class.

1.2.3.1 Phytoplankton

At the time of the 1996 Watershed Management Plan, the phytoplankton in Lake Ann included species edible by zooplankton such as diatoms (Bacillariophyta) and green algae (Chlorophyta). However, inedible blue-green algae had dominated the phytoplankton community throughout the 1975-1994, except for 1988, when cryptomonad algae were dominant. In 1990, green and blue-green algae again dominated. Per the 1999 UAA, blue-green and green algae continued to be, in general, the dominant types of phytoplankton observed in 1997.

Lake survey results for 2004 were analyzed to determine the composition and abundance of phytoplankton in Lake Lucy. The 2004 survey results demonstrated that Chlorophyta (green algae) and Cyanophyta (blue-green algae) were the dominant communities in the early summer. The Chlorophyta appears to quickly die off, and then becomes dominant again in the late summer. The Cyanophyta also dies off somewhat in mid-summer. Euglenophyta and Pyrrhophyta (the "Other" category shown in Figure LA-4) become the combined dominant community during most of the summer. Finally, there are significantly more phytoplankton species in Lake Ann in 2004 – almost double than in 1997.

FIGURE LA-4
Lake Ann Phytoplankton Data Summary (2004)



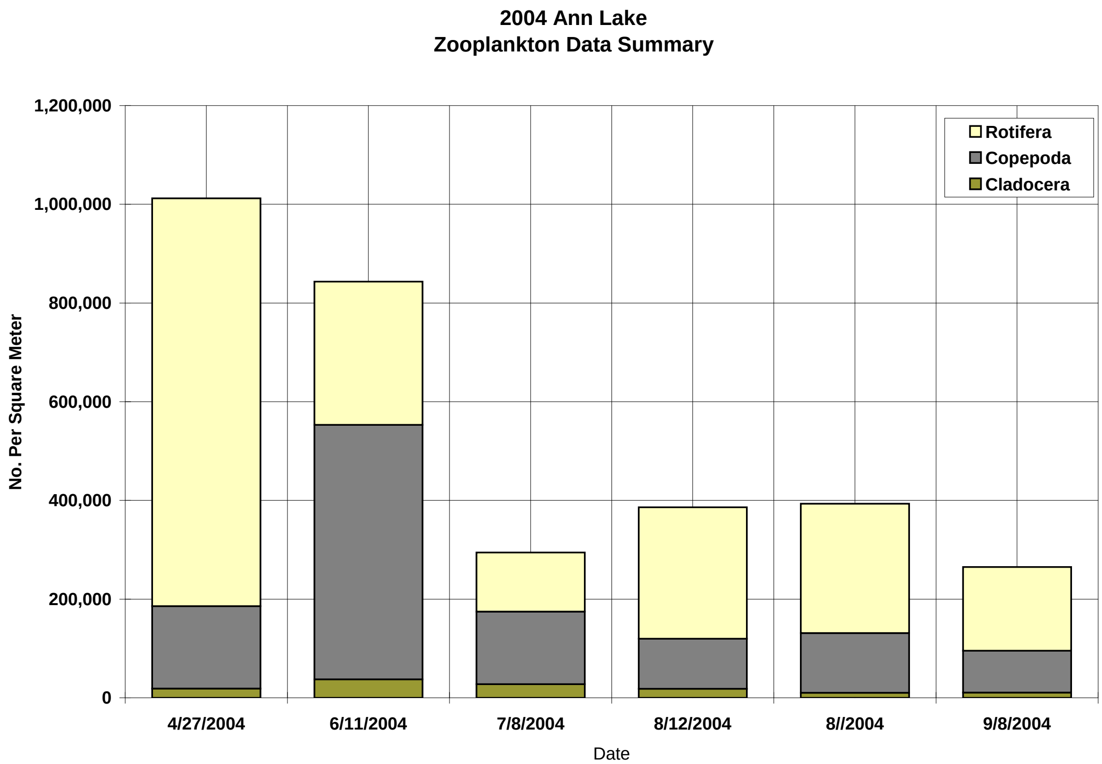
1.2.3.2 Zooplankton

Per the 1996 Plan, rotifers had dominated the community more frequently than clacoderans and copepods. A peak in the number of rotifers in July was seen in 1990 and 1994. Although the peak in 1994 was considerably higher, the abundance of cladocerans had not changed significantly since 1990. Average number of copepods decreased from 1990 to 1994, however, the large variability in the annual numbers of copepods made it difficult to tell if the decline was significant.

According to the 1997 data included in the UAA, all three groups of zooplankton – Cladocera, Copepoda, and Rotifera - are well represented in Lake Ann. The UAA notes that the 1997 Lake Ann zooplankton abundance was slightly lower than those observed in earlier sampling events. However, the zooplankton abundance varies greatly from year to year. The rotifera and copepoda in Lake Lucy graze primarily on extremely small particles of plant matter and do not significantly affect the lake's water quality. However, the cladocera graze primarily on algae and can improve water quality if present in abundance.

The 2004 data showed that the Rotifera was the dominant population during the season, with decreased count in the early summer. Copepods were also dominant, starting in the early summer.

FIGURE LA-5
Lake Ann Zooplankton Data Summary (2004)



1.2.3.3 Macrophytes

Macrophyte surveys of the aquatic plant community in Lake Ann were completed by the District in June and August of 1994, 1997, and 2004 and are summarized in Table 4.

TABLE 4
Lake Ann Aquatic Plants (1994, 1997 and 2004)

Common Name	Scientific Name	1994 Density	1997 Density	2004 Density
Submerged Aquatics				
Floating leaf pondweed	***P. natans***	**1-3**	**1**	**1**
Large-leaf pondweed	***P. amplifolius***	**1-3**	**1-2**	**2**
Variable pondweed	***P. gramineus***	**--**	**1**	**1**
Pondweed	***P. pusillus***	**--**	**--**	**--**
Curlyleaf pondweed	***P. crispus***	**1-3**	**1**	**1**
Flatstem pondweed	***P. zosteriformis***	**1-2**	**1-3**	**1-3**
Sago pondweed	***P. pectinatus***	**1-2**	**1-2**	**1-2**
Narrowleaf pondweed	***P. spp.***	**--**	**--**	**1-3**
Northern water milfoil	***Myriophyllum sibiricum***	**1**	**1-2**	**1-2**

TABLE 4
Lake Ann Aquatic Plants (1994, 1997 and 2004)

Common Name	Scientific Name	1994 Density	1997 Density	2004 Density
Northern watermilfoil	***Myriophyllum excalbescens***	**--**	**1-2**	**--**
Water stargrass	***Zosterella dubia***	**1**	**1**	**--**
Star duck weed	***Lemna trisulca***	**--**	**--**	**--**
Bladdwurt	***Utricularia spp.***	**--**	**--**	**--**
Illinois pondweed	***P. illinoensis***	**--**	**--**	**1**
Coontail	***Ceratophyllum demersum***	**1-2**	**1-3**	**1-3**
Elodea	***Elodea Canadensis***	**1**	**1**	**1-2**
Muskgrass	***Chara spp.***	**1**	**1**	**1-3**
Bushy pondweed and naiad	***Najas flexilis***	**1-3**	**1-3**	**1**
Leafy pondweed	***P. foliosus***	**--**	**1-2**	**--**
White waterbuttercup	***R. sp.***	**--**	**1**	**1**
Water celery	***Vallisneria americana***	**1-3**	**1-2**	
Eurasian watermilfoil	***M. spicatum***	**--**	**1**	**1-3**
Floating Leaf Plants				
White waterlily	***Nymphaea odorata*** ***Nymphaea turberosa***	**--**	**--**	**--**
Water Smartweed	***Polygonum spp.***	**--**	**--**	**--**
Emergent Plants				
Bulrush	***Scirpus spp.***	**--**	**--**	**--**
Cattail	***Typha spp***	**2**	**--**	**--**
Purple loosestrife	***Lythrum salicaria***	**--**	**--**	**--**

According to the 1996 Plan and 1994 survey, Lake Ann did not have Eurasian watermilfoil. The lake did have northern watermilfoil, which is closely related to Eurasian watermilfoil, but is a native, non-nuisance species. In June, there were some areas in the submerged aquatics which were dominated by a dense growth of curlyleaf pondweed, an undesirable non-native species, but the species quickly died off later in the summer. Other areas were dominated by large-leaf pondweed and bushy pondweed and Naiad.

The 1997 survey shows that there is Eurasian watermilfoil and curlyleaf pondweed in Lake Ann in June and August, though they represent light densities in some areas. The survey also observed purple loosestrife along the northern shoreline in August. In June and August, Flagstem pondweed was dominant in some areas, while Coontail was dominant in some areas in August.

The 2004 survey results revealed that Eurasian watermilfoil was dominant, with heavy densities in some areas, in both June and August. Curlyleaf pondweed was also present in light densities in some areas in June but died back by August. The growth of these invasive species should be controlled in order to protect water quality and lake habitat. Also present in heavy densities were flatstem pondweed, narrowleaf pondweed and coontail.

1.2.4 Water-Based Recreation

According to the 1996 Plan, Lake Ann is used for all types of recreational activities, including swimming. A municipal park with a swimming beach and boat access are located on the south side of the lake, and are owned and maintained by the City of Chanhassen. Per the 1999 UAA, Lake Ann is considered an excellent northern pike fishery, despite its small size and proximity to a metropolitan area.

1.2.5 Fish and Wildlife Habitat

According to its ecological classification, Lake Ann is a Class 24 lake, which signifies a good, permanent fish lake (Schupp, 1992). The average Secchi disc transparency for this ecological class is 1.3 m (Schupp, 1992). In 1997 and 2004, Lake Ann's average summer Secchi disc transparency was 3.2 m and 2.25 m, respectively. Therefore, Lake Ann's current conditions indicate that its water quality is considerably better than the average lake in its ecological class.

Lake Ann's most abundant fish species in 1995 were northern pike, yellow perch, bluegills and black crappies (according to the MDNR's 1995 fisheries survey). According to the 2006 MDNR fisheries survey of Lake Ann, the most abundant fish species were bluegills and northern pike. Also present in lower counts were black crappie, pumpkinseed, black bullhead, hybrid sunfish, largemouth bass, yellow bullhead and yellow perch. The northern pike catch increased from 12 fish per net in 2000 to 15.5 fish per net in 2006. Average length remained the same at about 24 inches and average weight increased to 3.5 pounds. The overall catch of bluegulls dropped slightly, while the average size of bluegills sampled increased to 6.1 inches and 48% of all bluegills sampled were over 7 inches. The black crappie catch also declined slightly, while the average length per fish dropped to 6.5 inches from 8.1 inches in 2000.

Lake Ann provides habitat for seasonal waterfowl such as ducks and geese through diverse macrophyte communities.

1.2.6 Natural and Urban Drainage Systems

1.2.6.1 Natural Conveyance Systems

The natural inflow to Lake Ann is comprised largely of outflow from Lake Lucy on the north side of Lake Ann. The remaining inflow is stormwater runoff from Lake Ann's direct watershed. The outlet of Lake Ann on the south side is Riley Creek.

1.2.6.2 Stormwater Conveyance Systems

Stormwater conveyances to Lake Ann were investigated in the 1999 UAA for the lake. The study found that the Lake Ann stormwater conveyance system is comprised mostly of overland flow from its direct watershed. There is only one wetland in the Lake Ann watershed that has enough wet detention to affect stormwater treatment. Because the stormwater runoff in the Lake Ann watershed come only from the lake's direct watershed, and because each contributing subwatershed is so small, all of Lake Ann's runoff information is presented together as one stormwater conveyance system in the UAA

1.2.6.3 Public Ditch Systems

There are no public ditch systems that affect Lake Ann.

1.2.7 Water Appropriations

There are no known water appropriations from Lake Ann.

Lake Lucy

August 2008

Contents

Lake Lucy

1.1 Lake Lucy Watershed Goals

The approved Riley-Purgatory-Bluff Creek Watershed District Water Management Plan, 1996, (Water Management Plan) inventoried and assessed Lake Lucy. The plan articulated five specific goals for Lake Lucy. These goals address recreation, aquatic communities, water quality, water quantity, and wildlife. The approved Lake Lucy and Lake Ann Use Attainability Analysis (UAA), 1999 further expanded the characterization of Lake Lucy by evaluating the watershed goals.

1.1.1 Water Quantity

The water quantity goal for Lake Lucy is to provide sufficient water storage during a regional flood (100-yr, 24-hr storm event). This goal is attainable with no action. (UAA, 1999)

1.1.2 Water Quality

The MPCA has classified Lake Lucy as "partial support of swimmable use", which has a desired range of Trophic State Index (TSI), less than 57 and greater than 53. The 1996 water quality of Lake Lucy (TSI_{SD}=57) slightly exceeded the MCPA's desired range of TSI_{SD}, and as such the water quality goal for Lake Lucy is a TSI_{SD} score of 53 or lower, reflecting the RPBCWD policy of non-degradation of current lake water quality conditions. Per the 1999 UAA report, this goal is attainable, but only with recommended BMPs throughout the Lake Lucy watershed.

1.1.3 Recreation

The primary recreation goal is to achieve full support of fishing activities and maintain waterfowl habitat. As discussed in Section below addressing aquatic communities, the recreation goal can be considered a non-degradation goal as fishing in Lake Lucy is currently considered satisfactory. This goal is attainable with recommended BMPs throughout the Lake Lucy watershed and in-lake management of Lake Lucy's fishery. (UAA)

1.1.4 Aquatic Communities

The aquatic communities goal for Lake Lucy is to maintain a MDNR ecological Class 42 rating, with a $TSI_{SD}$of 58.7. The UAA suggests that since the water quality goal for Lake Lucy is based on a non-degradation policy, it seems that a more reasonable aquatic communities goal would also involve non-degradation of the existing aquatic communities, as measured by water quality. This goal is attainable with recommended BMPs throughout the Lake Lucy watershed.

1.1.5 Wildlife

The wildlife goal for Lake Lucy is to protect existing beneficial wildlife uses. The wildlife goal can be achieved with no action, especially if the wetlands and park land surrounding the lakes in the City of Chanhassen's future land use plan stay intact.

1.1.6 Public Participation

The goal is to encourage public participation in achieving outcomes from the use attainability analysis. To achieve this goal, a public meeting will be called to obtain comments on the use attainability analysis.

1.2 Existing Watershed Conditions

Lake Lucy is located in the City of Chanhassen in the western part of the Riley-Purgatory-Bluff Creek watershed. It drains to Lake Ann which in turn drains to Riley Creek.

1.2.1 Watershed Description

1.2.1.1 Land Use

Land use is an important watershed characteristic that has a direct impact on a lake and its water quality. Increasingly intensive land use will increase both sediment and phosphorus loads, as well as, alter the routine hydrology of a lake and its tributaries. Urbanization can also lead to thermal impacts which in turn can play a role in fisheries habitat. Sound watershed planning needs to consider both existing and future land use.

Land use data was obtained from the Metropolitan Council Generalized Land Use Maps. The maps are based on 2005 existing land use and a projected land use for 2020. Both existing and projected are summarized in Table LU-1. Future land use mapping for 2020 indicates that there will be a significant increase in single family residential and parks land use.

TABLE LU-1
Lake Lucy Existing and Projected Land Use

Land Use	2005 Existing (ac)	2020 Projected (ac)
Single Family or Low Density Residential	**393.3**	
Multiple Family or Medium Density Residential	**2.04**	
Agricultural	**28.03**	
Industrial and Utility	**0.58**	
Commercial	**8.96**	
Parks, Undeveloped Land and Other Open Areas	**412**	
Water	**123.51**	
Total	**968.42**	

TABLE LU-1
Lake Lucy Existing and Projected Land Use

Land Use	2005 Existing (ac)	2020 Projected (ac)

1.3 Major Hydrologic Characteristics

Lake Lucy has a 969-acre tributary watershed, a surface area of 84.4 acres (during a year of average precipitation) at a lake elevation of 956 feet, a maximum depth of approximately 18 feet, and a mean depth of 6.9 feet. The UAA determined that the lakes' volumes, outflow volumes, and hydrologic residence times vary with climatic conditions (Table LU-2).

TABLE LU-2
Lake Lucy Estimated Volumes, Outflow Volumes and Hydrologic Residence Times

Climatic Condition (Water Year, Inches of Precipitation)	Estimated Lake Volume (m^3 / ac-ft)	Estimated Annual Lake Ouflow* (m^3/ac-ft)	Estimated Hydraulic Residence Time (years)
Wet Year (1983, 41 Inches)	735,000 / 595.9	828,000 / 671.4	0.9
Average Year (1995, 27 Inches)	721,000 / 584.9	368,000 / 298.4	2.0
Model Calibration Year (1997, 34 Inches	719,000 / 583.2	609,000 / 493.8	1.2
Dry Year (1988, 19 Inches)	640,000 / 519	37,000 / 30.0	17.3

*Outflows are based on the Mitchell Lake WATBUD model results.

Source: Lake Lucy and Lake Ann Use Attainability Analysis (Barr Engineering, July 1999)

Lake Lucy overflows into Lake Ann when its surface elevation exceeds 955.7 feet MSL.

Harrison Lake was also incorporated into the UAA study. Under average hydrologic conditions, this lake is land-locked. Under flood conditions, however, Harrison Lake overflows into the Lake Lucy watershed system.

1.3.1 Lake Lucy Water Quality

The water quality of a lake provides an indication of how a lake functions. A standardized lake rating system is often used to classify the ecological conditions of a lake. The rating system uses phosphorus, chlorophyll *a*, and Secchi disc transparency values to classify a lake into four categories: Oligotrophic (clear, low productivity lakes with excellent water quality), Mesotrophic (intermediate productivity lakes with good water quality), Eutrophic (high productivity lakes with poor water quality) and Hypereutrophic (extremely productive lakes with poor water quality).

1.3.1.1 Data Collection

Data for the previous watershed management plan was collected from 1972 to 1994. Additional data was collected in 1997 to support the Lake Lucy UAA. An additional sampling year was accomplished in 2004.

1.3.1.2 Baseline/Current Water Quality

In general, Lake Lucy water quality has not changed significantly throughout the more recent monitoring (1997 – 2004).

Total phosphorus concentrations were typically in the eutrophic (nutrient rich) category in the spring and increased to a peak in the hypereutrophic (extremely nutrient rich) category in the mid to late summer (Figure LU-1). Chlorophyll *a* concentrations from the monitoring period show a similar trend, though in 2004, the peak occurs later in the summer and at a higher concentration than in 1997. Secchi disc depths start within the eutrophic category and, extend into the hypereutrophic category, again peaking in mid to late summer (Figure LU-2 and Figure LU-3).

FIGURE LU-1
Lake Lucy Total Phosphorus.

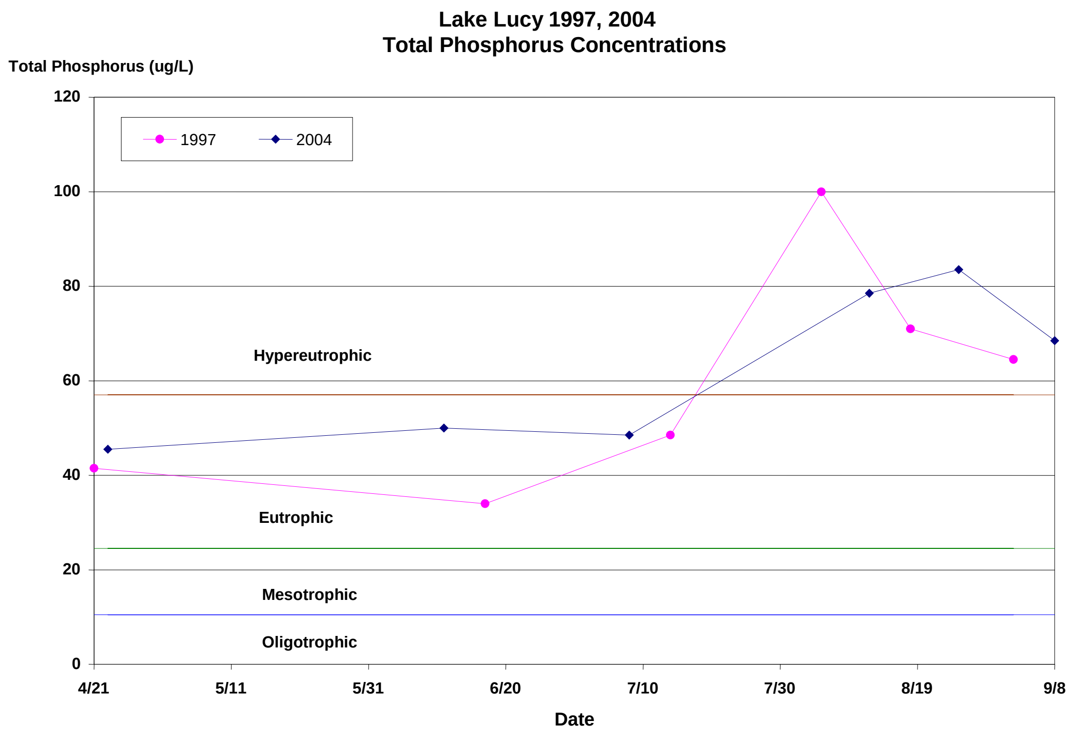


FIGURE LU-2
Lake Lucy Chlorophyll *a*

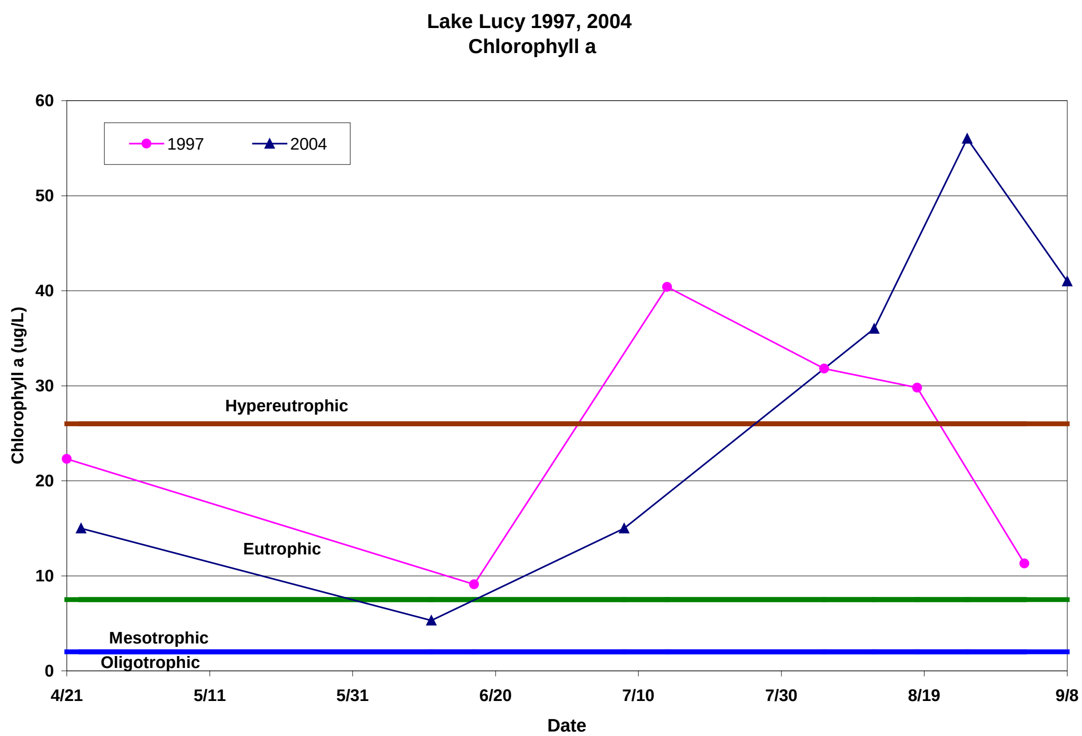
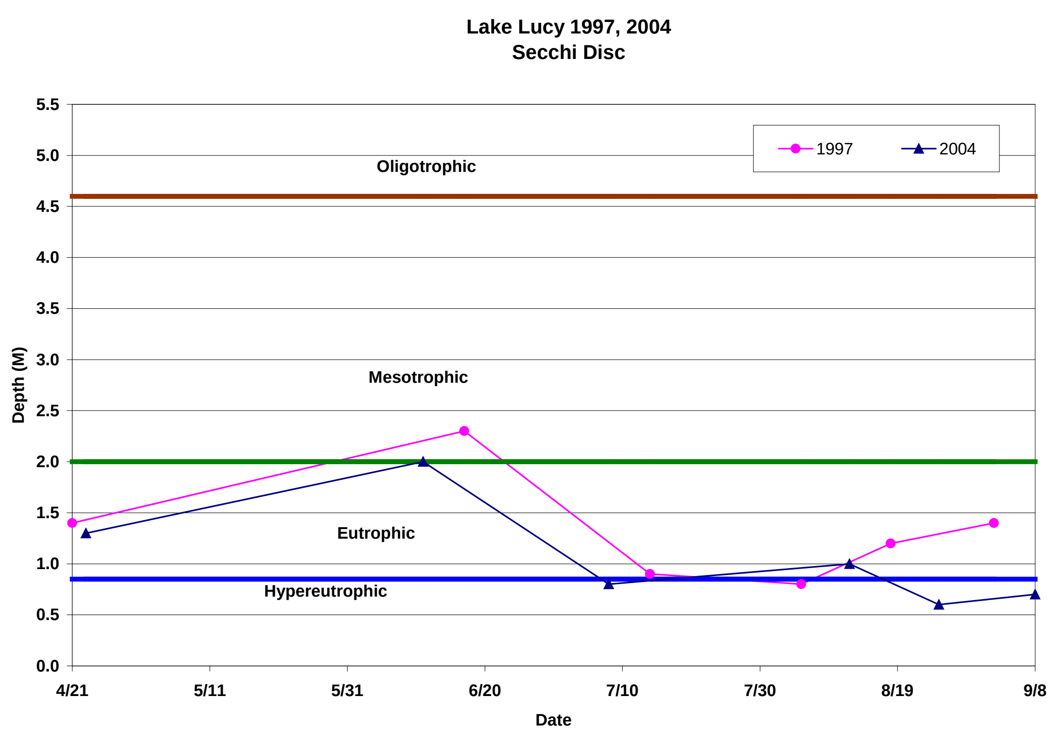


FIGURE LU-3
Lake Lucy Secchi Disc



1.3.2 Ecosystem Data

Lake Lucy is a Class 42 lake. Class 42 lakes are typically shallow, euthrophic lakes. The MDNR has assigned an ecological rating (TSI_{SD}) of 58.7 or lower. The lake's current water quality (2004 data) corresponds to a $TSI_{SD}$of 58.6. Impairment of the Lake Lucy fishery is caused by high phosphorus levels and severe summer algal blooms. The lake is prone to winter kills due to oxygen depletion. The lake does provide habitat for seasonal waterfowl, through diverse macrophyte communities in a large littoral zone.

1.3.2.1 Aquatic Ecosystems

According to the UAA, the Lake Lucy ecosystem is typical for a eutrophic, temperate lake in this region.

1.3.2.2 Phytoplankton

The phytoplankton species in Lake Lucy form the base of the lake's food web and directly impacts the lake's fish production. Phytoplankton, also called algae, are small aquatic plants naturally present in all lakes. They derive energy from sunlight (through photosynthesis) and from dissolved nutrients found in lake water. They provide food for several types of animals, including zooplankton, which are in turn eaten by fish. A phytoplankton population in balance with the lake's zooplankton population is ideal for fish production. An inadequate phytoplankton population reduces the lake's zooplankton population and adversely impacts the lake's fishery. Excess phytoplankton, however, reduces water clarity which in turn in interferes with the recreational usage of a lake.

As in years prior to 1997 and 2004 were analyzed to determine the composition and abundance of phytoplankton in Lake Lucy. As in years previous to 1997, blue-green (Cyanphyta) and green (Chlorophyta) algae were generally the dominant types of phytoplankton observed (UAA). Blue-green algae was especially dominant in Lake Lucy. The 2004 survey results demonstrated somewhat different results, showing blue-green algae has the dominant type of phytoplankton observed, with significant presence of green algae as well as cryptomonads (Cryptophyta) especially in the spring. The 1997 and 2004 results are summarized in Figures LU-4 and LU-5.

Green algae are edible to zooplankton and serve as a valuable food source. Blue-green algae are considered a nuisance type of algae because they:

- Are generally inedible to fish, waterfowl, and most zooplankters,
- Float at the lake surface in expansive algal blooms,
- May be toxic to animals when occurring in large blooms, and
- Can disrupt lake recreation because they are most likely to be present during the summer months.

Blue-green and green algal growth is stimulated by excess phosphorus loads. The growing conditions during July and August are particularly favorable to blue-greens as they have a competitive advantage over the other algal species during this time. Hence, phosphorus levels will need to be lowered to reduce blue-green algae populations in Lake Lucy.

FIGURE LU-4
Lake Lucy Phytoplankton Data Summary (1997)

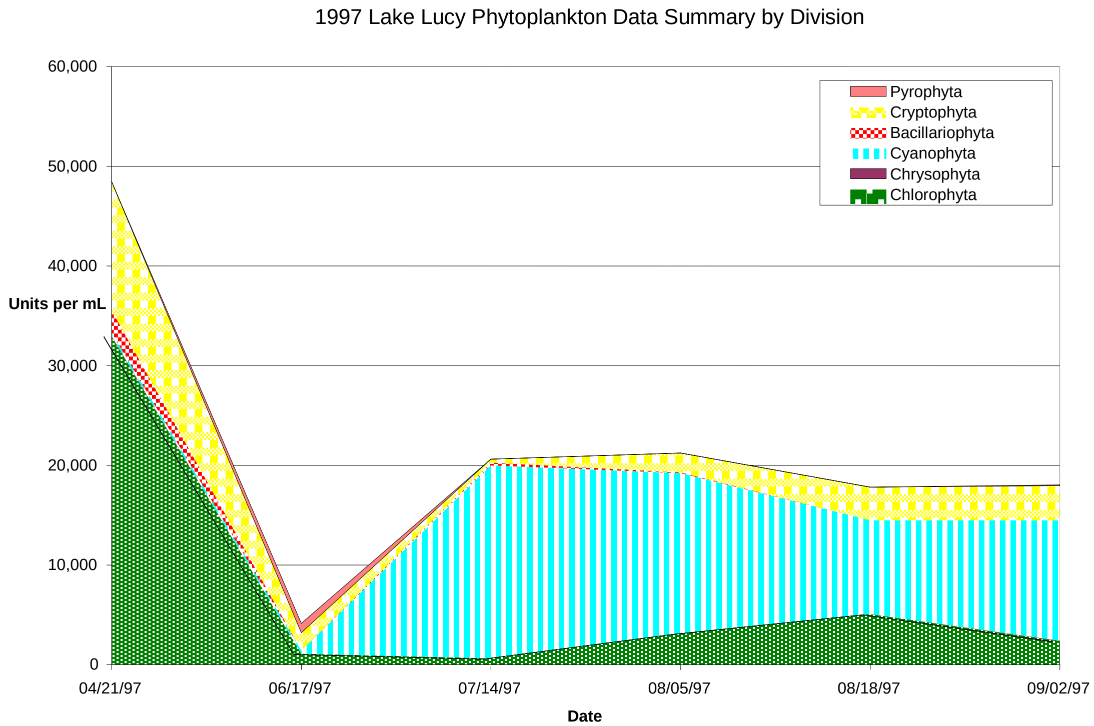
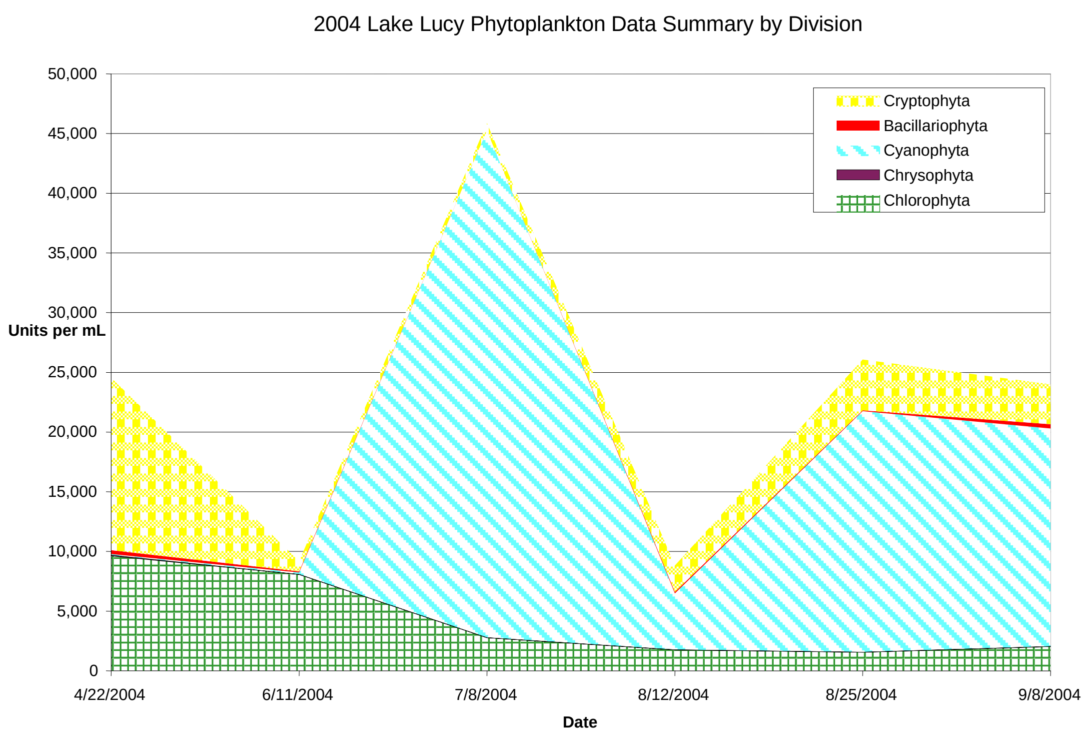


FIGURE LU-5
Lake Lucy Phytoplankton Data Summary (2004)



1.3.2.3 Zooplankton

Zooplankton are an important component of the aquatic ecosystem of Lake Lucy. They are the second step in the Lake Lucy food webs and particularly vital to the biological control of algae. They are microscopic animals that feed on particulate matter, including algae, and are in turn eaten by fish, making zooplankton vital to the lakes' fishery. Protection or enhancement of the lake's zooplankton community through judicious management practices affords protection to the lake's fishery. Healthy zooplankton communities are characterized by balanced densities (number per meter squared) of the three major groups of zooplankton: Cladocera, Copepoda, and Rotifera. Fish predation, however, may alter community structure and reduce the numbers of larger-bodied zooplankters (i.e., larger bodied Cladocera).

According to the 1997 data included in the UAA, all three groups of zooplankton are well represented in Lake Lucy. The UAA notes that the 1997 Lake Lucy zooplankton abundance was slightly lower than those observed in earlier sampling events. However, the 2004 data indicates that zookplankton abundance varies greatly from year to year. The rotifera and copepoda in Lake Lucy graze primarily on extremely small particles of plant matter and do not significantly affect the lake's water quality. However, the cladocera graze primarily on algae and can improve water quality if present in abundance.

The 1997 data showed that during the spring, the Copepodsa were the dominant population, with a shift in the early summer to Cladocera and Rotifera associated with a significant increase in population for both groups. By the end of the summer, the Cladocera population had almost doubled, representing the dominant count, while the Copepoda and Rotifera had declined by over 50%. In early fall, the Cladocera had also declined significantly. The 2004 data showed that the Rotifera and Copepods are the dominant population in the spring and early summer, with counts decreasing over the summer, then rising slightly in late summer/early fall.

1.3.2.4 Macrophytes

Aquatic plants are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. Typical functions of a lake's macrophyte community include the following:

- Provide habitat for fish, insects, and small invertebrates
- Provide food for waterfowl, fish, and wildlife
- Produce oxygen
- Provide spawning areas for fish in early spring/provide cover for early life stage of fish
- Help stabilize marshy borders and protect shorelines from wave erosion
- Provide nesting sites for waterfowl and marsh birds

Macrophyte surveys of the aquatic plant community in Lake Lucy were completed by the District in June and August of 1994, 1997, and 2004 and are summarized in Table 4.

TABLE 4
Lake Lucy Aquatic Plants (1994, 1997 and 2004)

Common Name	Scientific Name	1994 Density	1997 Density	2004 Density
Submerged Aquatics				
Variable pondweed	***P. gramineus***	**--**	**1**	**--**
Pondweed	***P. pusillus***	**--**	**1-2**	**--**
Curlyleaf pondweed	***P. crispus***	**1,3**	**1-3**	**1-3**
Flatstem pondweed	***P. zosteriformis***	**1-3**	**1-3**	**1-3**
Sago pondweed	***P. pectinatus***	**1-2**	**1**	**1-2**
Narrowleaf pondweed	***P. spp.***	**--**	**--**	**1-3**
Northern water milfoil	***Myriophyllum sibiricum***	**1,3**	**--**	**1-3**
Northern watermilfoil	***Myriophyllum excalbescens***	**--**	**1-2**	**--**
Water stargrass	***Zosterella dubia***	**1**	**1**	**1**
Star duck weed	***Lemna trisulca***	**--**	**1-2**	**--**
Bladdwurt	***Utricularia spp.***	**--**	**1**	**1**
Illinois pondweed	***P. illinoensis***			**1**
Coontail	***Ceratophyllum demersum***	**1-3**	**1-3**	**1-3**
Elodea	***Elodea Canadensis***	**1-2**	**1**	**1-2**
Muskgrass	***Chara spp.***	**1,3**	**1-3**	**1-3**
Bushy pondweed and naiad	***Najas flexilis***	**1-2**	**1**	**--**
White waterbuttercup	***R. sp.***	**--**	**--**	**--**
Eurasian watermilfoil	***M. spicatum***	**--**	**--**	
Floating Leaf Plants				
White waterlily	***Nymphaea odorata*** ***Nymphaea turberosa***	**--**	**--**	
Water Smartweed	***Polygonum spp.***	**--**	**--**	
Emergent Plants				
Bulrush	***Scirpus spp.***	**--**	**--**	
Cattail	***Typha spp***	**--**	**--**	
Purple loosestrife	***Lythrum salicaria***	**--**	**--**	

According to the 1999 UAA and the 1994 survey, macrophytes were identified to a relative depth of 10 feet. In some areas, the submerged plants were dominated by a dense growth of coontail (*Ceratophyllum demersum*, a native species) in June and August. Northern watermilfoil (*Myriophyllum sibiricum or Myriophyllum excalbescens*) was a prevalent species in

June, but dies back later in the summer. Northern watermilfoil, a species native to this region, is often confused with the related undersirable non-native Eurasian watermilfoil (*M. spicatum*). Northern watermilfoil is a desirable species that provides beneficial habitat for the lake's fishery. Curly-leaf pondweed (*Potamogeton crispus*) was also identified in some areas among the submerged plants in June but appeared to die off later in the summer. Curly-leaf pondweed is an undesirable non-native species. It frequently replaces native species in lakes and exhibits a dense growth that may interfere with the recreational use of a lake. A dense growth also creates a refuge for small fish, making it difficult for larger fish, such as bass, to find and capture the small fish they need for food. Purple loosestrife (*Lythrum salicaria*), an undesirable exotic species, was identified among the emergent plants in some areas. This plant should be controlled because it can replace cattails (*Typha sp.*) and subsequently destroy that wildlife habitat.

