Crystal Lake

Total Maximum Daily Load Study

Excess Nutrients

Submitted by:

Minnesota State University Mankato – Water Resources Center

MINNESOTA POLLUTION CONTROL AGENCY

MINNESOTA STATE UNIVERSITY MANKATO

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TMDL Summary Table

EPA/MPCA Required Elements	Summary	TMDL Page #
303(d) Listing Information	Impaired Water- Crystal Lake Lake ID# 07-0098-00 Affected designated use- Aquatic recreation Pollutant or Stressor – Nutrient/Eutrophication Biological indicators TMDL pollutant of concern - Phosphorus TMDL start date – 2006 Target end date – 2010	12
Location	The Crystal Lake watershed is located in Blue Earth County in south central Minnesota, adjacent to the community of Lake Crystal. Crystal Lake is one of three lakes within the Crystal, Loon, and Mills lake system, which is part of the Minneopa Creek watershed, which is in turn, part of the Middle Minnesota River Basin	14
Applicable Water Quality Standards/ Numeric Targets	Crystal Lake is a shallow lake in the Western Corn Belt Plains ecoregion. The water quality standard for this area and lake is a total phosphorus value: 90 ppb.	23
Seasonal Variation	Eutrophication and phosphorus standards for Minnesota lakes are based on average conditions for the critical months of June-September. Because target TMDL allocations and reductions are calculated to achieve these standards, both seasonality and critical conditions are accounted for.	26
Loading Capacity (expressed as daily load)	Using BATHTUB model results, the loading capacity was calculated at 6.04 lbs/day of phosphorus entering the lake system.	52

Wasteload Allocation	No existing permitted point sources of nutrient loading exist within the Lake watershed or contributing areas. Construction stormwater was estimated at 1% of the total LA (with the assumption that no more than 1% of the watershed would be under construction at any one time) and calculated at 0.05 lbs/day.	46
Load Allocation	Load allocation values include multiple non point loading sources. The load allocation values were not subdivided to individual loading sources. The load allocation calculated for the TMDL was 5.39 lbs/day.	48
Margin of Safety	The MOS was set at 10% of the loading capacity and was calculated at a value of 0.60 lbs/day.	52
Implementation	A general list of implementation activities has been included within the TMDL. The Crystal Lake Excess Nutrient TMDL will be included in the Minnesota River, Mankato Watershed Restoration and Protection Strategy (WRAPS) project. These strategies will cover specific practices, goals, and targeted areas.	53
Monitoring	A specific TMDL monitoring plan has not been created at this time. Monitoring will continue through existing projects and programs to be developed and implemented in the future.	57
Reasonable Assurance	To address the nonpoint sources, a variety of management practices will need to be considered and implemented. Various practices have been successful within the area, limiting nutrient loading and transport. Continued support from local government units will help ensure ongoing progress to address the impairments. Strategies developed in the WRAPS report will help guide implementation planning to be developed to address the impairment and the methods best suited to meeting the goals of the TMDL	58
Public Participation	This report includes a list of all meetings and events related to public and technical team involvement with the TMDL.	61

Executive Summary

The Federal Clean Water Act (CWA) requires states to adopt water quality standards to protect surface waters from pollution. These standards define how much of a pollutant can be in the water and still allow it to meet designated uses. These uses include drinking water, aquatic life support and recreation. A water body is "impaired" if it fails to meet one or more water quality standards.

Section 303(d) of the CWA requires that states develop Total Maximum Daily Load (TMDL) studies for surface waters that do not meet and maintain applicable water quality standards. The TMDL by definition is the sum of all Waste Load Allocations (point source) and Load Allocations (non-point source) with the inclusion of a margin of safety. A TMDL study reviews the conditions of a water body, determines the loading of a given pollutant from point and nonpoint sources, and determines the carrying capacity or necessary reductions to eliminate the impairment of that surface water's designated use. This study addresses excessive levels of phosphorus in Crystal Lake.

The Crystal Loon Mills Lakes (CLM) watershed is located in the Middle Minnesota River Basin, in south central Minnesota. Crystal Lake is 355 acres with a contributing watershed of approximately 14,000 acres. The watershed has significant local importance, as it is a popular recreational resource and contains the City of Lake Crystal.

In 2006, Crystal Lake was listed on the 303d impaired waters list for excess nutrients. In the fall of 2004, Crystal Lake experienced a toxic algae bloom. Minnesota Pollution Control Agency (MPCA) staff reported a concentration of microcystin, a blue-green algae toxin, at 7190 ug/L. The World Health Organization's provisional drinking water guideline value for microcystin is 1.0 ug/L and a range of 1-10 ug/L is recommended for recreational exposure.

The TMDL program provides a cooperative approach with MPCA assisting the Water Resources Center-Minnesota State University Mankato (WRC-MSUM) and the City of Lake Crystal in data collection, analysis and TMDL development. Following completion of a TMDL study and implementation planning, TMDL implementation funds will be available to the City of Lake Crystal, Blue Earth County, and other entities on a competitive basis.

Information utilized and collected for this project included existing monitoring data to create a nutrient budget, GIS analysis of the watershed, lake vegetation surveys and similar lake and watershed related studies.

Point sources such as: wastewater treatment facilities; construction and industrial stormwater; and Municipal Separate Storm Sewer Systems (MS4's) were reviewed based on permitted and actual discharge values. Due to the nature of the watershed and the location of the city's WWTP, the only calculated wasteload allocation is for construction stormwater permits.

Suspected non-point pollutant sources are addressed in general terms due to the variety and relative contributions of different sources within the watershed. These non-point contributions include both natural and anthropogenic sources. Internal nutrient release and cycling is also very

important to consider when calculating loading for the lake system. Releases from the sediment are suspected to be a major driver in the internal loading for Crystal Lake. Extremely high levels of phosphorus have been measured during anoxic winter conditions.

Causes of excessive nutrient loading can range from natural loading to widespread hydrologic modification from land use/cover changes. Additional site-specific examination/research will be beneficial in targeting specific areas for remediation, due to the variability of the landscape.

