CLEARWATER LAKE WATER QUALITY MODEL STUDY

Final Report

Red Lake Watershed District

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1.0 Acknowledgements

The Red Lake Watershed District Staff included Ryan Odenbach (grant application, project management, Sampling and Analysis Plan, sampling), Corey Hanson (project management and coordination, sampling, flow measurement, FLUX/PROFILE/BATHTUB modeling, semi-annual reporting, author of final report, GIS, and data analysis) Stephanie Hanson (GIS, sampling, flow

measurement, data entry/analysis, assisted with creation of final report), Zebulen Lamp (GIS, sampling, and flow measurement), Gary Lane (surveying and flow measurement), Loren Sanderson (surveying and flow measurement), Chuck Fritz, and Harry Farris.

Many people in addition to Red Lake Watershed Staff participated in this project. Eric Pearson and Melanie Johnson of the Beltrami Soil and Water Conservation District, along with John Cucci, Bob Widerski, and Roger Holm of the Clearwater Lake Area Association all assisted with sampling. Bob Widerski also collected daily evaporation pan and rainfall data for the project. Doug Thompson of the Clearwater Soil and Water Conservation Service helped with the planning process and provided technical expertise. The Board of Water and Soil Resources project managers for this project were Jeff Hrubes and Bill Best.

2.0 Introduction

During the summer of 2002, the Red Lake Watershed District (RLWD), along with the Beltrami Soil and Water Conservation District (SWCD), and the Clearwater Lake Area Association (CLAA) collected water samples from within the Clearwater Lake watershed for the Clearwater Lake Water Quality Study. A Challenge Grant from the Minnesota Board of Water and Soil Resources funded this project.

3.0 Background Information

According to the pre-settlement vegetation map from the Minnesota Department of Natural Resources, Clearwater Lake was considered a water or lake area before settlement. The surrounding local watershed was predominantly forested. The dam on Clearwater Lake raised the amount of storage in the lake. The Minnesota Department of Game and Fish constructed the dam at the outlet of Clearwater Lake in 1931. Normal lake elevation is considered 1273 feet Mean Sea Level, where the surface area at this height is 988 acres. The dam is designed so that 2-foot stop logs may be installed above the concrete crest. There is also a 4-foot wide slot in the dam where stop logs could be removed to draw the level down about three feet below the crest. Information on dam design and the rating curve is on file at the Red Lake Watershed District office.

Since the construction of the dam, development around the lake has increased to include approximately 127 cabins and lake homes. The recreation and economic value of the Clearwater Lake area has greatly increased. Due to this fact, maintaining and improving the water quality of Clearwater Lake has been a top priority of local and state government agencies. This has spurred the effort of developing a management plan for the lake as well as a water quality model study for the lake.

4.0 Previously Collected Water Quality Data and Information

There has been considerable data collected on Clearwater Lake in the past by state agencies and volunteers. This section summarizes the data collected to this point and some findings.

4.1 Clearwater River Nonpoint Study (RLWD)

During this diagnostic study, data was collected over approximately one year in 1992 and 1993. The study found that during 1992, the lake was mesotrophic with a mean total phosphorus concentration of 29 ug/L and a mean Secchi disk reading of 3.3 m (10.8 ft.). The lake was found to be moderately efficient at retaining phosphorus (approximately 37% of inlet load) as well as the retention of nitrogen (approximately 31% of inlet load). According to the study, solids retention generally does not occur, although there is not a differentiation between dissolved and suspended solids.

The difference in mass loads between nitrogen and phosphorus determined by the Nonpoint Study suggests that Clearwater Lake is phosphorus limited.

4.2 Long-term Monitoring Program (RLWD)

The Red Lake Watershed District has collected baseline water quality data on a periodic basis (mainly quarter annually) since 1984 at the outlet of Clearwater Lake. The Red River Watershed Assessment Protocol Project currently being conducted by the Red Lake Watershed District will perform a statistical analysis of this data. This will be done to compare this site to others within the RLWD and determine the long-term range of water quality parameters.

4.3 Lake Assessment (MPCA)

In 1996, the Minnesota Pollution Control Agency collected intensive in-pool measurements of several water quality parameters. A report of this study was not generated at this point.

4.4 General Lake Monitoring (Beltrami and Clearwater Counties, Clearwater Area Lake Association)

The Beltrami and Clearwater County Soil and Water Conservation Districts in cooperation with the Clearwater Area Lake Association have collected in-pool measurements of total phosphorus, chlorophyll-a, and Secchi disk. The information from the years 2000 and 2001 show that on average the trophic status of Clearwater Lake is bordering between mesotrophic and eutrophic.

5.0 Problem Description

The intensive set of water quality information gathered in 1996 for the Clearwater Lake Assessment used in-pool monitoring to display the trophic status of Clearwater Lake. Though, the study did not use collected data to determine hydrologic, nutrient and sediment budgets for Clearwater Lake. Furthermore, the information available at the time about Clearwater Lake did not identify the sources or provide any recommendations or solutions to lake water quality problems.

Concerns about water quality on Clearwater Lake include increases in the growth of problem algae and aquatic vegetation and the nutrient and/or sediment loading to the lake from the contributing drainage area. Concerns from the contributing drainage area include urban and rural land use.

6.0 Study Purpose and Goals

The purpose of this study is to provide feasible and economic solutions to maintaining and improving water quality in Clearwater Lake. The information from this study will be used to develop lake management goals and action steps in the Clearwater Lake Management Plan. The specific technical goals of this project include:

- Develop loading estimates from sites in question in the upper portion of the Clearwater Lake watershed (i.e. above and below the City of Bagley and Walker Brook)
- Develop an estimate of the hydrologic budget by measuring or estimating the amount of precipitation, surface inflow, surface outflow, evaporation, groundwater inflow/outflow and change in storage.
- Develop a statistical analysis of the flow and water quality data with graphical and tabular displays (i.e. boxplots, DO/water temp. area graphs), which will include a comparison of the trophic state of Clearwater Lake to other lake data. This information can also be compared to MPCA's Lake Assessment data.
- Develop an annual mass balance for total phosphorus, total nitrogen, total solids, and total suspended solids and chloride.
- Develop a water quality model of Clearwater Lake using the collected data (hydrologic and nutrient balances). The BATHTUB program from the Army Corps of Engineers will be used to develop the water quality model. The model will be used to evaluate effects of nutrient load reductions on in-lake water quality.
- Use the water quality model to estimate arbitrary load reductions in Clearwater Lake (i.e. reducing nutrient loads by 10%, 20%, etc.) and its predicted effect on lake water quality.
- Develop a technical report/memorandum to be used as a guide for the Clearwater Lake Management Plan.

7.0 Period of Study

The BWSR Local Water Planning Challenge Grant project implementation period began July 1, 2001 and ends June 30, 2003. The period of data collection for the mass balances and the water quality model will proceed from November 2001 to November 2002. Assessment of the data, model development and report development will occur from November 2002 to April 2002, with the report due April 2002 (See project workplan).

8.0 Methods

Samples were collected according to the Clearwater Lake Water Quality Model Sampling and Analysis Plan and the Standard Operating Procedures for Water Quality Monitoring in the Red River Watershed. The samples were collected at six sites along the Clearwater River, and two in-pool sites within Clearwater Lake. Samples were collected monthly during the ice-on period of the year and bi-weekly during the ice-off period. Nineteen samples were collected at each site over the course of the study, with the exception of the Buzzle Lake outlet, for which fifteen samples were collected. At times, two hydrolabs (SWCD's and RLWD's) were used during the lake monitoring in order to compare results and check for errors. In most cases, the two readings were averaged for summarization and graphical analysis purposes. The following is a description of the stream and lake monitoring sites:

- #52 - Clearwater Dam, (Clearwater Lake outlet)-located on Clearwater County Road # 4, in section 12 of Sinclair Township.