The 1999 UAA states that during 1997, in some areas, the submerged plants were dominated by a dense growth of curly-leaf pondweed (*Potamogeton crispus*) in June. Other areas, however, were dominated by coontail, as in 1994. Northern watermilfoil was less prevalent in Lake Lucy during 1997. The 1997 survey also revealed occurrences of purple loosetrife in some emergent plant areas.

The 2004 survey revealed that in some areas, the submerged plants were dominated by a dense growth of coontail in both June and August. Other areas were dominated by curlyleaf pondweed in June but the species was less prevalent in August. Northern watermilfoil and flatstem pondweed (*Potamogeton zosteriformis*) were also dominant in certain areas of the submerged aquatic plants. In general, Lake Lucy continues to maintain a diverse macrophyte community.

1.3.3 Water-Based Recreation

Lake Lucy is used primarily for fishing, as well for other types of recreational activities, including swimming. There is currently no fishing pier or public access to the lake, however, according to the UAA, in summer 1998, many anglers parked at Lake Ann and walked back into Lake Lucy in order to fish for large bluegills and largemouth bass. Per MDNR lake information, shoreline access is gained through City of Chanhassen park property on the south side of Lake Lucy. During high water, boats can travel from Lake Ann to Lake Lucy via Riley Creek. Otherwise, small boats can be carried from the parking lot of the city park and launched on the shore of Lake Lucy.

1.3.4 Fish and Wildlife Habitat

According to the MDNR's 1989 Lake Management Plan for Lake Lucy, there have been occasional winterkills (1955-56, 1963-64, 1974-75, 1977-78, 1978-79, 1988-89). As a result, fish populations have tended to fluctuate dramatically over time. During 1992, the MDNR classified Lake Lucy and other Minnesota lakes relative to fisheries (SCAP, 1992). This ecological classification is a function of lake area, percentage of the lake surface area that is littoral, maximum depth, degree of shoreline development, Secchi disc transparency and total alkalinity. According to its ecological classification, Lake Lucy is a Class 42 lake, which signifies a lake that may be better suited for wildlife than for fish (Schupp, 1992). The average Secchi disc transparency for this ecological class is 0.9 m (Schupp, 1992). In 1996 and 2004, Lake Lucy's average summer Secchi disk transparency was 1.3 m and 1.1 m respectively. Therefore, Lake Lucy's current conditions indicate that its water quality is better than the average lake in its ecological class.

The 1999 UAA states that Lake Lucy's most abundant fish species in 1995 (according to the MDNR's fisheries survey) were bluegills, black bullheads, pumpkinseed and hybrid sunfish, largemouth bass, black crappies and northern pike. Per the 2006 MDNR fisheries survey, these fish species were still the most abundant, along with the presence of other species including brown and yellow bullheads, and yellow perch. Northern pike were sampled at levels well above average for a lake like Lake Lucy. Bluegill were by far the most sampled fish in Lake Lucy, representing 65% of the total catch. Yellow perch, pumpkinseed and hybrid sunfish were all present in below average rates for a Class 42 lake, with a total of 6.6% of the total catch. Black crappie only accounted for 3% of the total catch,. Largemouth bass were sample at average and above average rates, with well above average weights. Yellow, black and brown bullheads were all present in Lake Lucy and accounted for respectively 9.5%, 3.8% and 0.9% of the total catch. Numbers and rates were about average for a Class 42 lake, with the exceptions that yellow bullheads were more abundant and black bullheads were much heavier than what would have been expected.

Threats to the lake's fishery habitat include oxygen depletion leading to winter fish kills. The most recent harsh winterkill was in 1994 according to the MDNR (UAA, 1999). Similar occurrences could be expected every 10 to 20 years, under current lake water quality conditions. However, if the lake water quality is degraded, the lake could experience more frequent winterkills. Species that are especially sensitive to low oxygen conditions are bluegills, sunfish and largemouth bass. More tolerant species include bullheads, northern pile and crappies.

Lake Lucy provides habitat for seasonal waterfowl, such as ducks and geese, through diverse macrophyte communities in a large littoral zone. Wooded areas on the north and south sides of the lake provide potential habitat for wildlife species.

1.3.5 Natural and Urban Drainage Systems

1.3.5.1 Natural Conveyance Systems

The inflow to Lake Lucy comes from surface runoff and groundwater discharge. The outlet of Lake Lucy on the south flows to Lake Ann. The stormwater runoff is from Lake Lucy's direct watershed, both overland and through wetland systems. There are no streams or rivers that convey flow to Lake Lucy. In many cases, stormwater conveyance systems in the upland areas discharge into the wetland systems described above, creating an interconnected network of natural and constructed flow paths. For this reason, the natural and constructed stormwater conveyance systems are discussed together in subsequent sections.

1.3.5.2 Stormwater Conveyance Systems

The stormwater conveyances to Lake Lucy were investigated in the 1999 UAA, and the findings are presented in this section.

The Lake Lucy stormwater conveyance systems are comprised of a network of storm sewers and BMPs (both natural wetlands and constructed ponds) within the watershed tributary to the lake. The BMPs provide water quality treatment of stormwater runoff. These wet detention ponds are comprised of five wet detention basins and 15 upland wetlands

Stormwater is conveyed to Lake Lucy via seven stormwater conveyance systems. For the purposes of the UAA, stormwater conveyance systems are defined as a system of watersheds, storm sewers, detention ponds and wetlands that all drain to the lake through the same terminating watershed. Public Ditch Systems

There are no public ditch systems that affect Lake Lucy.

1.3.6 Water Appropriations

There are no known water appropriations from Lake Lucy.

Lake Riley

August 2008

Contents

Lake Riley

1.1 Lake Riley Watershed Goals

The approved Riley-Purgatory-Bluff Creek Watershed District Water Management Plan, 1996, (Water Management Plan) inventoried and assessed Lake Riley. The plan articulated five specific goals for Lake Riley. These goals address recreation, aquatic communities, water quality, water quantity, and wildlife.

1.1.1 Water Quantity

The water quantity goal for Lake Riley is to provide sufficient water storage during a regional flood (100-yr, 24-hr storm event).

1.1.2 Water Quality

The MPCA has classified Lake Riley as partiallty supporting aquatic recreational use. Partially supporting aquatic recreational use would have a desired TSI_{SD} range of between 53 and 57. Fully supporting would have a TSI_{SD} of less than 53.

1.1.3 Recreation

The primary recreation goal is to achieve full support of fishing activities and maintain waterfowl habitat.

1.1.4 Aquatic Communities

The aquatic communities goal for Lake Riley is to maintain a MDNR ecological Class 24 rating, with a TSI_{SD} of 50.4.

1.1.5 Wildlife

The wildlife goal for Lake Riley is to protect existing beneficial wildlife uses.

1.1.6 Public Participation

The goal is to encourage public participation in achieving outcomes from the use attainability analysis. To achieve this goal, a public meeting will be called to obtain comments on the use attainability analysis.

1.2 Existing Watershed Conditions

Lake Riley is located in the City of Chanhassen and the City of Eden Prairie in the southern part of the Riley-Purgatory-Bluff Creek watershed. The central section of Riley Creek drains to Lake Riley which in turn drains to lower Riley Creek..

1.2.1 Watershed Description

1.2.1.1 Land Use

The land use for the Lake Riley watershed is summarized in Table 1. The total watershed area is not consistent between the 2005 and 2020 land use survey and the areas reported in the 1996 Watershed Management Plan from a 1991 survey and areas reported in the UAA in a 1997 survey. While firm conclusions cannot be confirmed with the data, it appears that residential land use has decreased as has agricultural, industrial, parks and open areas. These are consistent with the 2020 projected land use. Commercial land use appears to have increased; again, consistent with 2020 projections.

TABLE 1
Summary of Past and Projected Land Use Acreage – Lake Riley

Land Use Category	1991 [1]	1997 [2]	2005 [3]	2020 [3]
Single Family Residential		494	548	769
High Density Residential		14	9	41
Retail/Commercial/Industrial			13	37
Agricultural		231	154	0
Parks + Open		706	693	390
Highway/Roads		18		
Water		300	346	349
Institutional (School, etc)				177
Total		**1763**	**1762**	**1763**

* Land use category not reported
1. Data from 1996 Watershed Plan.
2. Data from 2002 Lake Riley UAA.
3. Metropolitan Council, Generalized Land Use 2005 for the Twin Cities Metropolitan Area and Regional Planned Land Use - Twin Cities Metropolitan Area.

1.2.1.2 Major Hydrologic Characteristics

Lake Riley has a 1763-acre tributary watershed, a surface area of 286 acres and a mean depth of 23 feet.

1.2.2 Lake Riley Water Quality

A standardized lake rating system is often used to classify the ecological conditions of a lake. The rating system uses phosphorus, chlorophyll *a*, and Secchi disc transparency values to classify a lake into four categories: Oligotrophic (clear, low productivity lakes with excellent water quality), Mesotrophic (intermediate productivity lakes with good water quality), Eutrophic (high productivity lakes with poor water quality) and Hypereutrophic (extremely productive lakes with poor water quality).

1.2.2.1 Data Collection

Data for the previous watershed management plan was collected from 1972 to 1993.

Additional data was collected in 1997 and 1998 to support the Lake Riley UAA. The lake was sampled again in 2004.

1.2.2.2 Baseline/Current Water Quality

In general, Lake Riley water quality has not changed significantly throughout the 1997-2006 monitoring period. The 1998 measurements of phosphorus were well into the hypereutrophic (extremely nutrient rich) category in the early spring and late summer months, while measurements taken between 2001 and 2004 remained within the eutrophic (nutrient rich) category (Figure RI-1). However, measurements in 2004 did not cover the same period as the 1998 data.

Chlorophyll *a* concentrations from 1998 and 2004 fluctuated between the eutrophic and hypereutrophic regions (Figure RI-2). Secchi disk depths start within the mesotrophic category and, extend into the eutrophic and hypereutrophic categories, peaking in mid to late summer (Figure RI-3).

FIGURE RI-1
Lake Riley Total Phosphorus.

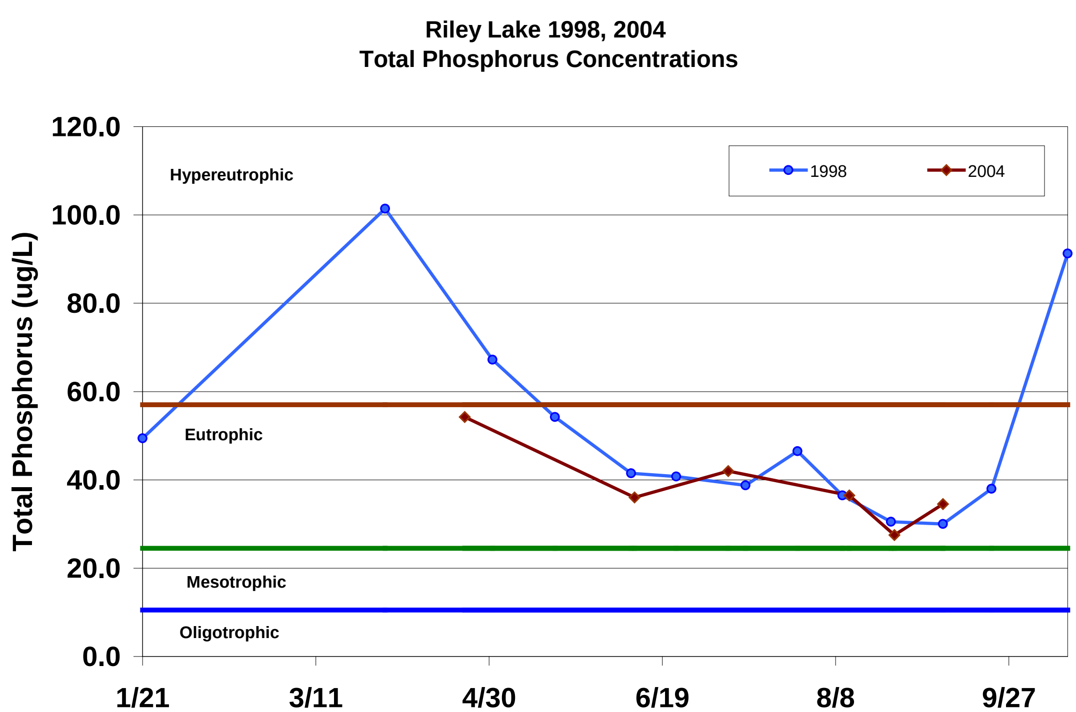


FIGURE RI-2
Lake Riley Chlorophyll *a*

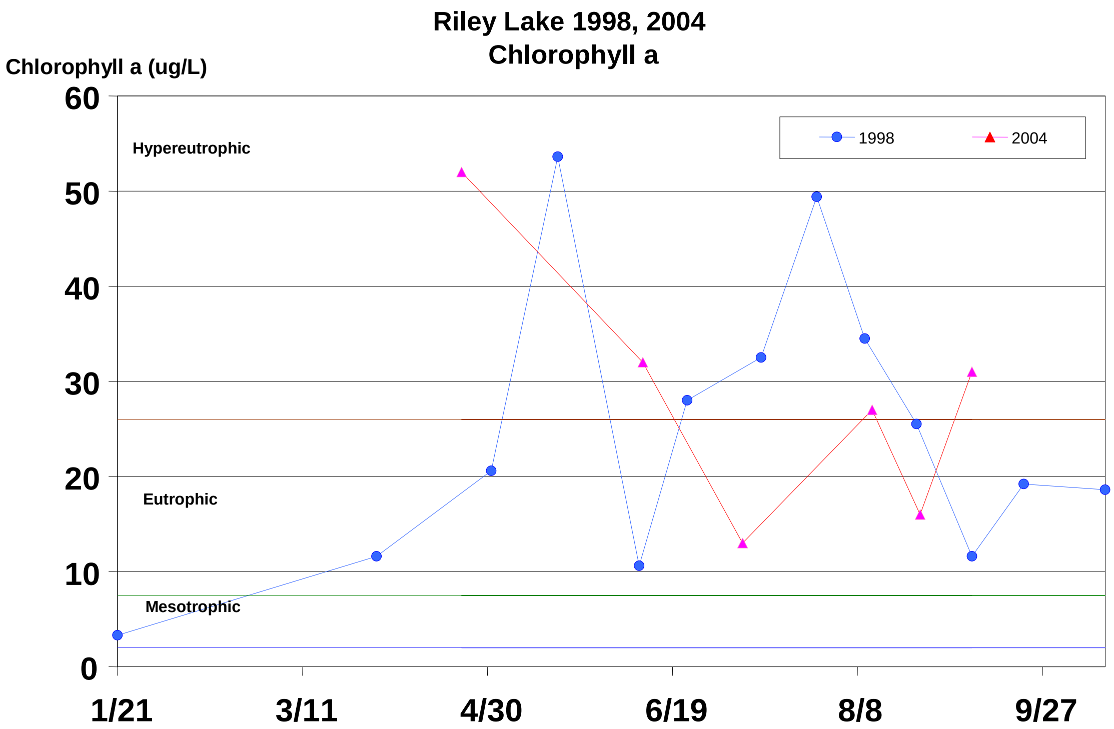
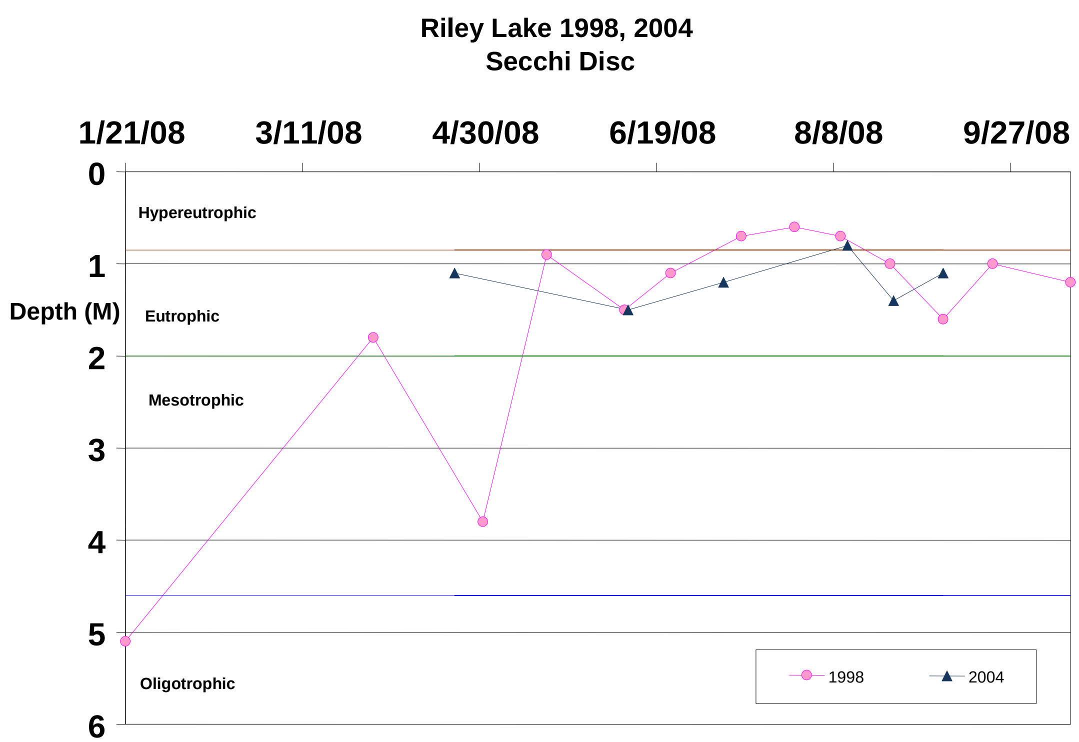


FIGURE RI-3
Lake Riley Secchi Disk



1.2.3 Ecosystem Data

The Water Quality Goal is a trophic state index score that meets or exceeds the necessary level to attain and maintain full support of swimming and fishing: a Trophic State Index. (TSIsD) of 53 or lower to fully support swimming and a Trophic State Index (TSIsD) of 56 or lower to fully support the lake's fishery. Lake Riley is Class 24 Lake, which signifies it as a good permanent fish lake. Average water quality for the ecological class is a TSI_{SD} of 54.5 or lower. The lake current has a TSI_{sd} of 62. Currently the lake does not meet its TSI recommendation based on data available (2002). Excessive total phosphorus is considered the cause of non attainment of the biological use and the lake does have Eurasian watermifoil, a problematic exotic plant that can affect phosphorus levels.

1.2.4 Aquatic Ecosystems

According to the UAA, the Lake Riley ecosystem is typical for a eutrophic, temperate lake in this region.

1.2.4.1 Phytoplankton

The phytoplankton species in Lake Riley form the base of the lake's food web and directly impacts the lake's fish production. Phytoplankton, also called algae, are small aquatic plants naturally present in all lakes. They derive energy from sunlight (through photosynthesis) and from dissolved nutrients found in lake water. They provide food for several types of animals, including zooplankton, which are in turn eaten by fish. A phytoplankton population in balance with the lake's zooplankton population is ideal for fish production. An inadequate phytoplankton population reduces the lake's zooplankton population and adversely impacts the lake's fishery. Excess phytoplankton, however, reduces water clarity which in turn in interferes with the recreational usage of a lake.

Lake survey results for 1997-1998 and 2004 were analyzed to determine the composition and abundance of phytoplankton in Lake Riley. As in years previous to 1997, blue-green (Cyanophyta) and green (Chlorophyta) algae were generally the dominant types of phytoplankton observed (UAA). Blue-green algae were especially dominant in the 1997-1998 survey. The 2004 survey results demonstrated somewhat different results, showing blue-green algae has the dominant type of phytoplankton observed, with significant presence of green algae as well as cryptomonads (Cryptophyta) especially in the spring. The 1997 and 2004 results are summarized in Figures RI-4 and RI-5.

Green algae are edible to zooplankton and serve as a valuable food source. Blue-green algae are considered a nuisance type of algae because they:

- Are generally inedible to fish, waterfowl, and most zooplankters,
- Float at the lake surface in expansive algal blooms,
- May be toxic to animals when occurring in large blooms, and
- Can disrupt lake recreation because they are most likely to be present during the summer months.

Blue-green and green algal growth is stimulated by excess phosphorus loads. The growing conditions during July and August are particularly favorable to blue-greens, and they have a competitive advantage over the other algal species during this time. Hence, phosphorus levels will need to be lowered to reduce blue-green algae populations in Lake Riley.

FIGURE RI-4
Lake Riley Phytoplankton Data Summary (1997-1998)

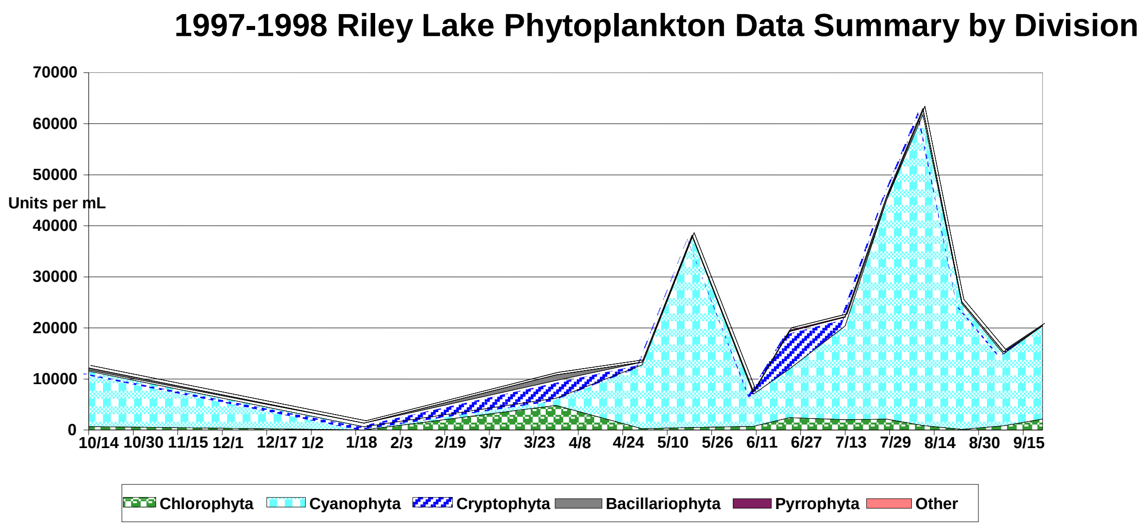
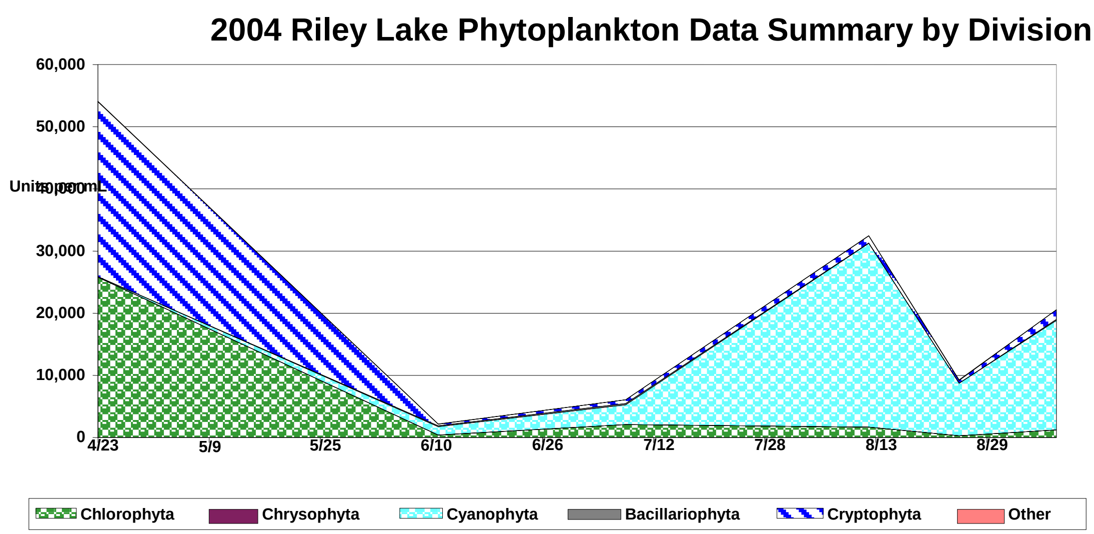


FIGURE RI-5
Lake Riley Phytoplankton Data Summary (2004)



1.2.4.2 Zooplankton

Zooplankton are an important component of the aquatic ecosystem of Lake Riley. They are the second step in the Lake Riley food webs and are particularly vital to the lake's fishery and for the biological control of algae. They are microscopic animals that feed on particulate matter, including algae, and are, in turn, eaten by fish. Protection or enhancement of the lake's zooplankton community through judicious management practices affords protection to the lake's fishery. Healthy zooplankton communities are characterized by balanced densities (number per meter squared) of the three major groups of zooplankton: Cladocera, Copepoda, and Rotifera. Fish predation, however, may alter community structure and reduce the numbers of larger-bodied zooplankters (i.e., larger bodied Cladocera).

According to the 1998 data included in the UAA, cladocera and copepoda were present in small numbers, likely due to predation by the lake's bluegill community. The UAA notes that the 1998 zooplankton community in Round Lake provided food for the lake's fishery, but had little predatory impact on the lake's algal community. The rotifers and copepods in Lake Riley graze primarily on extrmemely small particles of plant matter and do not significantly affect the lake's water quality. The cladocera graze primarily on algae and can improve water quality if present in abundance.

The 1998 and 2004 data summaries for Lake Riley (Figures RI-6 and RI-7) show Rotifera and Copepoda as the dominant zooplankton types. The Cladocera population peaked in both 2003 and 2004 in June, with a second peak in August in 2004, decreasing to very low levels in July. The low levels of Cladocera throughout both sampled summers suggest this group is out of balance with the Rotifera and Copepoda in the lake.

The 1997 data showed that during the spring, the Copepoda were the dominant population, with a shift in the early summer to Cladocera and Rotifera associated with a significant increase in population for both groups. By the end of the summer, the Cladocera population had almost doubled, representing the dominant count, while the Copepoda and Rotifera had declined by over 50%. In early fall, the Cladocera had also declined significantly. The 2004 data showed that the Rotifera and Copepods are the dominant population in the spring and early summer, with counts decreasing over the summer, then rising slightly in late summer/early fall.

FIGURE LU-6
Lake Riley Zooplankton Data Summary (1998)

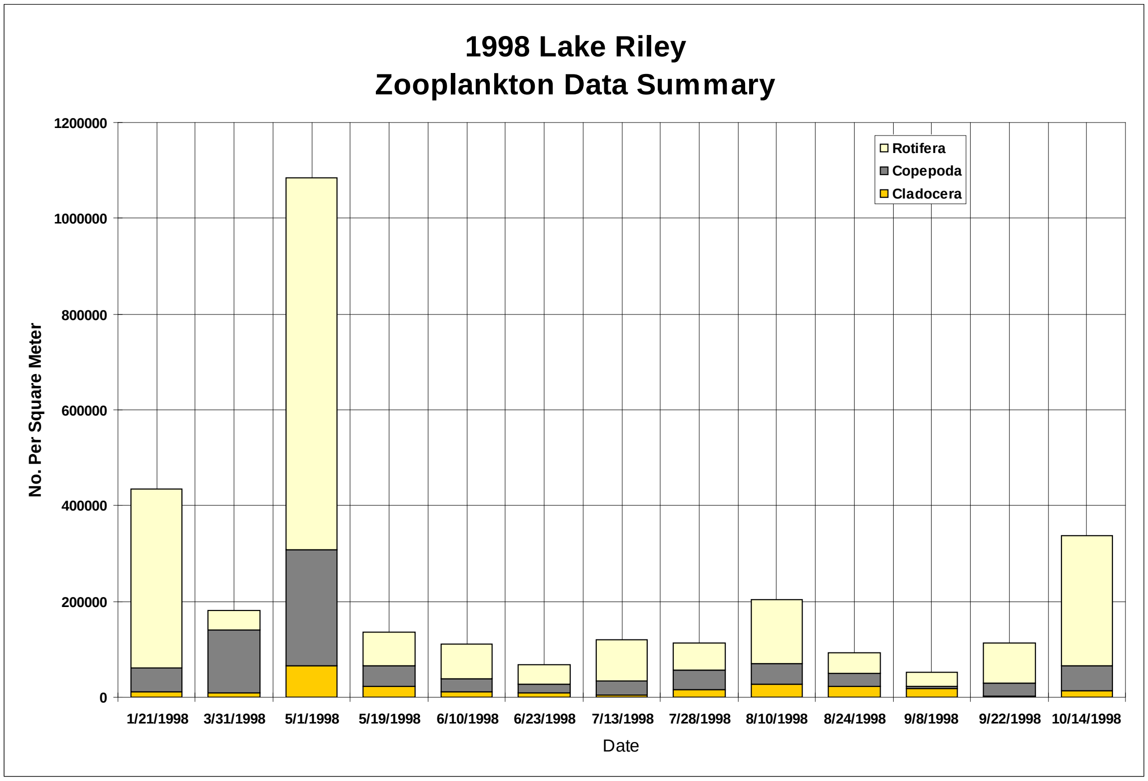
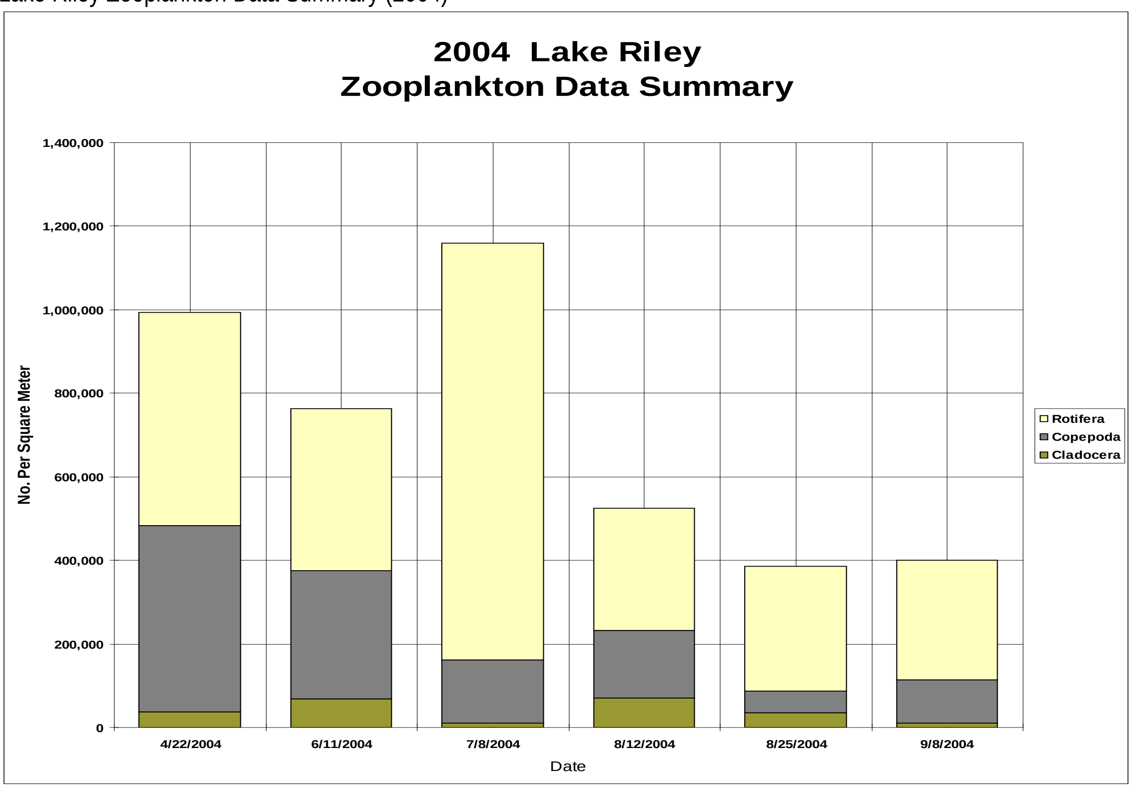


FIGURE LU-7
Lake Riley Zooplankton Data Summary (2004)



1.2.4.3 Macrophytes

Aquatic plants are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. Typical functions of a lake's macrophyte community include the following:

- Provide habitat for fish, insects, and small invertebrates
- Provide food for waterfowl, fish, and wildlife
- Produce oxygen
- Provide spawning areas for fish in early spring/provide cover for early life stage of fish
- Help stabilize marshy borders and protect shorelines from wave erosion
- Provide nesting sites for waterfowl and marsh birds

Macrophyte surveys of the aquatic plant community in Lake Riley were completed by the District in June and August of 1994, 1997, and 2004 and are summarized in Table 2. The densities referred to below correspond to 1: light density, 2: medium density, and 3: heavy density. Ranges of densities are listed if the density in one area of the lake were present at different densities than other areas of the lake. Dashed densities denote the presence of the macrophyte in the survey, but no density was listed in the survey.

TABLE 2
1994, 1997, 2004, and 2006 Lake Riley Aquatic Plants

Common Name	Scientific Name	1994 Density	1998 Density	2004 Density	2006 Density
Submerged Aquatics					
Curlyleaf pondweed	***P. crispus***	**1-2**	**1**	**1-2**	**1**
Sago pondweed	***P. pectinatus***	**1-2**	**1**	**1**	**1**
Coontail	***Ceratophyllum demersum***	**1-3**	**1-2**	**1-3**	**1-3**
Eurasian watermilfoil	***M. spicatum***	**1-3**	**1-3**	**1-3**	**1-3**
Floating Leaf Plants					
White waterlily	***Nymphaea turberosa***	**--**	**1**	**1**	**1**
Emergent Plants					
Cattail	***Typha spp***	**--**	**--**	**--**	**--**

According to the 1999 UAA and the 1994 survey, macrophytes were identified to a relative depth of 10 feet. In some areas, the submerged plants were dominated by a dense growth of coontail (*Ceratophyllum demersum*, a native species) in June and August. The undesirable non-native Eurasian watermilfoil (*M. spicatum*) were present at heavy densities in all years sampled. Curly-leaf pondweed (*Potamogeton crispus*) was also identified in some areas among the submerged plants in light to medium densities Curly-leaf pondweed is an undesirable non-native species. It frequently replaces native species in lakes and exhibits a dense growth that may interfere with the recreational use of a lake. A dense growth also creates a refuge for small fish, making it difficult for larger fish, such as bass, to find and capture the small fish they need for food.

The few species and heavy densities of watermilfoil in particular denote the poor health of this lake's macrophyte ecosystem.

1.2.5 Water-Based Recreation

Lake Riley is used for all types of recreational activities, including swimming. The municipal swimming beach and boat access for Lake Riley, located along the east shore, are owned and operated by the City of Eden Prairie. Fishing and recreational boating have also been identified as popular activities on Lake Riley (UAA, 2002).

1.2.6 Fish and Wildlife Habitat

According to MDNR's ecological classification, Lake Riley is a Class 24 lake, which signifies a good permanent fish lake. The MDNR has indicated that the mean TSI_{SD} for this ecological class is 56 or lower. The lake's 1998 water quality data indicate that Lake Riley does not meet this recommendation (with a TSI_{SD} of 62).

The primary fish populations for Lake Riley, according to it Class 24 classification, would be expected to be comprised of northern pike, carp, and bluegill.

According to the 2002 UAA, the Lake Riley fishery is comprised of panfish, gamefish, rough fish, and other fish species. Recent fisheries survey results have confirmed the variety of fish present in Lake Riley, including walleye, which have been stocked by the Lake Riley Association in previous years, dating back to 1997.

Lake Riley provides habitat for seasonal waterfowl, such as ducks and geese.

1.2.7 Natural and Urban Drainage Systems

1.2.7.1 Natural Conveyance Systems

The natural inflow to Lake Riley is comprised of stormwater runoff from its direct watershed, groundwater discharge, and Riley Creek, which enters on the northeast side of the lake. Riley Creek receives runoff from four conveyance systems (stormwater pond discharges) in the lake's district watershed and from the lake's large indirect watershed, comprised of the watershed tributary to Lakes Lucy, Ann, Susan, and Rice Marsh.

1.2.7.2 Stormwater Conveyance Systems

1.2.7.3 The Lake Riley stormwater conveyance system is comprised of a network of storm sewers and wet detention ponds within the direct watershed tributary to the lake. The wet detention ponds provide water quality treatment of stormwater runoff. Storm sewers convey stormwater runoff to and from many of the wet detention ponds, and eventually convey the runoff to Lake Riley. Some wet detention ponds convey runoff to Lake Riley via overland flow. Public Ditch Systems

There are no public ditch systems that affect Lake Riley.

1.2.8 Water Appropriations

There are no known water appropriations from Lake Riley.