A ten percent margin of safety was used to account for uncertainty within the TMDL process. The TMDL values are calculated as follows:

TMDL = LC = $\sum$WLA + $\sum$LA + MOS

TMDL = 6.04 lbs/day = 0.05 lbs/day + 5.39 lbs/day + 0.60 lbs/day

   $\sum$WLA = 0.05 lbs/day

   $\sum$LA = 5.39 lbs/day

   10 % MOS = 0.60 lbs/day

Existing monitoring programs will be used to track progress made towards meeting the TMDL. Best Management Practices (BMPs), many of which are state and federally supported, should be utilized to reduce soil erosion and nutrient transport to improve water quality. A general outline of BMPs and programs is offered in the implementation section as a basic guide to target different practices. Implementation planning can be guided by the WRAPS report to be completed as part of the Minnesota River - Mankato watershed process.

The changes to the Crystal Lake watershed that have contributed to water quality impairments took place over the course of decades. It is highly likely that changes necessary to improve water quality will also take an extended amount of time. In order to reach the reductions needed a variety of management changes must be considered across the landscape. Lake water quality will not improve unless there is a decrease in the amount of nutrients received by the lake from its watershed. Additionally, recycling of nutrients within the lake will need to be reduced through in-lake restoration techniques. Altering land-use practices in the contributing watersheds provides the greatest likelihood for decreased nutrient loading.

In general, changes in existing hydrology and water retention/storage capacity will need to be addressed to meet water quality standards. Any implementation will likely need to be handled in a phased approach, allowing for adjustments in new information, technology, and demands on both the landscape and water resources.

ACKNOWLEDGEMENTS

Acronyms and Glossary:

BMP –Best Management Practice

CREP –Conservation Reserve Enhancement Program

CRP –Conservation Reserve Program

CSMP -Citizen Stream Monitoring Program

CSP –Conservation Security Program

CWA –Clean Water Act

CWP –Clean Water Partnership

DNR –Department of Natural Resources

EPA –Environmental Protection Agency

GBERB –Greater Blue Earth River Basin

GBERBA –Greater Blue Earth River Basin Alliance

GIS –Geographic Information System

IWMI –Interagency Water Monitoring Initiative

LA –Load Allocation

MOS –Margin of Safety

MPCA –Minnesota Pollution Control Agency

MS4 –Municipal Separate Storm Sewer System

NPDES –National Pollution Discharge Elimination System

NPS –Non-point source

QAQC –Quality Assurance Quality Control

QAPP –Quality Assurance Protection Plan

RC –Reserve Capacity

RGA –Rapid Geomorphic Assessment

TMDL –Total Maximum Daily Load

TSS –Total Suspended Solids

USDA –United State Department of Agriculture

USGS –United State Geologic Survey

WLA –Waste Load Allocation

WRAPS –Watershed Restoration and Protection Strategy

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Section 1.0 – Introduction

1.1 Overview and Purpose

The Federal Clean Water Act (CWA) requires states to adopt water quality standards to protect surface waters from pollution. These standards define how much of a pollutant can be in the water and still allow it to meet designated uses, such as drinking water or aquatic recreation. A water body is "impaired" if it fails to meet one or more water quality standards.

Section 303(d) of the Clean Water Act requires that states develop Total Maximum Daily Load (TMDL) studies for surface waters that do not meet and maintain applicable water quality standards.

Figure 1.1 – TMDL Process Summary

In 2006, Crystal Lake was listed on the 303d impaired waters list for excess nutrients based on sample data and analysis. Modeling performed during the 1986 MPCA Lake Assessment Program and the 1995 Clean Water Partnership phase I diagnostic study demonstrated poor water quality and high nutrient loading values. With a Clean Water Partnership Phase II Implementation project being conducted within the Crystal Loon Mills Watershed, initiating this TMDL became a priority at both the local and state levels.

The TMDL Process

Assess the state's waters
↓
List those that do not meet standards
↓
Identify sources and reductions needed
(TMDL Study)
↓
Implement restoration activities
(Implementation Plan)
↓
Evaluate water quality

The TMDL by definition (40 CFR Part 130, section 130.2, 130.7, and 130.10) is the sum of all Waste Load Allocations (point source) and Load Allocations (non-point source) with the inclusion of a margin of safety and reserve capacity.

A TMDL reviews the conditions of a water body, determines the loading of a given pollutant from point and nonpoint sources, and determines the carrying capacity or necessary reductions to eliminate the impairment of that surface water's designated use.

This TMDL investigates the mechanisms of nutrient loading within the watershed, calculates the reductions necessary to meet the water quality standards, and proposes practices to help reduce and control the loading related to the impairment.

1.2 Problem Statement

In September 2004, Crystal Lake experienced a toxic algae bloom. This is a concern as some forms of blue-green algae are known to produce compounds toxic to wildlife, domestic animals, and humans. Minnesota Pollution Control Agency (MPCA) staff monitored the bloom and reported a concentration of microcystin, a blue-green algae toxin, at 7190 ug/L. This level is nearly three and a half times the very high risk level of 2,000 ppb for recreational exposure. In 2007, microcystin samples collected on Crystal Lake showed concentrations of 3,800 ppb, almost twice the very high risk level. Due to the potential danger of toxic algae blooms, as well as concerns from local officials and citizens, the lake was considered a priority for TMDL study.
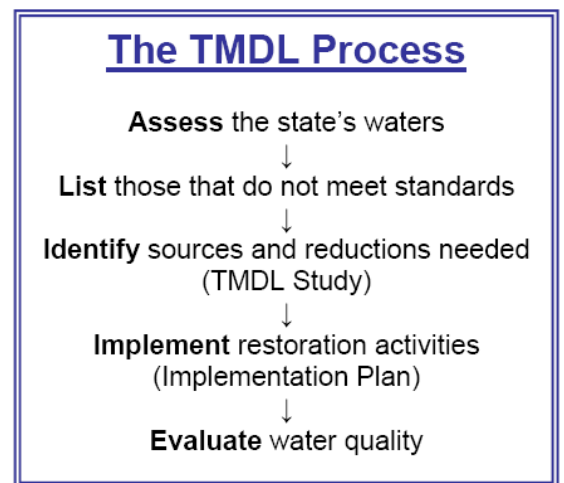
Trophic status is an indication of a lake's ability/potential to produce algae and other plant growth. This index was developed to rank the biomass growth potential within a system. It is commonly divided into the three following categories:

- *Oligotrophic* -generally very little or no aquatic vegetation, high water clarity
- *Mesotrophic* – Moderate aquatic vegetation, with moderate water clarity.
- E*utrophic*. – Abundant aquatic vegetation, with lower water clarity.