- #131 - Clearwater River (Clearwater Lake inlet)-located on Beltrami County Road #24, in section 31 of Buzzle Township and section 32 of Roosevelt Township.

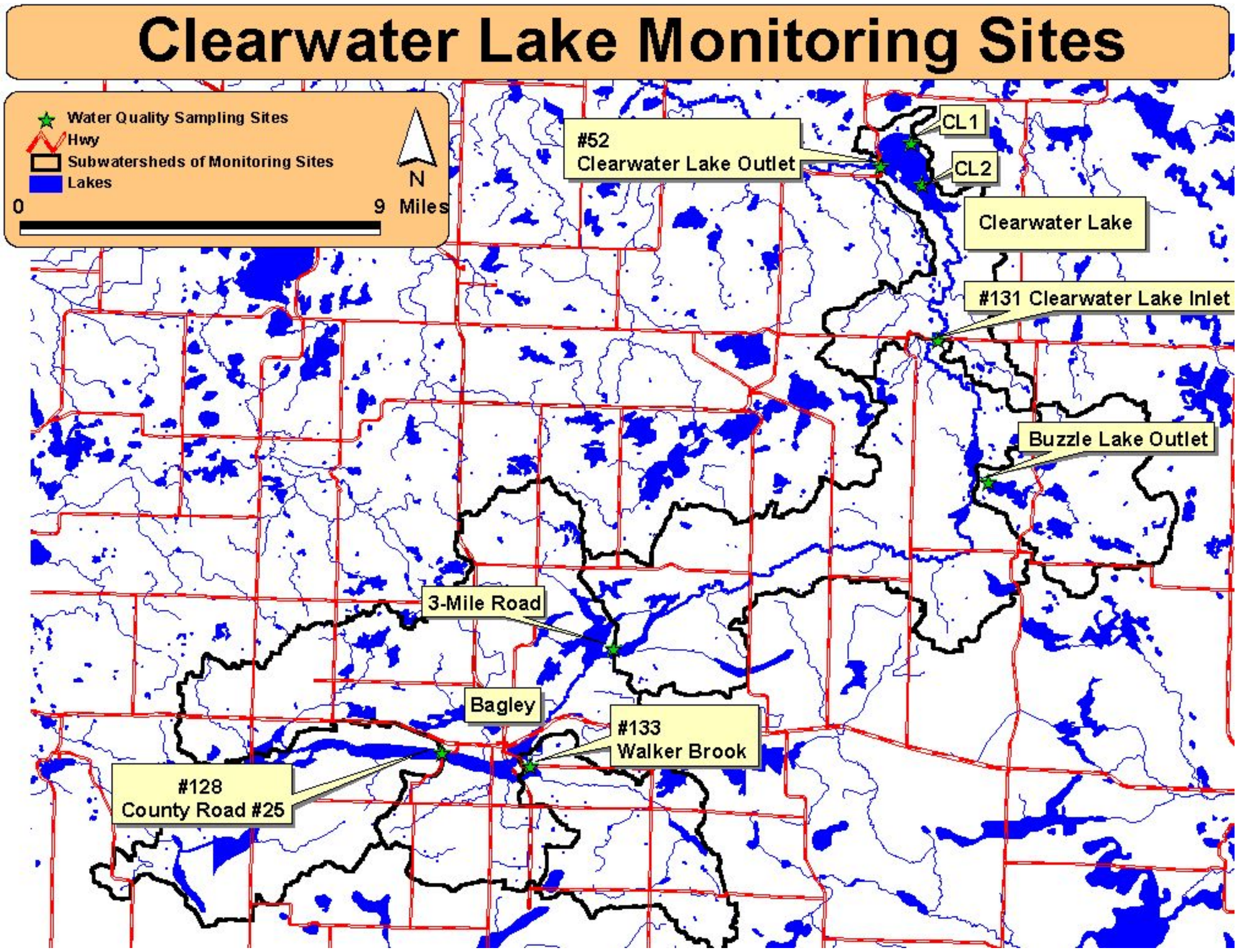
- Buzzle Lake outlet (tributary of the Clearwater River) located on a gravel township road northwest of Beltrami County Road # 5, north of Pinewood 2 miles, in section 20 & 21 of Buzzle Township.

- 3-mile road - Clearwater River - located on a gravel township road, 1 mile north of Clearwater County Road #91, in section 10 & 11 of Copley Township.

- #133 - Clearwater River (tributary of the Walker Brook)-located on Clearwater County Road #19 southeast of Bagley, in section 29 & 32 of Copley Township.

- #128 - Clearwater River-located on Clearwater County Road #25 southwest of Bagley, in section 25 of Popple Township.

- Two lake monitoring sites were sampled in Clearwater Lake and were named CL1 and CL2. CL1 was located in the deepest part of the lake, towards the northwest end of the lake, and CL2 was the shallower site located toward the southeast end of the lake. The sites were located in section 12 of Sinclair Township and section 7 of Roosevelt Township, respectively.



RMB Environmental Laboratories in Detroit Lakes performed the water quality sample analysis for the project. Stream samples were analyzed for: total phosphorus (TP), orthophosphorus (OP), total suspended solids (TSS), total dissolved solids (TDS), ammonia (NH_3), nitrates/nitrites (NO_2 + NO_3), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), and fecal coliform. Field measurements were taken for water temperature, dissolved oxygen (DO), conductivity, and pH at each site. Total phosphorus and chlorophyll-a samples were collected at the Clearwater Lake in-pool sites along with Secchi disk readings. Descriptions of parameters and some other terms that will be used in this report are listed on the following pages.

- **Chemical Oxygen Demand (COD)** is a measure of the amount of oxygen required to degrade organic compounds in water. This is the equivalent of the organic matter content in a sample that is susceptible to oxidation by a strong chemical oxidant. Elevated levels of COD may reduce the amount of dissolved oxygen in the water.

- **Chlorophyll-a** is a molecule that absorbs sunlight, and is an important part of photosynthesis. Chlorophyll-a samples taken from a lake are used as a measure of the amount of algae present in the water. Chlorophyll-a test results are used along with total phosphorus levels and Secchi disk readings to calculate the trophic state of a lake.

- **Conductivity** is the measurement of the water's capacity for conveying electrical current and is directly related to the concentrations of ionized substances in the water. The conductivity of water increases with an increase in the level of dissolved solids in the water. Elevated levels of conductivity may be related to geology, flow conditions, groundwater sources, urban runoff, and runoff from fields.

- **Dissolved Oxygen (DO)** is the amount of oxygen freely present in water. Dissolved oxygen is important for reproduction of aquatic life, natural degradation of pollutants in the water, and photosynthesis in plants. Decaying organic matter, warmer water temperatures, sediment in the river, and bacterial respiration are all potential causes of depleted dissolved oxygen levels. An average level of 5 mg/L, with levels not dropping below 4 mg/L is necessary for the survival of fish in a waterbody.

- **Fecal coliform bacteria** are microorganisms that are present inside the intestines of animals and humans. The presence of fecal coliform bacteria can indicate the presence of other disease-causing organisms. Sources of fecal coliform bacteria include animal waste (domestic animals and wildlife), sewage, and untreated urban stormwater runoff.

- **Hypolimnetic Oxygen Depletion (HOD)** The rate at which dissolved oxygen is decreased in the bottom layer (hypolimnion) of a water body when it is being consumed faster than it can be replaced. There are two ways of measuring it, volumetric hypolimnetic oxygen depletion rate (VHOD – g O_2/m^3/day) and aerial hypolimnetic oxygen depletion rate (AHOD – g O_2/m^2/day). VHOD is used in this study. The oxygen depletion rate can be used as a measure of the productivity within a water body.