Lake Susan

August 2008

Contents

Lake Susan

1.1 Lake Susan Watershed Goals

The approved Riley-Purgatory-Bluff Creek Watershed District Water Management Plan (Water Management Plan, 1996) inventoried and assessed all of the District's Lakes including Lake Susan. The plan articulated five specific goals for Lake Susan. These goals address recreation, aquatic communities, water quality, water quantity and wildlife. The approved Lake Susan and Rice Marsh Lake Use Attainability Analysis (UAA, 1999) further discusses the characterization of Lake Susan by evaluating the intended five goals.

1.1.1 Water Quantity

The water quantity goal for Lake Susan is to maintain a flood envelope that is reasonably capable of providing water storage during a regional flood (100-yr, 24-hr storm event).

1.1.2 Water Quality

The District's water quality goal for Lake Susan is the same as the aquatic communities goal - TSI_{SD} of approximately 53.

According to the 1999 UAA, however, its review of available information showed that specific water quality goals for Lake Susan and the downstream lake, Rice Marsh Lake, have not been previously established by the RPBCWD, the MPCA, the MDNR, or by the local municipality (City of Chanhassen). The UAA states that the TSI rating listed in the 1996 Plan can not be construed as a water quality goal for the two lakes. The District's 1996 Plan identifies the TSI rating corresponding to the lake fishery classification system of MDNR, however, MDNR staff indicate that this rating should be considered only as a representative value for a lake of the given fisheries lake class. Therefore, the MDNR cautions that fishery-related TSI values should not be construed as goals for the lakes. Neither have other agencies been involved in goal-setting for these two lakes. Because these lakes are not expected to be widely used for swimming or other full-body contact aquatic recreation, the Minnesota Pollution Control Agency (MPCA) is not involved in setting water quality goals for the lakes. The Cities of Chanhassen and Eden Prairie were not aware of any water quality targets for these lakes, either.

The UAA states that despite the lack of specific water quality targets for the lakes, the RPBCWD expects the two lakes to continue as valued recreational assets to the community. Lake Susan is expected to continue to be used for boating and fishing (although its water quality would not be expected to be generally suitable for swimming. Realistic water quality goals for the lake will therefore be those that protect and enhance these recreational uses for the two lakes.

The UAA consults other sources to identify appropriate water quality targets for the two lakes, and settles on the targets presented in the 1989 Lake Riley Chain of Lakes Improvement Project Work Plan (District, April 5, 1989). The report identifies total phosphorus concentrations consistent with several general lake use categories. The document indicates that a "Level II" water body (supporting boating but not full-body water contact activities such as swimming or scuba diving) should have total phosphorus concentrations in the 45 to 75 µg/L range. A "Level III" water body (supporting fish and wildlife populations, and providing aesthetic viewing) should have total phosphorus concentrations in the 75 to 105 µg/L range. These two ranges provide realistic targets for total phosphorus concentrations for Lake Susan (Level II) and Rice Marsh Lake (Level III).

Based on the above considerations, the UAA recommends that a reasonable water quality goal for Lake Susan would be to maintain total phosphorus concentrations in the lake at levels lower than 75 µg/L. The lake's history suggests that this total phosphorus would correspond to a chlorophyll *a* concentration of approximately 37 µg/L, and a Secchi transparency of 0.7 m. This Secchi transparency corresponds to a TSI_{SD} = 65. The 2004 data based on summer averages for total phosphorus concentration, chlorophyll *a* concentration, Secchi transparency and corresponding TSI_{SD} are 60.75 µg/L, 35.25 µg/L, 1.2 m and 57.4, respectively. This data indicates that Lake Susan's water quality is better than lakes in its category.

1.1.2.1 Recreation

The recreation goal is to fully support designated fishing activities.

1.1.2.2 Aquatic Communities

The fisheries goal for Lake Susan is to maintain a MDNR ecological class 38 rating, with a TSI_{SD} of approximately 53.

1.1.2.3 Wildlife

The wildlife foal for Lake Susan is to protect existing, beneficial wildlife uses.

1.1.2.4 Public Participation

The goal is to encourage public participation in achieving outcomes from the UAA.

1.2 Existing Watershed Conditions

Lake Susan is located in the City of Chanhassen in the western part of the Riley-Purgatory-Bluff Creek watershed. It drains to Riley Creek.

1.2.1 Watershed Description

1.2.1.1 Land Use

The land use for the Lake Susan watershed is summarized in Table LSU-1. The total watershed area is not consistent between the 2005 and 2020 land use survey and the areas reported in the 1996 Watershed Management Plan from a 1991 survey and areas reported in the UAA in a 1997 survey. While firm conclusions cannot be confirmed with the data, it appears that residential land use has decreased as has parks and open areas. These are consistent with the 2020 projected land use. Commercial, highway/roads and public sector/institutional land uses appear to have increased; again, consistent with 2020 projections.

TABLE 1
Summary of Past and Projected Land Use Acreage – Lake Susan

Land Use Category	1991 [1]	1997 [2]	2005 [3]	2020 [3]
Single Family & Low Density Residential	559	72	260.71	230.13
Medium Density Residential	67	194	47.62	82.87
High Density Residential	*	51	19.61	69.48
Commercial	25	49	115.73	288.48
Agricultural	*	84	104.72	*
Industrial	*	197	110.34	*
Parks + Open	547	512	435.49	202.47
Highway/Roads	*	25	53.71	203.34
Water	*	*	95.06	96.40
Institutional (School, etc)	*	3	18.18	88.01
TOTAL	1198	1187	1261.17	

* Land use category not reported
1. Data from 1996 Watershed Plan.
2. Data from 1999 Lake Susan and Rice Marsh Lake UAA.
3. Metropolitan Council, Generalized Land Use 2005 for the Twin Cities Metropolitan Area and Regional Planned Land Use - Twin Cities Metropolitan Area.

1.2.1.2 Major Hydrologic Characteristics

Lake Susan has a 1,262-acre watershed, a surface area of 81 acres, a maximum depth of 16 feet, and a mean depth of 10 feet. The lake volume is approximately 800 acre-feet.

Per the 1999 UAA, the water level of the lake has varied between 882.5 feet MSL (1986) and 879.5 feet MSL (1977). The lake water level fluctuates relatively little since Lake Susan is supplied by and drains to Riley Creek and water is not detained significantly by the lake, in general. This feature allows the lake to be considered (for lake water quality modeling purposes) as having volumes that do not vary significantly over time. The water level in the lake is controlled mainly by weather conditions (snowmelt, rainfall, and evaporation) and by the elevation of the streambed of Riley Creek, over which Lake Susan drains to the east.

The UAA states that Lake Susan is relatively shallow and has a relatively large littoral area, and that as such, the lake would be expected to be prone to frequent wind-drive mixing of the lake's shallow and deep waters during the summer. One would therefore expect Lake Susan to be polymictic (mixing many times per year) as opposed to lakes with deep, steep-sided basins that are usually dimictic (mixing only twice per year). Daily monitoring of the lake would be necessary to precisely characterize the mixing dynamics of a lake, but the limited data gathered from Lake Susan strongly suggests that the lake is indeed polymictic.

1.2.2 Lake Susan Water Quality

The water quality of a lake provides an indication of how a lake functions. A standardized lake rating system is often used to classify the ecological conditions of a lake. The rating system uses phosphorus, chlorophyll *a*, and Secchi disc transparency values to classify a lake into four categories: Oligotrophic (clear, low productivity lakes with excellent water quality), Mesotrophic (intermediate productivity lakes with good water quality), Eutrophic (high productivity lakes with poor water quality) and Hypereutrophic (extremely productive lakes with poor water quality).

1.2.2.1 Data Collection

Data for the previous watershed management plan was collected from 1971 through 1994. Additional data was collected in 1997 to support the Lake Susan UAA. An additional sampling year was accomplished in 2004.

1.2.2.2 Baseline/Current Water Quality

Lake Susan water quality has not changed significantly throughout the more recent monitoring period (1997-2004). While summer averages for total phosphorus have decreased over the period, the summer averages for chlorophyll *a* and Secchi disc depths have remained relatively the same.

Total phosphorus concentrations were in the eutrophic category throughout the spring and early summer, then increasing into the hypereutrophic category throughout the rest of the summer (Figure LS-1). In 1997, the total phosphorus concentrations were in the hypereutrophic category for most of the spring and summer. Chlorophyll *a* concentrations started in the mesotrophic category in the spring, then increased steadily to the eutrophic category then around mid-summer, into the hypereutrophic category (Figure LS-2). In 1997, there was a similar pattern, except the chlorophyll *a* concentrations started in the hypereutrophic category, decreased sharply into the mesotrophic category in late spring, then increased steadily to the eutrophic then hypereutrophic categories throughout the rest of the summer. Secchi disc depths were in the mesotrophic category in the spring, and declined steadily into the eutrophic category in early summer then into the hypereutrophic category in mid-summer (Figure LS-3). In 1997, there was a similar pattern, except, as with the chlorophyll *a* concentrations, the secchi disc depths started in the hypereutrophic category in the spring, increased sharply into the eutrophic category and then continued into the mesotrophic category in late spring/early summer, before declining steadily into the eutrophic and hypereutrophic categories over the rest of the summer.

FIGURE LS-1
Lake Susan Total Phosphorus.

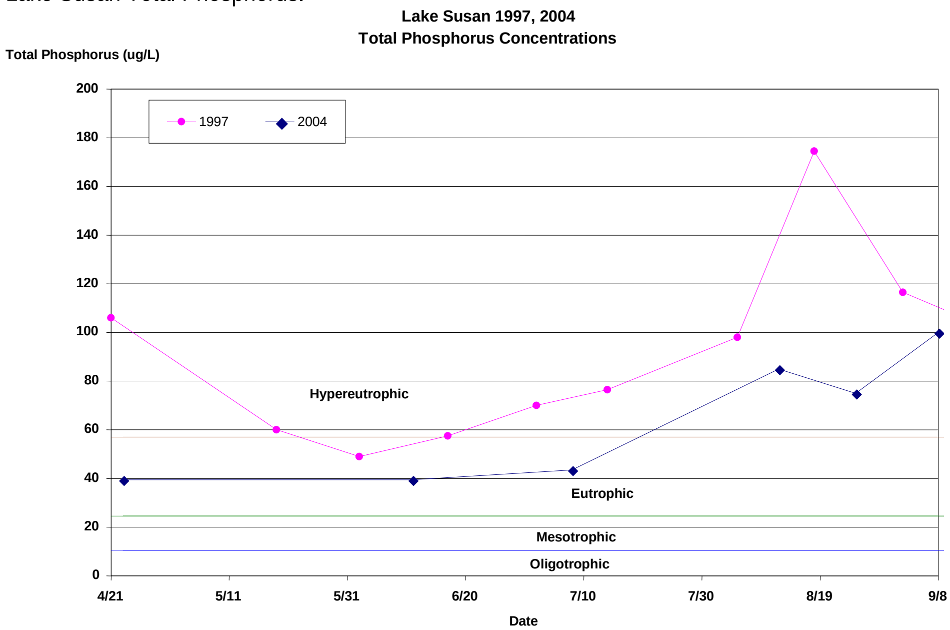


FIGURE LS-2
Lake Susan Chlorophyll *a*.

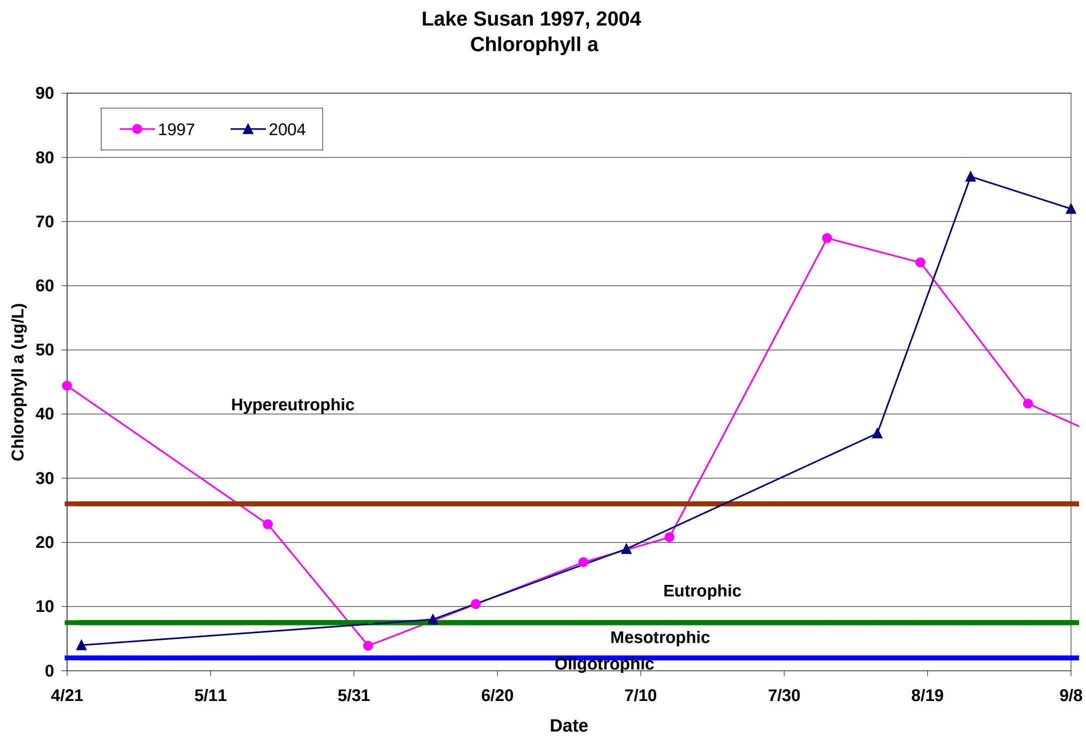
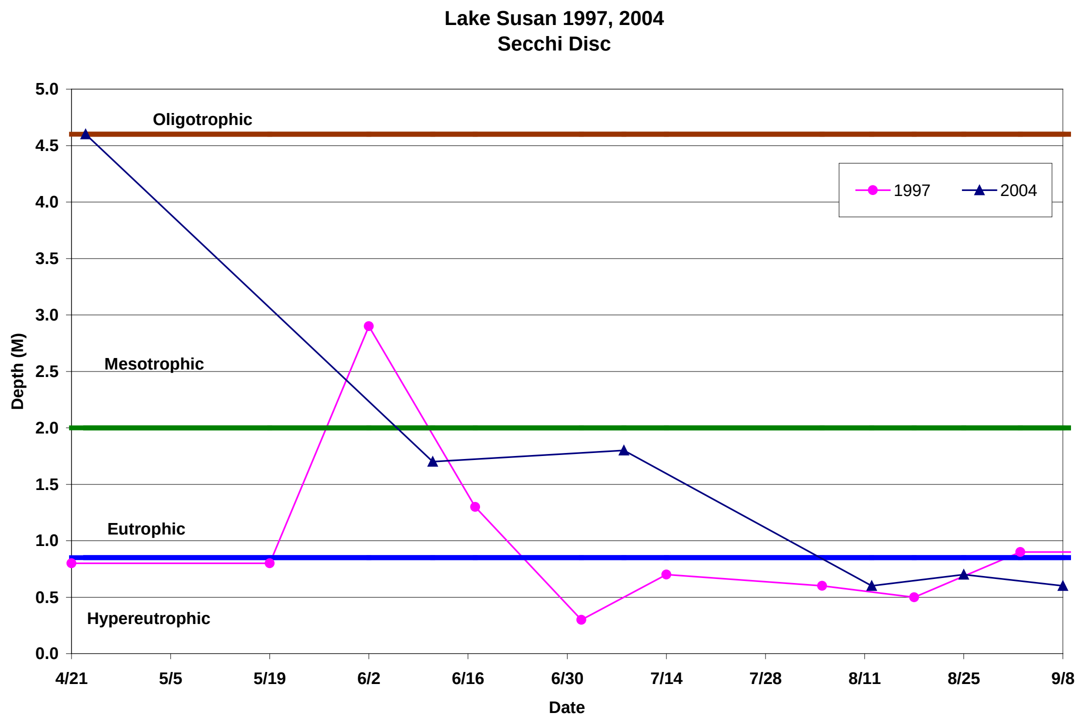


FIGURE LS-3
Lake Susan Secchi Disc



It should be noted that an alum treatment was applied to Lake Susan in April 1998, and the lake's quality improved greatly, according to the UAA. Average summer values for total phosphorus were 38 µg/L, and transparency averaged 2.1 m. A rapid and dramatic decline in total phosphorus concentrations (with resulting changes in chlorophyll *a* and Secchi transparency) is to be expected with alum treatment, and was seen immediately following the April alum application. However, the extremely low post-treatment total phosphorus concentration (20 µg/L on May 5, 1998) can be sustained only if the inflows from the lake's watershed are comparably low. Such is not the care for Lake Susan, and the late summer total phosphorus concentration (39 µg/L on August 28, 1999) reflects the gradual re-equilibrium of the lake with its watershed.

1.2.3 Ecosystem Data

Lake Susan is a Class 38 lake. Lakes in this category are not expected to be premier fishing lakes and are prone to winterkill. The MDNR has indicated that ecological rating for Class 38 is a TSI_{SD} of approximately 53. This is based on the aquatic communities goal. The lake's current water quality (2004 data) corresponds to a TSI_{SD} of 57.4, indicating that its condition is considered better than the average lake in its ecological class.

1.2.3.1 Aquatic Ecosystems

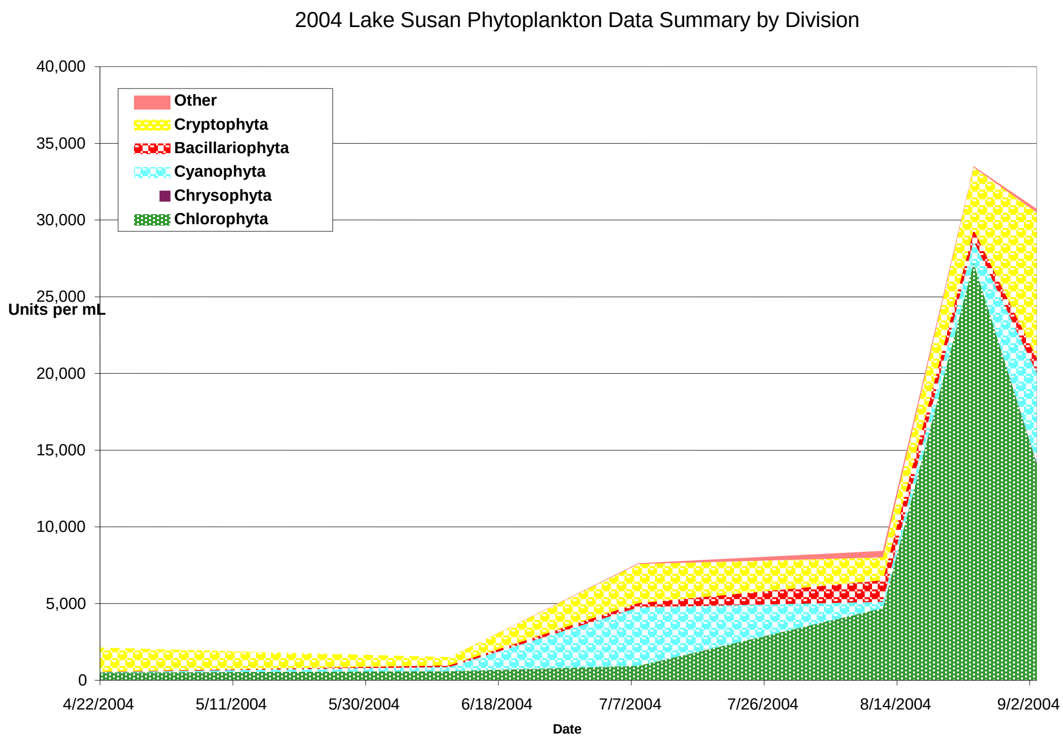
According to the UAA, Lake Susan's ecosystem is typical for a eutrophic lake. It has the yellow lotus, also found in Lotus Lake.

1.2.3.2 Phytoplankton

At the time of the 1996 Plan, the phytoplankton in Lake Susan were dominated by blue-green algae (Cyanophyta), as they had been in most other years, except 1990 when cryptomonads (Cryptophyta) were abundant. The percentage of blue-green algae increased throughout the 1994 growing season. In June, blue-green algae made up 88% of the phytoplankton community and in September the percentage had increased to 97%. Through 1997, according to the UAA, blue-green algae continued to be the dominant species.

The 2004 lake survey results demonstrated that Cryptophyta were dominant in the spring and mid-summer, and green algae were dominant in the late summer and early fall. There were quick growth spurts for blue-green algae in July and then again in early September. Excess phosphorus loads such as those seen in Lake Susan stimulate blue-green and green algal growth. The warm growing season conditions during July and August are particularly favorable to blue-greens, and blue-greens have a competitive advantage over the other algal species during this time. The data is summarized in Figure LS-4.

FIGURE LS-4
Lake Susan Phytoplankton Data Summary (2004)



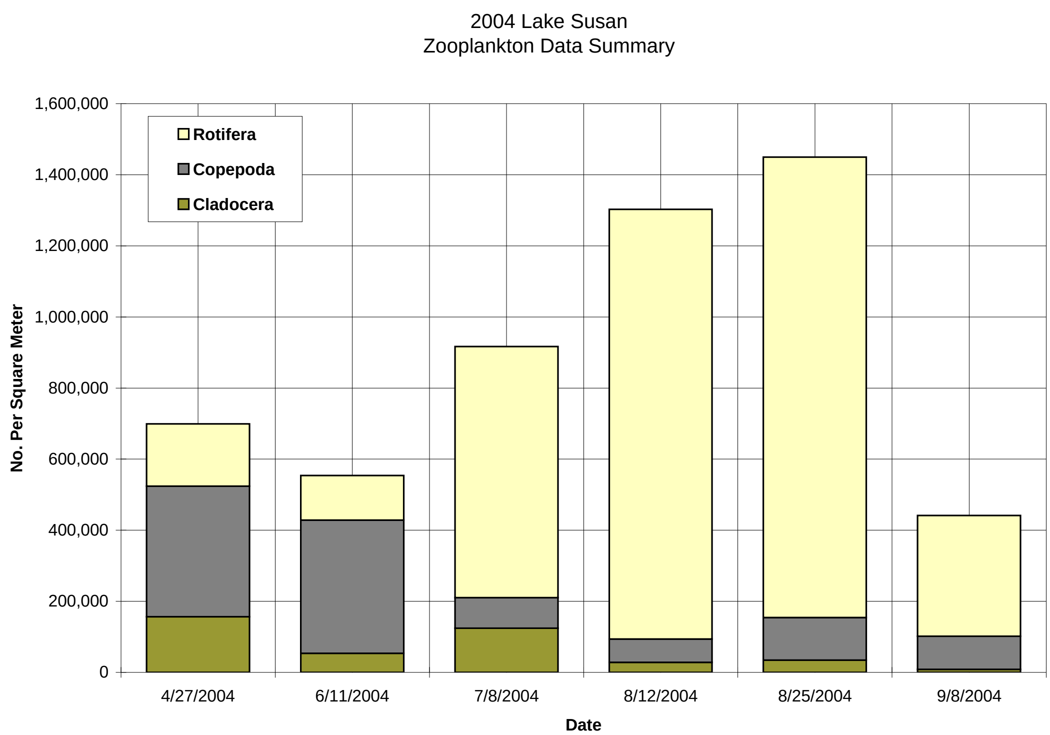
1.2.3.3 Zooplankton

The 1996 Plan states that in 1994, the total number of zooplankton was very high compared with previous years. The dominant group varied with changes in the populations, although the zooplankton were generally dominated by smaller-bodied cladocera (i.e. Bosmina and Chydorus spp.) and rotifers. Larger-bodied cladoera (Daphnia spp.) remained at a relatively stable number throughout 1994, but generally represented less than 10 percent of all cladocera.

The 1999 UAA cites data from 1981 to 1997 to discuss the abundance of zookplankton over time. In Lake Susan, the rotifera were the dominant group in the early part of the summer. However, by mid-July, the copepoda had achieved dominance. By August, the cladocera had exceeded both the rotifer and the copepoda, and continued to dominate the zooplankton community throughout the remainder of the sampling season.

Based on the 2004 data, the dominant groups were somewhat different from the 1999 UAA trend. Copepoda were the dominant group in the spring and early summer, and then for the remainder of the summer, rotifera was the dominant group.

FIGURE LS-5
Lake Susan Zooplankton Data Summary (2004)



1.2.3.4 Macrophytes

Recent macrophyte surveys of the aquatic plant community in Lake Susan were completed by the District in June and August of 1994, 1997, and 2004 and are summarized in Table 2.

TABLE 2
Lake Susan Aquatic Plants (1994, 1997 and 2004)

Common Name	Scientific Name	1994 Density	1997 Density	2004 Density
Submerged Aquatics				
Curlyleaf pondweed	***P. crispus***	**1-2**	**1**	**1-2**
Sago pondweed	***P. pectinatus***	**1-2**	**1**	**1-2**
Illinois pondweed	***P. illinoensis***	**--**	**--**	**1**

TABLE 2
Lake Susan Aquatic Plants (1994, 1997 and 2004)

Common Name	Scientific Name	1994 Density	1997 Density	2004 Density
Coontail	***Ceratophyllum demersum***	**--**	**--**	**1**
Elodea	***Elodea Canadensis***	**--**	**--**	**1-3**
Eurasian watermilfoil	***M. spicatum***	**--**	**--**	**1-2**
Floating Leaf Plants				
White waterlily	***Nymphaea odorata*** ***Nymphaea turberosa***	**--**	**--**	**--**
Water Smartweed	***Polygonum spp.***	**--**	**--**	**--**
Emergent Plants				
Bulrush	***Scirpus spp.***	**--**	**--**	**--**
Cattail	***Typha spp***	**--**	**--**	**--**
Purple loosestrife	***Lythrum salicaria***	**--**	**--**	**--**

In 1994 and 1997, no macrophytes were found at a depth greater than 3-4 feet. In 2004, the lake was surveyed to a depth of 6-7 feet. The 1994 survey showed moderate densities of curlyleaf pondweed (*Potamogeton crispus*), dominating the macrophytes in June, but dying back by August. Curlyleaf pondweed is a nuisance species that typically shows the pattern of dominance early in the growing season and dying back as the water temperature increased. It is an undesirable non-native species that frequently replaces native species in lakes and exhibits a dense growth that may interfere with the recreational use of a lake. The dominant species in August was sago pondweed (*Potamogeton pectinatus*). The 1997 survey showed a similar pattern as 1994 with light densities of curlyleaf pondweed and sago pondweed in June, along with some yellow lotus (*Nelumbo lutea*). Yello lotus is a protected species present in Lake Susan and is protected through the MDNR's Aquatic Plant Management Program. Some curlyleaf pondweed reduction was observed in August. To this point, Lake Susan, had not been yet been infested. However, in 2004, the macrophyte survey detected invasion and spreading of nuisance species, namely curlyleaf pondweed and Eurasian watermilfoil (*Myriophyllum spicatum*). In June, curlyleaf pondweed was observed in moderate densities, while Eurasian watermilfoil was newly observed and in light densities. Elodea (*Elodea Canadensis*) was the dominant species, with heavy densities along the water's edge. By August, Elodea was still the dominant species, but the two invasive species were both present in moderate densities. The growth of these invasive species should be controlled in order to protect water quality and lake habitat.

1.2.4 Water-Based Recreation

According to the 1996 Plan, recreational use of Lake Susan includes canoeing and aesthetic viewing. A municipal public access was constructed in 1990. MDNR (1994) noted that a recreational use survey in 1980 indicated boat anglers made up 100 percent of the fishing pressure.

1.2.5 Fish and Wildlife Habitat

According to its ecological classification, Lake Susan is a Class 38 lake, with primary fish species being northern pike, bluegill, and black bullhead. The MDNR has indicated that the average water quality for its ecological class is a TSI_{SD} of approximately 53. Currently, the lake's water transparency corresponds to a TSI_{SD} of 57.4 (2004 data). The lake has a history of winterkills. The 1994 MDNR Lake Survey Report for Lake Susan reports winterkills in the years 1954, 1974-1979, 1985, 1986, and 1988-1990. A winter aeration system was purchased and installed on the lake by the City of Chanhassen in 1993 (MDNR, 1994). In a further effort to improve Lake Susan's fishery, the City contracted with commercial fishermen to harvest carp and bullheads from the lake. In 1998, carp barriers were installed at Lake Susan.

The lake was stocked with largemouth bass fry and walleye fry in 1990. Walleye fry were again stocked in 1991 and 1994 (MDNR, 1994). The MDNR has been stocking walleye fry in consecutive years since 1990 (MDNR, 2003 fisheries survey).

The most recent fisheries survey (MDNR, 2003) showed that Lake Susan's fish community was dominated by black bullheads, comprising approximately 78% of all fish caught. Black crappie, bluegill, largemouth bass, northern pike, walleye, and yellow perch were also present in limited numbers.

Lake Susan provides habitat for seasonal waterfowl, such as ducks and geese, which find refuge and forage in the lake's diverse macrophyte communities in the lake's large littoral zone.

1.2.6 Natural and Urban Drainage Systems

1.2.6.1 Natural Conveyance Systems

Lake Susan's natural inflow and outflow is Riley Creek. There is an additional small inlet on the southeast side of the lake from an unnamed creek. Riley Creek, in addition to carrying water discharged from Lake Ann upstream, drains the northern and west central portion of the watershed. Stormwater runoff from the southern portion of the watershed enters the lake via a small canal draining the large pond and wetland complex southwest of Lake Susan. The remainder of the stormwater entering the lake does so via overland flow across the subwatersheds that drain directly to the lake.

1.2.6.2 Stormwater Conveyance Systems

The 1996 Plan and 1999 UAA do not further discuss the stormwater conveyance systems for Lake Susan.

1.2.6.3 Public Ditch Systems

The 1996 Plan and 1999 UAA do not further discuss any public ditch systems that affect Lake Susan.

1.2.7 Water Appropriations

There are no known water appropriations from Lake Susan.

Lotus Lake

August 2008

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Lotus Lake

1.1 Lotus Lake Watershed Goals

The approved Riley-Purgatory-Bluff Creek Watershed District Water Management Plan, 1996, (Water Management Plan) inventoried and assessed Lotus Lake. The plan articulated five specific goals for Lotus Lake. These goals address recreation, aquatic communities, water quality, water quantity, and wildlife. The approved Lotus Lake Use Attainability Analysis, 2005, (UAA) further expanded the characterization of Lotus Lake by evaluating the existing and potential beneficial uses intended in the five goals.

1.1.1 Water Quantity

Provide sufficient water storage during regional flood (100-yr, 24-hr storm event).

1.1.2 Water Quality

TSI_{SD} of 53 or lower to fully support swimming and TSI_{SD} of 50.4 or lower to support fishing.

1.1.3 Recreation

Primary – Swimming and Fishing (fully support). Secondary – Canoeing, boating and aesthetics (support).

1.1.4 Aquatic Communities

TSI_{SD} of 50.4 or lower to support fisheries in a Class 24 lake.

1.1.5 Wildlife

Protect existing beneficial wildlife uses.

1.1.6 Public Participation

The goal is to encourage public participation in reaching achievable outcomes for Lake Ann.

1.2 Existing Watershed Conditions

Lotus Lake is located in the city of Chanhassen in the northern part of the Riley-Purgatory-Bluff Creek watershed. It drains to Purgatory Creek which in turn drains to the Minnesota River.

1.2.1 Watershed Description

1.2.1.1 Land Use

Land use is an important watershed characteristic that has a direct impact on a lake and its water quality. Increasingly intensive land use will increase both sediment and phosphorus loads, as well as, alter the routine hydrology of a lake and its tributaries. Urbanization can also lead to thermal impacts which in turn can play a role in fisheries habitat. Sound watershed planning needs to consider both existing and future land use. The Lotus Lake watershed is approximately 1,339 acres and is comprised of the following components:

- Lotus Lake (240 acres)
- Land that drains directly to Lotus Lake (316 acres).
- Land that drains directly to stormwater treatment ponds (751 acres) and indirectly to Lotus Lake by a stormwater conveyance system.

Land use data was obtained from the Metropolitan Council Generalized Land Use Maps. The maps are based on 2005 existing land use and a projected land use for 2020. Both existing and projected are summarized in Table 1.

TABLE 1
Lotus Lake Existing and Projected Land Use

Land Use Category	2005 Existing (ac)	2020 Projected (ac)
Single Family Detached	**821**	**759**
Single Family Attached	**62**	**0**
Multifamily	**3**	**4**
Industrial and Utility	**<1**	**0**
Institutional	**17**	**70**
Park, Recreation, or Preserve	**98**	**79**
Right Of Way	**0**	**167**
Undeveloped	**80**	**0**
Water	**259**	**261**
Grand Total	**1339**	**1339**

1.2.2 Major Hydrologic Characteristics

At a water elevation of 895.5 feet, Lotus Lake has an area of 240 acres and an average depth of 16 feet. Water enters the lake by either direct precipitation, runoff from surrounding land, or storm water conveyances. Water exits the lake by ground water infiltration or through an outlet that discharges to Purgatory Creek. The outlet is at an elevation of 894.4 feet. The UAA determined that its outflow volume and hydrologic residence time vary with climatic conditions (Table 2).

TABLE2
Lotus Lake Climate Conditions

Climatic Condition (Water Year, Inches of Precipitation)	Average Lake Volume thousand m^3 (ac-ft)	Estimated Annual Lake Ouflow through Outlet* (thousand m^3/ac-ft)	Estimated Annual Lake Ouflow by Infiltration* (thousand m^3/ac-ft)	Hydraulic Residence Time (years)
Wet Year (1997, 39 Inches)	4,225 (3,425)	62.9 (51)	735.2 (596)	5.3
Average Year (1999, 34 Inches)	4,364 (3,538)	215.9 (175)	701.9 (569)	4.8
Dry Year (2000, 24 Inches)	4,281 (3,470)	64.2 (52)	751.3 (609)	5.2

*Outflows are based on the Lotus Lake WATBUD model results.

Lotus Lake UAA (Barr Engineering, 2005)

Concern has been expressed by the lake residents regarding the extent and duration of high water levels in the lake after large rain events or during periods of significant precipitation.

1.2.3 Lotus Lake Water Quality

1.2.3.1 Data Collection

Data for the previously watershed management plan was collected from 1972 to 1994. Additional data was collected by the District in 1999 to support the UAA. Data collected by the Metropolitan Council for 1985, 1990, 1999, and 2000 was also used to support the UAA. An additional sampling year was accomplished in 2004.

1.2.3.2 Baseline/Current Water Quality

Lotus Lake water quality remained poor throughout the more recent monitoring (1996 – 2005). Total phosphorus concentrations where typically in the eutrophic (nutrient rich) category in the spring and increased to a peak in the hypereutrophic (extremely nutrient rich) category in the mid to late summer (Figure LL-1). Chlorophyll a concentrations and Secchi disk depths from the monitoring period show similar trends. Most years start within the eutrophic category and quickly extend into the hypereutrophic category, again peaking in mid to late summer (Figure LL-2 and Figure LL-3).

FIGURE LL-1
Lotus Lake Total Phosphorus.

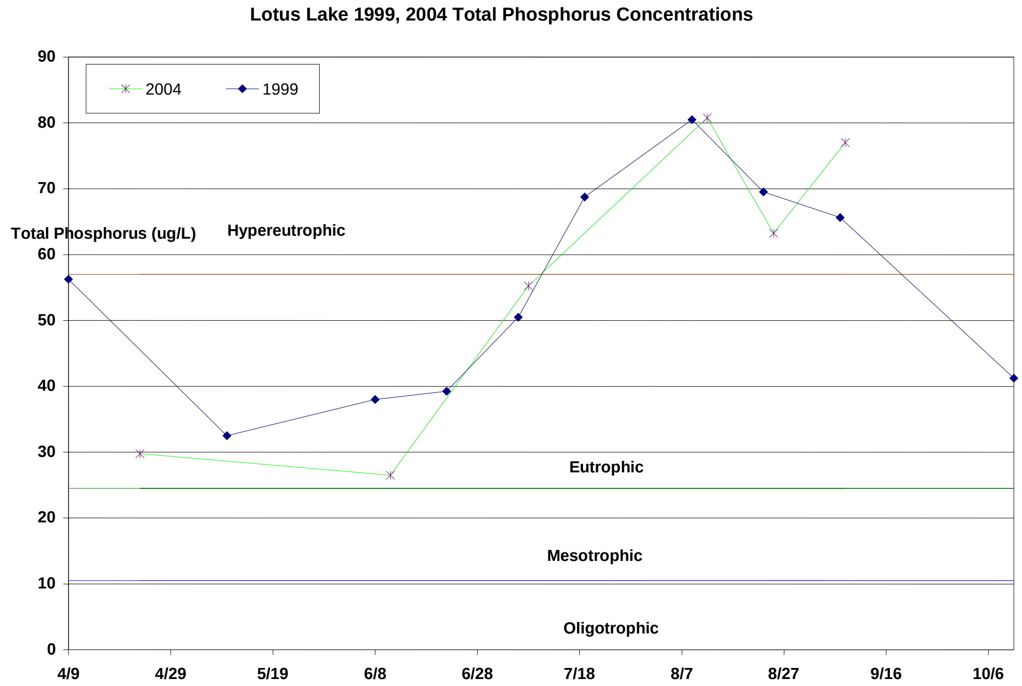


FIGURE LL-2
Lotus Lake Chlorophyll a.