Lakes with extreme trophic indices may also be considered *hyperoligotrophic* or *hypereutrophic,* meaning extremely low algal productivity potential and extremely high algal productivity potential, respectively. The TSI scale and parameters can been seen in figure 1.2

Figure 1.2 – Carlson Trophic Status Index

After Moore, 1. And K. Thornton, [Ed.]1988. Lake and Reservoir Restoration Guidance Manual. USEPA>EPA 440/5-88-002.
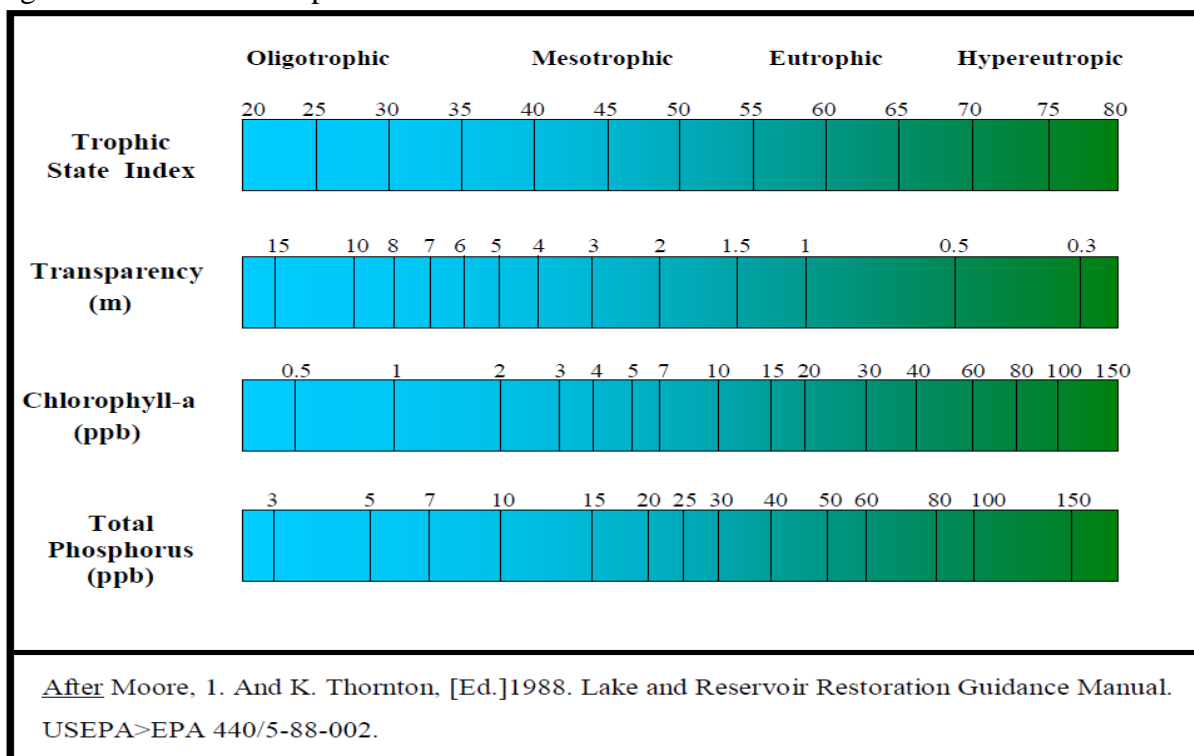
Crystal Lake is considered hypereutrophic based on the Carlson Trophic Status Index (TSI) with levels of phosphorus and algae considered excessive, causing negative impacts on the water quality. Excess nutrients increase the chances of toxic algae blooms within the lake system thereby affecting recreational opportunities.

Hypereutrophic lakes are typically shallow and rich in nutrients, in particular phosphorus. The status of Crystal Lake reflects that the lake has limited water clarity, is rich in nutrients and subject to numerous algal blooms (Proctor et al. 1998). Data suggests this is due to excess nutrients entering and accumulating in the lake from both rural and urban sources, increasing potential internal loading and phosphorus releases. Phosphorus is generally the limiting factor in determining algae and plant growth in a lake.

Poor water quality associated with eutrophication can lead to reduced recreational opportunities and can affect the fish and plant communities within the lake. Severe nuisance algal blooms yield unpleasant odor and appearance that reduce the appeal of swimming and fishing. Rough fish populations can increase at the expense of game fish. These conditions limit local utilization of the resource and the economic benefits associated with the draw of tourism.

Section 2.0 - Background Information

2.1 Landscape and Setting
    A. Watershed and Lake Description

The Crystal Lake watershed is located in Blue Earth County in south central Minnesota, adjacent to the community of Lake Crystal, population 2,420 (Appendix 1). Crystal Lake is one of three lakes within the Crystal, Loon, and Mills lake system, which is part of the Minneopa Creek watershed, which is in turn, part of the Middle Minnesota River Basin Figure 2.1A. An expanded view of the Lake Crystal watershed can be seen in Figure 2.1-B.