- **Load** is the mass of a particular water quality parameter such as suspended solids or phosphorus being carried past a point in a stream.

- **Metalimnetic Oxygen Depletion (MOD)** The rate at which dissolved oxygen is decreased in the middle layer (metalimnion) of a water body when it is being consumed faster than it can be replaced. The volumetric metalimnetic oxygen depletion rate (VMOD - g O_2/m^3/day) was used in this study. Warmer temperatures within the metalimnion and the subsequent higher rates respiration of zooplankton and heterotrophic bacteria may contribute to MOD. The metalimnion can also be a density barrier to sinking particles of organic matter, which are then be decomposed by bacteria, thus reducing oxygen levels.

- **Nitrogen - Ammonia Nitrogen (NH_3)** is a form of nitrogen that exists as a colorless gas with a strong odor mainly from fertilizers. Death can occur from large doses. Ammonia nitrogen is available as a nitrogen source for living organisms. In a lake, these organisms would include aquatic macrophytes and algae. Ammonia nitrogen is produced in rivers by decaying organisms, industrial waste, and fertilizer.

- **Nitrogen - Nitrates/Nitrites (NO_2 and NO_3)** are forms of nitrogen that are abundant in the environment, while nitrate is one of the primary forms of nitrogen for plant uptake, it is a major concern in water quality because of hemoglobonemia, or blue baby syndrome, that occurs when high nitrate concentrations in drinking water that cut off blood supply to the body. Nitrogen levels greater than .5 mg/L (milligrams per Liter, or ppm - parts per million) are toxic to rainbow trout. The standard for nitrates in drinking water is 10 mg/L. Nitrate levels that fall between 0 and .40 mg/L indicate a low level of impact from agriculture and other human activities. Nitrate levels that fall between 0 and 4.5 mg/L show a medium impact, and levels that are between 0 and 30 mg/L show a high degree of impact. Increased nitrogen concentrations can be caused by wastewater, low flow, failing septic systems, animal waste, atmospheric deposition, natural sources (dependant upon geology and soils of the area), and fertilizers applied to crops, lawns, and golf courses. Since nitrogen is often present in lower concentrations than phosphorus, it is often the limiting nutrient for algae growth in lakes.

- **Nitrogen - Total Kjeldahl Nitrogen (TKN)** is the amount of organic nitrogen and ammonia nitrogen together in water. Total Kjeldahl nitrogen can come from decaying plant matter, decaying animal waste, industrial waste and fertilizer.

- **Peak discharge** is the volume of runoff during a storm event per inch of rain per mile.

- **Peak runoff** is the peak amount of overland flow that enters the river during a 5-year 24-hour storm event. For the Clearwater Lake watershed, this is equal to 2.69 inches of rain in 24 hours.

- **pH** is the negative log of the activity of hydrogen ions in a liquid. It is used to determine whether water is acid or alkaline. A pH of 7 is neutral. A pH of less than 7 is acid and a pH of greater than 7 is alkaline. Organic acids produced by decaying organic matter in wetlands and bogs can cause a decrease in pH (an increase in acidity). Algae introduce Carbon Dioxide to the water column, which in turn, lowers pH and increases the acidity of the water. Water with a low pH (high acidity) can have an increased availability and toxicity of metals and toxins such as mercury and ammonia.

- **Phosphorus – Ortho Phosphorus (OP)** is the inorganic soluble (dissolved) reactive form of phosphorus that is readily used by algae and other plants.

- **Phosphorus – Total Phosphorus (TP)** is the total amount of organic phosphorus (living materials such as algae) and inorganic phosphorus in a water sample. Elevated levels of TP in lakes cause eutrophication and algae blooms. If phosphorus is the limiting nutrient within a lake (the nutrient in shortest supply), even a small increase in the amount of phosphorus can cause a large increase in the growth of aquatic vegetation. Keeping the inflow of TP at acceptable levels will help maintain the health of a lake. Reducing the levels of TP flowing into a lake will help improve the water quality within the lake. TP levels are adversely affected by wastewater effluent, failing septic systems, urban stormwater runoff (especially from lawns and streets), industrial wastewater, plant material, and agricultural runoff. Phosphorus readily attaches to sediment particles. An increase in the level of total suspended solids may increase the level of total phosphorus.

- **Secchi Disk** readings are taken using a round disk approximately 8 inches in diameter that is either marked with alternating black and white quadrants or is completely white. The disk, attached to an incrementally marked rope, is lowered to the deepest point at which the disk is still visible, in other words, the point just before it disappears. The depth to this point is then measured using markings on the rope to obtain the reading.

- **Total Dissolved Solids (TDS)** is the amount of material that is dissolved in the water (either organic or inorganic). In large amounts this can affect drinking water and corrode metals. Sources of dissolved solids include natural causes, erosion, sewage, urban runoff, and industrial wastewater.

- **Total Suspended Solids (TSS)** is a measure of the amount of material suspended in the water (either organic or inorganic materials). High levels of suspended solids can impair aquatic life and plant life by blocking sunlight. Suspended solids can enter waterways by means of erosion from cropland, roadways, ditches, building sites, stream banks, livestock grazing or confinement areas, urban areas, and forested lands. A portion of the suspended solids carried by a river comes from natural sources, but the level of total suspended solids in the river can be minimized by reducing the amount of human impact through the use of Best Management Practices (BMPs) such as vegetative cover, buffer strips and conservation tillage.

- **Water Temperature** is the warmth of the body of water. Temperature can exert great control over aquatic communities, lake stratification and water chemistry.

9.0 Stream Monitoring Results

There are two reaches within the Clearwater Lake watershed that are on the MPCA 2002 and 2004 303(d) impaired waters lists. These two reaches are Walker Brook from Walker Brook Lake to the Clearwater River, and the trout stream portion of the Clearwater River. Walker Brook is listed for low dissolved oxygen, which impairs the ability of the stream to support aquatic life. The trout stream portion of the Clearwater River, which begins at the Beltrami County line and ends at Clearwater Lake, is impaired for fecal coliform. This impairs the river for the designated use of swimming. The impairments are based upon Environmental Protection Agency standards for the State of Minnesota. The standard for dissolved oxygen is 5 mg/L and the standard for fecal coliform is 200 coliforms/100 ml.

During the RLWD's 2002 monitoring program in the Clearwater Lake watershed, only two potential impairments were found based upon the EPA standards. The Walker Brook sampling site and the 3-mile road sampling site were both impaired for aquatic life based on low dissolved oxygen levels. 3-mile road would be considered partially supporting (>10% of samples exceed the standard), but Walker Brook would be considered not supporting (>25% of the samples exceed the standard). Fecal coliform exceedances were also recorded, including a high spike at County Road #25. However, the frequency of exceedance of the fecal coliform standard at County Road #25 over the last ten years is only 6.52% based on RLWD district monitoring and the monitoring conducted for this study. Based on this information, the site would still pass as fully supporting in the first step of the process of determination of an impairment. Also, according to RLWD district monitoring data, the monitoring site at the Highway 2 crossing on the Clearwater River (S.G. #O-6) is impaired for dissolved oxygen because it has failed to meet the EPA standards in 22.9% of the samples taken there over the last ten years. That site would not be considered impaired in respect to fecal coliform because it has failed to meet the fecal coliform standards in just 6.1% of the samples. S.G. #O-6 is not yet listed on the 303(d) list because the data from the site was not in the EPA STORET database at the time of the assessment for the 2004 list. It is currently in the process of being entered. The MPCA only uses data from the STORET database to assess bodies of water.