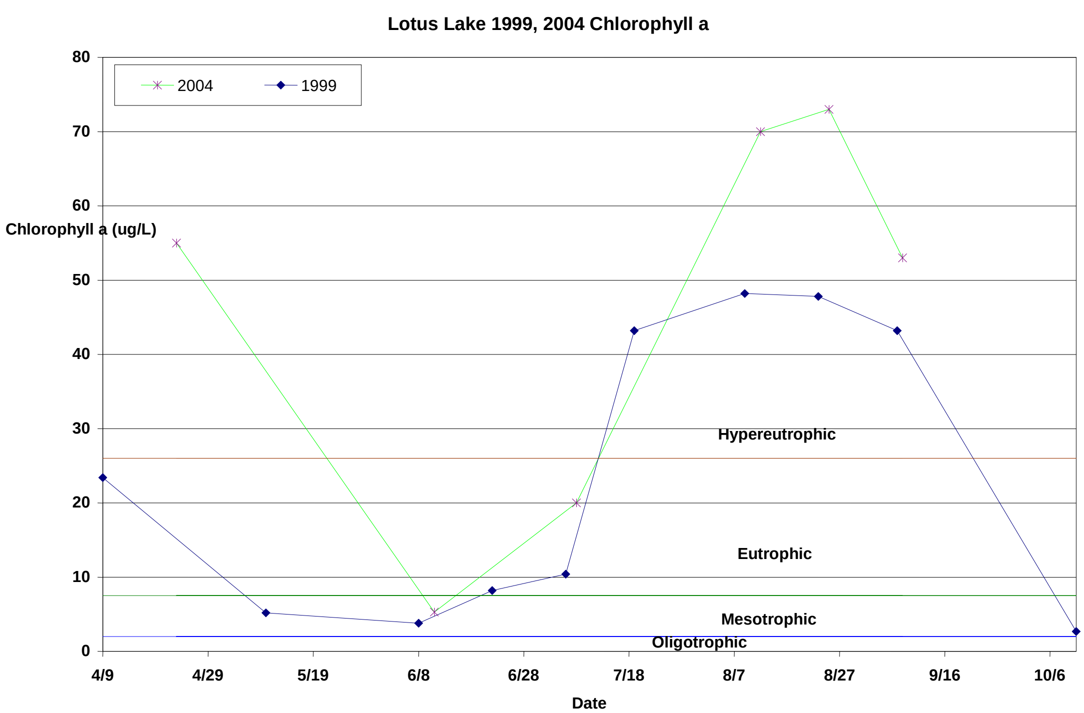
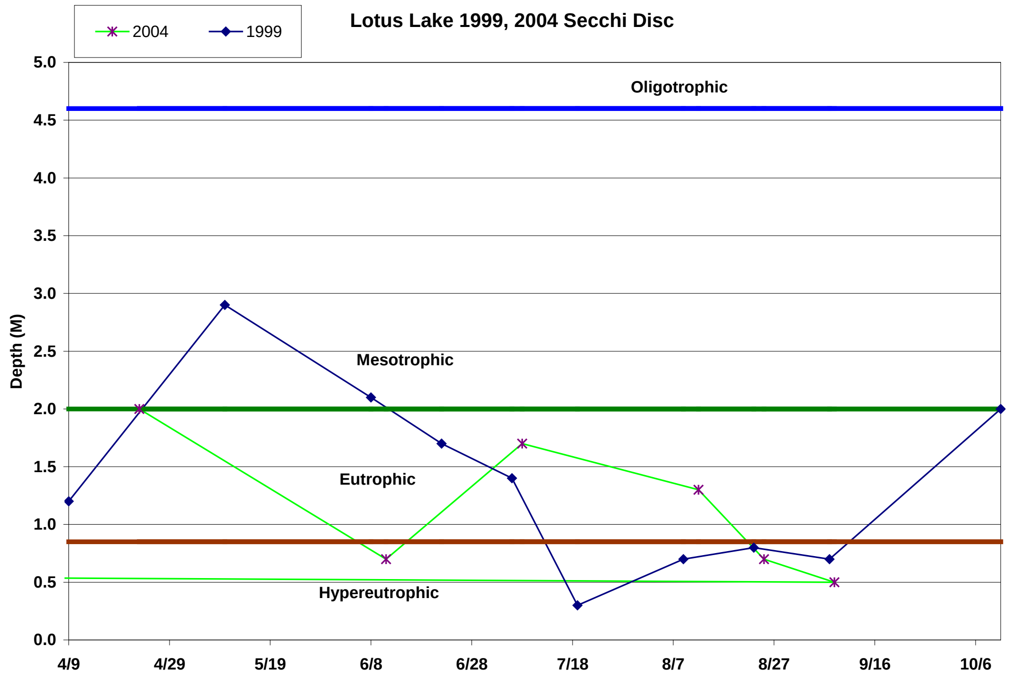


FIGURE LL-3
Lotus Lake Secchi Disk



Dissolved oxygen and temperature trends show that the lake stratifies after ice out in the spring. Stratification results in an anoxic zone at the bottom of the lake, typically extending from the bottom upwards to a depth of 3 or 4 meters. Autumn turnover appears to take place in September.

1.2.4 Ecosystem Data

Lotus Lake is a Class 24 lake. Class 24 lakes typically have a good permanent fishery. The MDNR has assigned an ecological rating (TSI_{sd}) of 50.4 or lower. The lakes current water quality corresponds to a TSI_{sd} of 57.8 for 1999 and a TSI_{sd} of 59.3 for 2004. Impairment of the Lotus Lake fishery is caused by high phosphorus levels and severe summer algal blooms.

1.2.4.1 Phytoplankton

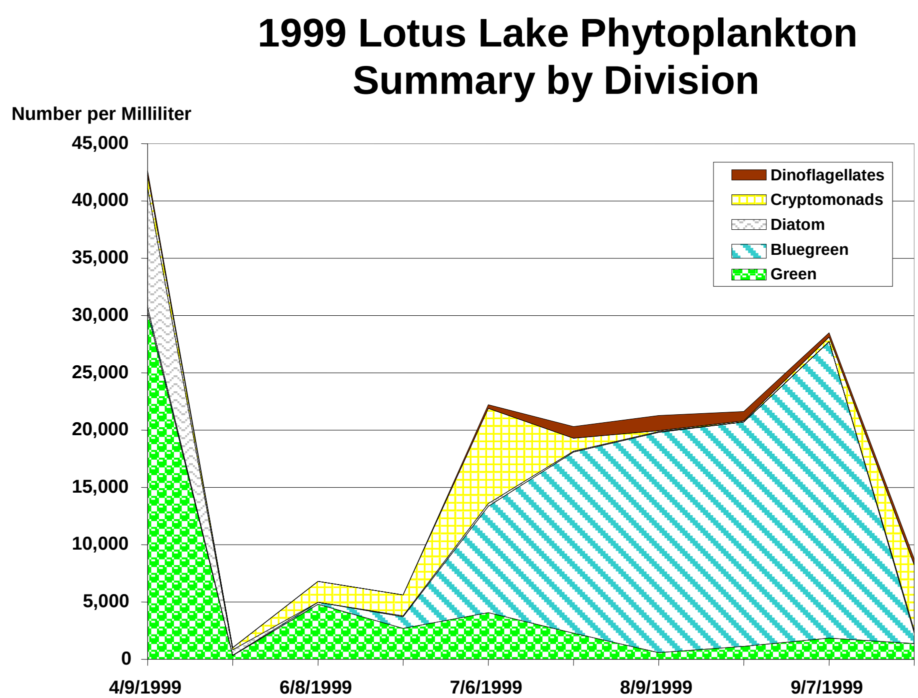
The diverse population of phytoplankton in Lotus Lake goes through a seasonal transformation where green algae are dominant in the spring but decline in the summer, while blue-green algae populations are low in spring and dominate in the summer and fall (Figures 6). Other taxa, including diatoms, cryptomonads, and dinoflagellates, fluctuate in number and volume during the growing season. Algal blooms are observed in Lotus Lake from July through September (Figures 6 and 7). The blooms primarily consist of blue-green algae which are large and visible and are often noted to be floating on the surface during periods of severe blooms.

There are several reasons why dominance of blue-green algae during summer is unfavorable for Lotus Lake:

- Blue-green algae are not a preferred food source for zooplankton,
- Blue-green algae can float at the lake surface causing highly visible algal blooms,
- Certain blue-green algae can be toxic to animals, and
- Blue-green algae disrupts lake recreation during the summer.

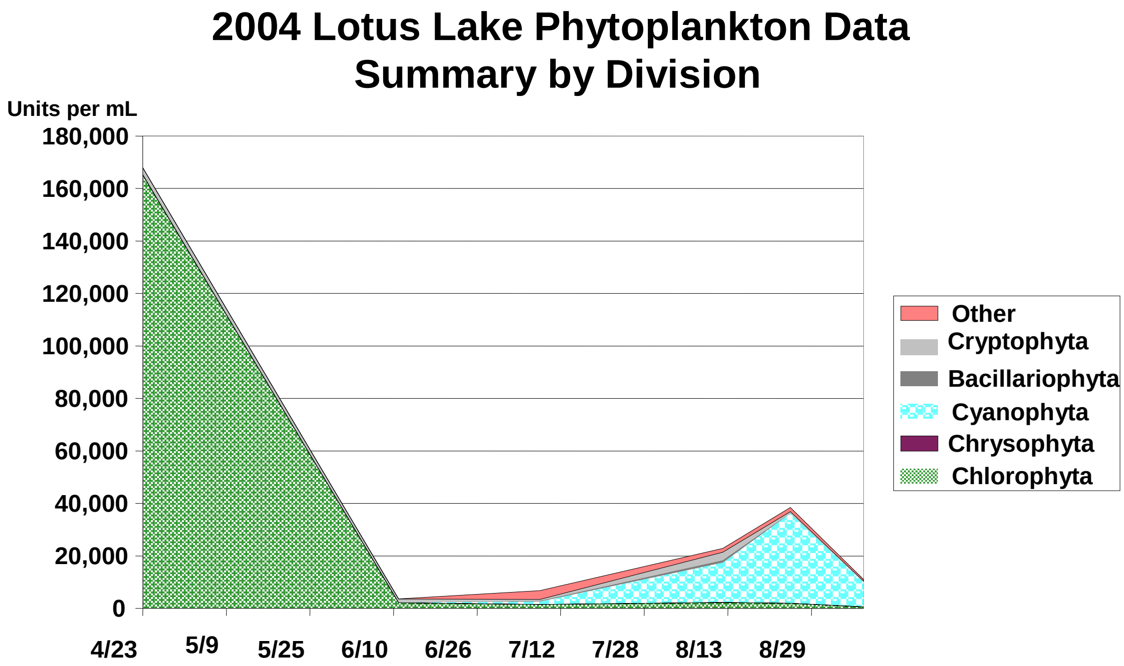
Large populations of blue-green algae are most often associated with high levels of phosphorus. Blue-green algae have a competitive advantage (i.e. grow more quickly) over other algal species when phosphorus levels are high. Hence, phosphorus levels will need to be reduced to reduce blue-green algae populations in Lotus Lake.

FIGURE 6.
Phytoplankton Abundance and Diversity in Lotus Lake - 1999



In 2004, Lotus Lake experienced a massive green algae bloom in April. This can be seen by the monitoring data in Figure LL-8.

FIGURE LL-8.
Phytoplankton Abundance and Diversity in Lotus Lake - 2004



1.2.4.2 Zooplankton

Zooplankton are an important component of the aquatic ecosystem of Lotus Lake. They are particularly important for the lake's fishery and for the biological control of algae. Healthy zooplankton communities are characterized by balanced densities (number per meter squared) of the three major groups of zooplankton: Cladocera, Copepods, and Rotifers. Fish predation, however, may alter community structure and reduce the numbers of larger-bodied zooplankters (i.e., larger bodied Cladocera).

According to the UAA, all three groups of zooplankton were well represented in Lotus Lake in 1999 (Figure LL-9). A large population of large-bodied cladocerans was observed during April through June, which is good because they have the capacity to biologically control algal growth. Daily zooplankton grazing rates of the lake's surface waters (0- to 6-feet) during April through June was estimated to range from 7 to 20 percent (See Figure LL-9). During this period, the phytoplankton (algae) community was comprised of small-bodied algae that are easily eaten by zooplankters. Biological control of the lake's algae resulted in a reduction of the lake's chlorophyll a concentration and improved water transparency during May and early June, despite an increase in the lake's phosphorus concentration.

The poor water quality seen in 2004, coupled with the green algae bloom appear to have influenced the zooplankton distribution as well. As can be seen in Figure LL-10, the population of cladocerans showed a large die off in the June-July timeframe that corresponds to the increase in blue-green algae and the worsening water quality conditions. This population doesn't start to recover until the end of August with the decline in blue-green algae levels.

FIGURE LL-9
Lotus Lake Zooplankton Data Summary – 1999

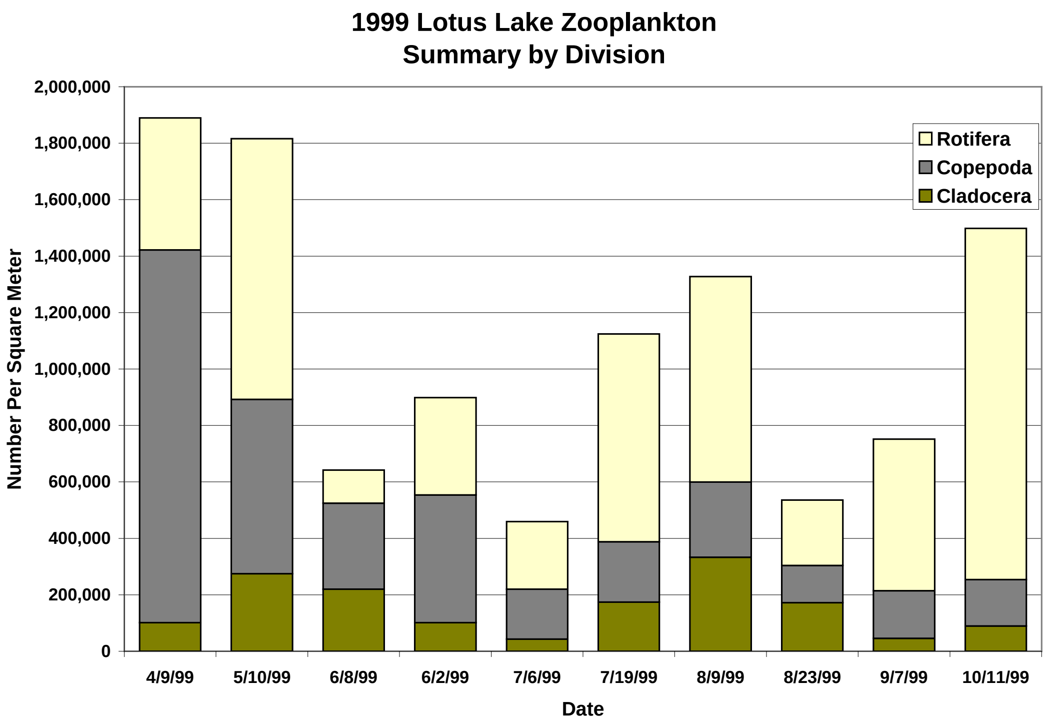
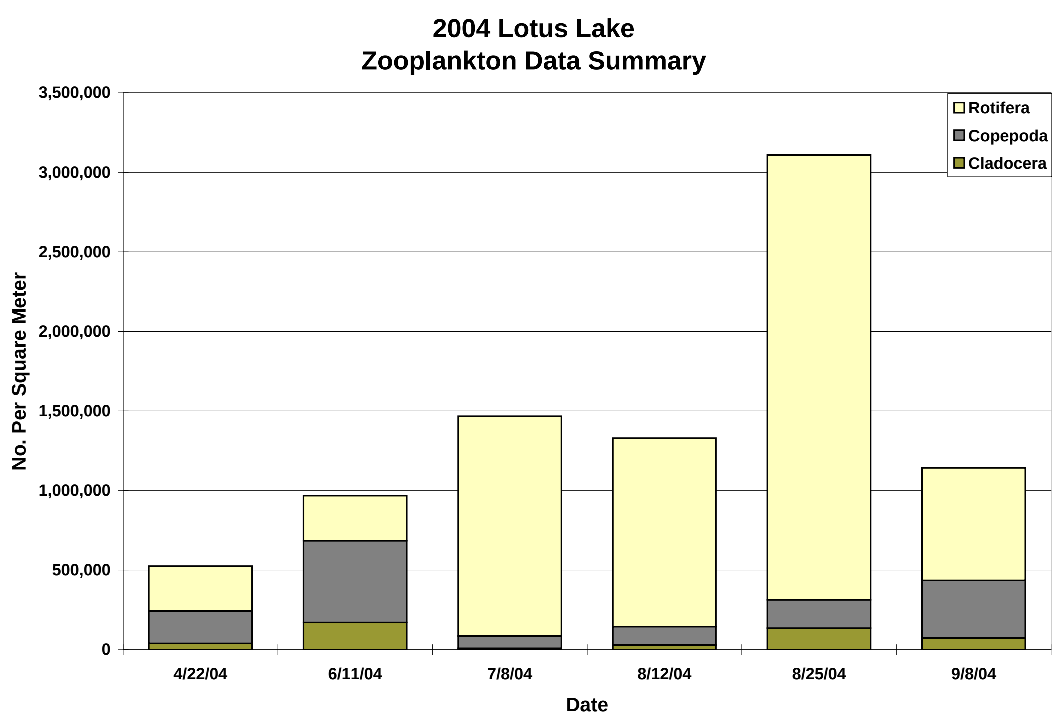


FIGURE LL-10
Lotus Lake Zooplankton Data Summary – 2004



1.2.4.3 Macrophytes

Lotus Lake's macrophytes were surveyed in June and August 1999 and June and August 2005 to identify the conditions of plant growth throughout the lake. Sixteen species were observed in both years. Many of these species are common to Minnesota lakes and provide good habitat for the fish and aquatic animals living within the lake.

Macrophytes were identified to a maximum depth of 4 to 5 feet during the June 1999 survey and 3 to 4 feet during the August 19999 survey. In general, the 1999 surveys noted macrophyte densities of light to moderate. The June 2005 survey identified macrophytes to a maximum depth of 12 to 13 feet and the August 2005 survey identified macrophytes to a maximum depth of 8 to 9 feet. Many of the macrophyte densities had increased to moderate to heavy in the 2005 surveys.

TABLE 3
1999 and 2005 Lotus Lake Aquatic Plants

Common Name	Scientific Name	1999 Density	2005 Density
Submerged Aquatics			
Narrowleaf pondweed (unidentified)	***Potamogeton sp. (narrowleaf)***		**1**
Sago pondweed	***Potamogeton pectinatus***	**1**	**1**
Curlyleaf pondweed	***Potamogeton crispus***	**1-2**	**1**
Eurasian watermilfoil	***Myriophyllum spicatum***	**1-3**	**1-3**
Coontail	***Ceratophyllum demersum***	**1-3**	**2-3**
Muskgrass	***Chara sp.***	**1**	**1**
Bushy pondweed and Naiad	***Najas flexilis***	**1**	
Water stargrass	***Zosterella dubia***	**1**	
Floating Leaf Plants			
Yellow waterlily	***Nuphar variegata***	**--**	**--**
White waterlily	***Nymphaea tuberosa***	**--**	**--**
American lotus	***Nelumbo lutea***	**--**	**--**
Emergent Plants			
Bulrush	***Scirpus spp.***	**--**	**--**
Cattail	***Typha spp***	**--**	**--**
Purple loosestrife	***Lythrum salicaria***	**--**	**--**
Blue flag iris	***Iris vericolor***		**--**

The growth of the exotic (nonnative) species, including curlyleaf pondweed, Eurasian watermilfoil, and purple loosestrife, in Lotus Lake is of concern. Curlyleaf pondweed was found at various locations in the lake during June in both 1999 and 2004. Once a lake becomes infested with curlyleaf pondweed, this plant typically replaces native vegetation, thereby increasing its coverage and density.

The light to moderate densities of curlyleaf pondweed in Lotus Lake during 1999 indicate a successful competition by native species has controlled curlyleaf pondweed growth in Lotus Lake. However, water quality management to improve the lake's water transparency is likely to result in heavier curlyleaf pondweed growth unless a curlyleaf pondweed management program is concurrently implemented.

Eurasian watermilfoil was observed during the 1999 and 2004 macrophyte surveys. Eurasian watermilfoil is a nuisance non-native species that typically replaces native vegetation (See Figure 14). It has a canopy style growth pattern that causes heavy growth near the surface, making it more visible and a greater nuisance for boaters and fishermen. Eurasian watermilfoil growth is currently problematic in Lotus Lake. Water quality management to improve the lake's water clarity is likely to result in increased Eurasian watermilfoil growth unless a program to manage this plant is completed first.

In 1999 and 2004, purple loosestrife was found along the eastern and northern Lotus lake shoreline. Purple loosestrife, an emergent plant, is native to Europe and the temperate regions of Asia. Once introduced into an area, the plant typically replaces native vegetation and rapidly becomes the sole emergent species.

1.2.5 Water-Based Recreation

Lotus Lake is used by local residents for all kinds of recreational activities, including swimming. A public access, provided by the City of Chanhassen, is located on the south end of the lake. A swimming beach is also located on the lake.

1.2.6 Fish and Wildlife Habitat

The MDNR has developed a classification system for Minnesota lakes relative to the chemical and physical properties of each lake class and the fishery that is supported by each lake (Schupp 1992). According to its ecological classification, Lotus Lake is a Class 24 lake. Class 24 lakes typically have a good permanent fishery (Schupp, 1992). The MDNR has indicated that the average water quality for a Class 24 lake is a TSISD (Trophic State Index in terms of Secchi disc transparency) of 50.4 or lower. The recommendation is based upon the water quality needs of the fishery found in a Class 24 lake. Lotus Lake's water quality does not meet this recommendation based upon the 1999 and 2004 data.

The lake's current water quality (monitoring years 1999 and 2004) corresponds to a $TSI_{SD}$of 57.8 and 59.3 respectively. These values correspond to summer average Secchi depths of approximately 3.9 and 3.5 feet. Lotus Lake has only met the MDNR recommended water quality goal two times, during the monitoring years 1972 and 1991.The trend appears to be steadily declining water transparency. Lotus Lake's water quality does not meet the recommended TSI_{SD} based upon the 1999 and 2004 data.

Lotus Lake's fishery currently (2004) consists of panfish, gamefish, and rough fish. The 2005 MDNR fish survey showed that the following species are present in Lotus Lake:

- Panfish—black crappie, bluegill, green sunfish, pumpkinseed sunfish
- Gamefish—largemouth bass, northern pike, walleye, yellow perch
- Rough fish—black bullhead, yellow bullhead, common carp
- Other fish—golden shiner

According to the 2004 survey, bluegill and black crappie are the most abundant fish species in Lotus Lake. Bluegill abundance was at a historical low and sizes on the small side (< 6 inches). Black crappie abundance was at a historical. Walleye population was dominated by two distinct size ranges, fish larger than 17 inches (mostly age 5) and fish less than 11 inches (mostly age 1). MDNR considered the large number of age 1 fish encouraging and may promise "some decent fishing in the future". Northern pike abundance was lower than the 1999 survey but most fish were greater than 30 inches in length. Moderate numbers of largemouth bass, black bullhead, and yellow bullhead were present during the 2004 survey.

The 2001 MDNR Lotus Lake Management Plan reiterates the emphasis of walleye management. Walleye stocking has occurred periodically during 1965 through 1989 and biennially since 1989. Walleye stocking was increased to 2 pounds per littoral acre (364 pounds) in 2001. The MDNR 2001 Lotus Lake Management Plan indicates the MDNR will work with the Riley Purgatory Bluff Creek Watershed District and the City of Chanhassen to lower phosphorus loading, thereby improving the lake's water quality.

Lotus Lake provides good habitat for waterfowl such as ducks and geese.

1.2.7 Natural and Urban Drainage Systems

1.2.7.1 Natural Conveyance Systems

The natural inflow to Lotus Lake consists of direct runoff from areas surrounding the lake and groundwater inflows.

1.2.7.2 Stormwater Conveyance Systems

The Lotus Lake stormwater conveyance system is comprised of a network of storm sewers and wet detention ponds within the lake's watershed. Runoff from this part of the watershed is treated by at least one wet detention pond before entering the lake. Storm sewers convey stormwater runoff to and from many of the wet detention ponds, and eventually convey the runoff to Lotus Lake. Some wet detention ponds convey runoff to Lotus Lake via overland flow.

According to the Lotus Lake UAA, stormwater is treated by 25 treatment ponds. Details of each storm water detention system are provided in UAA Appendix B. Figure LL-17 shows many of the stormwater conveyance systems and the stormwater detention systems of the Lotus Lake watershed..

1.2.7.3 Public Ditch Systems

There are no public ditch systems that affect Lotus Lake.

1.2.8 Water Appropriations

There are no known water appropriations from Lotus Lake.

Mitchell Lake

August 2008

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Mitchell Lake

1.1 Mitchell Lake Watershed Goals

The approved Riley-Purgatory-Bluff Creek Watershed District Water Management Plan, 1996, (Water Management Plan) inventoried and assessed Mitchell Lake. The plan articulated five specific goals for Mitchell Lake. These goals address recreation, aquatic communities, water quality, water quantity, and wildlife. The approved Mitchell Lake Use Attainability Analysis, 2005, (UAA) further expanded the characterization of Mitchell Lake by evaluating the existing and potential beneficial uses intended in the five goals.

1.1.1 Watershed Goals

1.1.1.1 Water Quantity

Provide sufficient water storage during regional flood (100-yr, 24-hr storm event).

1.1.1.2 Water Quality

The MPCA has classified Mitchell Lake as non-supporting of swimmable use. In order to be partially supporting, Mitchell Lake needs a TSI_{SD} less than 57 and greater than 53. To be fully supporting, Mitchell Lake's TSI_{SD} needs to be less than 53.

TSI_{SD} of 58.7 or lower to support fishing in a Class 42 lake. Support passive aquatic recreation designated use with a TSI_{SD} of 63 or lower.

1.1.1.3 Recreation

The primary recreation goal is to achieve full support of fishing activities and maintain waterfowl habitat.

1.1.1.4 Aquatic Communities

TSI_{SD} of 58.7 or lower to support fisheries in a Class 42 lake.

1.1.1.5 Wildlife

The wildlife goal for Lake Lucy is to protect existing beneficial wildlife uses. The wildlife goal can be achieved with no action, especially if the wetlands and park land surrounding the lakes in the City of Chanhassen's future land use plan stay intact.

1.1.1.6 Public Participation

The goal is to encourage public participation in achieving outcomes from the use attainability analysis. To achieve this goal, a public meeting will be called to obtain comments on the use attainability analysis.

1.2 Existing Watershed Conditions

Mitchell Lake is located in the City of Eden Prairie in the central part of the Riley-Purgatory-Bluff Creek watershed. It drains to Red Rock Lake which in turn drains to Staring Lake.

1.2.1 Watershed Description

1.2.1.1 Land Use

Land use is an important watershed characteristic that has a direct impact on a lake and its water quality. Increasingly intensive land use will increase both sediment and phosphorus loads, as well as, alter the routine hydrology of a lake and its tributaries. Urbanization can also lead to thermal impacts which in turn can play a role in fisheries habitat. Sound watershed planning needs to consider both existing and future land use.

Land use data was obtained from the Metropolitan Council Generalized Land Use Maps. The maps are based on 2005 existing land use and a projected land use for 2020. Both existing and projected are summarized in Table ML-1. Future land use mapping for 2020 indicates that there will be a significant increase in single family residential and parks land use.

TABLE 1
Mitchell LakeExisting and Projected Land Use

Land Use	2005 Existing (ac)	2020 Projected (ac)
Single Family or Low Density Residential	**405.2**	**360.0**
Multiple Family or Medium Density Residential	**105.3**	**109.2**
Agricultural	**.7**	**0**
Industrial and Utility	**107.0**	**101.4**
Commercial	**8.9**	**8.1**
Parks, Undeveloped Land and Other Open Areas	**166.4**	**83.5**
Water	**121.9**	**122.7**
Total	**980.2**	**980.2**

1.2.1.2 Major Hydrologic Characteristics

At a water elevation of 871.5 feet, Mitchell Lake has an area of 123 acres and an average depth of 5.8 feet. Water enters the lake by either direct precipitation, runoff from surrounding land, or storm water conveyances. Water exits the lake by ground water infiltration or through a man-made outlet structure (a manhole with a weir) at the south end of the lake. The outlet is at an elevation of 871.06 feet. The UAA determined that its outflow volume and hydrologic residence time vary with climatic conditions (Table ML-2).

TABLE 2
Mitchell Lake Estimated Outflows

Climatic Condition (Water Year, Inches of Precipitation)	Average Lake Volume (m^3 / ac-ft)	Estimated Annual Lake Ouflow through Outlet* (m^3/ac-ft)	Estimated Annual Lake Ouflow by Infiltration* (m^3/ac-ft)	Hydraulic Residence Time (years)
Wet Year (1997, 39 Inches)	840,040 / 681	875,950 / 710	225,640 / 183	0.763
Average Year (1999, 33 Inches)	780,120 / 632	440,650 / 357	225,640 / 183	1.170
Calibration Year (Spring 1998-Spring 1999, 32 Inches	742,880 / 602	523,490 / 425	225,640 / 183	0.990
Dry Year (2000, 25 Inches)	743,500 / 603	122,210 / 99	225,640 / 183	2.138

*Outflows are based on the Mitchell Lake WATBUD model results.

Mitchell Lake UAA (Barr Engineering, 2005)

During high water level conditions, Round Lake flows to Mitchell Lake and Mitchell Lake overflows to Red Rock Lake.

1.2.2 Mitchell Lake Water Quality

1.2.2.1 Data Collection

Data for the previously watershed management plan was collected from 1972 to 1993. Additional data was collected in 1996 and 1999 to support the UAA. An additional sampling year was accomplished in 2005.

1.2.2.2 Baseline/Current Water Quality

Mitchell Lake water quality remained poor throughout the more recent monitoring (1996 – 2005). Total phosphorus concentrations where typically in the eutrophic (nutrient rich) category in the spring and increased to a peak in the hypereutrophic (extremely nutrient rich) category in the mid to late summer (Figure ML-1). Chlorophyll a concentrations and Secchi disk depths from the monitoring period show similar trends. Most years start with in the eutrophic category and quickly extend into the hypereutrophic category, again peaking in mid to late summer (Figure ML-2 and Figure ML-3).

FIGURE ML-1
Lake Mitchell Total Phosphorus.

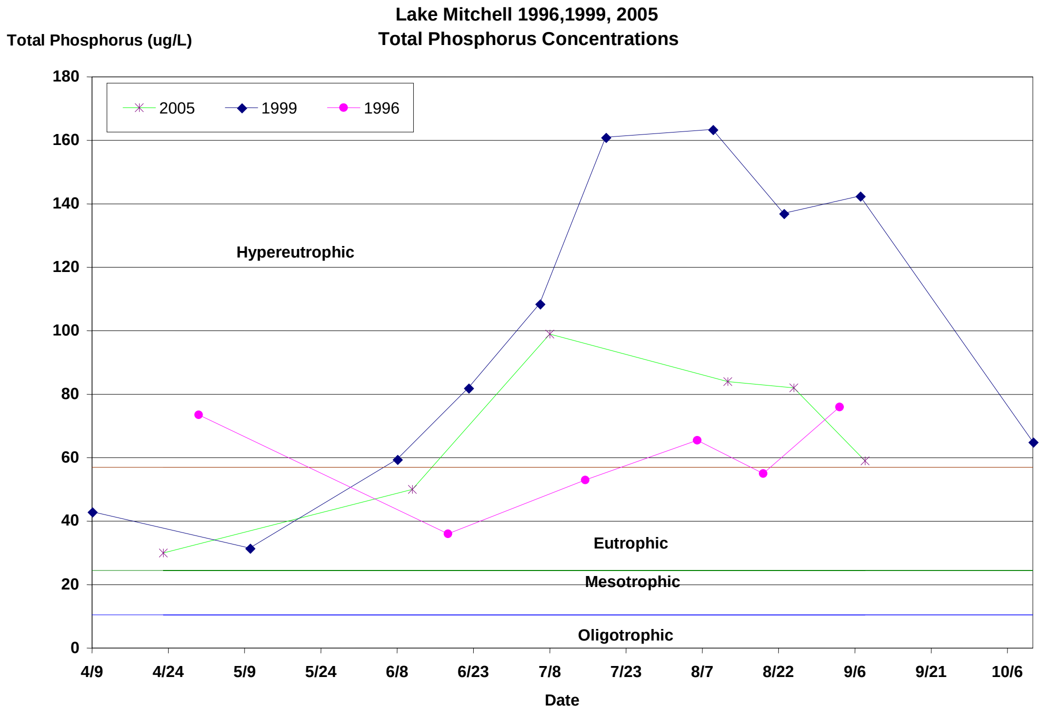


FIGURE ML-2
Lake Mitchell Chlorophyll a.

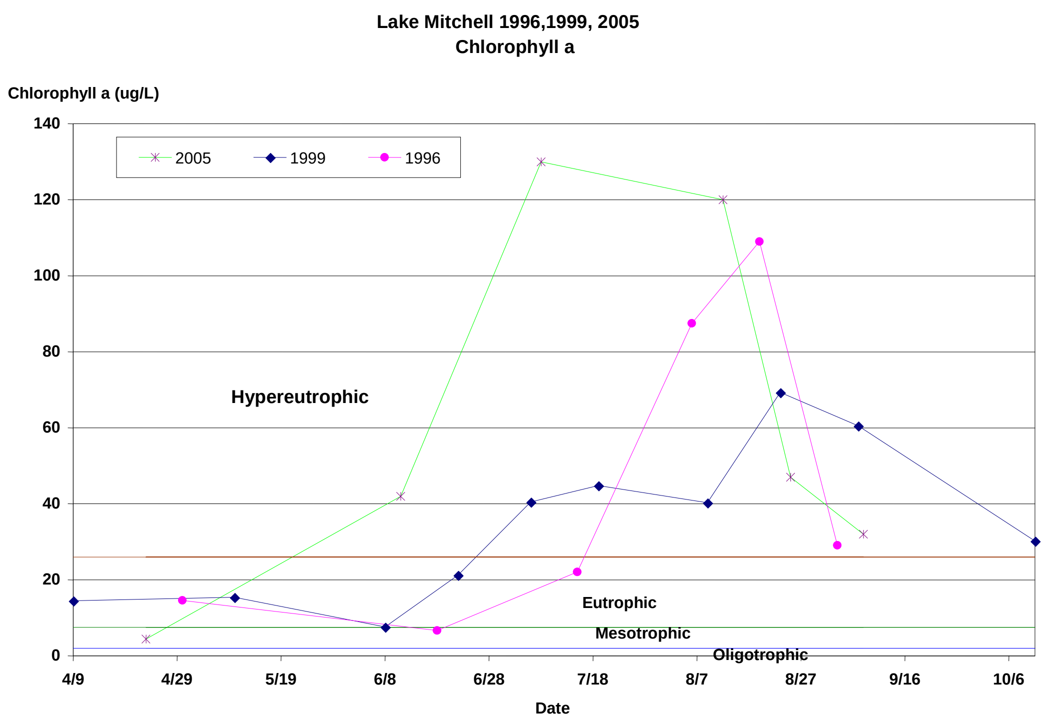
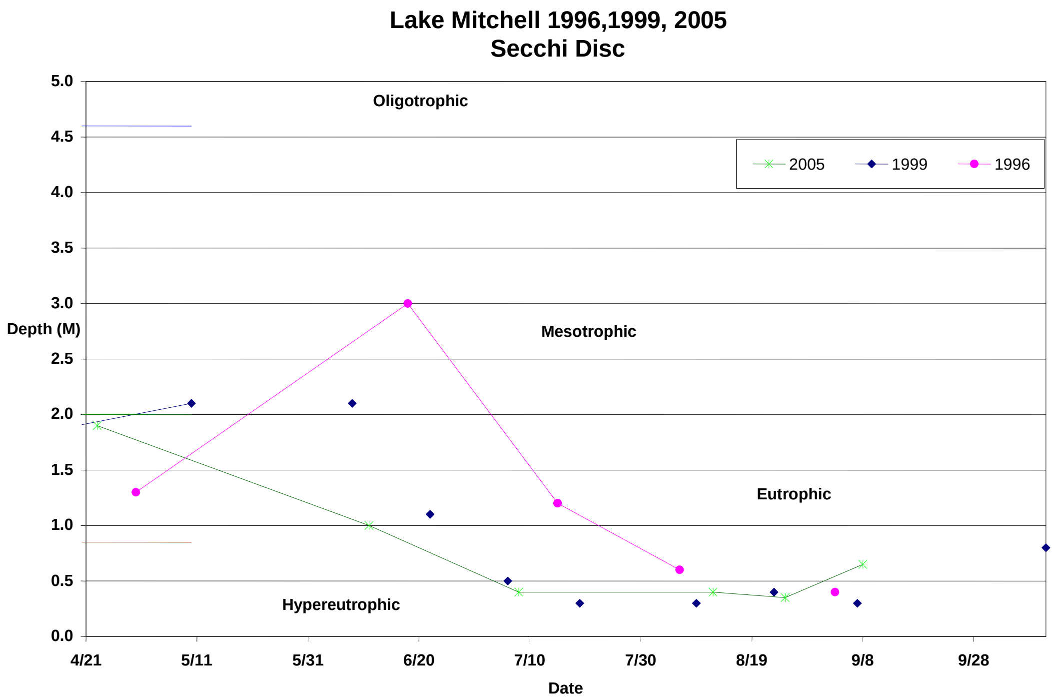


FIGURE ML-3
Lake Mitchell Secchi Disk



Dissolved oxygen and temperature trends show that the lake stratifies after ice out in the spring. Stratification results in an anoxic zone at the bottom of the lake, typically extending from the bottom upwards to a depth of 3 or 4 meters. Autumn turnover appears to take place in September.

1.2.3 Ecosystem Data

Mitchell Lake is a Class 42 lake. Class 42 lakes are typically shallow, euthrophic lakes. The MDNR has assigned an ecological rating (TSI_{SD}) of 58.7 or lower. The lakes current water quality (2005 data) corresponds to a TSI_{SD} of 68.9. Impairment of the Mitchell Lake fishery is caused by high phosphorus levels and severe summer algal blooms.