Figure 2.1A – Watershed Location
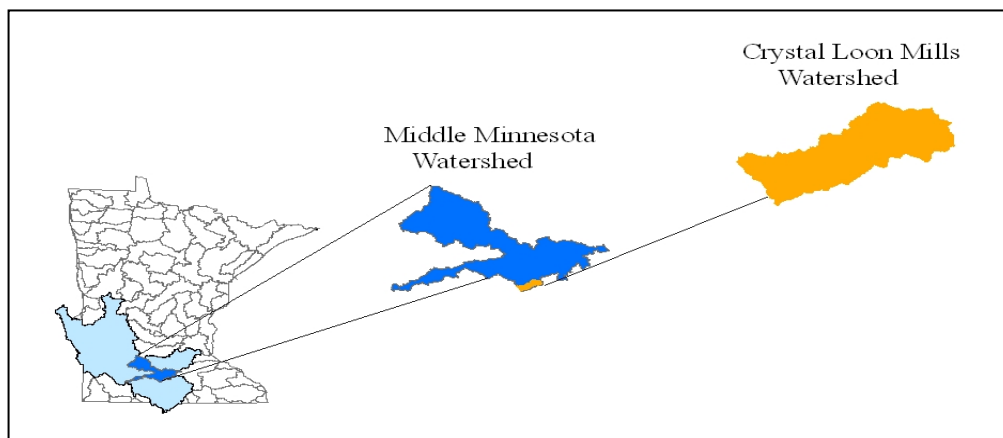
Figure 2.1B – Crystal Lake Watershed
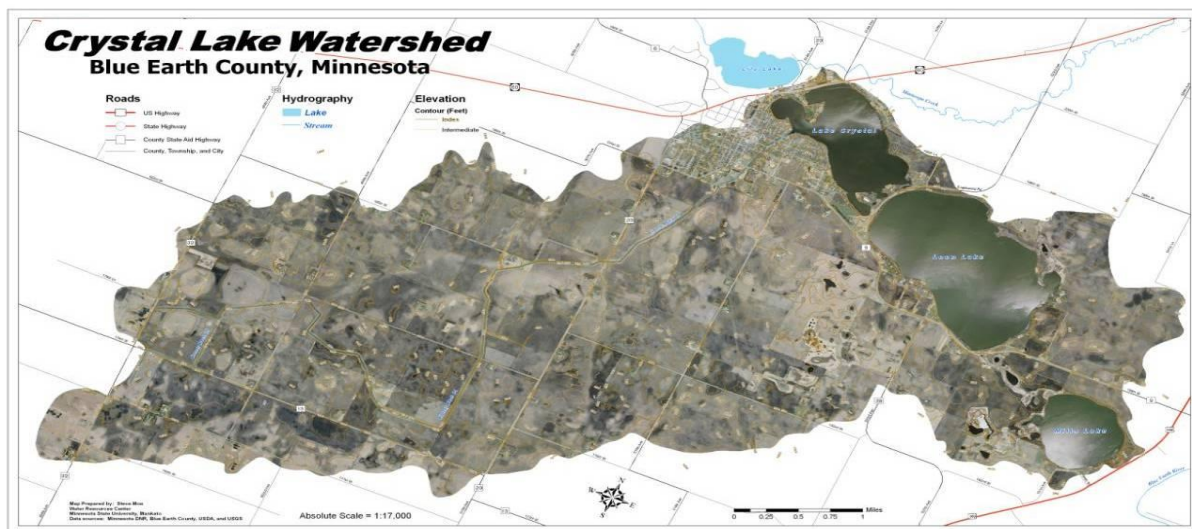
The Crystal Lake watershed covers approximately 14,000 acres and is primarily drained by County Ditch (CD) 56 and private field tiles which outlet into Crystal Lake. In addition, approximately 75% of the urban residential areas for the City of Lake Crystal are drained into CD 56 through several storm sewers (Proctor et al. 1998).

The total contributing area to the Crystal Lake watershed includes four additional watersheds. While the TMDL focuses on Crystal Lake, it is important to determine the levels of loading coming from the additional contributing watersheds. For the purposes of this TMDL study, watersheds considered included the Loon Lake watershed, the Mills Lake Watershed, the CD 56 watershed, the city of Lake Crystal watershed and the Crystal Lake watershed (Figure 2.1C). Since each of the watersheds flow into Crystal Lake, the individual watersheds contribute to the total loading within the system.

Figure 2.1C – Crystal Lake Catchment areas
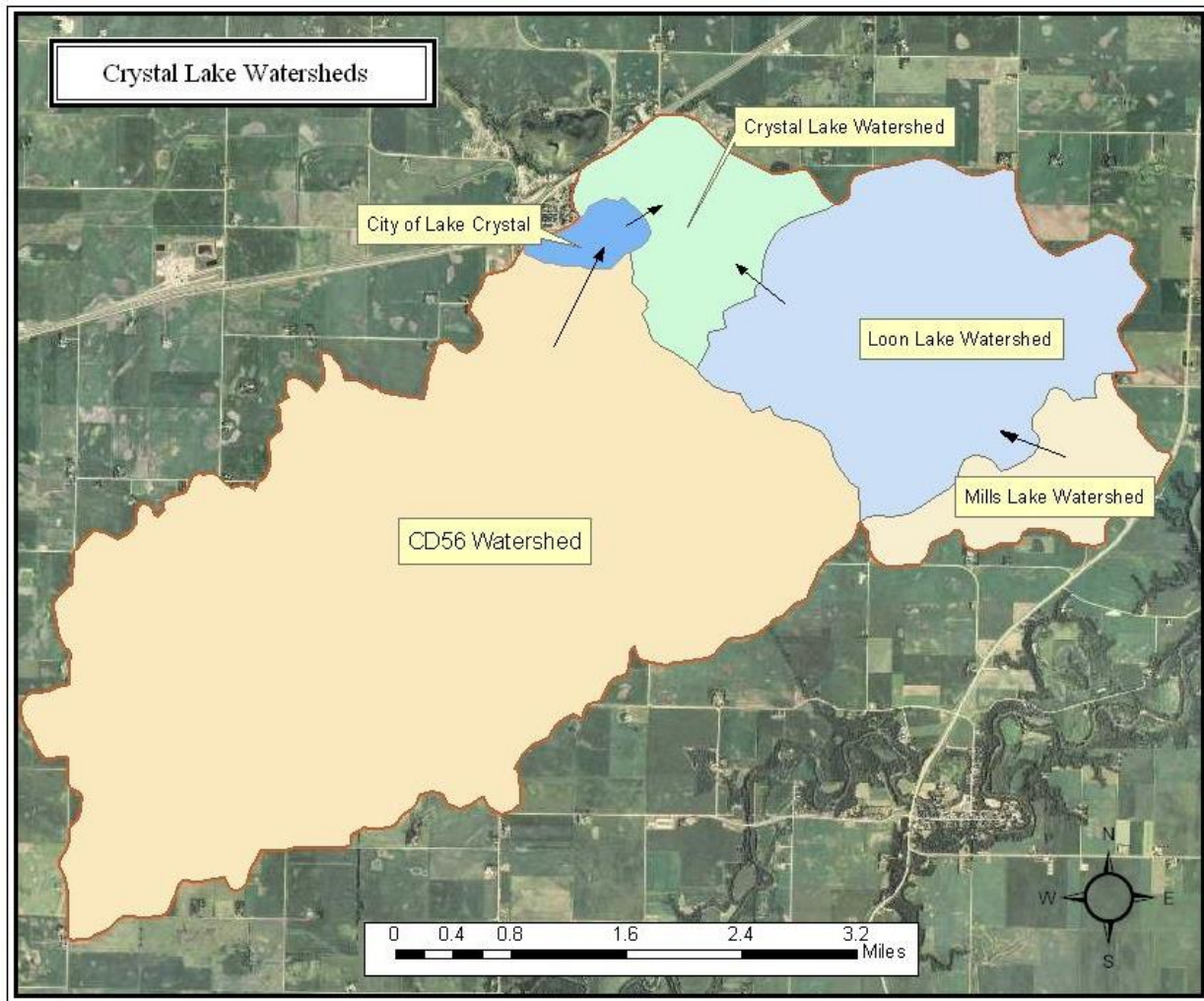
B. History and Development

Crystal Lake is believed to have been named by John C Freemont and J. N. Nicollet, two explorers who traveled the area in 1838, due to its "unusual brilliancy and crystal purity of the waters". The city of Lake Crystal was originally platted in May 1869, and incorporated in February of 1870.