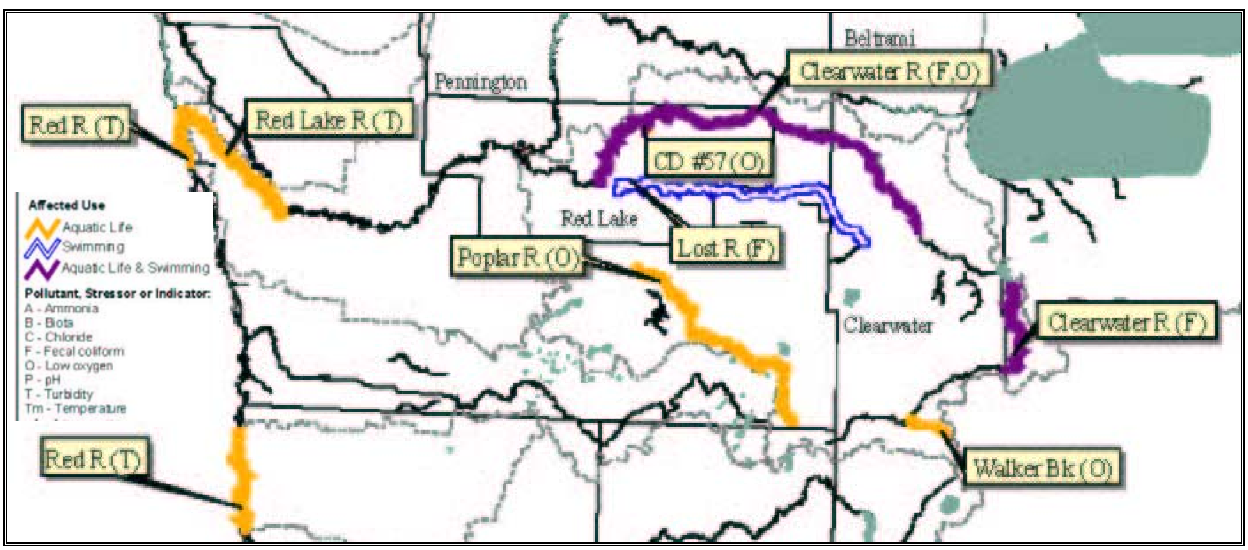
Exceedances occurred at other sites and for other parameters during the Clearwater Lake Water Quality Model Study, but at a lower frequency. These are noted in the following table.

Percentage of 2002 Samples Not Meeting EPA Standards					
Site	**DO**	**Fecal Coliform**	**Conductivity**	**TSS**	**TDS**
Standard	5 mg/L	200 col./100 ml	1,000 mg/L	25 mg/L	500 mg/L
Co. Rd. 25	5.3%	7.1%	0.0%	0.0%	0.0%
Walker Brook	26.3%	7.1%	0.0%	0.0%	0.0%
3-Mile Road	15.8%	0.0%	0.0%	5.3%	0.0%
Buzzle Lake	0.0%	0.0%	0.0%	0.0%	0.0%
CL Inlet	0.0%	0.0%	0.0%	5.3%	0.0%
CL Outlet	0.0%	0.0%	0.0%	0.0%	0.0%

The Minnesota Pollution Control Agency also has a list of standards for minimally impacted streams for each ecoregion within the state. These standards are not currently used in the 305(b) report assessment process or for placing water bodies on the 303(d) list of impaired waters. For the Clearwater Lake watershed, most of these standards are tougher since the water quality within the Northern Lakes and Forests ecoregion is expected to be better than the water quality within the Red River Valley based upon land use, geology, and position within the overall watershed. The ecoregion standards are listed and exceedances during the Clearwater Lake Water Quality Model Study are highlighted in the table below.

Percentage of 2002 Samples Exceeding Ecoregion Standards for Minimally Impacted Streams							
Site	**TSS**	**Fecal Coliform**	**Conductivity**	**Ammonia**	**TP**	**Nitrates and Nitrites**	**Water Temp.**
Northern Lakes and Forests							
Standard	**6.4 ppm**	**20 col./100 ml**	**270 ppm**	**.20 ppm**	**.052 ppm**	**.09 ppm**	**17.6 ºC**
Co. Rd. 25	10.5%	26.3%	100.0%	15.8%	21.1%	0.0%	47.4%
Walker Brook	0.0%	57.9%	94.7%	21.1%	57.9%	0.0%	47.4%
Buzzle Lake	0.0%	5.3%	68.4%	0.0%	0.0%	0.0%	47.4%
CL Inlet	42.1%	31.6%	100.0%	15.8%	47.4%	42.1%	42.1%
North Central Hardwood Forests							
Standard	**16.1 ppm**	**330 col./100 ml**	**340 ppm**	**.22 ppm**	**.170 ppm**	**.29 ppm**	**20.0 ºC**
CL Outlet	0.0%	0.0%	94.7%	5.3%	0.0%	0.0%	26.3%
3-Mile Road	5.3%	0.0%	100.0%	10.5%	0.0%	0.0%	36.8%

When compared to EPA standards (single values applied to the whole state), the Clearwater River does well for most parameters, but when compared with ecoregion standards, it is evident that there is room for improvement. Although natural causes contribute to some of the impairments on the river, human activities often have a direct affect on water quality. Below is a map reaches within the RLWD that are listed on the 2002 Impaired Waters List.



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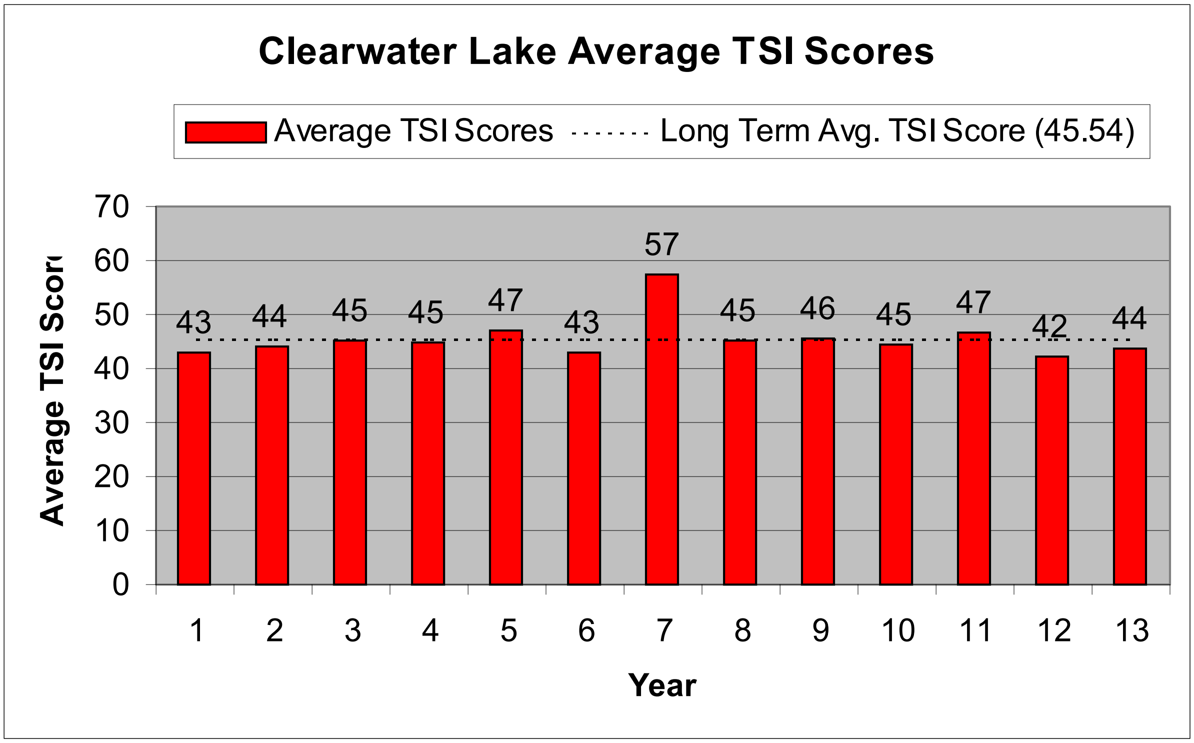
10.0 Lake Monitoring Results

The monitoring site used to determine the trophic state of the Clearwater Lake is CL1 (also called site #204 by the MPCA), which is located at the deepest point of the lake. This site was monitored prior to this study and continues to be monitored by the RLWD and the Clearwater Lake Area Association.