1.2.4 Aquatic Ecosystems

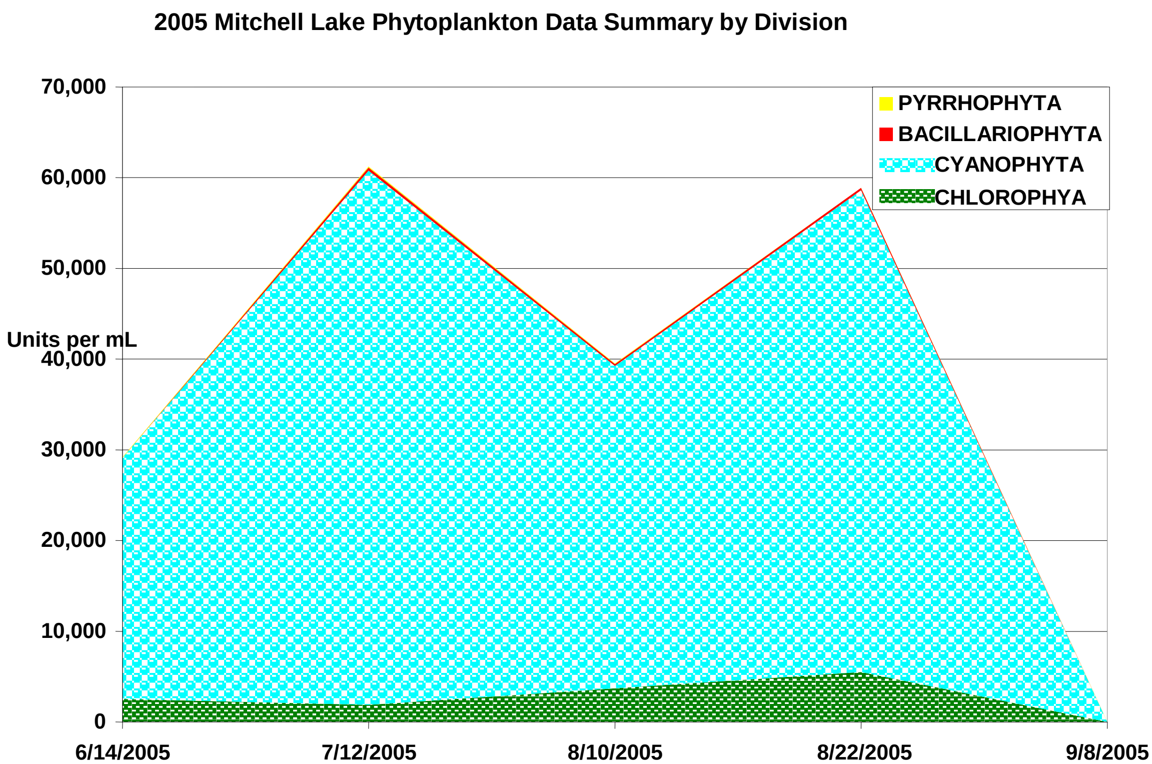
1.2.4.1 Phytoplankton

The diverse population of phytoplankton in Mitchell Lake goes through a seasonal transformation where green algae and Cryptomonads are dominant in the spring but decline in the summer, while blue-green algae populations are low in spring and dominate in the summer and fall. Algal blooms are observed in Mitchell Lake from late June through September. The blooms primarily consist of blue-green algae which are large and visible and are often noted to be floating on the surface during periods of severe blooms.

There are several reasons why dominance of blue-green algae during summer is unfavorable for Mitchell Lake:

- Blue-green algae are not a preferred food source for zooplankton,
- Blue-green algae can float at the lake surface causing highly visible algal blooms,
- Certain blue-green algae can be toxic to animals, and
- Blue-green algae disrupts lake recreation during the summer.

Large populations of blue-green algae are most often associated with high levels of phosphorus. Blue-green algae have a competitive advantage (i.e. grow more quickly) over other algal species when phosphorus levels are high. Hence, phosphorus levels will need to be reduced, in order to reduce blue-green algae populations in Mitchell Lake.

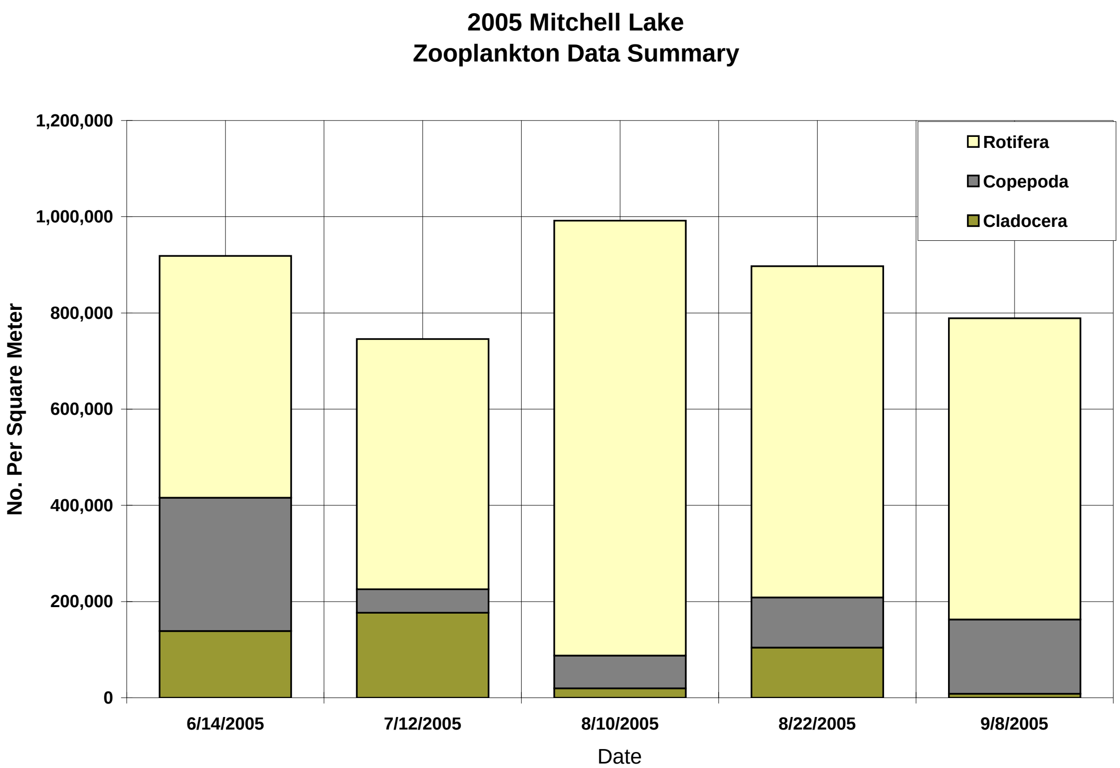


1.2.4.2 Zooplankton

Zooplankton are an important component of the aquatic ecosystem of Mitchell Lake. They are particularly important for the lake's fishery and for the biological control of algae. Healthy zooplankton communities are characterized by balanced densities (number per meter squared) of the three major groups of zooplankton: Cladocera, Copepods, and Rotifers. Fish predation, however, may alter community structure and reduce the numbers of larger-bodied zooplankters (i.e., larger bodied Cladocera).

According to the UAA, all three groups of zooplankton are well represented in Mitchell Lake. A large population of Cladocerans was observed during May through early June, which is good because they have the capacity to biologically control algal growth. Daily zooplankton grazing rates of the lake's surface waters (0- to 6-feet) during May through early June was estimated to range from 40 to 44 percent. During this period, the phytoplankton (algae) community was comprised of small-bodied algae that are easily eaten by zooplankters. Biological control of the lake's algae resulted in a reduction of the lake's chlorophyll *a* concentration and improved water transparency during early June, despite an increase in the lake's phosphorus concentration.

The UAA study noted reductions in the numbers of large-bodied cladocera and in the fraction of the algal community comprised of small-bodied, edible algae are the apparent causes of the lack of biological control on the lake's algal growth during late June through July. Declining grazing rates observed during late June through July corresponded with declining numbers of large-bodied cladocera and increasing volumes of blue-green algae. The algal community was primarily comprised of inedible blue-green algae during late June through October. Hence, zooplankters were unable to exert biological control during this period.



1.2.4.3 Macrophytes

Mitchell Lake's macrophytes were surveyed in June and August 1999 and June and August 2005 to identify the conditions of plant growth throughout the lake. Sixteen species were observed in both years. Many of these species are common to Minnesota lakes and provide good habitat for the fish and aquatic animals living within the lake.

Macrophytes were identified to a maximum depth of 4 to 5 feet during the June 1999 survey and 3 to 4 feet during the August 19999 survey. In general, the 1999 surveys noted macrophyte densities of light to moderate. The June 2005 survey identified macrophytes to a maximum depth of 12 to 13 feet and the August 2005 survey identified macrophytes to a maximum depth of 8 to 9 feet. Many of the macrophyte densities had increased to moderate to heavy in the 2005 surveys.

TABLE 3
1999 and 2005 Mitchell Lake Aquatic Plants

Common Name	Scientific Name	1999 Density	2005 Density
Submerged Aquatics			
Curlyleaf pondweed	***P. crispus***	**1-2**	**1-3**
Flatstem pondweed	***P. zosteriformis***	**1**	**--**
Sago pondweed	***P. pectinatus***	**1-2**	**1**
Narrowleaf pondweed	***P. spp.***	**1-2**	**1-2**
Northern water milfoil	***Myriophyllum sibericum***	**1-3**	**2-3**
Water stargrass	***Zosterella dubia***	**1-2**	**1**
Coontail	***Ceratophyllum demersum***	**1-3**	**1-3**
Elodea	***Elodea Canadensis***	**1**	**1**
Bushy pondweed and naiad	***Najas flexilis***	**1-2**	**--**
White waterbuttercup	***R. sp.***	**--**	**2-3**
Eurasian watermilfoil	***M. spicatum***	**--**	**1-3**
Floating Leaf Plants			
White waterlily	***Nymphaea odorata*** ***Nymphaea turberosa***	**--**	**--**
Water Smartweed	***Polygonum spp.***	**--**	**--**
Emergent Plants			
Bulrush	***Scirpus spp.***	**--**	**--**
Cattail	***Typha spp***	**--**	**--**
Purple loosestrife	***Lythrum salicaria***	**--**	**--**

The growth of the exotic (nonnative) species, including curlyleaf pondweed, Eurasian watermilfoil, and purple loosestrife, in Mitchell Lake is of concern. Curlyleaf pondweed was found throughout the lake during June in both 1999 and 2005. Once a lake becomes infested with curlyleaf pondweed, this plant typically replaces native vegetation, thereby increasing its coverage and density.

Results of water quality and plant surveys during 1993, 1996, and 1999 were evaluated to determine whether lake water transparency influenced the density of curlyleaf pondweed growth in Mitchell Lake. Survey results indicate curlyleaf pondweed grew more densely when the lake's water transparency was better and less densely when the lake's water transparency was poorer. Average summer Secchi disc water transparency in Mitchell Lake was 1.4 meters in 1993, 1.2 meters in 1996, and 0.8 meters in 1999 (See UAA Appendix A) . Curlyleaf pondweed densities were moderate to heavy in June of 1993, light to heavy in

June of 1996, and light to moderate in June of 1999 (See UAA Appendix A). The data suggest that shading from increased algal growth in 1999 severely limited curlyleaf pondweed growth in the lake. However, improved water transparency during 1993 and 1996 encouraged heavy curlyleaf pondweed growth. This relationship indicates that water quality management to improve the lake's water transparency is likely to result in heavier curlyleaf pondweed growth unless a curlyleaf pondweed management program is concurrently implemented.

The Minnesota Department of Natural Resources (MDNR) observed a sparse growth of Eurasian watermilfoil in Mitchell Lake during 2002 (See Figure 15). Eurasian watermilfoil was not observed during 1993, 1996, and 1999 macrophyte surveys but was observed throughout the lake in 2005.

In 1999, purple loosestrife was found in four locations along the Mitchell lake shoreline (one on the northwest and three on the east). Purple loosestrife, an emergent plant, is native to Europe and the temperate regions of Asia. Once introduced into an area, the plant typically replaces native vegetation and rapidly becomes the sole emergent species.

1.2.5 Water-Based Recreation

Mitchell Lake is used by local residents for canoeing, sailing, fishing, and aesthetic viewing. The lake's primary use is fishing. The Minnesota Department of Natural Resources (MDNR) installed a boat access in 1991 and a fishing pier in 1998 to provide fishing opportunities to the public. Winterkills occurred in 1985 and 1989. An aeration system has been used to prevent winterkill since 1991. Miller Park was built by the city of Eden Prairie in the mid to late 1980's. The heavily used park is located along the south side of the lake.

1.2.6 Fish and Wildlife Habitat

The MDNR has developed a classification system for Minnesota lakes relative to the chemical and physical properties of each lake class and the fishery that is supported by each lake (Schupp 1992). According to its ecological classification, Mitchell Lake is a Class 42 lake. Class 42 lakes are typically shallow and productive lakes with fish assemblages that include white sucker, bluegills, and black bullhead (Schupp, 1992). The MDNR has indicated that the average water quality for a Class 42 lake is a TSI_{SD} (Trophic State Index in terms of Secchi disc transparency) of approximately 62 or lower (i.e., a summer average Secchi disc transparency of about 3.0 feet or greater). The recommendation is based upon the water quality needs of the fishery found in a Class 42 lake.

The last three monitoring years, 1996, 1999, and 2005, produced average Secchi depths of 1.60 m, 0.78 m, and 0.54 m respectively. Corresponding TSI_{SD} are 53.2, 63.5, and 68.9. The trend appears to be steadily declining water transparency. Mitchell Lake's water quality does not meet the recommended TSI_{SD} based upon the 1999 and 2005 data.

Mitchell Lake's fishery currently (2005) consists of panfish, gamefish, and rough fish. The 2005 MDNR fish survey showed that the following species are present in Mitchell Lake:

- Panfish—black crappie, bluegill, hybrid sunfish, and pumpkinseed sunfish
- Gamefish—largemouth bass, northern pike, walleye
- Rough fish—black bullhead

According to the 2005 survey, bluegill and black crappie are the most abundant fish species in Mitchell Lake. Bluegill abundance appears to be down from 1999, but size is similar. The mean length and weight in 1999 was 6.1 inches and 0.1 lb., respectively, and the mean length and weight in 2005 was 6.3 inches and 0.2 lb, respectively. Black crappie had similar numbers and sizes as compared to the 1999 survey.

The northern pike numbers seem to indicate a good potential fishery. Numbers collected were the highest ever for Mitchell Lake and place it in the upper quartile for Class 42 lakes in Minnesota. There are signs that the northern pike population is one the rise as the first three fish were sampled in 1999.

Mitchell Lake will present limited angling opportunities for walleye. Only three walleye (the largest being 17 inches) were sampled in both gill and trap nets, thus abundance appears to be low. Other species sampled in minimal abundance include black bullhead, hybrid sunfish, largemouth bass, and pumpkinseed.

Mitchell Lake is managed by MDNR as a bluegill and largemouth bass fishery. The MDNR operational plan for the lake includes:

1. Annual winter fish house counts
2. Lake survey in 2005 and population assessment in 2011
3. Monitor oxygen levels in cooperation with the Eden Prairie Parks and Recreation Department
4. Net bluegills for stocking into other lakes and kid’s fishing ponds and
5. Continue lake management partnering with the watershed district and Eden Prairie Parks and Recreation Department to improve the lake’s water quality and the aquatic plant and fish community.

The MDNR mid-range goal for the lake is to maintain the present fishing pressure with a fish community represented by bluegill (summer trapnetting) and largemouth bass (spring electrofishing) that will support 100 angler hours per acre. The MDNR long range goal for Mitchell Lake is to establish quality bass-bluegill fishing that is measured by:

1. A largemouth bass electrofishing catch > 20 stock fish per hour with at least 15 of the fish measuring at least 16 inches in length
2. A bluegill summer trap net catch > 30 fish per set with at least 20 of the fish measuring at least 7.5 inches in length and
3. A fishery that is capable of supporting 100 angler hours per acre. No stocking is needed for Mitchell Lake.
4. Mitchell Lake provides good habitat for waterfowl such as ducks and geese.

1.2.7 Natural and Urban Drainage Systems

1.2.7.1 Natural Conveyance Systems

The natural inflow to Mitchell Lake consists of direct runoff from parkland and single family homes surrounding the lake and groundwater inflows.

1.2.7.2 Stormwater Conveyance Systems

Stormwater, treated by 34 treatment ponds and Round Lake, is conveyed to the lake through nine stormwater conveyance systems. Details of each storm water detention system are provided in the UAA Appendix B.

1.2.7.3 Public Ditch Systems

There are no public ditch systems that affect Mitchell Lake.

1.2.8 Water Appropriations

There are no known water appropriations from Mitchell Lake.

Red Rock Lake

August 2008

Contents

Red Rock Lake

1.1 Red Rock Lake Watershed Goals

The approved Riley-Purgatory-Bluff Creek Watershed District Water Management Plan, 1996, (Water Management Plan) inventoried and assessed Red Rock Lake. The plan articulated five specific goals for Red Rock Lake. These goals address recreation, aquatic communities, water quality, water quantity, and wildlife.

1.1.1 Water Quantity

The water quantity goal for Red Rock Lake is to provide sufficient water storage during a regional flood (100-yr, 24-hr storm event).

1.1.2 Water Quality

The MPCA has classified Red Rock Lake as not supporting aquatic recreational use (Trophic State Index (TSI_{SD}) of greater than 57. Partially supporting aquatic recreational use would have a desired range of between 53 and 57. Fully supporting would have a value of less than 53.

1.1.3 Recreation

The primary recreation goal is to achieve full support of fishing activities and maintain waterfowl habitat.

1.1.4 Aquatic Communities

The aquatic communities goal for Red Rock Lake is to maintain a MDNR ecological Class 42 rating, with a TSI_{SD} of 58.7.

1.1.5 Wildlife

The wildlife goal for Red Rock Lake is to protect existing beneficial wildlife uses.

1.1.6 Public Participation

The goal is to encourage public participation in achieving outcomes from the use attainability analysis. To achieve this goal, a public meeting will be called to obtain comments on the use attainability analysis.

1.2 Existing Watershed Conditions

Red Rock Lake is located in the City of Eden Prairie in the southern part of the Riley-Purgatory-Bluff Creek watershed. It drains to Purgatory Creek via McCoy Lake during high water conditions.

1.2.1 Watershed Description

1.2.1.1 Land Use

Land use is an important watershed characteristic that has a direct impact on a lake and its water quality. Increasingly intensive land use will increase both sediment and phosphorus loads, as well as, alter the routine hydrology of a lake and its tributaries. Urbanization can also lead to thermal impacts which in turn can play a role in fisheries habitat. Sound watershed planning needs to consider both existing and future land use.

Land use data was obtained from the Metropolitan Council Generalized Land Use Maps. The maps are based on 2005 existing land use and a projected land use for 2020. Both existing and projected are summarized in Table RRL-1.

RRL-1
Existing and Projected Land Use
Red Rock Lake

Land Use Category	Existing Land Use – 2005 (ac)	Projected Land Use – 2020 (ac)
Agricultural	**8**	**0**
Single Family Residential	**0**	**521**
Medium Density Residential	**0**	**65**
Single Family Detached	**654**	**0**
Single Family Attached	**35**	**0**
MultiFamily Residential	**1**	**0**
Retail and Other Commercial	**4**	**0**
Office	**0.5**	**0.3**
Mixed Use	**2**	**0**
Industrial and Utility	**17**	**30**
Institutional	**92**	**87**
Park, Recreation, or Preserve	**178**	**149**
Right Of Way	**0**	**286**
Major Highway	**45**	**0**
Undeveloped	**115**	**0**
Water	**110**	**124**
Total	**1262**	**1262**

1.2.1.2 Red Rock Lake Major Hydrologic Characteristics

Red Rock Lake has a 1262-acre tributary watershed, a surface area of 71 acres and a mean depth of 5.2 feet.

1.2.2 Red Rock Lake Water Quality

The water quality of a lake provides an indication of how a lake functions. A standardized lake rating system is often used to classify the ecological conditions of a lake. The rating system uses phosphorus, chlorophyll *a*, and Secchi disc transparency values to classify a lake into four categories: Oligotrophic (clear, low productivity lakes with excellent water quality), Mesotrophic (intermediate productivity lakes with good water quality), Eutrophic (high productivity lakes with poor water quality) and Hypereutrophic (extremely productive lakes with poor water quality).

Based on the 1999 and 2005 monitoring data, TSI_{SD} scores were 61.3 and 62.8, respectively, both of which indicate that the lake is not supporting for aquatic recreation use. The 2005 TSI_{SD} score does not meet the aquatic communities goal (TSI_{SD}=58.7). The water quality goal that satisfies all criteria is the fully supporting aquatic recreation goal - TSI_{SD} of 57 or lower.

1.2.2.1 Data Collection

Data for the previous watershed management plan was collected from 1972 to 1994. Additional data was collected in 1999 and 2005.

1.2.2.2 Baseline/Current Water Quality

In general, Red Rock Lake water quality has not changed significantly throughout the more recent monitoring (1999 – 2005). Total phosphorus concentrations were typically in the eutrophic (nutrient rich) category in the spring and increased to a peak in the hypereutrophic (extremely nutrient rich) category in the mid to late summer. Chlorophyll *a* concentrations from the monitoring period show a similar trend. Secchi disc depths start within the eutrophic category and, extend into the hypereutrophic category, again peaking in mid to late summer.

1.2.3 Ecosystem Data

Red Rock Lake is a Class 42 lake. Class 42 lakes are typically shallow, eutrophic lakes. The MDNR has assigned an ecological rating TSI_{SD} of 62 or lower. The lake's current water quality (2005 data) corresponds to a TSI_{SD} of 62.8. Impairment of the Red Rock Lake fishery is caused by high phosphorus levels and severe summer algal blooms. The lake does provide habitat for seasonal waterfowl, through diverse macrophyte communities in a large littoral zone.

1.2.3.1 Aquatic Ecosystems

The Red Rock Lake ecosystem is typical for a eutrophic, temperate lake in this region.

1.2.3.2 Phytoplankton

The phytoplankton species in Red Rock Lake form the base of the lake's food web and directly impacts the lake's fish production. Phytoplankton, also called algae, are small aquatic plants naturally present in all lakes. They derive energy from sunlight (through photosynthesis) and from dissolved nutrients found in lake water. They provide food for several types of animals, including zooplankton, which are in turn eaten by fish. A phytoplankton population in balance with the lake's zooplankton population is ideal for fish production. An inadequate phytoplankton population reduces the lake's zooplankton population and adversely impacts the lake's fishery. Excess phytoplankton, however, reduces water clarity which in turn in interferes with the recreational usage of a lake.

Lake survey results for 1999 and 2005 were analyzed to determine the composition and abundance of phytoplankton in Red Rock Lake. As in years previous to 1999, blue-green (Cyanphyta) and green (Chlorophyta) algae were generally the dominant types of phytoplankton observed in 1999. Blue-green algae were especially dominant in Red Rock Lake from late June to the end of the sampling period (September). The 2004 survey results demonstrated somewhat different results, showing blue-green algae has the dominant type of phytoplankton observed throughout the sampling period. The 1999 and 2005 results are summarized in Figures RRL-4 and RRL-5.

Green algae are edible to zooplankton and serve as a valuable food source. Blue-green algae are considered a nuisance type of algae because they:

- Are generally inedible to fish, waterfowl, and most zooplankters,
- Float at the lake surface in expansive algal blooms,
- May be toxic to animals when occurring in large blooms, and
- Can disrupt lake recreation because they are most likely to be present during the summer months.

Blue-green and green algal growth is stimulated by excess phosphorus loads. The growing conditions during July and August are particularly favorable to blue-greens, and they have a competitive advantage over the other algal species during this time. Hence, phosphorus levels will need to be lowered to reduce blue-green algae populations in Red Rock Lake.

FIGURE RRL-4
Red Rock Lake Phytoplankton Data Summary (1999)

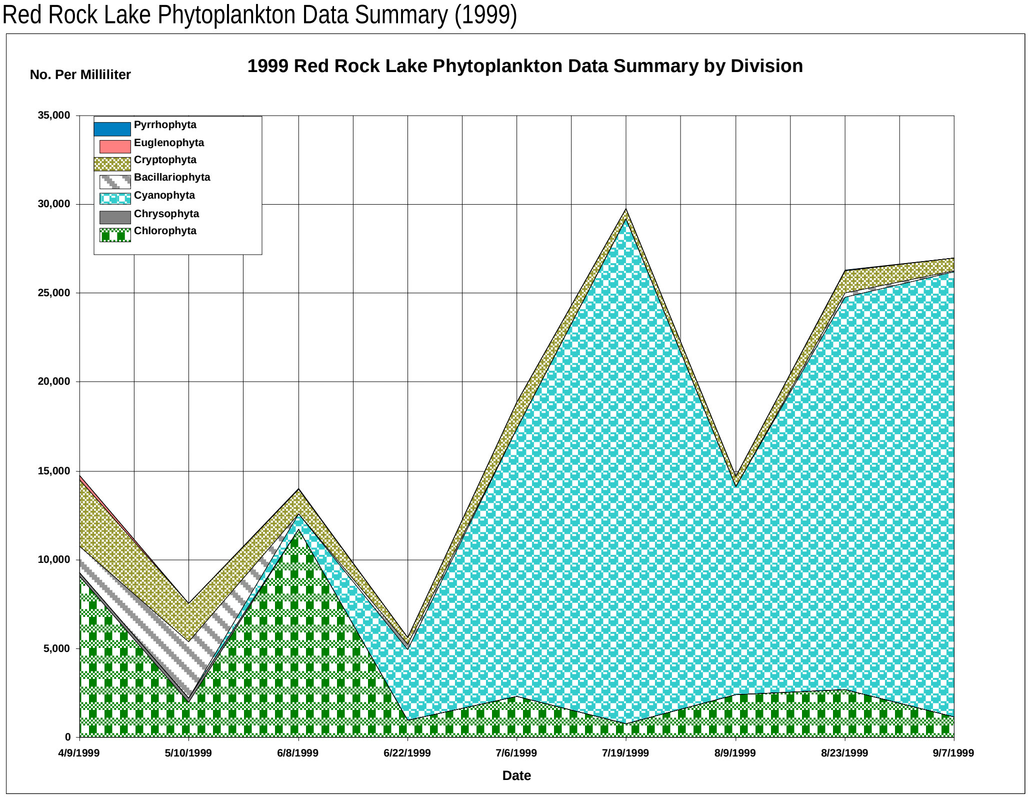
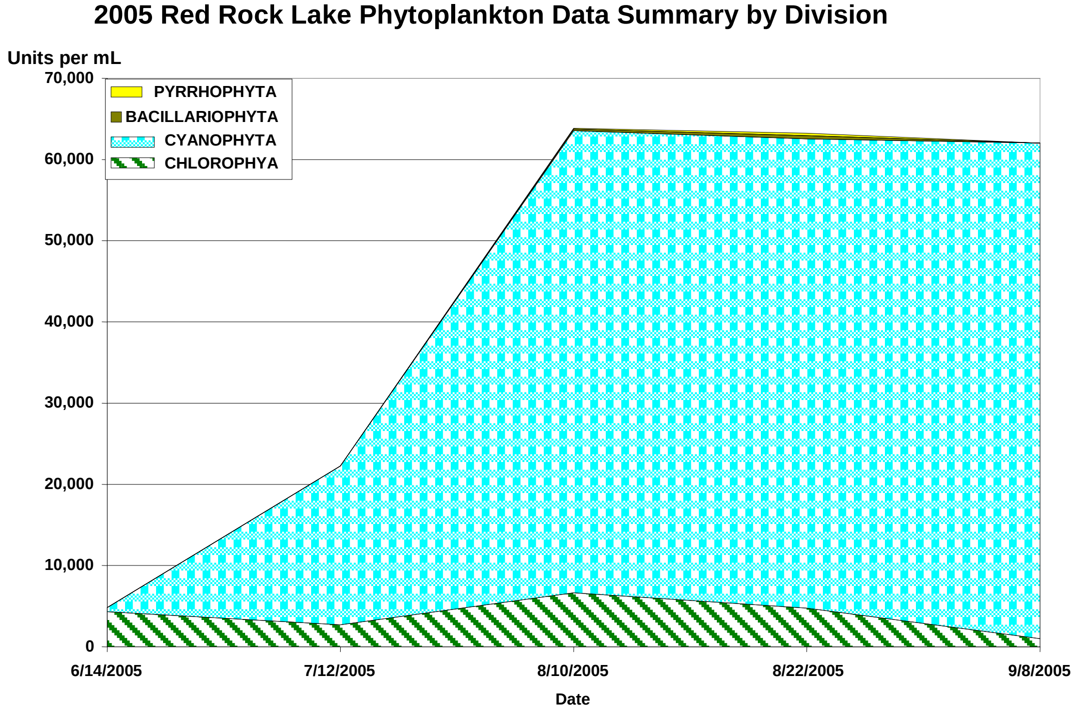


FIGURE RRL-5
Red Rock Lake Phytoplankton Data Summary (2005)



1.2.3.3 Zooplankton

Zooplankton are an important component of the aquatic ecosystem of Red Rock Lake. They are the second step in the Red Rock Lake food webs and are particularly vital to the lake's fishery and for the biological control of algae. They are microscopic animals that feed on particulate matter, including algae, and are, in turn, eaten by fish. Protection or enhancement of the lake's zooplankton community through judicious management practices affords protection to the lake's fishery.

Healthy zooplankton communities are characterized by balanced densities (number per meter squared) of the three major groups of zooplankton: Cladocera, Copepoda, and Rotifera. The rotifera and copepoda in Red Rock Lake graze primarily on extremely small particles of plant matter and do not significantly affect the lake's water quality. However, the cladocera graze primarily on algae and can improve water quality if present in abundance. Fish predation, however, may alter community structure and reduce the numbers of larger-bodied zooplankter (i.e., larger bodied Cladocera).

The 1999 data showed that during the spring, the rotifera were the dominant population, with a shift in the early summer to a more equal balance between the three groups. In late July and early August, rotifera again are the predominate group. By the end of summer and early fall there is another shift to a more equal balance.

The 2005 data showed that a large spike in cladocera growth in early July followed by a rapid crash in its population. Rotifera for the remainder of the summer.

1.2.3.4 Red Rock Lake Macrophytes

Aquatic plants are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. Typical functions of a lake's macrophyte community include the following:

- Provide habitat for fish, insects, and small invertebrates
- Provide food for waterfowl, fish, and wildlife
- Produce oxygen
- Provide spawning areas for fish in early spring/provide cover for early life stage of fish
- Help stabilize marshy borders and protect shorelines from wave erosion
- Provide nesting sites for waterfowl and marsh birds

Macrophyte surveys of the aquatic plant community in Red Rock Lake were completed by the District in June and August of 1993, 1999, and 2005 and are summarized in Table 4.

TABLE 4
Red Rock Lake Aquatic Plants (1993, 1999 and 2005)

Common Name	Scientific Name	1993 Density	1999 Density	2005 Density
Submerged Aquatics				
Curlyleaf pondweed	***P. crispus***	**3**	**1-2**	**1-3**
Flatstem pondweed	***P. zosteriformis***	**--**	**1**	**1**
Sago pondweed	***P. pectinatus***	**2-3**	**1-2**	**1**
Narrowleaf pondweed	***P. spp.***		**1**	**1**
Northern water milfoil	***Myriophyllum sibiricum***		**1**	**1**
Water stargrass	***Zosterella dubia***	**--**	**1-2**	**1-2**
Bladderwort	***Utricularia spp.***		**--**	
Coontail	***Ceratophyllum demersum***	**1**	**1-3**	**1-3**
Elodea	***Elodea canadensis***		**1-2**	**1**
Floating Leaf Plants				
White waterlily	***Nymphaea odorata*** ***Nymphaea turberosa***	**--**	**--**	**--**
Yellow Water Lilly	***Nupar variegatum***		**--**	**--**
American lotus	***Nelumbo lutea***		**--**	**--**
Star duckweed	***Lemna trisulca***		**--**	**--**
Lesser duckweed	***Lemna minor***		**--**	**--**
Greater duckweed	***Spirodela polyrhiza***		**--**	**--**
Common watermeal	***Wolffia columbiana***		**--**	**--**
Emergent Plants				
Bulrush	***Scirpus spp.***	**--**	**--**	**--**

TABLE 4
Red Rock Lake Aquatic Plants (1993, 1999 and 2005)

Common Name	Scientific Name	1993 Density	1999 Density	2005 Density
Cattail	***Typha spp***	--	--	--
Purple loosestrife	***Lythrum salicaria***	--	--	--

-- Plants Present but Density Not Provided in Survey

According to the 1999 and 2005 surveys, macrophytes were identified to a relative depth of 5-6 feet. In some areas, the submerged plants were dominated by a dense growth of coontail (*Ceratophyllum demersum*, a native species) in June and August. Northern watermilfoil (*Myriophyllum sibiricum*) was a prevalent species in June, but dies back later in the summer. Northern watermilfoil, a species native to this region, is often confused with the related undesirable non-native Eurasian watermilfoil (*M. spicatum*). Northern watermilfoil is a desirable species that provides beneficial habitat for the lake's fishery. Curly-leaf pondweed (*Potamogeton crispus*) was also identified in some areas among the submerged plants in June but appeared to die off later in the summer. Curly-leaf pondweed is an undesirable non-native species. It frequently replaces native species in lakes and exhibits a dense growth that may interfere with the recreational use of a lake. A dense growth also creates a refuge for small fish, making it difficult for larger fish, such as bass, to find and capture the small fish they need for food. Purple loosestrife (*Lythrum salicaria*), an undesirable exotic species, was identified among the emergent plants in some areas. This plant should be controlled because it can replace cattails (*Typha sp.*) and subsequently destroy that wildlife habitat.

1.2.4 Water-Based Recreation

Red Rock Lake is used primarily for fishing, as well for other types of recreational activities, including swimming. There is currently a single boat ramp located at the southern end of the lake at Red Rock Lake Park.

1.2.5 Fish and Wildlife Habitat

During 1992, the MDNR classified Red Rock Lake and other Minnesota lakes relative to fisheries (SCAP, 1992). This ecological classification is a function of lake area, percentage of the lake surface area that is littoral, maximum depth, degree of shoreline development, Secchi disc transparency and total alkalinity. According to its ecological classification, Red Rock Lake is a Class 42 lake, which signifies a lake that may be better suited for wildlife than for fish (Schupp, 1992). Red Rock Lake's current conditions indicate that its water quality is does not support the uses for its ecological class.

Red Rock Lake's most abundant fish species in 2005 (according to the MDNR's fisheries survey) were black crappie, bluegill, hybrid sunfish, largemouth bass, northern pike, pumpkinseed sunfish, walleye and yellow perch. Bluegill were by far the most sampled fish in Red Rock Lake, representing 62% of the total catch. Northern pike, walleye and largemouth bass inhabit Red Rock Lake in varying numbers. Although pike numbers are slightly down from last survey, they still are good-sized and moderately abundant. Red Rock Lake has a reputation as a quality bass fishery. Red Rock Lake offers a diverse panfish community consisting of bluegills, black crappies, pumpkinseeds, hybrid sunfish, and yellow perch

Red Rock Lake provides habitat for seasonal waterfowl, such as ducks and geese, through diverse macrophyte communities in a large littoral zone.

1.2.6 Natural and Urban Drainage Systems

1.2.6.1 Natural Conveyance Systems

The inflow to Red Rock Lake comes from surface runoff and groundwater discharge. The stormwater runoff is from Red Rock Lake's direct watershed, both overland and through wetland systems. In 1988, an inlet to Red Rock Lake from Mitchell Lake was installed to accommodate high water level flows. An outlet was also installed to drain overflows into McCoy Lake, which in turn overflows to Staring Lake. In many cases, stormwater conveyance systems in the upland areas discharge into the wetland systems described above, creating an interconnected network of natural and constructed flow paths. For this reason, the natural and constructed stormwater conveyance systems are discussed together in subsequent sections.

1.2.6.2 Stormwater Conveyance Systems

Further information on stormwater conveyance to Red Rock Lake will be investigated in the in course of any future use attainability analysis.

1.2.6.3 Public Ditch Systems

There are no public ditch systems that affect Red Rock Lake.

1.2.7 Water Appropriations

There are no known water appropriations from Red Rock Lake.

Rice Marsh Lake

August 2008

Contents

Rice Marsh Lake

1.1 Lake Watershed Goals

The approved Riley-Purgatory-Bluff Creek Watershed District Water Management Plan (Water Management Plan, 1996) inventoried and assessed all of the District's Lakes including Rice Marsh Lake. The plan articulated five specific goals for Rice Marsh Lake. These goals address recreation, aquatic communities, water quality, water quantity and wildlife. The approved Lake Susan and Rice Marsh Lake Use Attainability Analysis (UAA, 1999) further discusses the characterization of Rice Marsh Lake by evaluating the intended five goals.

1.1.1 Water Quantity

The water quantity goal for Rice Marsh Lake is to provide sufficient water storage during regional flood (100-yr, 24-hr storm event).

1.1.2 Water Quality

The MPCA has not classified Rice Marsh Lake for support of aquatic recreational use. Rice Marsh Lake water quality reported in the 1996 Plan (TSI_{SD} = 70) does not meet the aquatic communities goal ($TSI_{SD} \leq 58.7$. The District's water quality goal for Rice Marsh Lake is the same as the aquatic communities goal - TSI_{SD} of 58.7or lower.

According to the 1999 UAA, however, its review of available information showed that specific water quality goals for Lake Susan and the downstream lake, Rice Marsh Lake, have not been previously established by the RPBCWD, the MPCA, the MDNR, or by the local municipality (City of Chanhassen). The UAA states that the TSI rating listed in the 1996 Plan can not be construed as a water quality goal for the two lakes. The District's 1996 Plan identifies the TSI rating corresponding to the lake fishery classification system of MDNR, however, MDNR staff indicate that this rating should be considered only as a representative value for a lake of the given fisheries lake class. Therefore, the MDNR cautions that fishery-related TSI values should not be construed as goals for the lakes. Neither have other agencies been involved in goal-setting for these two lakes. Because these lakes are not expected to be widely used for swimming or other full-body contact aquatic recreation, the Minnesota Pollution Control Agency (MPCA) is not involved in setting water quality goals for the lakes. The Cities of Chanhassen and Eden Prairie were not aware of any water quality targets for these lakes, either.