The right-of-way for County Ditch 56 was secured in 1900 and flows through the community of Lake Crystal into Crystal Lake. Construction of the ditch improved drainage within the watershed, allowing additional acres to be put into agricultural production and increased production from existing acres. The ditch continues to provide economic benefit to the agricultural community.

In 1958, a study was performed by Douglas Barr of Barr Engineering to investigate sedimentation rates within the lake. This appears to be the first lake specific information relating water quality and the effects of watershed alterations on the lake system. The study found large depositions of soft sediment in portions of the lake. Investigation into the source of the sediments found that while CD 56 may have been a large contributor during the initial construction, it was now at a stable state due to grass covering the banks. The study estimated that newer sediment was the result of a buildup of rotting organic material from aquatic vegetation due to nutrients entering the lake system from the watershed.

Dredge operations were incorporated in 1967 and 1968 to remove the buildup of sediment and deepen the lake. The target areas of the dredging were near the outlet of CD 56 and on and around Cemetery Point. Dredge material was used to enlarge Cemetery Point, with the remaining material placed west of CD 56 and southeast of County Road 9. During this time period, an aeration system was installed and is still in use today.

Crystal Lake receives surface water from two primary sources, County Ditch 56 and the outlet of Loon Lake. The Barr Engineering study found County Ditch 56 to be the major contributor of nutrients and sediment to Crystal Lake. The ditch drains agricultural land to the southwest of Crystal Lake and then enters the City of Lake Crystal before discharging into the lake

C. Modern Land Use and Cover

Minnesota is divided into seven ecoregions based on vegetation, soils type, geology, and climate. The Crystal Lake Watershed is located in the Western Corn Belt Plains Ecoregion. The dominant land use in this region is agricultural, followed by varying amounts of urban development.

The 2009 National Agricultural Statistics Service (NASS) land use statistics were utilized for this study, the most current available during the creation of the TMDL. Conservation easement information was calculated for modeling efforts. Specific land use area from these programs are not categorized in table 2.1 but considered under the Pasture/Grass category. With current market activity in commodities and land values, the future of existing CRP easements is unknown and is subject to change with market conditions.

The land use characteristics for the CLM watershed are summarized in Table 2.1. For land use map and land cover class definitions see appendix 3.

Table 2.1 - Summary of Land Use Characteristics for the Watershed

Classification	Acres	%
Corn	5713.5	44.4%
Soybeans	3914.9	24.4%
Sweet Corn	17.8	0.1%
Spring Wheat	96.1	0.7%
Winter Wheat	5.4	0.0%
Other Hays	6.2	0.0%
Sugar beets	0.8	0.0%
Peas	30.2	0.2%
Pasture/Grass	465.7	3.6%
NLCD - Open Water	1194.2	9.3%
NLCD - Developed/Open Space	1043.0	8.1%
NLCD - Developed/Low Intensity	282.1	2.2%
NLCD - Developed/Medium Intensity	55.0	0.4%
NLCD - Developed/High Intensity	10.8	0.1%
NLCD - Barren	9.3	0.1%
NLCD - Deciduous Forest	130.2	1.0%
NLCD - Grassland Herbaceous	11.6	0.1%
NLCD - Pasture/Hay	135.6	1.1%
NLCD - Woody Wetlands	30.2	0.2%
NLCD - Herbaceous Wetlands	502.1	3.9%

Crystal Lake TMDL
Land Cover/ Land Use Map
2009 NASS Coverage

CD56 Watershed

City of Lake Crystal

Crystal Lake Watershed

Loon Lake Watershed

Mills Lake Watershed

1 inch = 4,678 feet

0   0.3750.75   1.5   2.25   3
Miles

Legend

Watershed boundaries
1 - Corn
5 - Soybeans
12 - Sweet Corn
23 - Spring Wheat
24 - Winter Wheat
37 - Other Hays
41 - Sugarbeets
53 - Peas
62 - Pasture/Grass
111 - Open Water
121 - Developed - Open space
122 - Developed - Low intensity
123 - Developed - Medium intensity
124 - Developed - High intensity
131 - Barren
141 - Deciduous Forest
171 - Grassland/Herbaceous
181 - Pasture/Hay
190 - Woody wetlands
195 - Herbaceous wetlands

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2.2 Climate

Climate greatly affects the conditions of the lake and the watershed in general. Temperature and rainfall may be the most obvious factors, as they influence the amount of water within the system, potential runoff, as well as potential for algal productivity.

A. Temperature

Average monthly air temperatures in the Crystal Lake watershed are presented in Figure 2.2A and Table 2.2A. Spring melt typically occurs between the end of March and early April. The melting snow will raise the levels of the contributing waters and lakes. Temperatures reach peak levels during July/August and then gradually decline.

While nutrient loading is not directly related to temperature, some relations can be seen through seasonal variation. High nutrient concentrations may occur with rising spring temperatures as snow melt increases run off potential and flow volumes, moving sediment and nutrients though the system. This relationship can be seen in the loading data collected within CD 56 and from other data sources across the Minnesota River basin.

Algae production is also related to temperature. In general, once ambient water temperature reaches 16-27 °C (60-80 °F), with 18-20 °C (64 - 68°F) being the optimal range, algal productivity will be high (Food and Agriculture Organization of the United Nation, 1991). Other parameters influencing productivity levels include time of exposure to sunlight, pH, availability of nutrients (phosphorus) and temperature (often related to time of sunlight exposure) which can create a situation for large scale algal growth.

The lake is also subject to release of phosphorus during the winter. When conditions are right, a low oxygen environment may develop in the lake. These anaerobic conditions can lead to a release of phosphorus from the lake sediments. These releases were recorded in the sample data in 2008 and 2009.