The trophic state index (TSI) is a score based upon total phosphorus, Secchi disk, and chlorophyll-a readings. It is used to classify the growth and productivity of a lake. Lakes may be oligotrophic (<30), mesotrophic (40-50), eutrophic (50-60), or hypereutrophic (>70). The average trophic state index score for Clearwater Lake in 2002 was 42.18. This score is on the lower end of the mesotrophic range and is an improvement from previous years. The average trophic state of the lake is normally around the middle of the mesotrophic range. This means that the lake has enough nutrients to support aquatic life but does not have an excessive amount of nutrients. This is a desirable condition for the lake. The lake is unable to support salmonids (trout), but supports a predominant walleye population.

The charts below show yearly average trophic state scores for all the years in which data was collected. Although the average score of the lake is in the low-to-mid-40's, there is a great range in scores throughout the year. During the summer of 2002, the TSI scores ranged from 31 to 47. In 2003, the TSI scores ranged from 40-54.

The water in Clearwater Lake can be very clear at times. The lake had average Secchi disk readings of 7.54 in 2002 and 9.5 in 2003. On June 9, 2003, the Secchi disk reading was 16.5 feet. Although the water quality in the lake is relatively good, Clearwater Lake is still listed on the MPCA's 2004 303(d) list of impaired waters. Due to mercury content, the use of aquatic consumption is impaired and the lake has a fish consumption advisory. A lake is considered impaired for mercury content if fish consumption for a species of fish is limited to one meal or less per week. According to the *Minnesota Department of Health Fish Consumption Guidelines for the General Population*, northern pike longer than 15 inches should be limited to one meal per week. Walleye longer than 15 inches should be limited to one meal per week and walleye longer than 20 inches should be limited to one meal per month. Bluegill sunfish, white sucker, and yellow bullhead are listed as unlimited.


Clearwater Lake Average TSI Scores
Average TSI Scores
Long Term Avg. TSI Score (45.54)
Average TSI Scor
70
60
50
40
30
20
10
0
43
44
45
45
47
43
57
45
46
45
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42
44
1
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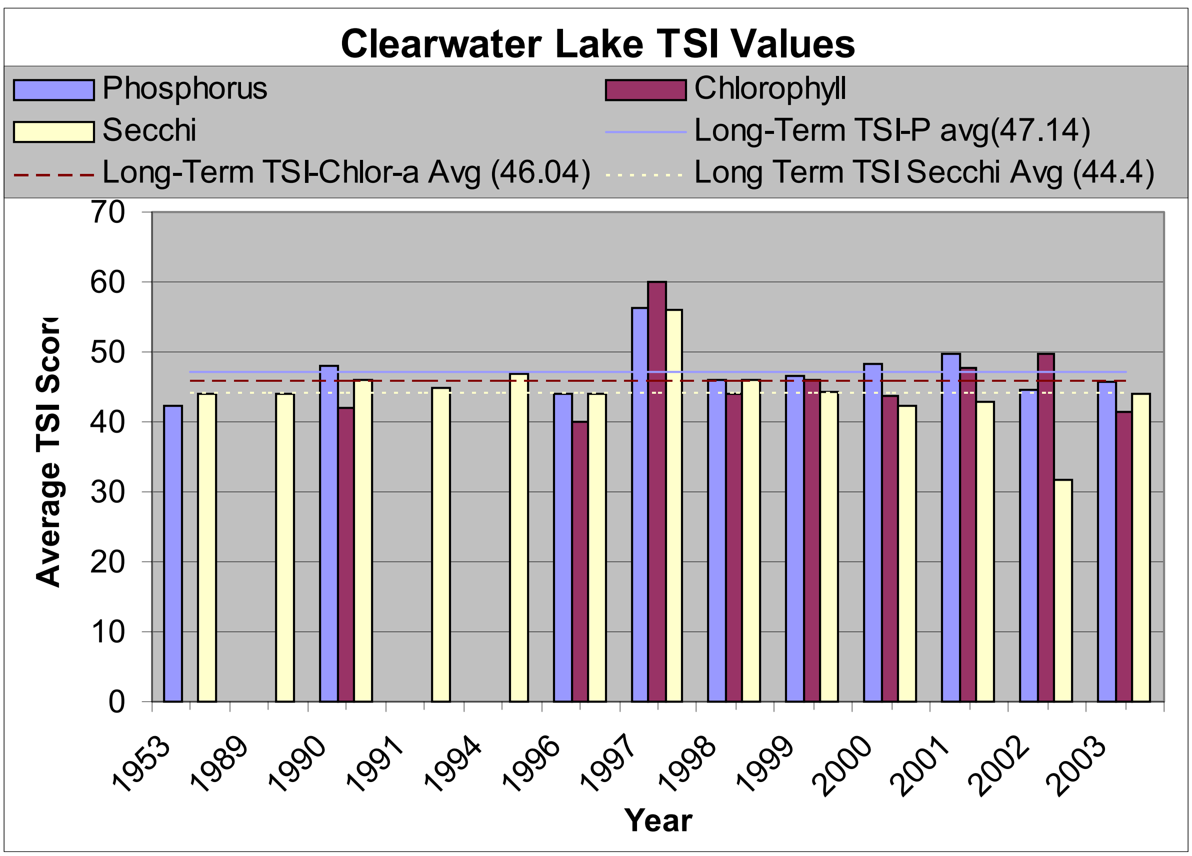
10
11
12
13
Year


Clearwater Lake TSI Values
Phosphorus
Chlorophyll
Secchi
Long-Term TSI-P avg(47.14)
Long-Term TSI-Chlor-a Avg (46.04)
Long Term TSI Secchi Avg (44.4)
Average TSI Scor
70
60
50
40
30
20
10
0
1953
1989
1990
1991
1994
1996
1997
1998
1999
2000
2001
2002
2003
Year

How does the lake compare to other lakes within the same ecoregion? Based on the 1994 Minnesota Lake Water Quality Data Base Summary, Clearwater Lake has ranked at about the 18th percentile for area, at the 25th percentile for depth, between the 50th and 75th percentiles for TSI-phosphorus, between the 50th and 80th percentiles for TSI-chlorophyll-a, between the 50th and the 100th percentiles for TSI-Secchi, and between the 50th and the 60th percentiles for TSI-mean. The table below is a comparison of 2002 monitoring results at CL-1 with average values for all lakes within the Northern Lakes and Forests ecoregion. Also listed below are the MPCA thresholds for determination of use support (swimming) for lakes. All values below the threshold values listed are fully supporting and those above the threshold values are listed as impaired and would fall under the category of partially supporting or potentially non-supporting in the 305(b) assessment process. If a lake is listed as partially supporting or potentially non-supporting, it is either reviewed or listed as impaired on the 303(d) list, based on the degree of impairment. Clearwater Lake meets all of the MPCA standards so it would be determined to be fully supporting for swimming use based on the data collected for this study.