The UAA states that despite the lack of specific water quality targets for the lakes, the RPBCWD expects the two lakes to continue as valued recreational assets to the community. Lake Susan is expected to continue to be used for boating and fishing (although its water quality would not be expected to be generally suitable for swimming. Realistic water quality goals for the lake will therefore be those that protect and enhance these recreational uses for the two lakes.

The UAA consults other sources to identify appropriate water quality targets for the two lakes, and settles on the targets presented in the 1989 Lake Riley Chain of Lakes Improvement Project Work Plan (District, April 5, 1989). The report identifies total phosphorus concentrations consistent with several general lake use categories. The document indicates that a "Level II" water body (supporting boating but not full-body water contact activities such as swimming or scuba diving) should have total phosphorus concentrations in the 45 to 75 µg/L range. A "Level III" water body (supporting fish and wildlife populations, and providing aesthetic viewing) should have total phosphorus concentrations in the 75 to 105 µg/L range. These two ranges provide realistic targets for total phosphorus concentrations for Lake Susan (Level II) and Rice Marsh Lake (Level III).

Based on the above considerations, the UAA recommends that a reasonable water quality goal for Rice Marsh Lake would be to maintain total phosphorus concentrations in the lake at levels lower than 105 µg/L. The lake's history suggests that this total phosphorus would correspond to a chlorophyll *a* concentration of approximately 42 µg/L, and a Secchi transparency of 0.3 m. This Secchi transparency corresponds to a TSI_{SD} = 77. The 2004 data based on summer averages for total phosphorus concentration, chlorophyll *a* concentration, Secchi transparency and corresponding TSI_{SD} are 67.79 µg/L, 8.55 µg/L, 1.63 m and 53.0, respectively. This data indicates that Rice Marsh Lake's water quality has significantly improved since the 1996 Plan, and is currently far better than lakes in its category.

1.1.3 Recreation

The recreation goal is to fully support designated fishing and wildlife habitat.

1.1.4 Aquatic Communities

The fisheries goal for Rice Marsh Lake is to maintain a MDNR ecological class 42 rating with TSI_{SD} of 58.7 or lower.

1.1.5 Wildlife

The wildlife goal for Rice Marsh Lake is to protect existing, beneficial wildlife uses. Achieving this goal supports the recreational goal, as described above.

1.1.6 Public Participation

The goal is to encourage public participation in achieving outcomes from the UAA.

1.2 Existing Watershed Conditions

Rice Marsh Lake is located in the cities of Chanhassen and Eden Prairie in the western part of the Riley-Purgatory-Bluff Creek watershed. It drains to Riley Creek.

1.2.1 Watershed Description

1.2.1.1 Land Use

The land use for the Rice Marsh Lake watershed is summarized in Table 1. The total watershed area is not consistent between the 2005 and 2020 land use survey and the areas reported in the 1996 Watershed Management Plan from a 1991 survey and areas reported in the UAA in a 1997 survey. While firm conclusions cannot be confirmed with the data, it appears that residential land use has decreased as has agricultural, industrial, parks and open areas. These are consistent with the 2020 projected land use. Commercial land use appears to have increased; again, consistent with 2020 projections.

TABLE 1
Summary of Past and Projected Land Use Acreage – Rice Marsh Lake

Land Use Category	1991 [1]	1997 [2]	2005 [3]	2020 [3]
Single Family & Low Density Residential	378	98	273.63	267.64
Medium Density Residential	19	165	28.16	77.63
High Density Residential	*	53	22.56	15.19
Commercial	26	139	134.54	121.45
Agricultural	*	69	30.67	*
Industrial	50	13	13.07	*
Parks + Open	348	257	285.87	128.03
Highway/Roads	*	22	32.32	224.48
Water	*	*	83.04	86.88
Institutional (School, etc)	*	37	51.36	33.92
Total	821	853	955.22	955.22

* Land use category not reported
1. Data from 1996 Watershed Plan.
2. Data from 1999 Lake Susan and Rice Marsh Lake UAA.
3. Metropolitan Council, Generalized Land Use 2005 for the Twin Cities Metropolitan Area and Regional Planned Land Use - Twin Cities Metropolitan Area.

1.2.1.2 Major Hydrologic Characteristics

Rice Marsh Lake has a 956-acre watershed, a surface area of 81 acres, a maximum depth of approximately 10 feet, and a mean depth of approximately 5 feet. The lake volume is approximately 350 acre-feet. Riley Creek is the inlet (from Lake Susan) and outlet (to Lake Riley) for Rice Marsh Lake.

Per the 1999 UAA, the water level of the lake has varied between 877.0 feet MSL (1978) and 872.0 feet MSL (1976). The lake water level fluctuates relatively little since Rice Marsh Lake is supplied by and drains to Riley Creek and water is not detained significantly by the lake, in general. This feature allows the lake to be considered (for lake water quality modeling purposes) as having volumes that do not vary significantly over time. The water level in the lake is controlled mainly by weather conditions (snowmelt, rainfall, and evaporation) and by the elevation of the streambed of Riley Creek, over which Rice Marsh Lake drains to the southeast.

The UAA states that Rice Marsh Lake is quite shallow, especially in comparison with its large surface area. Therefore, the lake would be expected to be prone to frequent wind-drive mixing of the lake’s shallow and deep waters during the summer. One would therefore expect Lake Susan to be polymictic (mixing many times per year) as opposed to lakes with deep, steep-sided basins that are usually dimictic (mixing only twice per year). Daily monitoring of the lake would be necessary to precisely characterize the mixing dynamics of a lake, but the limited data gathered from Rice Marsh Lake strongly suggests that the lake is indeed polymictic.

1.2.2 Rice Marsh Lake Water Quality

The water quality of a lake provides an indication of how a lake functions. A standardized lake rating system is often used to classify the ecological conditions of a lake. The rating system uses phosphorus, chlorophyll *a*, and Secchi disc transparency values to classify a lake into four categories: Oligotrophic (clear, low productivity lakes with excellent water quality), Mesotrophic (intermediate productivity lakes with good water quality), Eutrophic (high productivity lakes with poor water quality) and Hypereutrophic (extremely productive lakes with poor water quality).

1.2.2.1 Data Collection

Data for the previous watershed management plan was collected from 1972 through 1994. Additional data was collected in 1997 to support the Rice Marsh Lake UAA. An additional sampling year was accomplished in 2004.

1.2.2.2 Baseline/Current Water Quality

Rice Marsh Lake water quality has improved throughout the more recent monitoring period (1997-2004).

Total phosphorus concentrations in 2004 were lower than in 1997, although concentrations still remained in the hypereutrophic category for the most of the sampling season (Figure RM-1). Similarly, chlorophyll *a* concentrations have decreased (Figure RM-2), and concentrations are no longer in the hypereutrophic category as in 1997, but now in the eutrophic category, for most of the sampling season. Secchi disc transparency has increased over this period, moving from the hypereutrophic category to the eutrophic category for most of the sampling season (Figure RM-3).

FIGURE RM-1
Rice Marsh Lake Total Phosphorus.

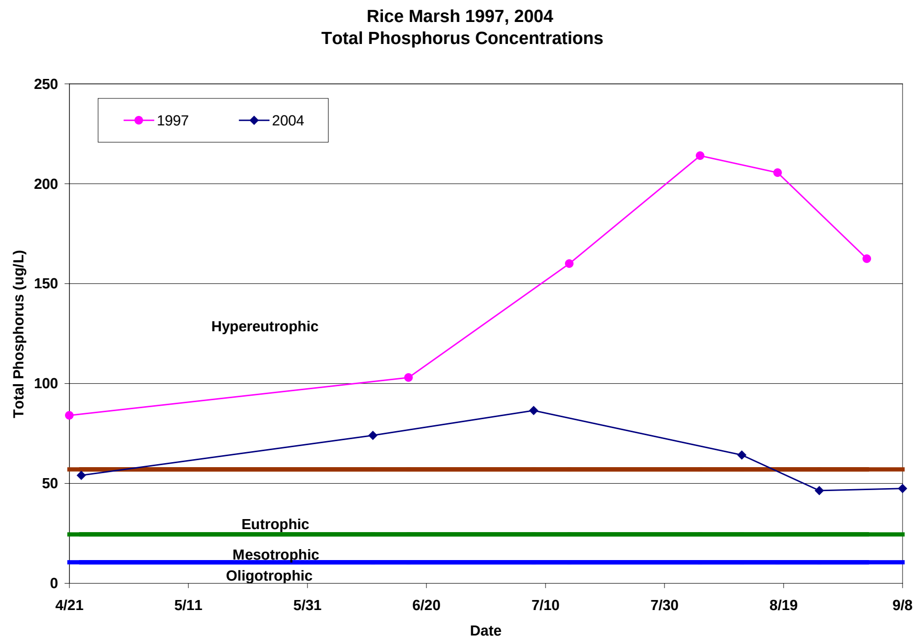


FIGURE RM-2
Rice Marsh Lake Chlorophyll *a*.

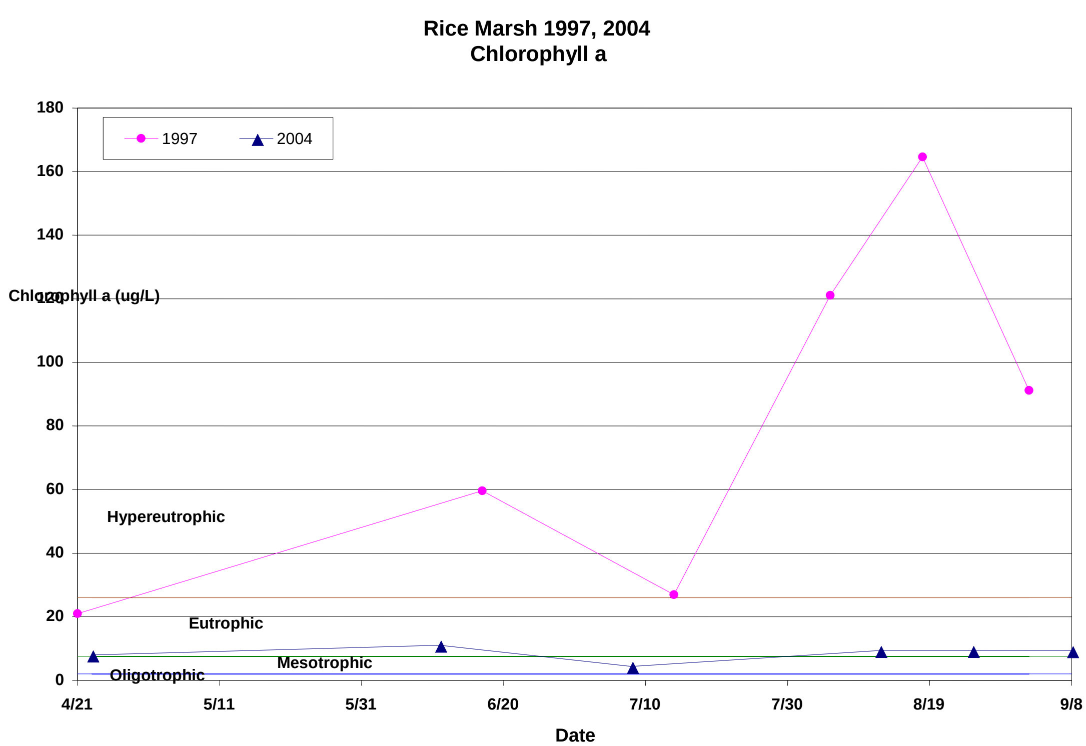
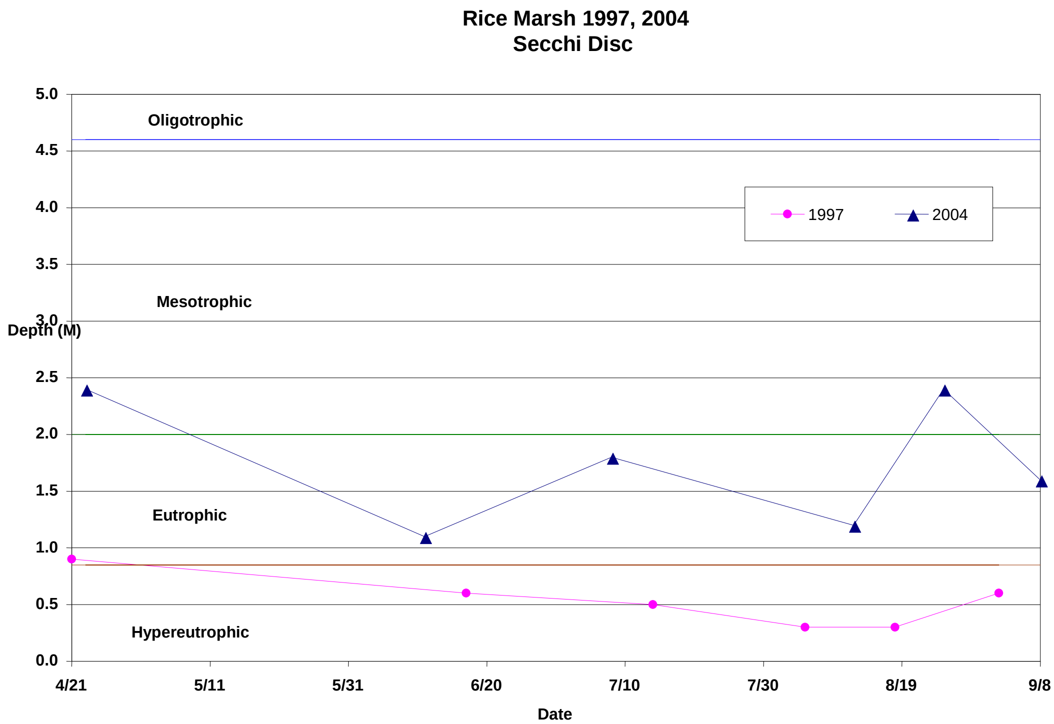


FIGURE RM-3
Rice Marsh Lake Secchi Disc



1.2.3 Ecosystem Data

According to the MDNR's classification system, Rice Marsh Lake is a Class 42 lake. Lakes in this category, being relatively shallow and eutrophic, can be expected to experience frequent winterkills. The MDNR considers lakes of this class to be "marginal" fish lakes, and suggests that they may be better suited for wildlife than for support of a thriving game fish population. The MDNR has indicated that ecological rating for Class 42 is a TSI_{SD} of 58.7. This is based on the aquatic communities goal. The lake's current water quality (2004 data) corresponds to a TSI_{SD} of 53, indicating that its condition is considered better than the average lake in its ecological class.

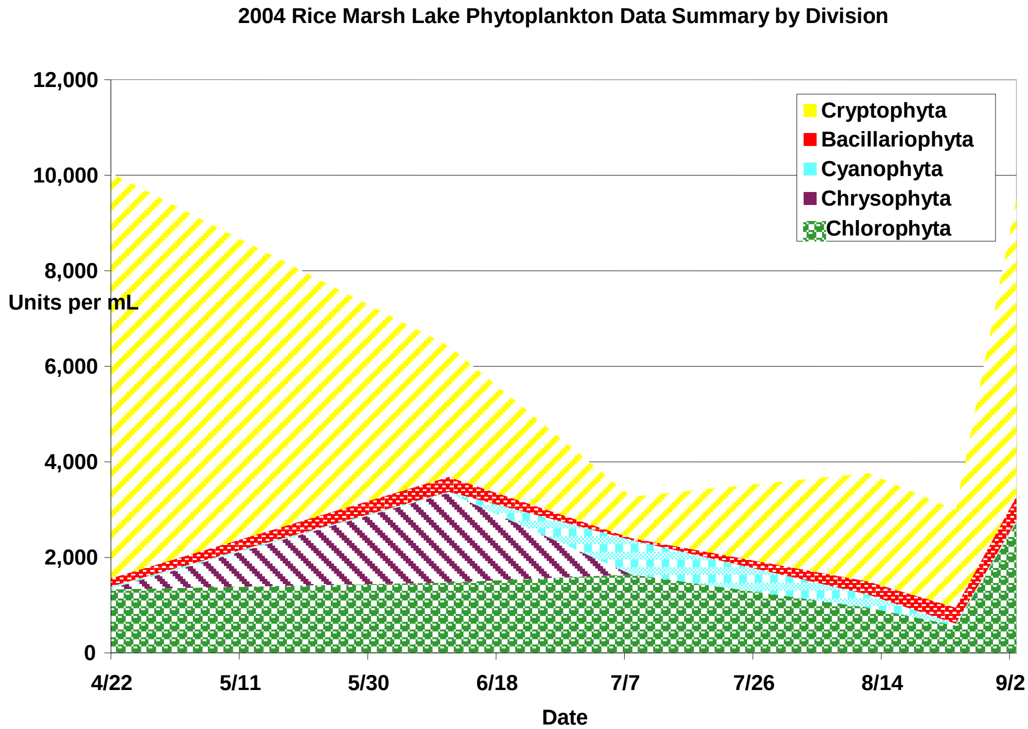
1.2.3.1 Aquatic Ecosystems

According to the UAA, the Rice Marsh Lake ecosystem shows characteristics typical of hypereutrophic lakes.

1.2.3.2 Phytoplankton

Based on 2004 data, the phytoplankton community was dominated by Cryptophyta and Chlorophya (green algae) through most of the sampling season. Cyanophyta were significantly less in abundance as compared to historical data from the 1996 Plan and the 1999 UAA. The data is summarized in Figure RM-4.

FIGURE RM-4
Rice Marsh Lake Phytoplankton Data Summary (2004)

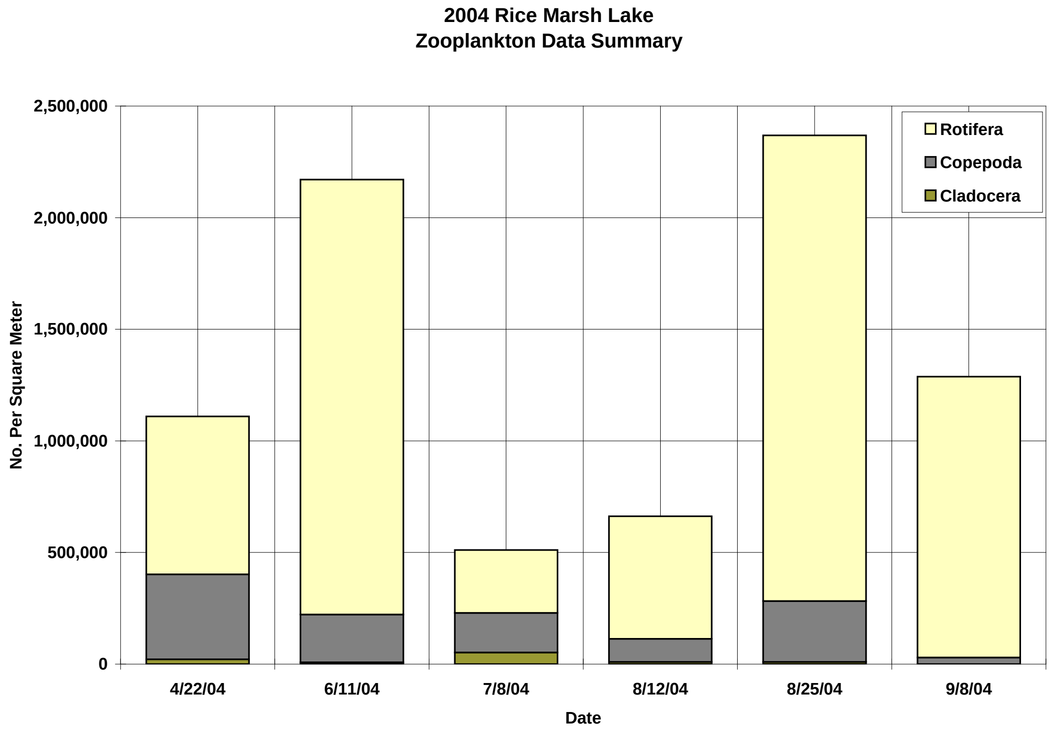


1.2.3.3 Zooplankton

In 2004, Rotifera was the dominant species in the zooplankton community through the entire sampling season. This is somewhat different from the historical data from the 1996 Plan and 1999 UAA which show a smaller rotifer population, but a larger and more stable copepod population for Rice Marsh Lake. The data is summarized in Figure RM-5.

The rotifers and copepods in lakes graze primarily on extremely small particles of plant matter and therefore do not significantly affect lake water transparency by removing algae. By contrast, cladocera graze primarily on algae and can increase transparency if they are present in abundance.

FIGURE RM-5
Rice Marsh Lake Zooplankton Data Summary (2004)



1.2.3.4 Macrophytes

Recent macrophyte surveys of the aquatic plant community in Rice Marsh Lake were completed by the District in June and August of 1994, 1997, and 2004 and are summarized in Table RML-3.

TABLE RML-3
Rice Marsh Lake Aquatic Plants (1994, 1997 and 2004)

Common Name	Scientific Name	1994 Density	1997 Density	2004 Density
Submerged Aquatics				
Pondweed	***P. pusillus***	**--**	**1**	**1-2**
Curlyleaf pondweed	***P. crispus***	**1-3**	**1**	**1**
Flatstem pondweed	***P. zosteriformis***	**1-2**	**--**	**--**
Sago pondweed	***P. pectinatus***	**2**	**1-2**	**1-2**
Water stargrass	***Zosterella dubia***	**--**	**--**	**1-2**
Star duck weed	***Lemna trisulca***	**--**	**1**	**--**
Coontail	***Ceratophyllum demersum***	**1-3**	**1-3**	**1-3**
Elodea	***Elodea Canadensis***	**--**	**--**	**1**
Bushy pondweed and naiad	***Najas flexilis***	**--**	**--**	**1-2**
Floating Leaf Plants				

TABLE RML-3
Rice Marsh Lake Aquatic Plants (1994, 1997 and 2004)

Common Name	Scientific Name	1994 Density	1997 Density	2004 Density
White waterlily	***Nymphaea odorata*** ***Nymphaea turberosa***	--	--	--
Water Smartweed	***Polygonum spp.***	--	--	--
Emergent Plants				
Bulrush	***Scirpus spp.***	--	--	--
Cattail	***Typha spp***	--	--	--
Purple loosestrife	***Lythrum salicaria***	--	--	--

In 1994 and 1997, no macrophytes were found at a depth greater than 4-5 feet. In 2004, macrophytes were found throughout the entire waterbody. Purple loosestrife (*Lythrum salicaria*) was observed in all three surveys. This is consistent with previous surveys. Purple loosestrife is an undesirable exotic species that should be controlled because it can replace cattails and subsequently destroy wildlife habitat. The 1994 survey showed that heavy densities of coontail (*Ceratophyllum demersum*) dominated the macrophytes in June. Curlyleaf pondweed (*Potamogeton crispus*) was also present in one area along the eastern shoreline in heavy density. Curlyleaf pondweed is also an undesirable non-native species which frequently replaces native species in lakes and exhibits a dense growth that may interfere with the recreational use of a lake. Light densities of Sago pondweed (*Potamogeton pectinatus*) and Flatstem pondweed (*Potamogeton zosteriformis*) were also observed. By August, the curlyleaf pondweed had died back and moderate densities of coontail, sago pondweed and flatstem pondweed were observed. In the June 1997 survey, the macrophytes were dominated by coontail, with moderate densities of pondweed, and sago pondweed. Curlyleaf pondweed was also present. The community remained relatively unchanged in August. The most recent survey in 2004 demonstrated that coontail remained the dominant species in June and August, showing heavy densities in more areas than in the previous surveys. In June, sago pondweed and curlyleaf pondweed were also observed in moderate and light densities, respectively. In August, sago pondweed and curlyleaf pondweed were still present. The management of the invasive species – purple loosestrife and curlyleaf pondweed – will be important in protecting Rice Marsh Lake's water quality and lake habitat.

1.2.4 Water-Based Recreation

According to the 1996 Plan, Rice Marsh Lake is used mainly as a waterfowl nesting area and at the time, the recreational value of the lake is directed towards viewing waterfowl. The lake also has an important role as a fish spawning area for other area lake, particularly Lake Riley (UAA, 1999).

1.2.5 Fish and Wildlife Habitat

According to MDNR's ecological classification, Rice Marsh Lake is a Class 42 lake. Class 42 lakes, being relatively shallow and eutrophic, can be expected to experience frequent winterkills. The MDNR considers lakes of this class to be “marginal” fish lakes, and suggests that they may be better suited for wildlife than for support of a thriving game fish population. The MDNR has indicated that the mean TSI_{SD} for this ecological class is 58.7 or lower. The lake’s 2004 water transparency corresponds to a TSI_{SD} of 53.

The primary fish populations for Class 42 lakes would be expected to be comprised of white sucker, bluegill, and black bullhead. Secondary (less numerous) populations for Class 42 lakes typically would include northern pike, pumpkinseed sunfish, black crappie and yello perch.

According to the 1999 UAA, because Rice Marsh Lake is not considered to be a significant regional fishery, the MDNR does not conduct fish surveys on the lake. However, the MDNR has noted that Rice Marsh Lake does serve as an important spawning area for northern pile migrating upstream from Lake Riley. It also appears to serve as a spawning area for carp.

The diverse macrophyte communities of Rice Marsh Lake provide habitat for seasonal waterfowl, such as ducks and geese. Its large fringe wetland area also provides important refuge and nesting habitat for many other wildlife species, including birds, mammals and amphibians.

1.2.6 Natural and Urban Drainage Systems

1.2.6.1 Natural Conveyance Systems

The inlet flow to Rice Marsh Lake comes from Riley Creek on the west side, via a fairly well-defined channel. Another identifiable point of inflow is at the east end of the lake, where a pond network discharges directly to the lake’s open water. Much of the water reaching the open water portion of Rice Marsh Lake arrives indirectly, forced to diffuse through the wetland fringe surrounding the lake. Such is the case with the water arriving via the intermittent creeks that drain the north and northwest portions of the lake’s watershed, for the water flowing from the southeastern and southwestern subwatersheds, and from the lake’s direct subwatersheds. The outlet of Rice Marsh Lake on the south is a continuation of Riley Creek that flows to Lake Riley.

1.2.6.2 Stormwater Conveyance Systems

The 1996 Plan and 1999 UAA do not further discuss the stormwater conveyance systems for Rice Marsh Lake.

1.2.6.3 Public Ditch Systems

There are no public ditch systems that affect Rice Marsh Lake.

1.2.7 Water Appropriations

There are no known water appropriations from Rice Marsh Lake.

Round Lake

August 2008

Contents

Round Lake

1.1 Round Lake Watershed Goals

1.1.1 Water Quantity

The water quantity goal for the lake is to provide sufficient water storage during a regional flood to prevent flooding of shoreline residents. The regional flood is defined as 100-year, 24-hour storm. This goal was achieved with the construction of an outlet at Round Lake as part of the Eden Prairie Chain-of-Lakes Basic Water Management Project (UAA, 1999).

1.1.2 Water Quality

The water quality goal is a Trophic State Index (TSI_{SD}) score that meets or exceeds the necessary level to attain and maintain full support of swimming and fishing, as defined in the *MPCA Use Support Classification for Swimming Relative to Carlson's Trophic State Index by Ecoregion*. This requires a TSI_{SD} of 53 or lower.

The water quality goal has not been achieved, but it can be achieved if watershed best management practices are implemented (UAA, 1999).

1.1.3 Recreation

The recreation goal is the same as the water quality goal: to attain and maintain fully supporting fishing and swimming use.

1.1.4 Aquatic Communities

The fisheries goal is to maintain a MDNR ecological class 30 rating with a TSI_{SD} of 52.8.

1.1.5 Wildlife

The wildlife goal is to protect existing beneficial wildlife uses.

1.1.6 Public Participation

The public participation goal is to encourage public participation in achieving outcomes recommended from the UAA.

1.2 Existing Watershed Conditions

Round Lake is located in the City of Eden Prairie and is part of the Riley-Purgatory-Bluff Creek watershed. Round Lake drains to Mitchell Lake.

1.2.1 Watershed Description

1.2.1.1 Land Use

The land use for the Round Lake watershed is summarized in Table 1. The total watershed area is not consistent between the 2005 and 2020 land use survey and the areas reported in the 1996 Watershed Plan from a 1991 survey and areas reported in the UAA in a 1997 survey. While firm conclusions cannot be confirmed with the data, it appears that residential land use has increased and open areas have decreased. This is consistent with the projected 2020 land use, however the commercial land use is expected to decrease by 2020.

TABLE 1
Summary of Past and Projected Land Use – Round Lake

Land Use Category	1991 [1]	1997 [2]	2005 [3]	2020 [3]
Single Family & Low Density Residential	289	158	209.91	113.50
Medium Density Residential	23	4	16.07	60.11
Commercial	21	2	84.20	75.30
Parks + Open	150	106	88.47	149.74
Water	*	42	30.78	30.78
High Density Residential	*	9	*	*
Roads	*	59	*	*
Public Sector (High School, etc)	*	64	*	*
Total	**483**	**444**	**429.43**	**429.43**

* Land use category not reported
1. Data from 1996 Watershed Plan.
2. Data from 1999 Round Lake UAA.
3. Metropolitan Council, Generalized Land Use 2005 for the Twin Cities Metropolitan Area and Regional Planned Land Use - Twin Cities Metropolitan Area.

1.2.1.2 Major Hydrologic Characteristics

Round Lake has a 430 acre watershed, a surface area of 32 acres, and a maximum depth of approximately 36 feet, and a mean depth of approximately 11 feet. The Lake's volume, outflow volume and hydrologic residence time vary with climatic conditions, and is summarized in Table 2.

TABLE 2
Round Lake Estimated Volume, Outflow Volume and Hydrologic Residence Time During Varying Climatic Conditions

Climatic Condition (Water Year, Inches of Precipitation)	Average Lake Volume (m^3 / ac-ft)	Estimated Annual Lake Ouflow through Outlet* (m^3/ac-ft)	Hydraulic Residence Time (years)
Wet Year (1983, 41 Inches)	418,856 340	314,600 255	1.3
Average Year (1995, 27 Inches)	418,412 339	27,600 22	15.2

TABLE 2
Round Lake Estimated Volume, Outflow Volume and Hydrologic Residence Time During Varying Climatic Conditions

Model Calibration Year (1997, 34 Inches	418,412 339	70,182 57	6.0
Dry Year (1988, 19 Inches)	378,341 307	0 0	----

Data obtained from Round Lake UAA, June 1999.

1.2.2 Lake Water Quality

A standardized lake rating system is often used to classify the ecological conditions of a lake. The rating system uses phosphorus, chlorophyll *a*, and Secchi disc transparency values to classify a lake into four categories: Oligotrophic (clear, low productivity lakes with excellent water quality), Mesotrophic (intermediate productivity lakes with good water quality), Eutrophic (high productivity lakes with poor water quality) and Hypereutrophic (extremely productive lakes with poor water quality).

1.2.2.1 Data Collection

Data for the previous watershed management plan was collected from 1972 to 1994. Additional data was collected in 1996 and 1997 to support the 1999 Round Lake UAA. Round Lake was also sampled in 2001, 2002, 2003, and 2004 for water quality.

1.2.2.2 Baseline/Current Water Quality

In general, Round Lake water quality trends were mixed over the period 1996-2006, though some trends imply the water quality has improved. The 1997 measurements of phosphorus were well into the hypereutrophic (extremely nutrient rich) category in the summer months, while measurements taken between 2001 and 2004 remained within the eutrophic (nutrient rich) category (Figure RO-1).

Chlorophyll *a* concentrations from the monitoring period show mixed results. Though the months sampled do not fully correspond from year to year, it appears the Chlorophyll a concentrations were higher in 2000 than in 1996 or 2005 (Figure RO-2). Secchi disk depths for the sample years 1996 and 2000 are within the eutrophic range, while 2005 measurements show the lake was mesotrophic, or less than eutropic, during the early summer months (Figure RO-3). The Round Lake UAA stated that the average summer Secchi disc transparency declined from 3.2 meters in 1972 to 1.5 meters in 1997. The averages in Secchi depth over the 1997-2006 time period are similar to the 1997 average.

FIGURE RO-1
Round Lake Total Phosphorus.

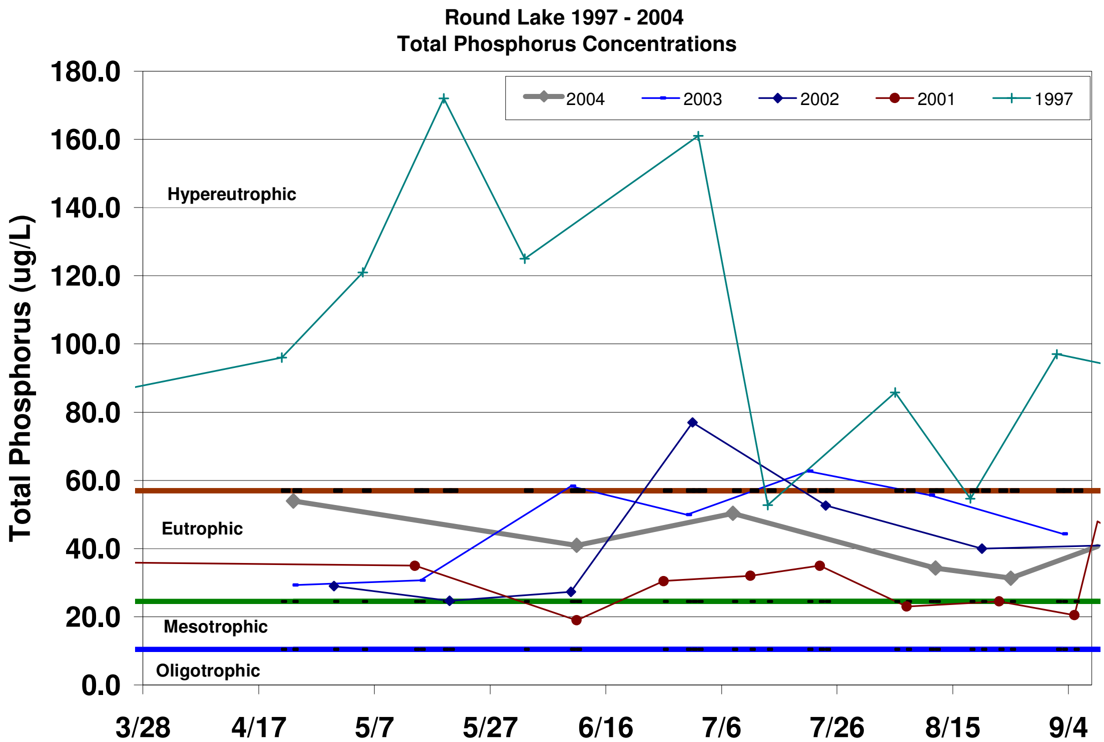


FIGURE RO-2
Round Lake Chlorophyll *a*

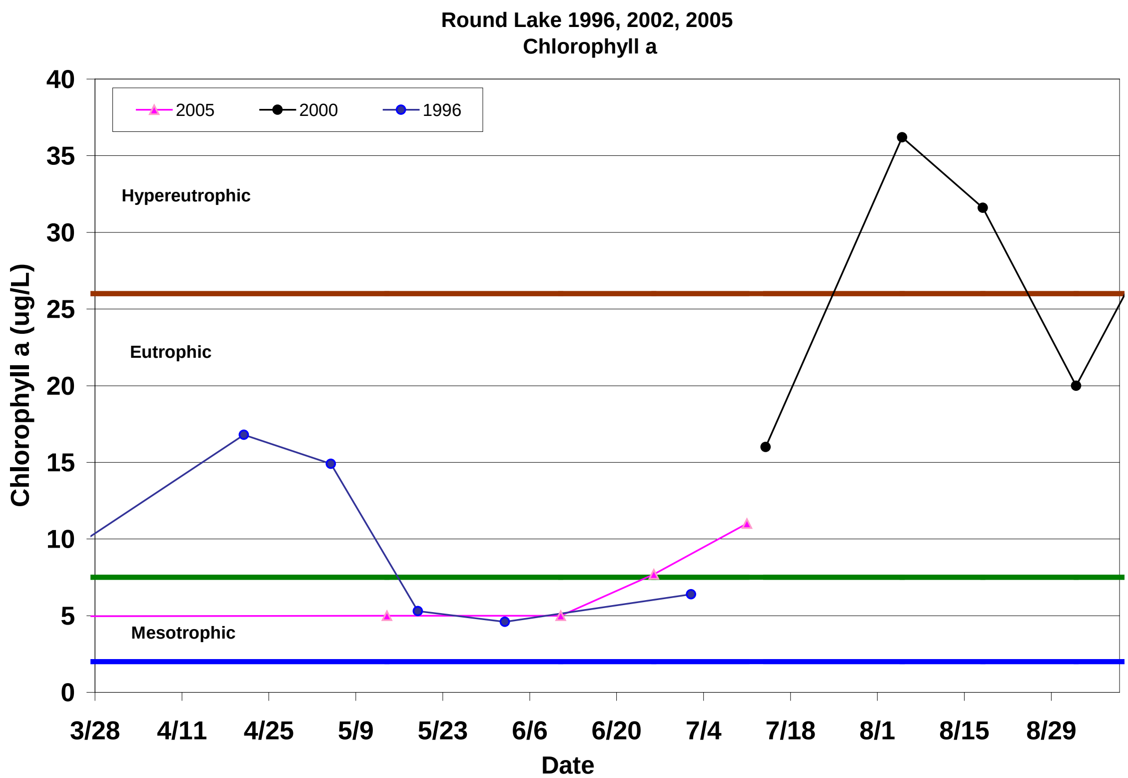
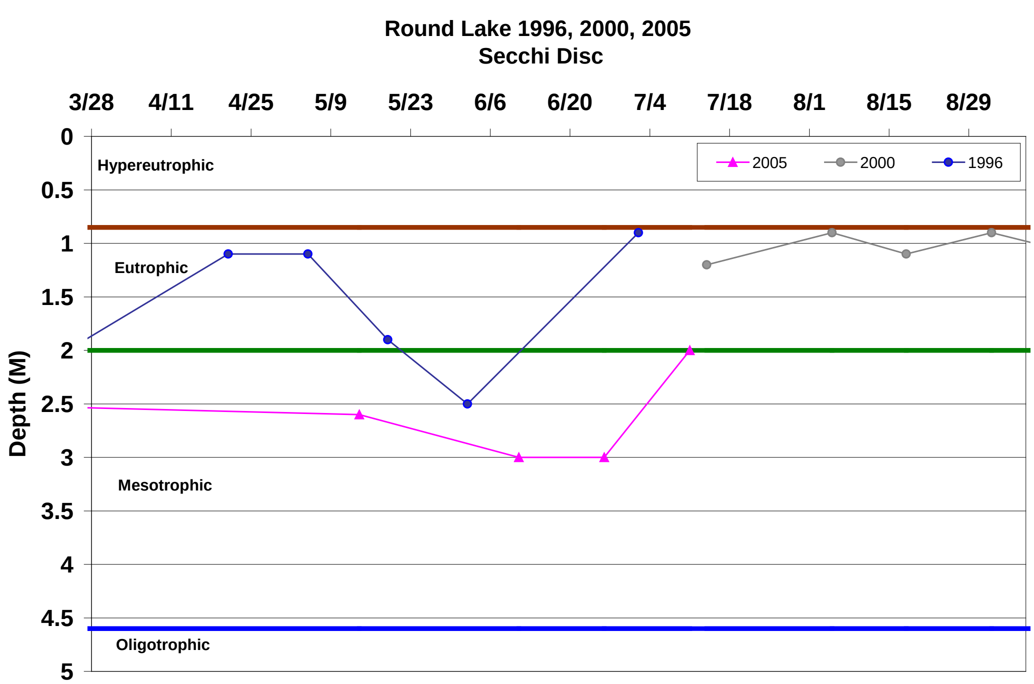


FIGURE RO-3
Round Lake Secchi Disk



1.2.3 Ecosystem Data

Round Lake is a class 30 lake, which signifies a good permanent lake. The MDNR has assigned an ecological classification (TSI_{sd}) of 52.8. The lake water quality, based on 2004 data, corresponds to a TSI_{sd} of 56. Using 2006 data, which did not cover the period of the summer when Secchi Depth would be most limited, yielded a TSISD of 51, but this value is likely skewed lower than actual. The fishery for the lake is close to meeting MDNR criteria, but more monitoring is recommended. Water quality issues are considered the cause of the impairment.