Figure 2.2A – Average Monthly Temperature

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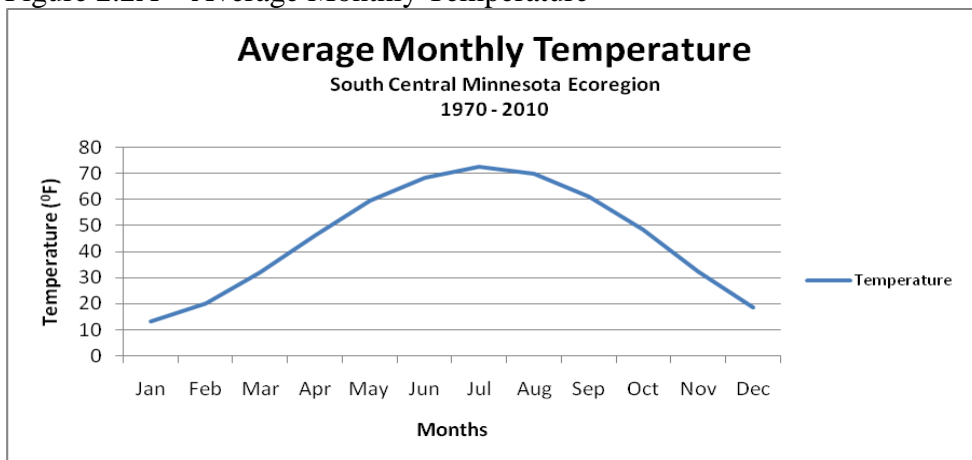
Table 2.2A – Average Monthly Temperature

South Central MN, Average Monthly Temperature Minnesota Climatology Working Group : 1970 - 2010												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature	13.1	20	32.1	46.3	59.4	68.5	72.6	70	61	48.6	32.5	18.6

B. Precipitation

Based on data collected by the National Weather Service (NWS) and the National Oceanic Atmospheric Administration (NOAA), the average precipitation rate is around 27-28" per year. Seasonal summaries can be seen in figure 2.2B and table 2.2B. This value is very similar to the findings of the Minnesota Climatology Working Group and the Blue Earth County Township Rain Monitoring System data.

Figure 2.2B − Average Monthly Precipitation
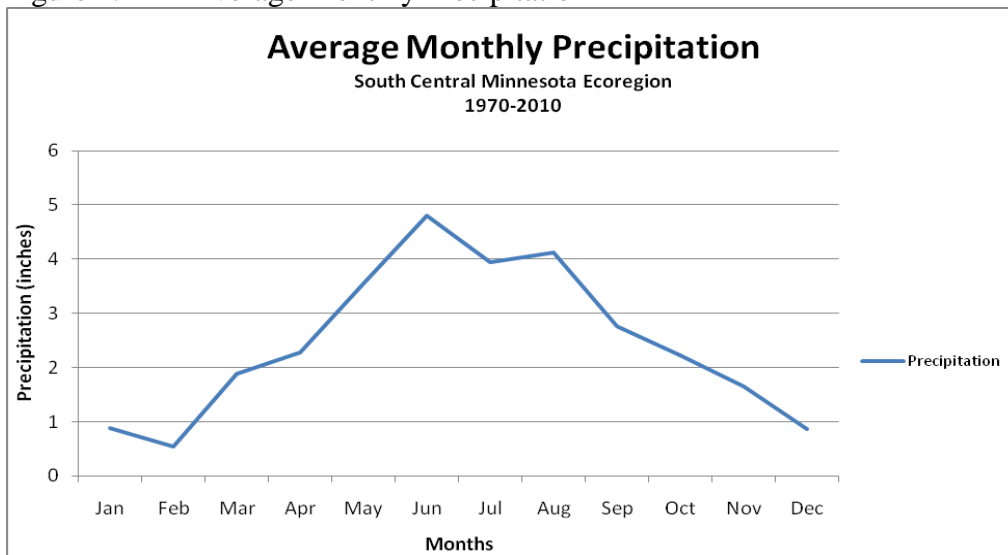
Table 2.2B – Average Monthly Precipitation

South Central MN, Average Monthly Precipitation Minnesota Climatology Working Group : 1970 - 2010												
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation	0.89"	0.55"	1.89"	2.28"	3.55"	4.8"	3.94"	4.12"	2.76"	2.22"	1.66"	0.86"

2.3 Soils

While not directly related to nutrient loading, it is important to examine soil types within the watershed. The nature of the soils plays a role in land use, drainage, and other factors that can be related to nutrient transport within the system.

Drained wetland soils can release nutrients, depending on soil moisture conditions. Wetlands typically act as a natural isolated settling or storage basin. When drained or altered, stored nutrients can be leached from the soil and move through the watershed by increased connectivity of the drainage system. The five most common soil types (Appendix 2) found within the watershed are as follows:

Dassel loam (11.41%), Fieldon loam (10.25%), Darfur loam (7.25%), Clarion loam, 2 to 6 percent slopes (6.91%), Litchfield loamy fine sand, 1 to 3 percent slopes (6.46%).

Of these soil types, the top three are described as typically wet, and require drainage to make them suitable for agricultural use. This drainage includes both ditching and tile systems. Surface and subsurface drainage result in land use and cover change, loss of "leaked" agricultural nutrients and contaminants to surface and ground waters, and complex changes in hydrology and geomorphology relative to pre-drained conditions (Blann et all, 2008). However, the specific impacts of this drainage are difficult to quantify within the context of this TMDL.

2.4 Aquatic Vegetation

The littoral zone of the lake, according to the Minnesota Department of Natural Resources, is defined as that portion of the lake that is less than 15 feet in depth. It is this region of the lake where the majority of the aquatic plants are found, due to the availability of sunlight reaching the bottom.

Lake related plant types include emergent, floating and submerged vegetation. Due to the shallow nature of Crystal Lake, the entire area of the lake is considered within the littoral zone. Very little aquatic vegetation is found in Crystal Lake, and is noted as N/A for vegetation types in the MN DNR lake surveys.

Vegetation provides essential habitat for fish and macroinvertebrates and is important in stabilizing sediments and preventing shoreline erosion. Crystal Lakes' lack of aquatic vegetation is partially due to algae development inhibiting light penetration. Other factors include rough fish populations and sediment composition that likely play a role in reduced plant viability.