Parameter	MPCA Thresholds	Northern Lakes and Forests Ecoregion	Clearwater Lake 2002	Clearwater Lake 2003
Total Phosphorus (ppb)	30	14-27	30	22.4
Chlorophyll-a Maximum (ppb)		<15	16	21
Chlorophyll-a Mean (ppb)	10	<10	8.45	7.57
Secchi Disk (ft)	5.25	8-15	7.54	9.5
Total Kjeldahl Nitrogen (ppm)		<0.75	.44	.42*
Nitrates and Nitrites (ppm)		<0.01	.006*	.057*
pH		7.2-8.3	8.35	8.39
Total Suspended Solids (ppm)		<1-2	2.06	2*
Conductivity		50-250	409.46	383.80
TN:TP ratio		25:1 – 35:1	14.8	21.28

*Concentrations are based on results from the Clearwater Lake outlet since no analysis for this parameter was conducted on lake samples.
*ppb = parts per billion, or micrograms per Liter (µg/L)

The lake is mixed in the spring, stratified throughout the summer, and then mixed again in the fall. When a lake is stratified, it has three layers, the epilimnion (top layer), metalimnion or thermocline (middle, transitional layer), and the hypolimnion (bottom layer). The lake experiences its highest trophic state levels when it is mixed as nutrients are brought up from the bottom of the lake and mixed with the rest of the water column. Clearwater Lake experiences anoxia (no dissolved oxygen) in the hypolimnion during late summer. Hypoxia (low dissolved oxygen) occurs in the hypolimnion of Clearwater Lake throughout the year, with the exception of when the lake was mixed. During anoxia, there is not enough oxygen for fish to survive, plus, phosphorus can be released from the sediment on the bottom of the lake by bacteria. This phosphorus is relatively isolated in the hypolimnion until the lake mixes or “turns over.”

Phosphorus may then be mixed into the rest of the water column and increases the levels of phosphorus in the upper water column where water quality samples are taken.

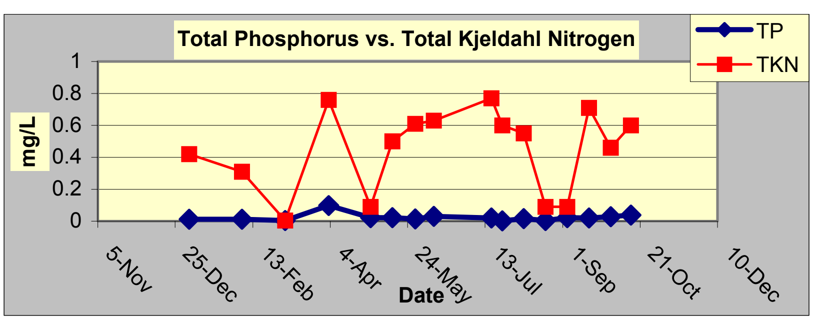
The conductivity levels in the lake are high relative to the ecoregion values; this is possibly due to the geology of the area and suggests a strong interaction between the lake and ancient ground water that contains a high amount of dissolved solids. Ground water with high TDS levels entering the lake would increase the electrical conductivity of the lake.

The lake exhibits a clinograde oxygen profile throughout the year. This means that dissolved oxygen levels decrease from the epilimnion to the hypolimnion. This may be due to decomposition of organic matter on the lake bottom, lack of circulation of water (oxygen levels dramatically decrease in the hypolimnion during stratification in Clearwater lake), lack of sunlight penetration into the hypolimnion for photosynthesis, water temperature, the volume of the hypolimnion, and/or chemical oxidation of dissolved organic matter.

A series of profiles are included in this report, starting on page 17. Lines that are relatively straight indicate periods of mixed conditions. The kinked lines that are vertical near the surface and vertical near the bottom, but sloping in the middle indicate stratified conditions. The vertical section near the surface is the epilimnion, the sloping section is the metalimnion, and the vertical section near the bottom is the hypolimnion. Clearwater Lake is dimictic, meaning it mixes twice per year, once in the spring and once in the fall.

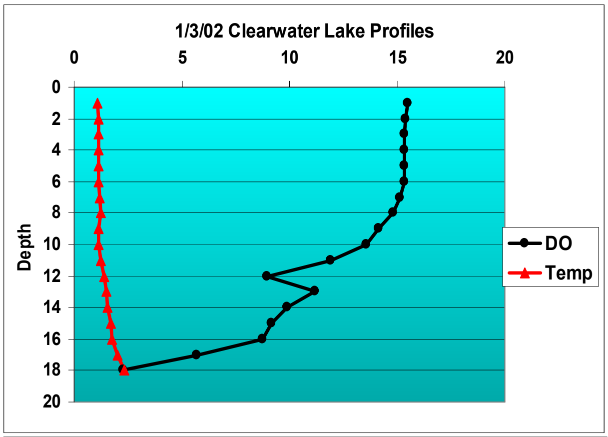
Through the monitoring of two sites on the lake, a gradient between two different zones of the lake became apparent. The shallower, more nutrient rich zone in the southeast end of the lake represents a transitional zone (CL2) between the riverine and the lacustrine (CL1) zones of the lake. The riverine zone is the relatively narrow area of the lake immediately down-stream of the river inflow where current velocities decrease and significant sediment transport still occurs. The EPA defines the lacustrine zone of the lake as that area of a reservoir that is most lake-like. Current velocities are much slower in this zone than for riverine or transitional zones. Little sediment deposition normally occurs since most sediment load has been deposited in the riverine or transitional zones. This explains the thick vegetation on that end of the lake that makes navigation difficult. This gradient and zone of sediment deposition are common on lakes and reservoirs that are located on rivers.

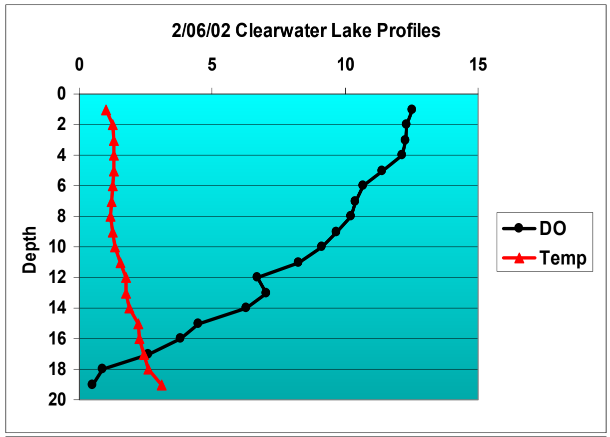
As was determined by the Clearwater Nonpoint Study, the lake appears to be phosphorus limited. The total nitrogen concentrations are nearly always higher than the total phosphorus concentrations as evidenced by the following graph.