1.2.3.1 Aquatic Ecosystems

According to the UAA, the Round Lake ecosystem is typical for a eutrophic, temperate lake in this region.

1.2.3.2 Phytoplankton

The phytoplankton species in Round Lake form the base of the lake's food web and directly impacts the lake's fish production. Phytoplankton, also called algae, are small aquatic plants naturally present in all lakes. They derive energy from sunlight (through photosynthesis) and from dissolved nutrients found in lake water. They provide food for several types of animals, including zooplankton, which are in turn eaten by fish. A phytoplankton population in balance with the lake's zooplankton population is ideal for fish production. An inadequate phytoplankton population reduces the lake's zooplankton population and adversely impacts the lake's fishery. Excess phytoplankton, however, reduce water clarity which in turn in interferes with the recreational usage of a lake.

Lake survey results for 2003 and 2004 were analyzed to determine the composition and abundance of phytoplankton in Round Lake. As in years previous to 1997, blue-green (Cyanphyta) and green (Chlorophyta) algae were generally the dominant types of phytoplankton observed (UAA). The blue-green algae population peaked in late August in 2003 but peaked in mid-July in 2004. The 2003 and 2004 results are summarized in Figures RO-4 and RO-5.

Green algae are edible to zooplankton and serve as a valuable food source. Blue-green algae are considered a nuisance type of algae because they:

- Are generally inedible to fish, waterfowl, and most zooplankters,
- Float at the lake surface in expansive algal blooms,
- May be toxic to animals when occurring in large blooms, and
- Can disrupt lake recreation because they are most likely to be present during the summer months.

Blue-green and green algal growth is stimulated by excess phosphorus loads. The growing conditions during July and August are particularly favorable to blue-greens, and they have a competitive advantage over the other algal species during this time. Hence, phosphorus levels will need to be lowered to reduce blue-green algae populations in Lake Lucy.

FIGURE RO-4
Round Lake Phytoplankton Data Summary (2003)

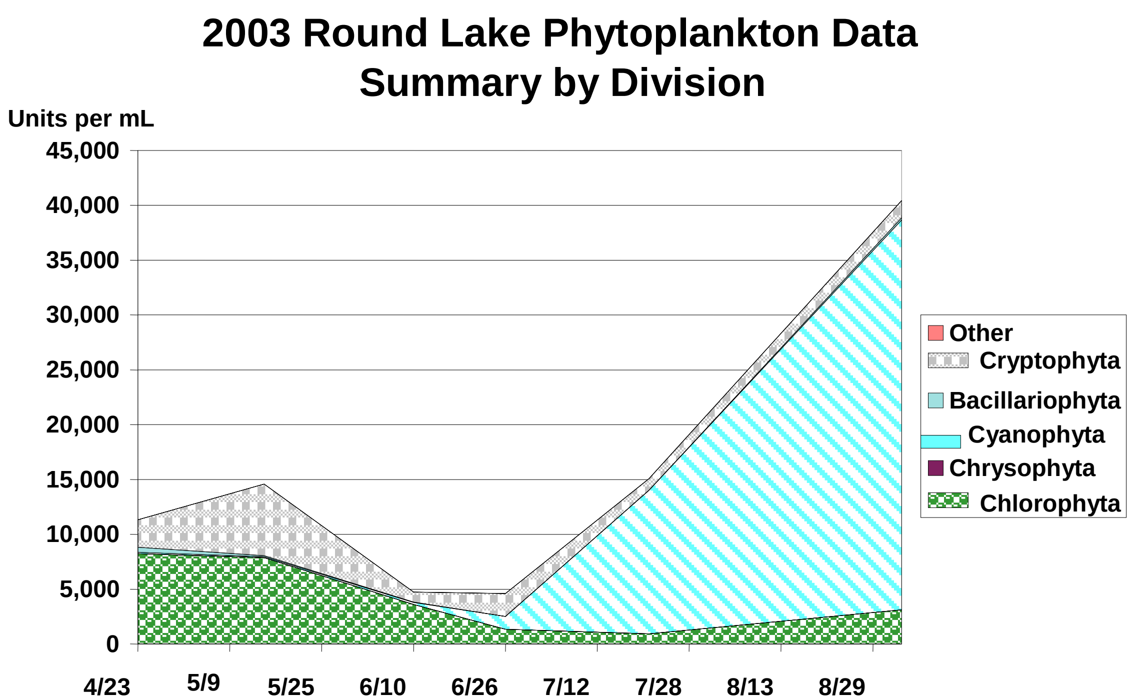
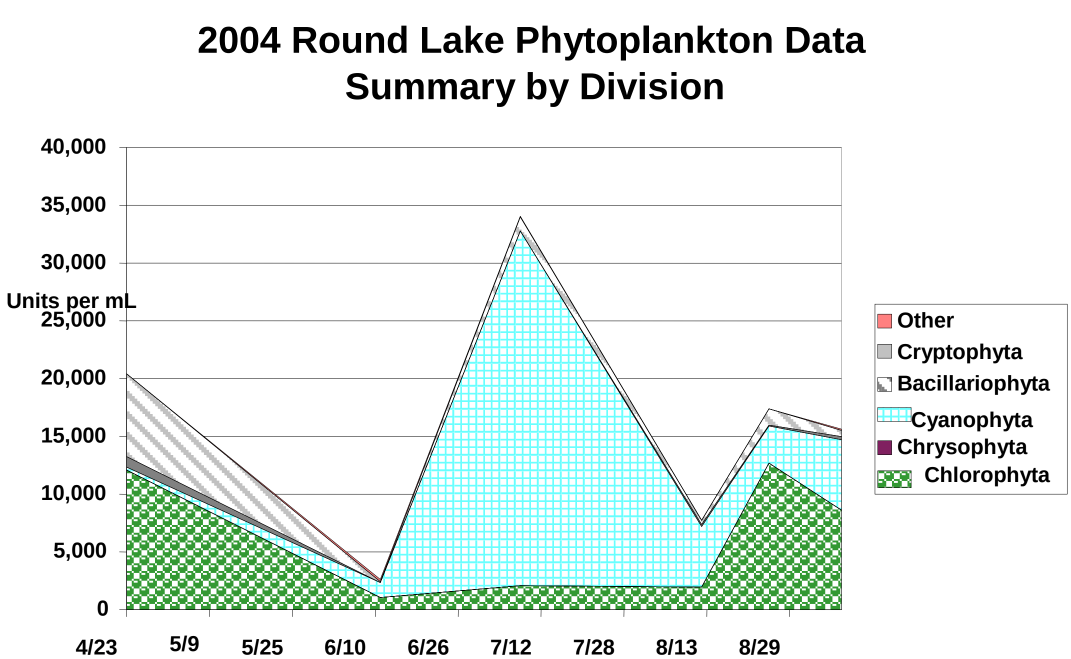


FIGURE RO-5
Round Lake Phytoplankton Data Summary (2004)



1.2.3.3 Zooplankton

Zooplankton are an important component of the aquatic ecosystem of Round Lake. They are the second step in the Round Lake food webs and are particularly vital to the lake's fishery and for the biological control of algae. They are microscopic animals that feed on particulate matter, including algae, and are, in turn, eaten by fish. Protection or enhancement of the lake's zooplankton community through judicious management practices affords protection to the lake's fishery. Healthy zooplankton communities are characterized by balanced densities (number per meter squared) of the three major groups of zooplankton: Cladocera, Copepoda, and Rotifera. Fish predation, however, may alter community structure and reduce the numbers of larger-bodied zooplankters (i.e., larger bodied Cladocera).

According to the 1997 data included in the UAA, cladocera and copepoda were present in small numbers, likely due to predation by the lake's bluegill community. The UAA notes that the 1997 zooplankton community in Round Lake provided food for the lake's fishery, but had little predatory impact on the lake's algal community. The rotifers and copepods in Round Lake graze primarily on extrmemely small particles of plant matter and do not significantly affect the lake's water quality. The cladocera graze primarily on algae and can improve water quality if present in abundance.

The 2003 and 2004 data summaries for Round Lake (Figures RO-6 and RO-7) show Rotifera and Copepoda as the dominant zooplankton types. The Cladocera population peaked in both 2003 and 2004 in June, decreasing to very low levels in August . The low levels of Cladocera throughout both sampled summers suggest this group is out of balance with the Rotifera and Copepoda in the lake.

FIGURE RO-6
Round Lake Zooplankton Data Summary (2003)

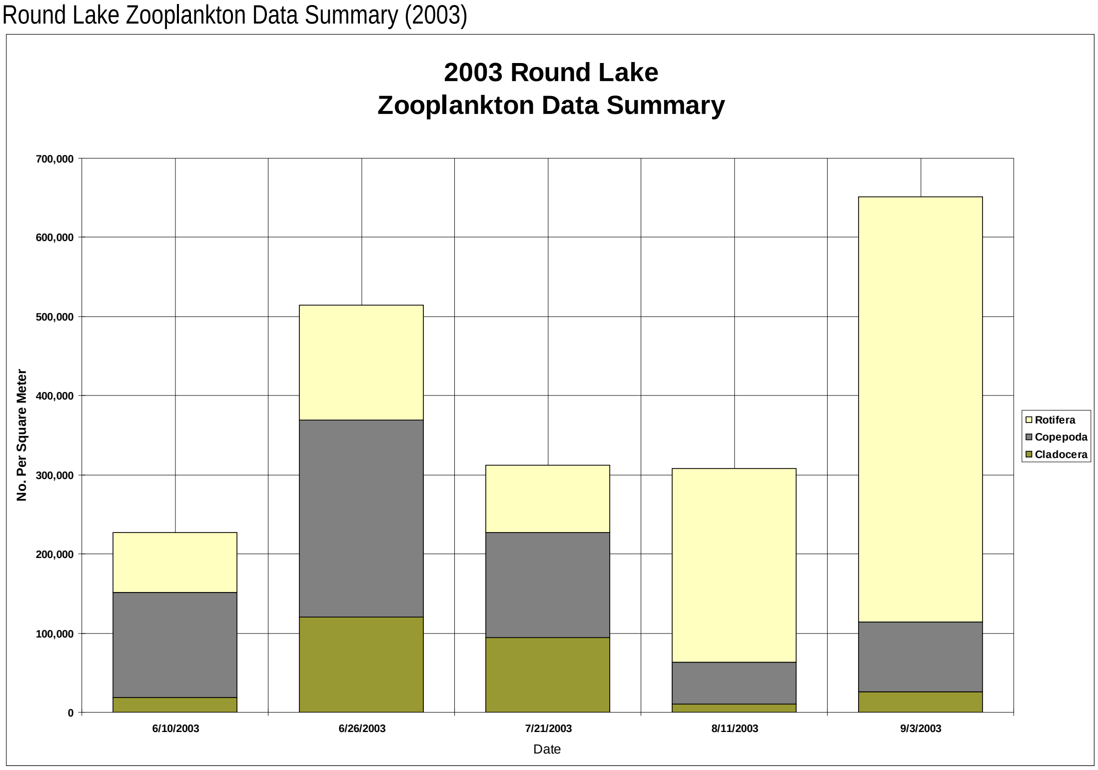
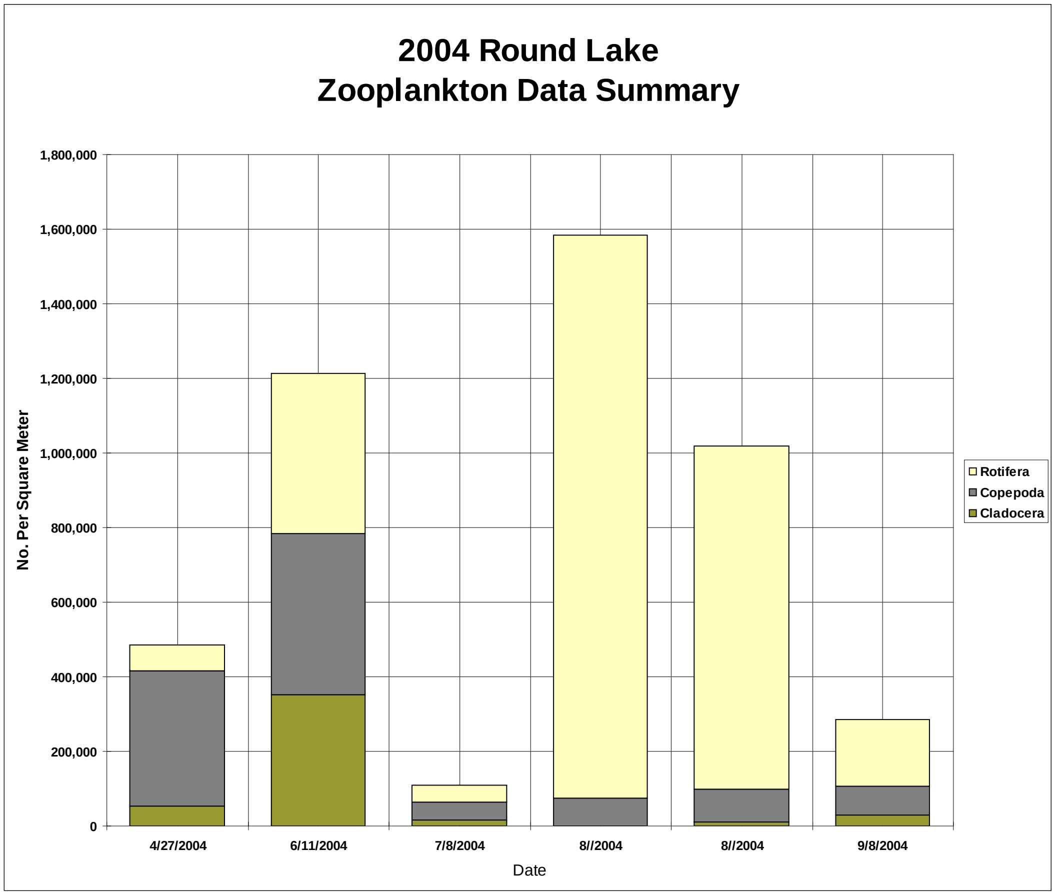


FIGURE RO-7
Round Lake Zooplankton Data Summary (2004)



1.2.3.4 Macrophytes

Aquatic plants are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. Typical functions of a lake's macrophyte community include the following:

- Provide habitat for fish, insects, and small invertebrates
- Provide food for waterfowl, fish, and wildlife
- Produce oxygen
- Provide spawning areas for fish in early spring/provide cover for early life stage of fish
- Help stabilize marshy borders and protect shorelines from wave erosion
- Provide nesting sites for waterfowl and marsh birds

Macrophyte surveys of the aquatic plant community in Round Lake were completed by the District in June and August of 1997, 2001, 2002, 2004 and 2006 and are summarized in Table 3. A density of 1 denotes a light presence of macrophytes, 2: medium, and 3: heavy. Dashed entries denote the presence of the macrophyte in the survey, but no density was given.

TABLE 3
1997, 2001, 2002, 2004 and 2006 Round Lake Aquatic Plants

Common Name	Scientific Name	1997 Density	2001 Density	2002 Density	2004 Density	2006 Density
Submerged Aquatics						
Variable pondweed	***Potamogeton gramineus***		**1**	**1**	**1**	
Largeleaf pondweed	***P. amplifolius***		**1**	**1**	**--**	**--**
Floatingleaf Pondweed	***P. natans***		**1**	**1**	**--**	**--**
Curlyleaf pondweed	***P. crispus***		**1**	**1**	**1**	**--**
Flatstem pondweed	***P. zosteriformis***		**1**	**--**	**--**	**--**
Sago pondweed	***P. pectinatus***	**1**	**--**	**1**	**1**	**1**
Narrowleaf pondweed	***P. spp.***	**--**	**1**	**1**	**1-2**	**1-2**
Northern watermilfoil	***Myriophyllum excalbescens***	**1**				
Water stargrass	***Zosterella dubia***		**1**			**1**
Illinois pondweed	***P. illinoensis***					**1**
Coontail	***Ceratophyllum demersum***	**1-3**	**1-3**	**1-3**	**1-3**	**1-3**
Elodea	***Elodea Canadensis***		**1**	**1**		**1**
Muskgrass	***Chara spp.***		**1**			
Slender naiad	***Najas flexilis***	**1**	**1**	**1**		**1-2**
Eurasian watermilfoil	***M. spicatum***	**1**	**1-3**	**1-3**	**1-2**	**1-2**
Floating Leaf Plants						
White waterlily	***Nymphaea spp.***	**--**	**1-2**	**1-2**	**--**	**--**
Yellow Waterlily	***Nuphar variegatum***	**--**	**1**	**1**	**--**	**--**
Watershield	***Brasenia schreberi***		**1**			
Emergent Plants						
Bulrush	***Scirpus spp.***	**--**	**1**	**1**	**--**	**--**
Cattail	***Typha spp***	**--**	**1**	**1**	**--**	**--**
Purple loosestrife	***Lythrum salicaria***		**1**			
Spikerush	***Eleocharis spp.***		**1**	**1**		

According to the macrophyte surveys, macrophytes were identified to a relative depth of 10 feet. For all survey years, a dense growth of coontail (*Ceratophyllum demersum*, a native species) was present in June and August. Northern watermilfoil (*Myriophyllum* *sibericum/excalbescens*) was noted in the 1997 survey but not in the other surveys. Northern watermilfoil, a species native to this region, is often confused with the related undersirable non-native Eurasian watermilfoil (*M. spicatum*). Northern watermilfoil is a desirable species that provides beneficial habitat for the lake's fishery. Curly-leaf pondweed (*Potamogeton crispus*) was also identified in some areas among the submerged plants during 2001, 2002, and 2004. Curly-leaf pondweed is an undesirable non-native species. It frequently replaces native species in lakes and exhibits a dense growth that may interfere with the recreational use of a lake. A dense growth also creates a refuge for small fish, making it difficult for larger fish, such as bass, to find and capture the small fish they need for food. Purple loosestrife (*Lythrum salicaria*), an undesirable exotic species, was identified among the emergent plants in 2001. This plant should be controlled because it can replace cattails (*Typha sp.*) and subsequently destroy that wildlife habitat.

Eurasian watermilfoil had only been recently observed in Round Lake at the time of the 1999 UAA, but the densities of this undesirable species have increased from moderate to heavy. Management of these species is recommended to protect and/or improve the lake's fishery habitat.

1.2.4 Water-Based Recreation

Round Lake is used for several types of activities, including swimming and fishing. A municipal swimming area and boat access owned by the City of Eden Prairie is located on the eastern shore. A fishing pier extends into the Lake approximately 75-feet at the southeast corner of the Lake. Recreational boating with canoes, sailing and electric powered boats is also popular.

1.2.5 Fish and Wildlife Habitat

Fish habitat within Round Lake is impacted by poor water quality, including phosphorus and sediment loading to the Lake and phosphorus cycling within the Lake. The phosphorus loading has caused algae blooms and has encouraged excessive aquatic plant growth. The MDNR has conducted fish stocking, however this practice will likely have limited long term success until water quality problems are addressed.

The UAA reported that the Lake has refuge for small fish the prevents control of the bluegill community by predators such as bass. Curly leaf pond weed and Eurasian watermilfoil are non native species in the Lake. These species may exhibit an aggressive growth pattern and widespread dense growth may occur in the future. If the two species follow an aggressive growth pattern and eliminate native species, the refuge for smaller fish may increase and cover a larger portion of the lake. This refuge can create greater difficulties by bass and other predator fish to consume the smaller fish that will seek refuge in the vegetation.

The Lake provides good wildlife habitat but the wildlife have undesirable effects on fisheries, water quality and recreation. This is primarily because wildlife, such as geese, provide bacteria and additional phosphorus loads to the Lake. The UAA estimated that the geese population contributes about 8 percent of the annual phosphorus load to the Lake. The Round Lake beach has been closed to the public several times because of high bacteria levels.

1.2.6 Natural and Urban Drainage Systems

1.2.6.1 Natural Conveyance Systems

There are no natural channels that discharge into Round Lake. All tributary flows are direct runoff from the Round Lake watershed, ground water inflow, or through storm sewer discharges. Round Lake outfalls through a pipe located along the south-central shoreline.

1.2.6.2 Stormwater Conveyance Systems

The Round Lake watershed has a developed storm sewer and detention pond network that has six discharge locations into Round Lake.

Ten detention ponds are located in the watershed. The detention ponds provide stormwater detention to reduce flooding potential and the ponds provide water quality improvements by reducing suspended solids and phosphorus loading to Round Lake.

The detention ponds provide a dead storage volume that is displace during a storm event. The dead storage volume water is assumed to be "clean" and is discharge from the pond when "dirty" stormwater enters the pond. The District is currently evaluating the existing storage ponds to determine if they provide enough storage volume to reduce phosphorus loading to the Lake.

1.2.6.3 Public Ditch Systems

There are no public ditch systems within the Round Lake watershed.

1.2.7 Water Appropriations

There are no known water appropriations from Round Lake.

Silver Lake

August 2008

Contents

Silver Lake

1.1 Silver Lake Watershed Goals

The approved Riley-Purgatory-Bluff Creek Watershed District Water Management Plan, 1996, (Water Management Plan) inventoried and assessed the thirteen lakes in the district. The plan articulated five specific goals for these lakes, and the 2003 Silver Lake Use Attainability Analysis refined the watershed for to Silver Lake. These goals address recreation, aquatic communities, water quality, water quantity, and wildlife.

1.1.1 Watershed Goals

1.1.1.1 Water Quantity

The water quantity goal for Silver Lake is to provide sufficient water storage during a regional flood (100-yr, 24-hr storm event). This goal is attainable with no action (UAA, 2003).

1.1.1.2 Water Quality

Silver Lake is unclassified by the MPCA, MDNR, and the City of Chanhassen. Hence, the lake's target water quality goals were based upon the RPBCWD policy of nondegredation of current lake water quality conditions.

The RPBCWD The intended water quality goal is protection of the lake's current water quality. The 1996 plan listed the TSI_{SD} as 70, or a Secchi disk measurement of 0.5 meters (Table IA2). The 2003 UAA states that this goal was based on modeled predictions of the lake's current water quality, and not on actual data. Primary data collected during 1996 and 2000 indicate the lake's average summer Secchi disk measurement was poorer than modeled estimates, but closer to 80. The 2003 UAA recommended a goal change to TSI_{SD} 83 (i.e. Secchi disc measurement of 0.2 meters).

1.1.1.3 Recreation

Water based recreation uses of Silver Lake include canoeing and aesthetic viewing. The lake is not used for swimming due to the snapping turtles living within the lake that create unsafe conditions for swimmers (UAA, 2003). The recreation goals for this lake are currently being met with no additional action.

District lake management policy is nondegredation of the lakes' current water quality and achievement of national and state goals and policies. However, in 2001, changes in state lake management criteria were made that were based on the assumption that all waters of the state must achieve a full support of swimmable use. The criteria are both unreasonable and unattainable for Silver Lake. The state criteria change mandates a District policy change. The recommended change in District policy is to achieve national and state criteria deemed reasonable by the District and work to affect change in unreasonable criteria.

1.1.1.4 Aquatic Communities

The aquatic communities goal for Silver Lake is preservation of the lake's wetland habitat. The habitat is used by seasonal waterfowl, such as ducks and geese, and other aquatic life. The goal has been attained. However, nuisance non-native plants threaten future non-attainment of the goal. Management of non-native plants will insure continued goal attainment (UAA, 2003).

1.1.1.5 Wildlife

The wildlife goal for Silver Lake is to protect existing beneficial wildlife uses. The wildlife goal can be achieved with no action. (UAA, 2003)

1.2 Existing Watershed Conditions

Silver Lake is located in the City of Shorewood in the northwestern part of the Riley-Purgatory-Bluff Creek watershed. The outlets to Silver and Lotus Lakes are the beginning of Purgatory Creek. The two streams later merge to become a single stream.

1.2.1 Watershed Description

1.2.1.1 Land Use

Land use is an important watershed characteristic that has a direct impact on a lake and its water quality. Increasingly intensive land use will increase both sediment and phosphorus loads, as well as alter the routine hydrology of a lake and its tributaries. Urbanization can also lead to thermal impacts which in turn can play a role in fisheries habitat. Sound watershed planning needs to consider both existing and future land use.

Land use data was obtained from the Metropolitan Council Generalized Land Use Maps. The maps are based on 2005 existing land use and a projected land use for 2020. Both existing and projected are summarized in Table SI-1. No land use changes are anticipated as this watershed is fully built out. The small differences in the single family residential and parkland numbers are accounted for in the 2020 accounting of total road right-of-ways. The 2005 existing land use data set includes only major highways, grouping smaller right-of-ways in with residential developments, commercial areas, or other land uses.

TABLE SI-1

Silver Lake Existing and Projected Land Use

Land Use	2005 Existing Area (ac)	2020 Projected Area (ac)
Single family or low density residential	**254.73**	**245.19**
Parks, undeveloped land and other open areas	**10.94**	**3.57**
Major Highway/Road Right-of-Way (2020)	**0**	**17.41**
Water	**94.78**	**95.76**

TABLE SI-1

Silver Lake Existing and Projected Land Use

Land Use	2005 Existing Area (ac)	2020 Projected Area (ac)
Single family or low density residential	**254.73**	**245.19**
Total	**361**	**361**

1.2.1.2 Major Hydrologic Characteristics

Silver Lake has a 361-acre tributary watershed, a surface area of 84.4 acres (during a year of average precipitation) at a lake elevation of 898 feet, a maximum depth of approximately 13 feet, and a mean depth of 3.0 feet. The UAA determined that the lakes' volumes, outflow volumes, and hydrologic residence times vary with climatic conditions (Table SI-2).

TABLE SI-2

Silver Lake Estimated Volumes, Outflow Volumes and Hydrologic Residence Times

Climatic Condition (Water Year, Inches of Precipitation)	Estimated Lake Volume (m^3 / ac-ft)	Estimated Annual Lake Ouflow* (m^3/ac-ft)	Estimated Hydraulic Residence Time (years)
Wet Year (1983, 41 Inches)	248,042 / 201	259,250 / 210	1
Average Year (1995, 27 Inches)	248,042 / 201	76,328 / 62	3
Model Calibration Year (1997, 34 Inches	248,042 / 201	39,365 / 32	6
Dry Year (1988, 19 Inches)	248,042 / 201	8,556 / 7	17.3

Source: Silver Lake Use Attainability Analysis (Barr Engineering, May 2003)

1.2.2 Silver Lake Water Quality

The water quality of a lake provides an indication of how a lake functions. A standardized lake rating system is often used to classify the ecological conditions of a lake. The rating system uses phosphorus, chlorophyll *a*, and Secchi disc transparency values to classify a lake into four categories: Oligotrophic (clear, low productivity lakes with excellent water quality), Mesotrophic (intermediate productivity lakes with good water quality), Eutrophic (high productivity lakes with poor water quality) and Hypereutrophic (extremely productive lakes with poor water quality).

1.2.2.1 Data Collection

Data for the previous watershed management plan was collected from 1972 to 1994. Additional data was collected in 1996 and 2000 to support the Silver Lake UAA. An additional sampling year was accomplished in 2005.

1.2.2.2 Baseline/Current Water Quality

In general, Silver Lake water quality has not changed significantly throughout the more recent monitoring (1996 – 2006).

Total phosphorus concentrations were typically in the eutrophic (nutrient rich) category in the spring and increased to a peak in the hypereutrophic (extremely nutrient rich) category in the mid to late summer (Figure SI-1). Chlorophyll *a* concentrations from the monitoring period show a similar trend. Secchi disc depths start within the eutrophic category and, extend into the hypereutrophic category for most of the summer (Figure SI-2 and Figure SI-3).

FIGURE SI-1
Silver Lake Total Phosphorus

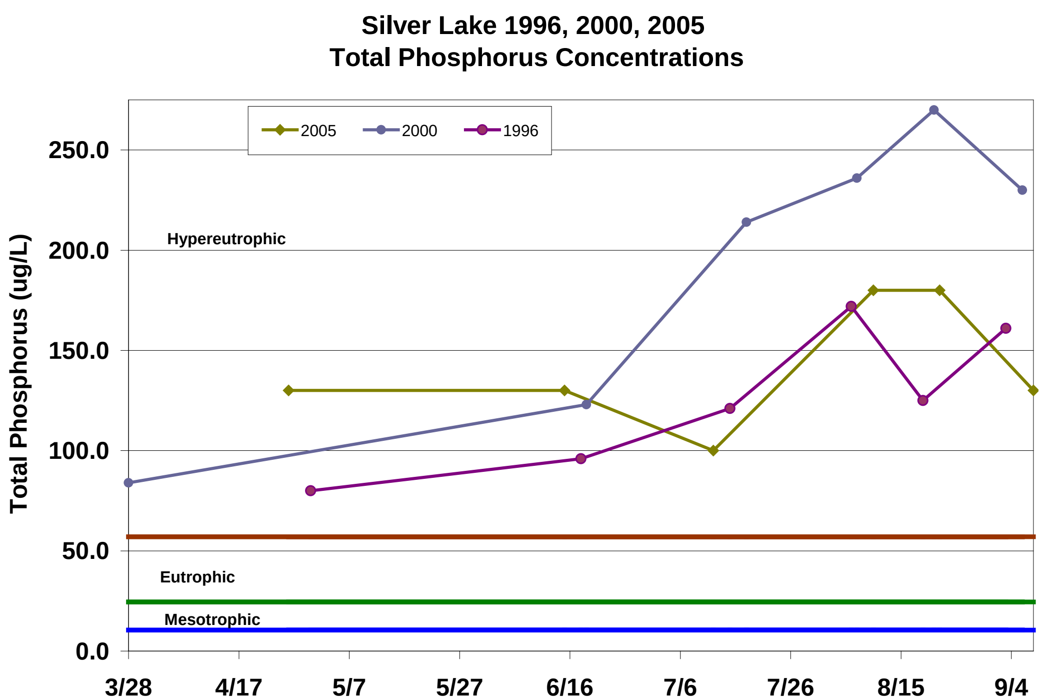


FIGURE SI-2
Silver LakeChlorophyll *a*

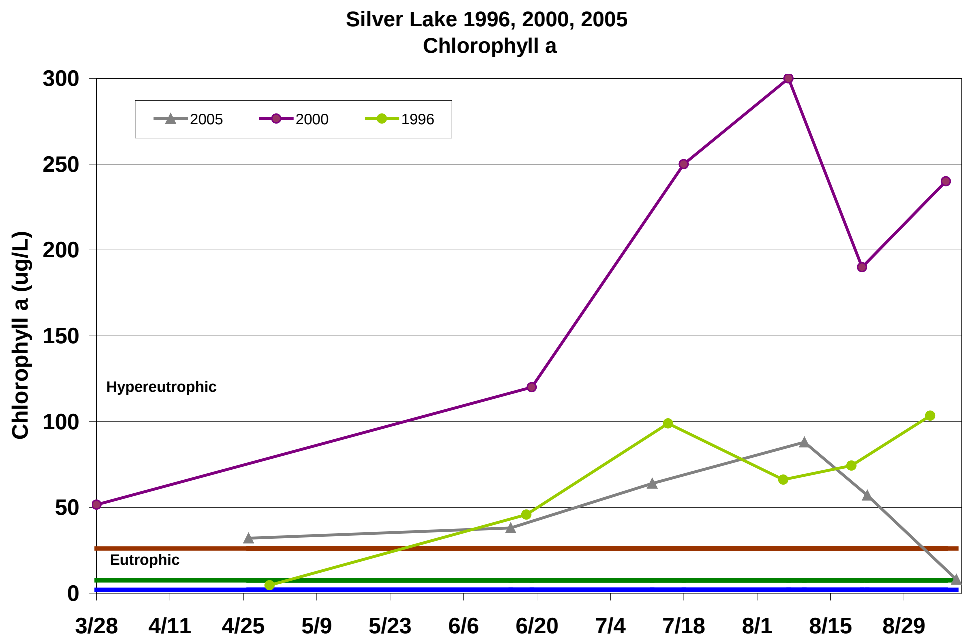
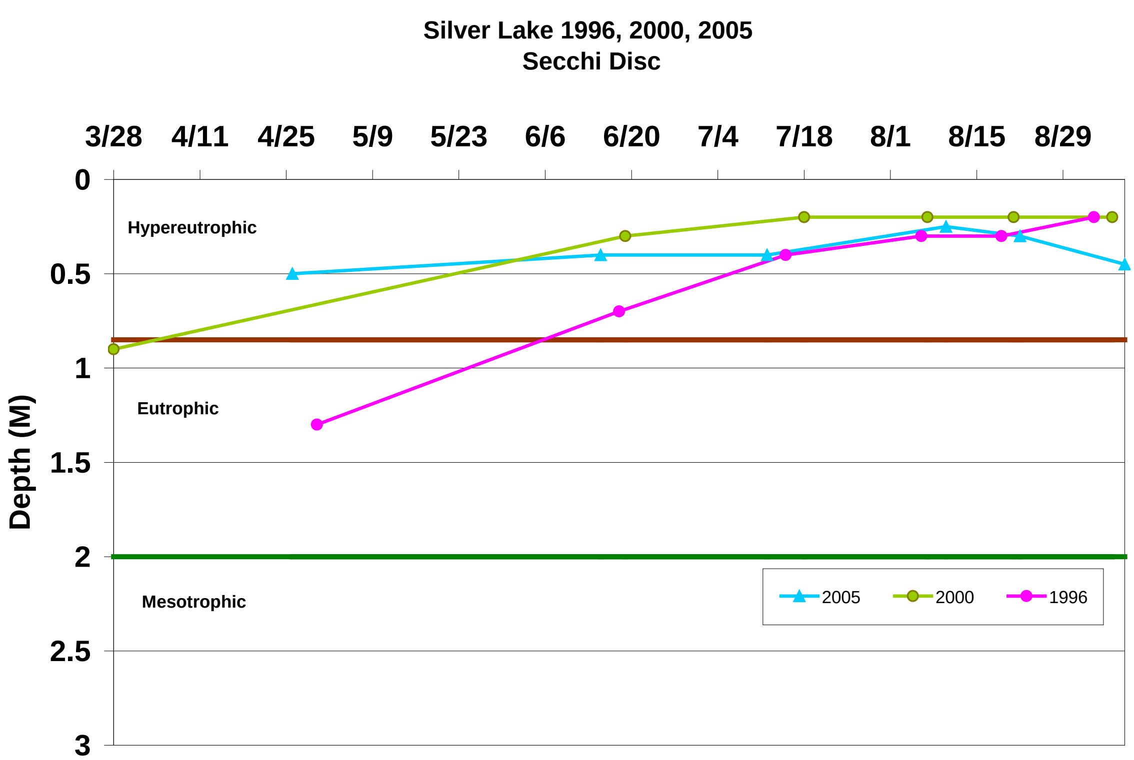


FIGURE SI-3
Silver LakeSecchi Disc



1.2.3 Ecosystem Data

No current lake classification is available in the data set. The lake has been stocked with fish until 1943 (UAA, 2003). Silver Lake provides habitat for seasonal waterfowl and other wildlife.

1.2.3.1 Aquatic Ecosystems

The encroachment of non-native species is the main threat to the aquatic ecosystem of Silver Lake (UAA 2003).

1.2.3.2 Phytoplankton

The phytoplankton species in Silver Lake form the base of the lake's food web and directly impacts the lake's fish production. Phytoplankton, also called algae, are small aquatic plants naturally present in all lakes. They derive energy from sunlight (through photosynthesis) and from dissolved nutrients found in lake water. They provide food for several types of animals, including zooplankton, which are in turn eaten by fish. A phytoplankton population in balance with the lake's zooplankton population is ideal for fish production. An inadequate phytoplankton population reduces the lake's zooplankton population and adversely impacts the lake's fishery. Excess phytoplankton, however, reduces water clarity which in turn in interferes with the recreational usage of a lake.

Lake survey results for 1996, 2000 and 2005 were analyzed to determine the composition and abundance of phytoplankton in Silver Lake. Blue-green algae was especially dominant in 2000 and 2005. In 1996 and 2000, the blue-green algae peaked in early August, but peaked in late August in 2005.. The 1996, 2000, and 2005 results are summarized in Figures SI-4, SI-5 and SI-6.