2.5 Fisheries Status

The Minnesota Department of Natural Resources conducted a fishery survey in 2006 to determine the status of the fish community as well as assess general lake conditions. Based on the survey, approximately 60% of the shoreland is listed as disturbed, while 40% is listed natural and classified as Large Woody Debris (LWD), with no emergent or floating vegetation and lawn/turf grass maintained to the shore based on survey transects.

Current available spawning habitat was best suited for benthic omnivores such as common carp and black bullheads. These types of fish, along with the excess nutrient loads, contribute to the overall poor water quality through the re-suspension of sediments and phosphorus. Rough fish reduce water clarity by stirring up the lake bottom; a behavior that inhibits the growth of rooted aquatic vegetation and changes water chemistry. These increased levels of turbidity impact aquatic plant communities.

The lack of emergent, submergent, and floating leaf vegetation in the lake greatly limits fisheries potential for other game species, such as northern pike, largemouth bass, and bluegill. Overall the survey indicated that spawning conditions were fair to poor on Crystal Lake, although good spawning habitat exists for some pan fish, such as black crappie. Walleye populations, which are primarily maintained through stocking, appeared strong in the lake. Channel catfish also appeared to be self-sustaining and good spawning habitat may exist within the lake. The fisheries population has been dominated by black bullhead since 2000. Bluegills and black crappies were also present in moderate numbers (MDNR, 2007). The DNR's overall assessment determined that the lake has been greatly influenced by agricultural and urban runoff, resulting in lower water quality, which affects the fish and aquatic plant ecosystems.

2.6 Recreational use

Crystal Lake has long been a source of recreation for the community. In 1883, the lake was viewed as being "in the front as a summer resort" with the anticipated arrival of a new steamer, the building of a lakeside pavilion, and discussion of the "boat club" adding a new sailing yacht to the lake (MPCA, 1989). A 37' long "steamer" boat arrived in June 21, 1893 and was used for recreation and as a tourist attraction in the area.

Between 1904 and 1910, several steps were taken to improve the lake system including widening the channel within the lake system. Due to the success of the first steamer boat, a second steam powered passenger boat was used on the Lake. The north side of Crystal Lake was "repaired", and a canal was created by dredging and widening of the existing channel between Loon Lake and Crystal Lake to allow boating traffic between the two lakes.

The lakes are still very important to the community. Primary uses include boating, fishing, swimming, water skiing, and ice-skating. Fishing contests are held on occasion and Crystal Lake has also been host to boat parades and water skiing competitions. Other activities held include annual Duck Days festivities and community education classes on canoeing.

The condition of the lake continues to be a concern to many area residents and organizations. Issues with water quality can not only impact the aquatic life and recreational opportunities, it can also negatively impact the property values of lakeshore owners, as well as the surrounding municipality (Krysel et al. 2003).

Section 3.0 – Applicable Water Quality Standards and Water Quality Numeric Targets

3.1 Description of Excess Nutrients

The state of Minnesota has long recognized excess nutrient loading as a primary factor contributing to eutrophication of lakes (Minnesota's 305B report to Congress), yet few Federal or State water quality criteria exist for the purposes of protecting waters from eutrophication. Phosphorus (P) and nitrogen (N) are the primary nutrients that in excessive amounts pollute our lakes, streams, and wetlands (MPCA, 2008). Phosphorus is the focus of this TMDL based on the nutrient standards criteria.

In order to properly assess the water quality within a lake system, water quality standards and criteria were developed using eco-region and area specific sample data. This means that lakes are ranked and categorized by common characteristics, such as depth/lake morphometry, lake ecology, geographic setting, and reference lake conditions. Because of regional diversity in lake and watershed characteristics, it was felt that a single total phosphorus value could not be adopted as a statewide criterion for lake protection in Minnesota (Heiskary, et al. 1987). By using the eco-region derived data, natural lake loading is taken into account, and lakes are assessed based on landscape settings, local land use, and loading typical of the region. Shallow lakes in Southern Minnesota typically fall within the Western Corn Belt Plains (WCBP) and Northern Glaciated Plains (NGP) category for class 2b waters.

Phosphorus is an essential nutrient for plant and algal growth and development within a lake, as it is necessary for the conversion of sunlight into the usable energy for cellular activities. It is important to note that the actual amount available for biological uptake depends on its chemical form. The two types of phosphorus sampled within Crystal Lake are total phosphorus (TP) and ortho-phosphorus (OP). While ortho-phosphorus is the form most readily available to plant life, total phosphorus values are most commonly used to predict and model lake eutrophication.

In Crystal Lake concentrations of TP averaged 264 ug/L (micrograms per liter or parts per billion) during the 2008 and 2009 monitoring seasons. This value is very high, and outside the range expected for similar lakes in the region, almost three times the standard of 90 ug/L.

Nitrogen is another important nutrient for biological growth. Like phosphorus, it also can exist in several chemical forms that influence its availability to plants and algae. The ratio of nitrogen to phosphorus can give an indication as to which nutrient is limiting the production of algae in the lake. For Lake Crystal, the N/P ratio is 13:1 which suggests phosphorus is the limiting nutrient. Additional monitoring data confirms that nitrogen levels (as sampled through nitrate-nitrite) are not the limiting nutrient within the lake system.

Nutrient loading and decreased water quality can also be examined through the measurement of total suspended solids (TSS). TSS is a measure of the suspended organic and inorganic matter in the water, including algae and soil particles. Often, nutrients such as phosphorus are bound to particulate matter and carried into lakes. Particulate phosphorus is continually deposited from the

water column due to sedimentation, but can potentially be resuspended through bioturbation, anoxic conditions, or other chemical and biological processes.

Bioturbation, particularly by fish species including bullheads and carp, can cause additional exchange of nutrients from sediments back to the water column. Rooted aquatic plants provide habitat for game fish and help counteract algae blooms by stabilizing bottom sediments. They also protect the sediment from wind mixing in shallow lakes, holding nutrients in place.

Chlorophyll, specifically chlorophyll–a, is a pigment produced by algae. By measuring chlorophyll concentrations, it is possible to estimate the level and frequency of algal production within a lake. Lake Crystal chlorophyll values indicate severe nuisance algae levels occurring throughout the summer. During the monitoring seasons of 2008 and 2009, the average chlorophyll–a concentrations were 86.9 ug/L. Concentrations from 10-20 ug/L would be perceived as a mild algal bloom, while concentrations greater than 30 ug/L would generally be perceived as severe nuisance conditions (Heiskary and Walker, 1988).