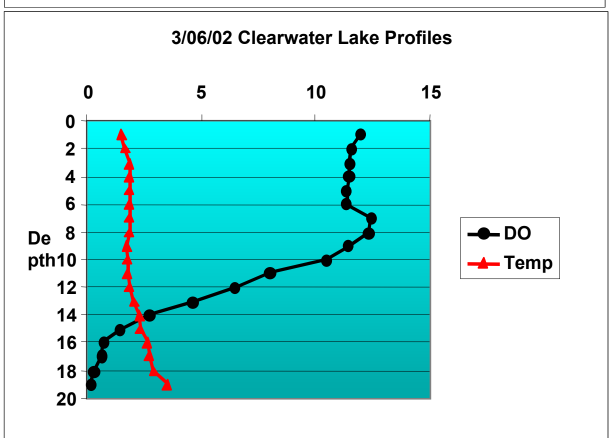


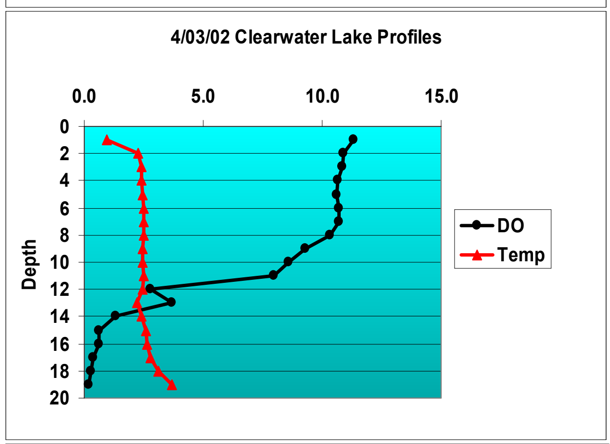
The lake has recovered from extreme eutrophication and resulting TSI levels that neared 60 during the summer of 1997. The eutrophication that occurred during that summer was due a flooding related influx of nutrients that included overflows from the sewage treatment facility of the City of Bagley. Since 1997, Bagley's sewage treatment plant has been upgraded to prevent future sewage bypass. The city has also recently constructed stormwater treatment ponds to reduce the amount of sediment and nutrients entering the river.