Green algae are edible to zooplankton and serve as a valuable food source. Blue-green algae are considered a nuisance type of algae because they:

- Are generally inedible to fish, waterfowl, and most zooplankters,
- Float at the lake surface in expansive algal blooms,
- May be toxic to animals when occurring in large blooms, and
- Can disrupt lake recreation because they are most likely to be present during the summer months.

Blue-green and green algal growth is stimulated by excess phosphorus loads. The growing conditions during July and August are particularly favorable to blue-greens, and they have a competitive advantage over the other algal species during this time. However, the phytoplankton populations profiled in 1996 and 2005 do show the green algae surviving in significant numbers throughout the period when blue-green algae normally outcompetes the green algae, decimating the green algae population.

FIGURE SI-4
Silver Lake Phytoplankton Data Summary (1996)

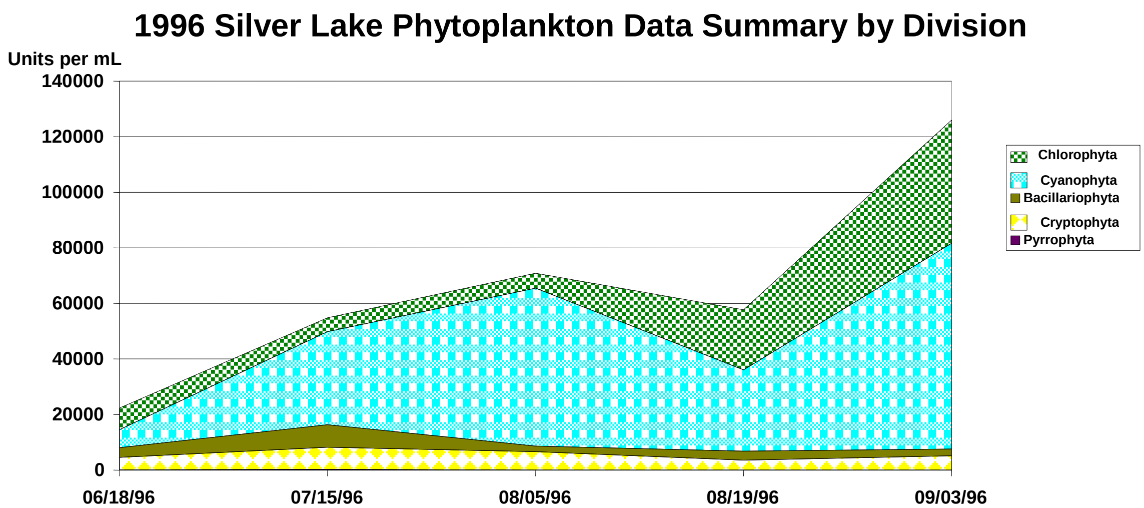


FIGURE SI-5
Silver Lake Phytoplankton Data Summary (2000)

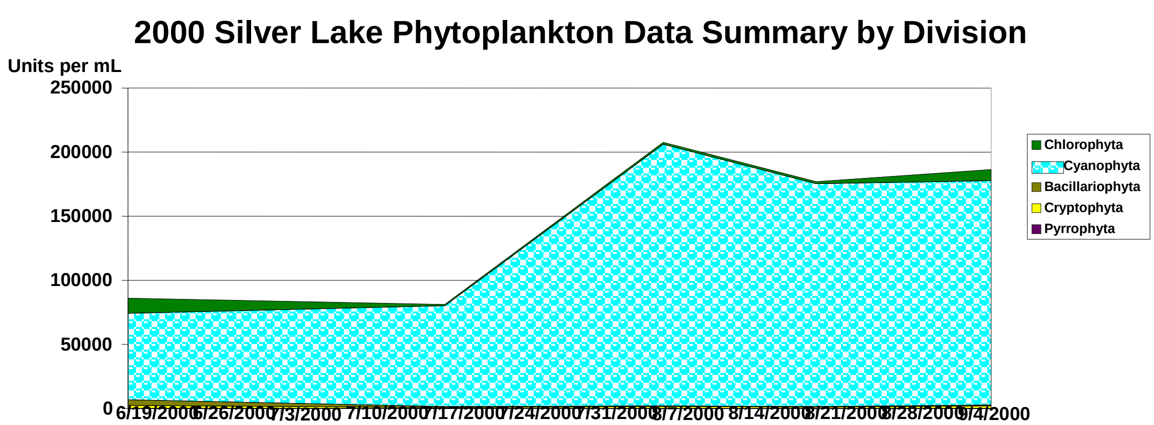
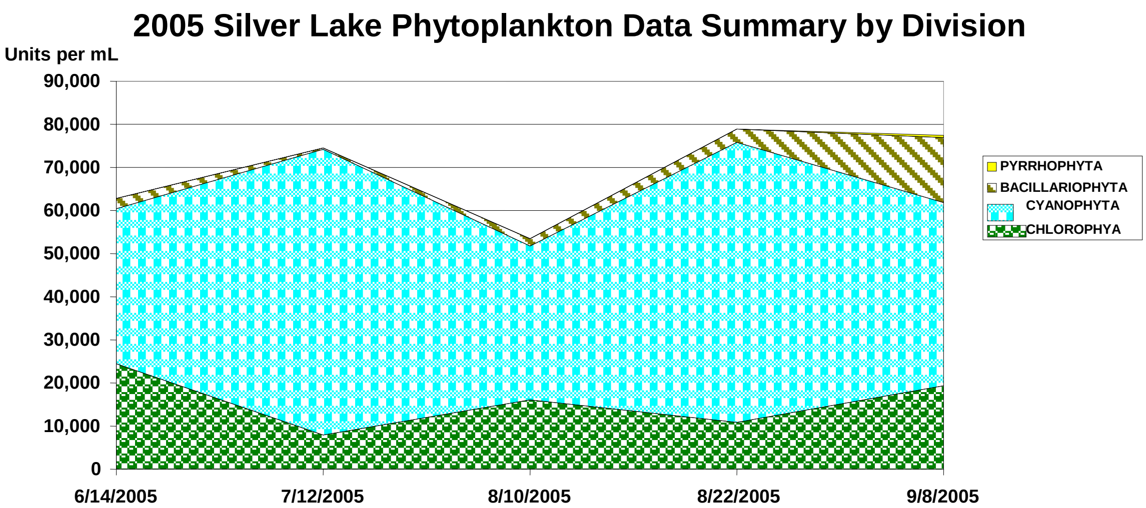


FIGURE SI-6
Silver Lake Phytoplankton Data Summary (2005)



1.2.3.3 Zooplankton

Zooplankton are an important component of the aquatic ecosystem of Silver Lake. They are the second step in the Silver Lake food webs and are particularly vital to the lake's fishery and for the biological control of algae. They are microscopic animals that feed on particulate matter, including algae, and are, in turn, eaten by fish. Protection or enhancement of the lake's zooplankton community through judicious management practices affords protection to the lake's fishery. Healthy zooplankton communities are characterized by balanced densities (number per meter squared) of the three major groups of zooplankton: Cladocera, Copepoda, and Rotifera. Fish predation, however, may alter community structure and reduce the numbers of larger-bodied zooplankters (i.e., larger bodied Cladocera).

The rotifera and copepoda in Silver Lake graze primarily on extremely small particles of plant matter and do not significantly affect the lake's water quality. However, the Cladocera graze primarily on algae and can improve water quality if present in abundance. The 2000 survey (Figure SI-8) showed the greatest abundance of Cladocera.

FIGURE SI-7
Silver Lake Phytoplankton Data Summary (1996)

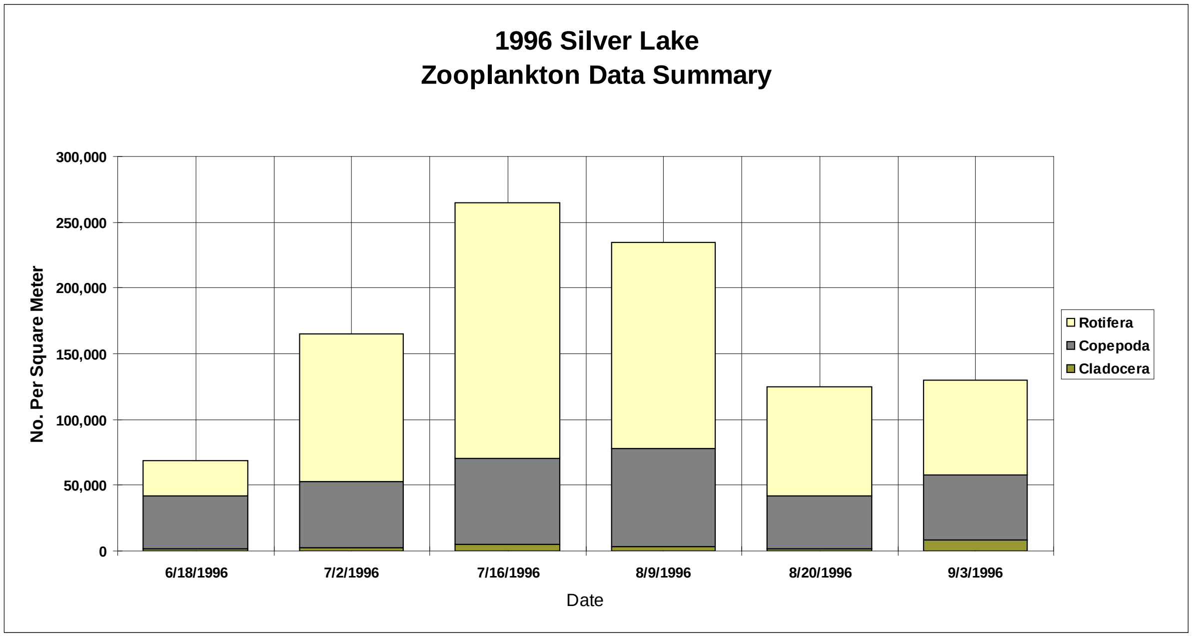


FIGURE SI-8
Silver Lake Phytoplankton Data Summary (2000)

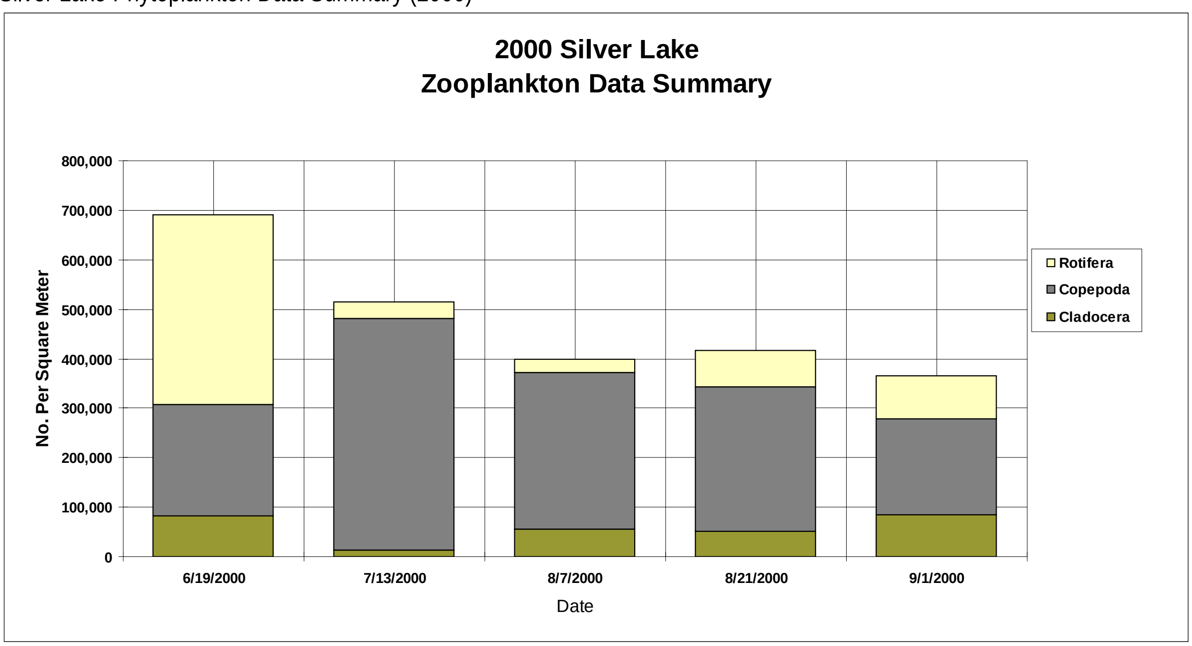
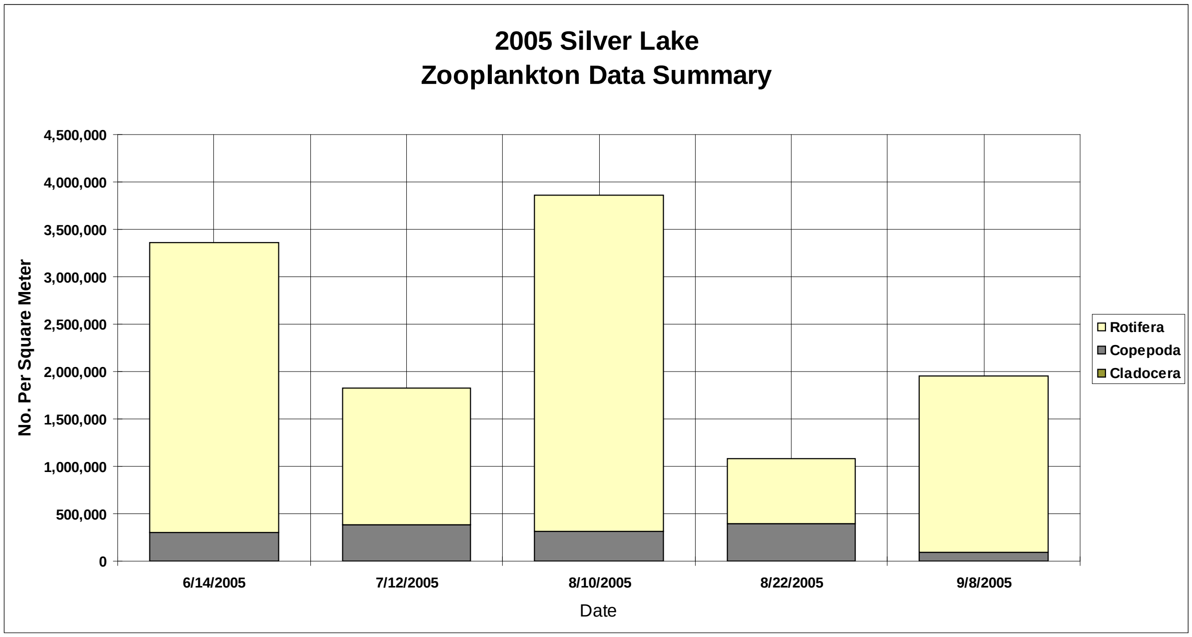


FIGURE SI-9
Silver Lake Phytoplankton Data Summary (2005)



1.2.3.4 Macrophytes

Aquatic plants are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. Typical functions of a lake's macrophyte community include the following:

- Provide habitat for fish, insects, and small invertebrates
- Provide food for waterfowl, fish, and wildlife
- Produce oxygen
- Provide spawning areas for fish in early spring/provide cover for early life stage of fish
- Help stabilize marshy borders and protect shorelines from wave erosion
- Provide nesting sites for waterfowl and marsh birds

Macrophyte surveys of the aquatic plant community in Silver Lake were completed by the District in June and August of 1996, 2000, and 2005 and are summarized in Table 4. A density rating of 1 denotes a density rating of light, 2 of medium, and 3 of dense. Dashes in the floating leaf plants and emergent plants categories denote the presence of the plant during the macrophyte surveys, but no density rating was recorded.

TABLE 4
Silver Lake Aquatic Plants (1996, 2000, and 2005)

Common Name	Scientific Name	1996 Density	2000 Density	2005 Density
Submerged Aquatics				
Curlyleaf pondweed	***P. crispus***	**1-2**	**1-2**	**1-2**
Flatstem pondweed	***P. zosteriformis***	**1-3**	**1-3**	**1-3**
Sago pondweed	***P. pectinatus***	**1-2**	**1**	**1-2**

TABLE 4
Silver Lake Aquatic Plants (1996, 2000, and 2005)

Common Name	Scientific Name	1996 Density	2000 Density	2005 Density
Narrowleaf pondweed	***P. spp.***	**1-3**	**--**	**1-3**
Bladdwort	***Utricularia spp.***	**--**	**1**	**1**
Coontail	***Ceratophyllum demersum***	**1-2**	**1-2**	**1-3**
Elodea	***Elodea Canadensis***	**1**	**1-2**	**1-3**
Wild rice	***Zizania aquatica***	**--**	**1**	**1-2**
Floating Leaf Plants				
White waterlily	***Nymphaea turberosa***	**--**	**--**	**--**
Greater duckweed	***Spirodela polyrhiza***	**--**	**--**	**--**
Lesser duckweed	***Lemna minor***	**--**	**--**	**--**
Emergent Plants				
Bulrush	***Scirpus spp.***	**--**	**--**	
Cattail	***Typha spp***	**--**	**--**	**--**
Purple loosestrife	***Lythrum salicaria***	**--**	**--**	**--**

According to the 2003 UAA, macrophytes were identified to a relative depth of 4-6 feet for these surveys. In some areas, the submerged plants were dominated by a dense growth of coontail (*Ceratophyllum demersum*, a native species) in June and August. Curly-leaf pondweed (*Potamogeton crispus*) was also identified in some areas among the submerged plants in June but appears to die off later in the summer as it is not present in the August surveys. Curly-leaf pondweed is an undesirable non-native species. It frequently replaces native species in lakes and exhibits a dense growth that may interfere with the recreational use of a lake. A dense growth also creates a refuge for small fish, making it difficult for larger fish, such as bass, to find and capture the small fish they need for food. Purple loosestrife (*Lythrum salicaria*), an undesirable exotic species, was identified among the emergent plants in some areas. This plant should be controlled because it can replace cattails (*Typha sp.*) and subsequently destroy that wildlife habitat.

1.2.4 Water-Based Recreation

Silver Lake is used by riparian residents for canoeing and aesthetic viewing. Riparian residents report that snapping turtles living in the lake prevent swimming as the presence of the turtles would be unsafe for swimmers. The lake has no public access.

1.2.5 Fish and Wildlife Habitat

MN DNR discontinued stocking of the lake in 1943. The DNR currently believes the lake does not hold permanent gamefish and is unsuitable for game fish. Silver Lake is classified by the U.S. Fish and Wildlife Service as a Type 25 wetland, indicating it is comprised of shallow open water. Silver Lake provides habitat for seasonal waterfowl, such as ducks and geese. MN DNR recommends management of the lake to maintain or improve its wetland function. Hence, the recommended management focus of Silver Lake is the preservation of its current habitat and aquatic life community.

1.2.6 Natural and Urban Drainage Systems

1.2.6.1 Natural Conveyance Systems

The natural inflow to Silver Lake is comprised of stormwater runoff from its direct watershed and groundwater discharge. There are no streams or rivers that convey flow to Silver Lake.

1.2.6.2 Stormwater Conveyance Systems

The stormwater conveyances to Silver Lake were investigated in the 2003 UAA, and the findings are presented below.

1.2.6.3 Public Ditch Systems

There are no public ditch systems that affect Silver Lake.

1.2.7 Water Appropriations

There are no known water appropriations from Silver Lake.

Staring Lake

August 2008

Contents

Staring Lake

1.1 Staring Lake Watershed Goals

The approved Riley-Purgatory-Bluff Creek Watershed District Water Management Plan, 1996, (Water Management Plan) inventoried and assessed Staring Lake. The plan articulated five specific goals for Staring Lake. These goals address recreation, aquatic communities, water quality, water quantity, and wildlife.

The 1996 Plan identified a Staring Lake project intended to protect a major water storage area along Purgatory Creek prior to discharging from Staring Lake. The project was developed to be implemented over the course of five phases. Four of the five phases were constructed. The fifth phase, a constructed outlet to Staring Lake, was not completed due to the previous four phases of work satisfying the project's objectives.

1.1.1 Water Quantity

The water quantity goal for Staring Lake is to provide sufficient water storage during a regional flood (100-yr, 24-hr storm event).

1.1.2 Water Quality

The MPCA has classified Staring Lake as not supporting aquatic recreational use (Trophic State Index (TSI_{SD}) of greater than 57. Partially supporting aquatic recreational use would have a desired range of between 53 and 57. Fully supporting would have a value of less than 53.

1.1.3 Recreation

The primary recreation goal is to achieve full support of fishing activities and maintain waterfowl habitat. The Outdoor Center at Staring Lake was previously a private home, which had a sand blanket put down in front of the property. Since the City of Eden Prairie took ownership of the site, the sand blanket is used as a launch pad for aquatic equipment such as canoes or kayaks. No beach is planned by the City at this time due to the muddy bottom and poor water quality.

1.1.4 Aquatic Communities

The aquatic communities goal for Staring Lake is to maintain a MDNR ecological Class 43 rating, with a TSI_{SD} of 65.4. A TSI_{SD} of 65.4 corresponds to the average Secchi disk transparency (0.6 m) of the Class 43 lakes studied by the MDNR.

1.1.5 Wildlife

The wildlife goal for Staring Lake is to protect existing beneficial wildlife uses.

1.1.6 Public Participation

The goal is to encourage public participation in achieving outcomes from the use attainability analysis.

1.2 Existing Watershed Conditions

Staring Lake is located in the City of Eden Prairie in the southern part of the Riley-Purgatory-Bluff Creek watershed. Purgatory Creek serves as a major source of inflow and outflow. The Staring Creek watershed encompasses parts of the following municipalities: Deephaven, Minnetonka, Shorewood, Chanhassen, and Eden Prairie.

1.2.1 Watershed Description

1.2.1.1 Land Use

Land use is an important watershed characteristic that has a direct impact on a lake and its water quality. Increasingly intensive land use will increase both sediment and phosphorus loads, as well as, alter the routine hydrology of a lake and its tributaries. Urbanization can also lead to thermal impacts which in turn can play a role in fisheries habitat. Sound watershed planning needs to consider both existing and future land use.

Land use data was obtained from the Metropolitan Council Generalized Land Use Maps. The maps are based on 2005 existing land use and a projected land use for 2020. Both existing and projected are summarized in Table 1.

TABLE 1
Existing and Projected Land Use
Staring Lake

Land Use Category	Existing Land Use – 2005 (ac)	Projected Land Use – 2020 (ac)
Single Family Residential	**0**	**4487**
Medium Density Residential	**0**	**797**
Single Family Detached	**4978**	**0**
Single Family Attached	**409**	**0**
Multifamily	**361**	**110**
Retail and Other Commercial	**525**	**466**
Office	**68**	**108**
Mixed Use	**1**	**0**
Industrial and Utility	**333**	**485**
Institutional	**361**	**438**
Park, Recreation, or Preserve	**1493**	**1520**
Golf Course	**109**	**0**
Right Of Way	**0**	**1658**
Railway	**0**	**20**
Major Highway	**325**	**0**
Airport	**25**	**43**
Undeveloped	**1152**	**0**
Water	**334**	**342**
Total	**10474**	**10474**

1.2.1.2 Staring Lake Major Hydrologic Characteristics

Staring Lake has a 10,474-acre tributary watershed, a surface area of 150 acres and a mean depth of 7.0 feet.

1.2.2 Staring Lake Water Quality

The water quality of a lake provides an indication of how a lake functions. A standardized lake rating system is often used to classify the ecological conditions of a lake. The rating system uses phosphorus, chlorophyll *a*, and Secchi disc transparency values to classify a lake into four categories: Oligotrophic (clear, low productivity lakes with excellent water quality), Mesotrophic (intermediate productivity lakes with good water quality), Eutrophic (high productivity lakes with poor water quality) and Hypereutrophic (extremely productive lakes with poor water quality).

Based on the 2002 and 2005 monitoring data, TSI_{SD} scores were 60.0 and 73.2, respectively, both of which indicate that the lake is not supporting for aquatic recreation use. The 2005 TSI_{SD} score does not meet the aquatic communities goal (TSI_{SD}=63). The water quality goal that satisfies all criteria is the aquatic recreation goal - TSI_{SD} of 57 or lower.

1.2.2.1 Data Collection

Data for the previous watershed management plan was collected from 1972 to 1994. Additional data was collected in 2002 and 2005.

1.2.2.2 Baseline/Current Water Quality

In general, Staring Lake water quality has faced a general decline during the more recent monitoring (2002 – 2005). Total phosphorus concentrations were typically in the hypereutrophic (extremely nutrient rich) category throughout the entire monitoring cycle. Chlorophyll *a* concentrations from the monitoring period typically are in the eutrophic range in the spring but quickly move into the hypereutrophic range by early summer. Secchi disc depths follow a trend similar to the total phosphorus data.

1.2.3 Ecosystem Data

Staring Lake is a Class 43 lake. Class 43 lakes are typically shallow, eutrophic lakes. The MDNR has assigned an ecological rating TSI_{SD} of 65.4 or lower. The lake's current water quality (2005 data) corresponds to a TSI_{SD} of 77.3. Impairment of the Staring Lake fishery is caused by high phosphorus levels and severe summer algal blooms. The lake does provide habitat for seasonal waterfowl, through diverse macrophyte communities in a large littoral zone.

1.2.3.1 Aquatic Ecosystems

The Staring Lake ecosystem is typical for a eutrophic, temperate lake in this region.

1.2.3.2 Phytoplankton

The phytoplankton species in Staring Lake form the base of the lake's food web and directly impacts the lake's fish production. Phytoplankton, also called algae, are small aquatic plants naturally present in all lakes. They derive energy from sunlight (through photosynthesis) and from dissolved nutrients found in lake water. They provide food for several types of animals, including zooplankton, which are in turn eaten by fish. A phytoplankton population in balance with the lake's zooplankton population is ideal for fish production. An inadequate phytoplankton population reduces the lake's zooplankton population and adversely impacts the lake's fishery. Excess phytoplankton, however, reduces water clarity which in turn in interferes with the recreational usage of a lake.

Lake survey results for 2002 and 2005 were analyzed to determine the composition and abundance of phytoplankton in Staring Lake. In 2002, blue-green algae were especially dominant in Staring Lake from late June to early August. From mid-August through October, the balance between the blue-green and green algae was reestablished. The 2005 survey results demonstrated similar results. The 2002 and 2005 results are summarized in Figures STL-4 and STL-5.

Green algae are edible to zooplankton and serve as a valuable food source. Blue-green algae are considered a nuisance type of algae because they:

- Are generally inedible to fish, waterfowl, and most zooplankters,
- Float at the lake surface in expansive algal blooms,
- May be toxic to animals when occurring in large blooms, and
- Can disrupt lake recreation because they are most likely to be present during the summer months.

Blue-green and green algal growth is stimulated by excess phosphorus loads. The growing conditions during July and August are particularly favorable to blue-greens, which have have a competitive advantage over the other algal species during this time. Hence, phosphorus levels will need to be lowered in order to reduce blue-green algae populations in Staring Lake.

FIGURE STL-1
Staring Lake Phytoplankton Data Summary (1999)

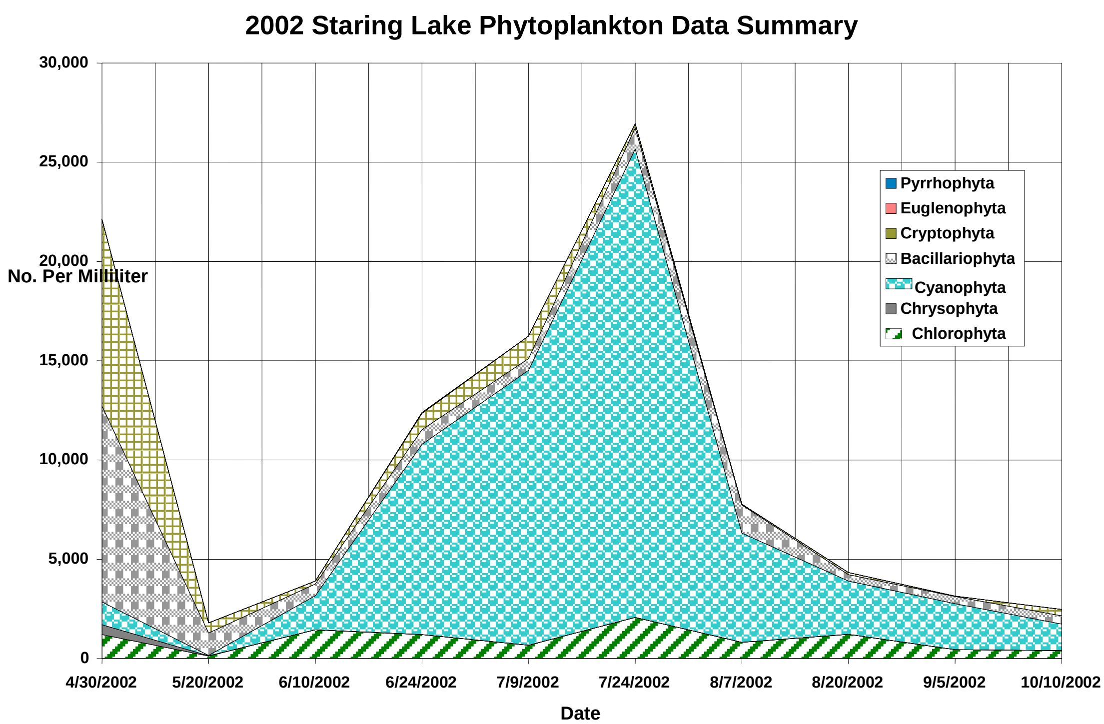
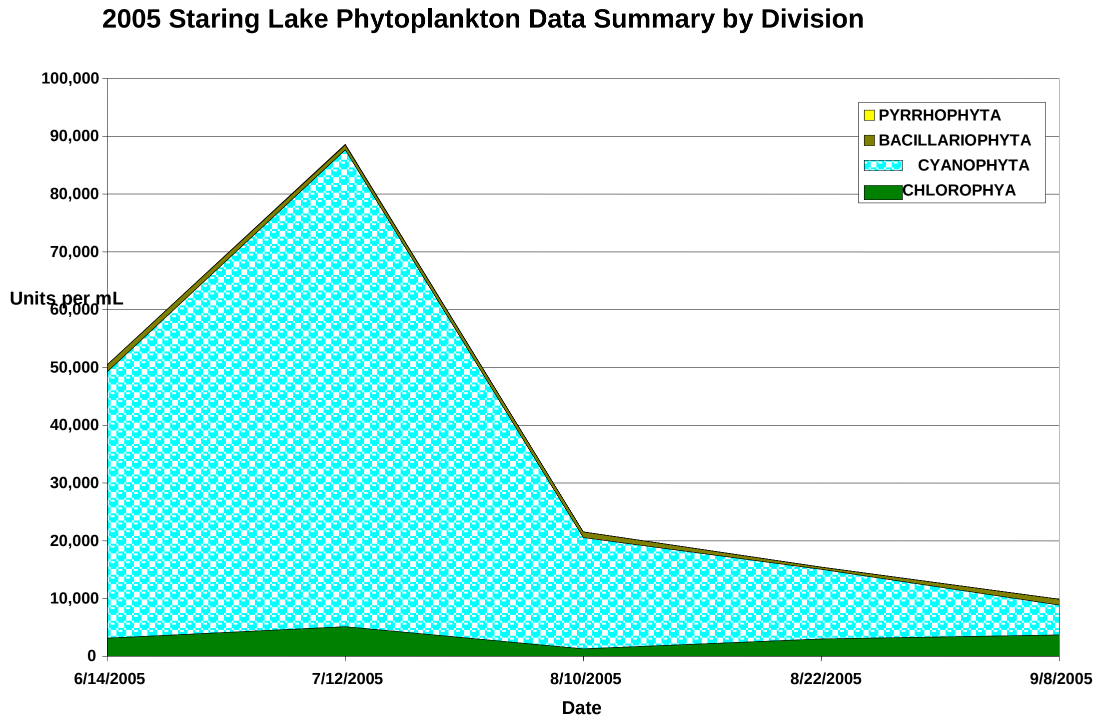


FIGURE STL-2
Staring Lake Phytoplankton Data Summary (2005)



1.2.3.3 Zooplankton

Zooplankton are an important component of the aquatic ecosystem of Staring Lake. They are the second step in the Staring Lake food webs and are particularly vital to the lake's fishery and for the biological control of algae. They are microscopic animals that feed on particulate matter, including algae, and are, in turn, eaten by fish. Protection or enhancement of the lake's zooplankton community through judicious management practices affords protection to the lake's fishery.

Healthy zooplankton communities are characterized by balanced densities (number per meter squared) of the three major groups of zooplankton: Cladocera, Copepoda, and Rotifera. The rotifera and copepoda in Staring Lake graze primarily on extremely small particles of plant matter and do not significantly affect the lake's water quality. However, the cladocera graze primarily on algae and can improve water quality if present in abundance. Fish predation, however, may alter community structure and reduce the numbers of larger-bodied zooplankter (i.e., larger bodied Cladocera).

The 2002 data showed that during the spring, the rotifera were the dominant population, with a shift in the early summer to a more equal balance between the three groups. The 2005 data showed that that both cladocera rotifera predominated over Copepoda.

1.2.3.4 Staring Lake Macrophytes

Aquatic plants are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. Typical functions of a lake's macrophyte community include the following.

- Provide habitat for fish, insects, and small invertebrates
- Provide food for waterfowl, fish, and wildlife
- Produce oxygen
- Provide spawning areas for fish in early spring/provide cover for early life stage of fish
- Help stabilize marshy borders and protect shorelines from wave erosion
- Provide nesting sites for waterfowl and marsh birds

Macrophyte surveys of the aquatic plant community in Staring Lake were completed by the District in June and August of 2002 and 2005 and are summarized in Table 2. Water quality, in particular clarity, was so poor in 2002 and 2005 that no submerged aquatic plants were observed or collected in either year's August sample.

TABLE 2
Staring Lake Aquatic Plants (2002 and 2005)

Common Name	Scientific Name	2002 Density	2005 Density
Submerged Aquatics			
Curlyleaf pondweed	***P. crispus***	**1-2**	**1-3**
Sago pondweed	***P. pectinatus***	**1-2**	**1-2**
Narrowleaf pondweed	***P. spp.***	**1-2**	**1-2**
Coontail	***Ceratophyllum demersum***	**1**	**1**
Muskgrass	***Chara sp.***	**1**	**1**
Floating Leaf Plants			
White waterlily	***Nymphaea odorata*** ***Nymphaea turberosa***	**--**	**--**
Yellow Water Lilly	***Nupar variegatum***	**--**	**--**
Emergent Plants			
Water smartweed	***Polygonum amphibium***	**--**	
Giant Reed	***Phragmites australis***		**--**
Purple loosestrife	***Lythrum salicaria***	**--**	

-- Plants Present but Density Not Provided in Survey

According to the 2002 and 2005 surveys, macrophytes were identified to a relative depth of >4-5 feet in June. Water quality, in particular clarity, was so poor that no submerged aquatic plants were observed or collected in either year's August sample. Curly-leaf pondweed (*Potamogeton crispus*) was also identified in some areas among the submerged plants in June but appeared to die off later in the summer. Curly-leaf pondweed is an undesirable non-native species. It frequently replaces native species in lakes and exhibits a dense growth that may interfere with the recreational use of a lake. A dense growth also creates a refuge for small fish, making it difficult for larger fish, such as bass, to find and capture the small fish they need for food. Purple loosestrife (*Lythrum salicaria*), an undesirable exotic species, was identified among the emergent plants in some areas in 2002 only. This plant should be controlled because it can replace cattails (*Typha sp*.) and subsequently destroy that wildlife habitat. By 2005 it appears that another non-native invasive species, giant reed (*Phragmites australis)* made an appearance on the eastern shore near the inflow point.

1.2.4 Water-Based Recreation

Staring Lake is used primarily for fishing, as well for other types of recreational activities, including swimming. There is currently a single boat ramp located at the northern end of the lake as well as two docks..

1.2.5 Fish and Wildlife Habitat

During 1992, the MDNR classified Staring Lake and other Minnesota lakes relative to fisheries (SCAP, 1992). This ecological classification is a function of lake area, percentage of the lake surface area that is littoral, maximum depth, degree of shoreline development, Secchi disc transparency and total alkalinity. According to its ecological classification, Staring Lake is a Class 43 lake, which signifies a lake that may be better suited for wildlife than for fish (Schupp, 1992). Staring Lake's current conditions indicate that its water quality does not support the uses for its ecological class.

According to the MDNR's 2002 fisheries survey, northern pike remain the most abundant predator species in Staring Lake. The bluegill population in Staring Lake was measured at its lowest abundance level since the 1980 survey. Despite the decline in abundance, Staring Lake bluegill maintained an average size and weight that compared favorably to previous surveys. Pumpkinseed and hybrid sunfish, as well as both black and white crappie are also present in the lake but at very low abundance levels. Yellow perch were found to be extremely abundant in Staring Lake during the 2002 survey and were sampled at an historically high catch rate for this lake.

The black bullhead population was also sampled at historically high abundance levels for Staring Lake. However, black bullhead average size was very small. Common carp and freshwater drum populations were also sampled with moderate frequency and with average sizes in Staring Lake.

Staring Lake provides habitat for seasonal waterfowl, such as ducks and geese, through diverse macrophyte communities in a large littoral zone.

1.2.6 Natural and Urban Drainage Systems

1.2.6.1 Natural Conveyance Systems

The inflow to Staring Lake comes from surface runoff, groundwater discharge, and Purgatory Creek. The stormwater runoff is from Staring Lake's direct watershed, both overland and through wetland systems. In 1988, an inlet to Staring Lake from Red Rock Lake via McCoy Lake was installed to accommodate high water level flows. For this reason, the natural and constructed stormwater conveyance systems are discussed together in subsequent sections.

1.2.6.2 Stormwater Conveyance Systems

Further information on stormwater conveyance to Staring Lake will be investigated in the in course of any future use attainability analysis.

1.2.6.3 Public Ditch Systems

There are no public ditch systems that affect Staring Lake.

1.2.7 Water Appropriations

There are no known water appropriations from Staring Lake.