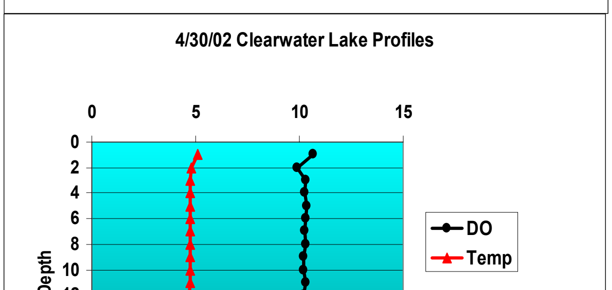
Page Break

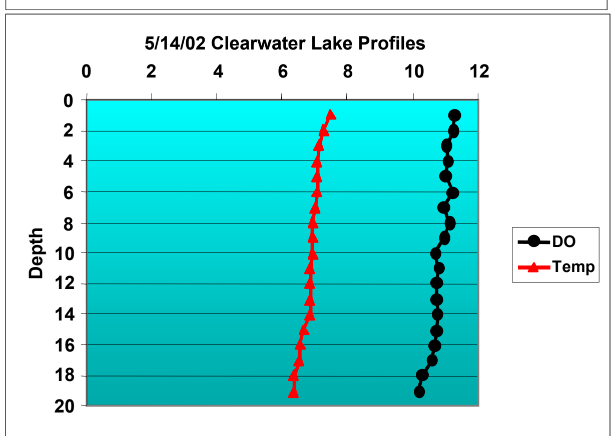


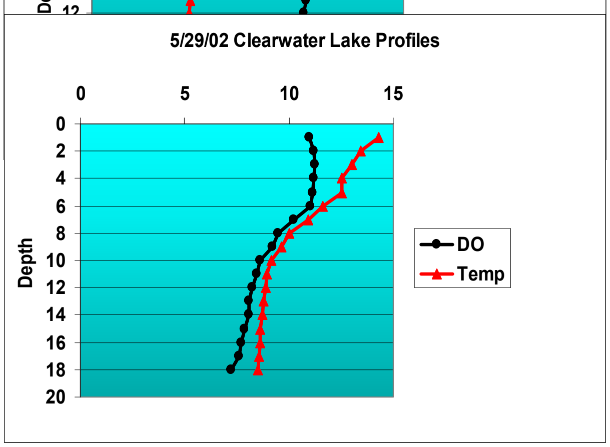


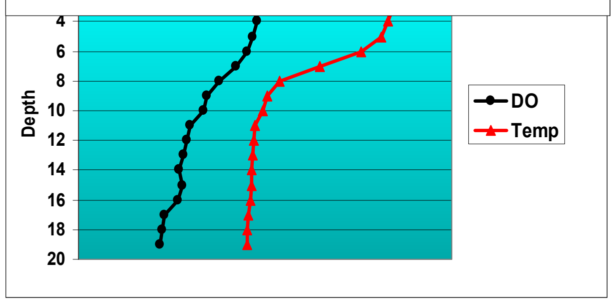


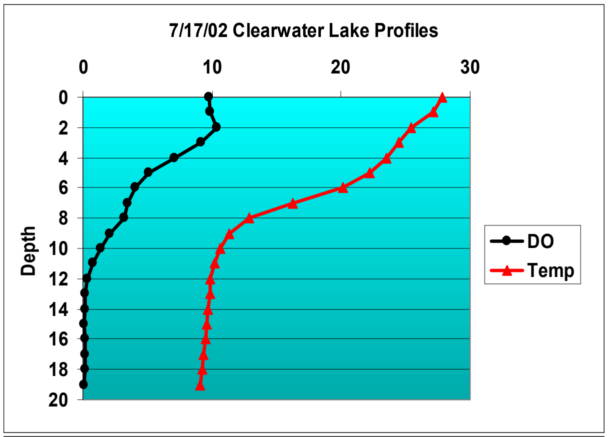











7/17/02 Clearwater Lake Profiles
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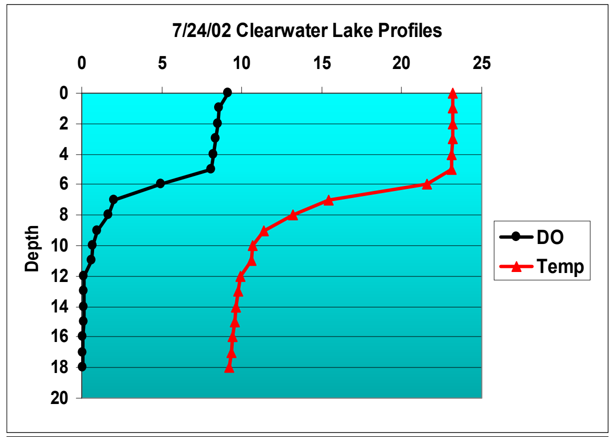
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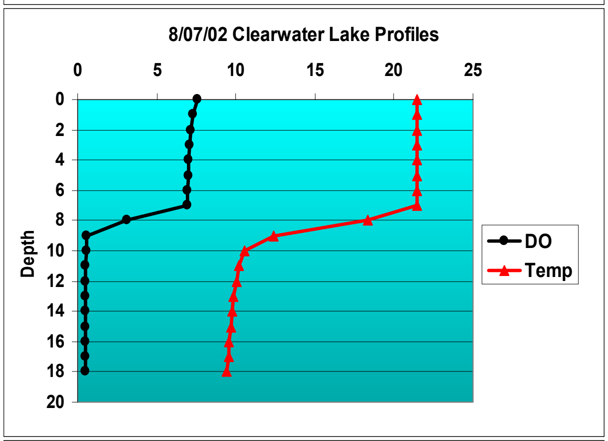
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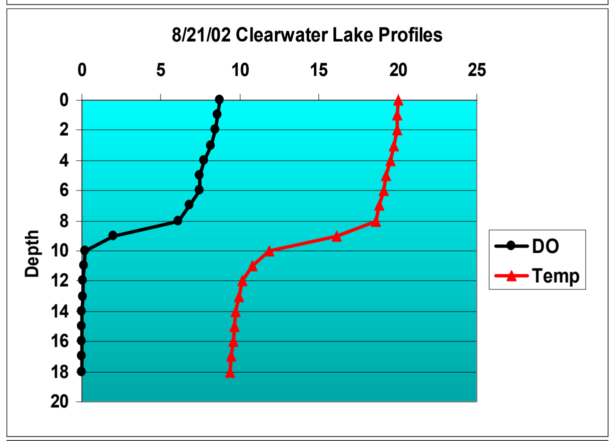
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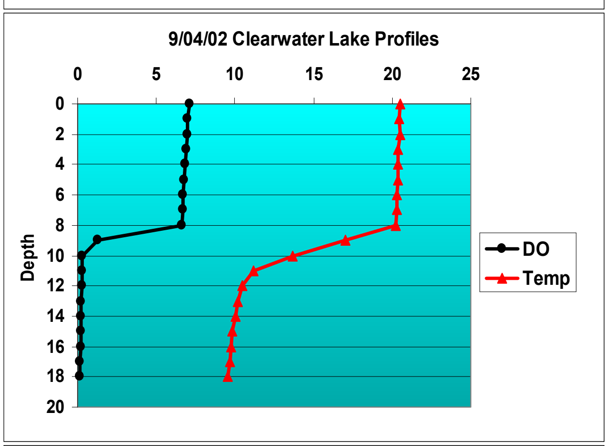
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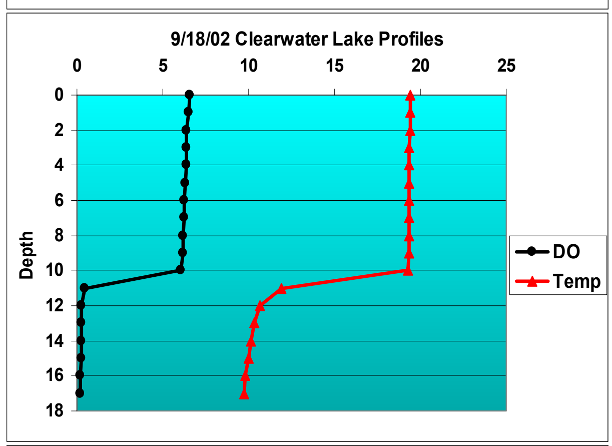
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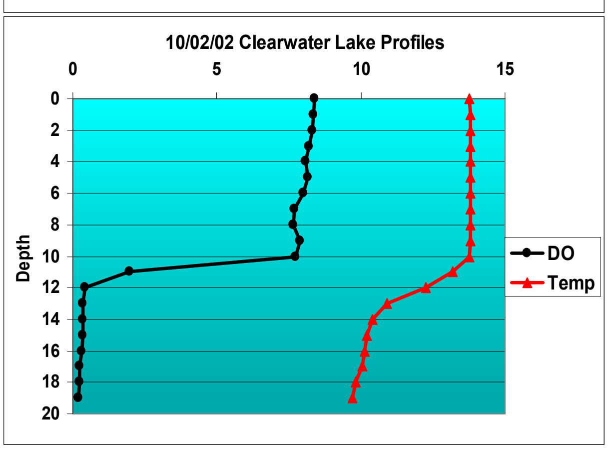
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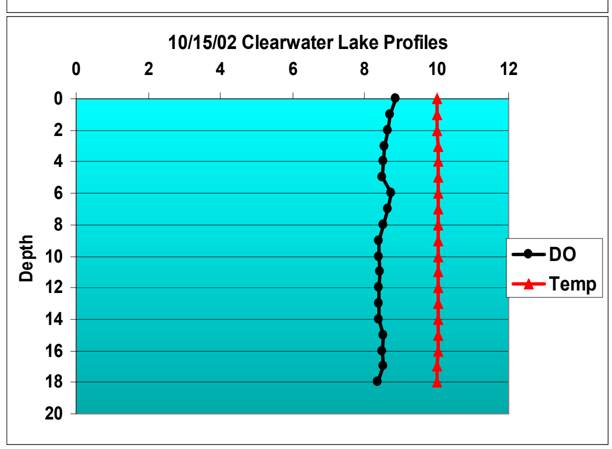
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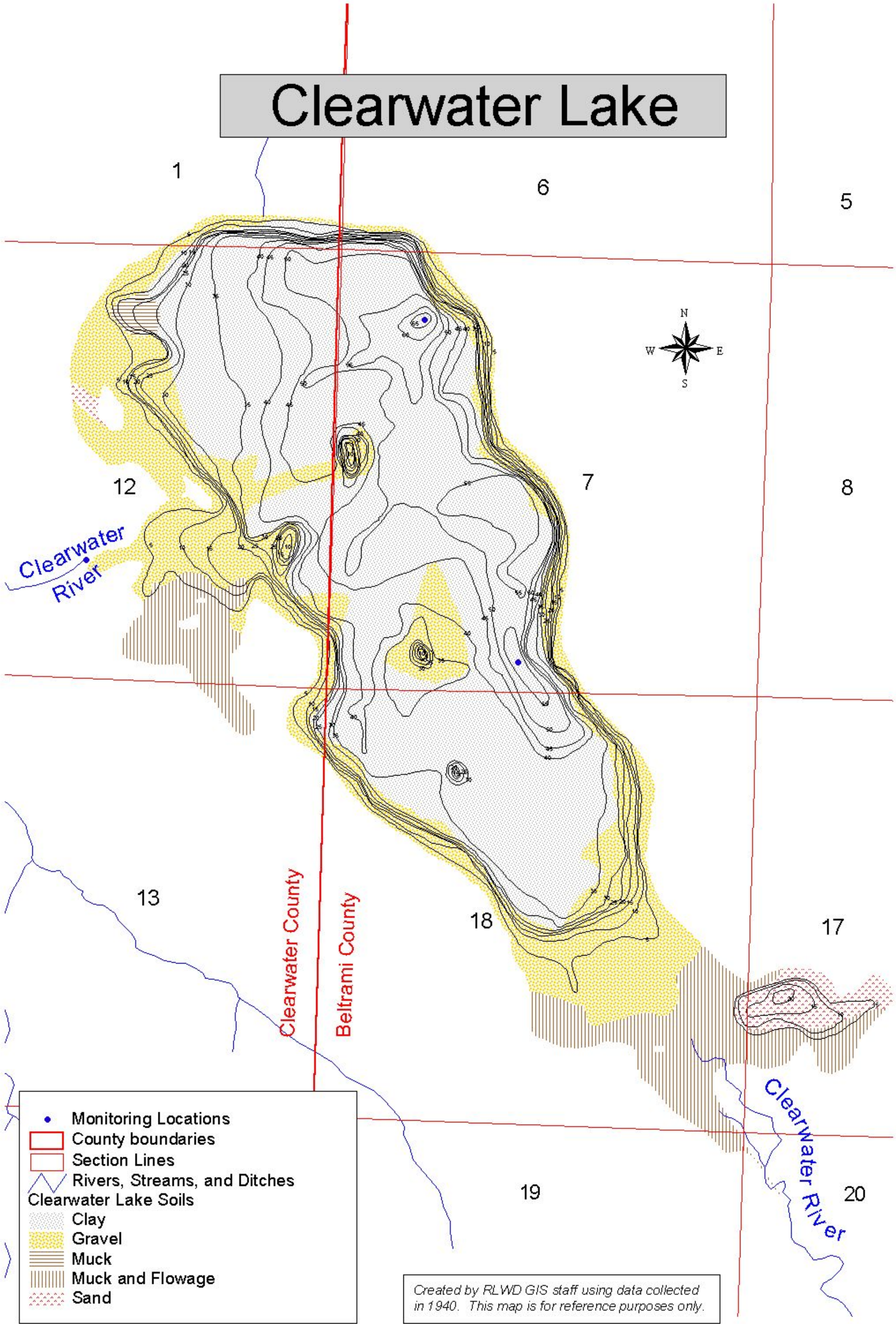

Clearwater Lake Bathymetric Map