In developing the lake nutrient standards for Minnesota (Minn. Rule 7050) the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (Heiskary and Wilson, 2005). Clear relationships were established between the causal factor, total phosphorus, and the response variables chlorophyll-a and Secchi disk. Based on these relationships it is expected that by meeting the phosphorus target of 90 µg/L for Crystal Lake the chlorophyll-a and Secchi standards (30 µg/L and 0.7 m, respectively) will likewise be met.

3.2 Applicable Minnesota Water Quality Standards

The MPCA uses ecoregion-based total phosphorus guidelines in conjunction with Carlson's Trophic State Index (TSI) to classify lakes and their level of quality for aquatic recreation. The recommended standards can be found in Table 3.2.

Table 3.2 – Applicable Minnesota Water Quality Standards

Ecoregion	TP	Chl-a	Secchi
	ppb	ppb	meters
NLF – Lake trout (Class 2A)	< 12	< 3	> 4.8
NLF – Stream trout (Class 2A)	< 20	< 6	> 2.5
NLF – Aquatic Rec. Use (Class 2B)	< 30	< 9	> 2.0
CHF – Stream trout (Class 2a)	< 20	< 6	> 2.5
CHF – Aquatic Rec. Use (Class 2b)	< 40	< 14	> 1.4
CHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
WCP & NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
WCP & NGP – Aquatic Rec. Use (Class 2b) Shallow lakes	< 90	< 30	> 0.7

These values can be compared to the TSI scale as the parameters used to develop the final TSI calculation include the total phosphorus (ppb), chlorophyll-a (ppb), and transparency (m) measurements. Water bodies that fail to meet the water quality standards are then listed as impaired. Crystal Lake falls outside of the normal expected range of values for the TSI and does not meet the water quality standards for lakes in its region.

Water quality standards have existed in Minnesota since 1967, and have been expanded and updated since that time. Minnesota's water quality standards meet or exceed federal requirements (MPCA website, 2008). Two important aspects of these water quality standards are "beneficial uses" and "numeric standards".

A. Beneficial Uses.

All water bodies in Minnesota are assigned beneficial uses. While this classification is performed by the state, the process is governed by federal rules contained within the CWA. Seven beneficial uses are defined in Minn. R. 7050.0200. These uses and the use-class designations are listed below. The class numbers 1–7 do not imply a priority ranking (MPCA website, 2008).

> Class 1 Domestic Consumption
> Class 2 Aquatic Life and Recreation
> Class 3 Industrial Consumption
> Class 4 Agriculture and Wildlife
> Class 5 Aesthetic Enjoyment and Navigation
> Class 6 Other Uses
> Class 7 Limited Resource Value

B. Numeric Standards

Minnesota's water quality standards include a numeric criterion for nutrient impairment as a measure of whether a water body meets its designated uses. Specifically, Minn R. ch. 7050.0220, Specific Standards of Quality by Associated Use Classes, states:

> ... "The numerical and narrative water quality standards in parts 7050.0221 to 7050.0227 prescribe the qualities or properties of the waters of the state that are necessary for the designated public uses and benefits. If the standards in this part are exceeded, it is considered indicative of a polluted condition which is actually or potentially deleterious, harmful, or injurious with respect to designated uses or established classes of the waters of the state."

The numeric and narrative water quality standards in this part prescribe the qualities or properties of the waters of the state that are necessary for the aesthetic enjoyment and navigation for designated public uses and benefits.

C. Crystal Lake -Class 2B water

The water classification for the Crystal Lake TMDL is 2B. Class 2 waters concern aquatic life and recreation, and subclass B refers to cool/warm water fisheries with the water body not protected as a drinking water source. Class 2 waters are formally defined as:

> Aquatic life and recreation includes all waters of the state which do or may support fish, other aquatic life, bathing, boating, or other recreational purposes, and where quality control is or may be necessary to protect aquatic or terrestrial life or their habitats, or the public health, safety, or welfare. (https://www.revisor.leg.state.mn.us/arule/7050/0200.html)

3.3 Seasonality

Eutrophication and phosphorus standards for Minnesota lakes are based on average conditions for the critical months of June-September. Because target TMDL allocations and reductions are calculated to achieve these standards, both seasonality and critical conditions are accounted for.

Nutrient loading can vary due to seasonal influences. Based on data collected within the Crystal Lake system, phosphorus levels typically start off near or below the lake standard in the spring and climb until they peak early in July. Similar results are seen with chlorophyll-a concentration, with the peak occurring in late July and into August. These changes are typically the result of the development and growth of algae as the temperature of the lake water warms.

It is important to note that there has been large phosphorus releases recorded in Crystal Lake during winter months. Samples show that the lake sediments will release phosphorus into the water column due to the lake entering an anoxic state. These anoxic conditions can occur if the rate of oxidation of organic matter by bacteria is greater than the supply of dissolved oxygen. Under these conditions, ferric iron is reduced to ferris iron, and phosphate is released into the water column (Lee et al, 1976). Although this release occurs in the winter, some of the phosphorus may impact the lake in the spring and summer.

Section 4.0 – Water Quality data

4.1 – Data collection

Water quality within Crystal Lake has long been a concern. One early study performed by Barr Engineering in 1958, examined the sediment loading and possible sources to the lake system. Additional studies have been completed by various state and local agencies. A lake assessment was conducted by the MPCA through the Lake Assessment Program (LAP) in 1989.

Crystal Lake, and the surrounding watershed, have completed Clean Water Partnership Phase One (Diagnostic Study) and Phase Two (Implementation) projects through the MPCA with cooperation from Blue Earth County, the City of Lake Crystal, and Minnesota State University Mankato. Local residents too have provided data collected through the MPCAs Citizen Lake Monitoring Program (CLMP).

Additional monitoring was completed through the TMDL to assess the current water quality conditions and gather the necessary data to be used for the BATHTUB modeling program.

The water quality data gathered was utilized for modeling efforts within the TMDL process. While many of the previous studies have investigated similar problems (such as sediment and nutrient loading), these reports were not completed within the requirements or timeline of the TMDL process. Much of the work from this research is valuable for use within the TMDL study, and provides a basis to investigate how the lake has changed over time.

4.2 Monitoring Parameters

A - Phosphorus
Phosphorus data was collected via grab samples using sterile bottles supplied through Minnesota Valley Testing Laboratories (MVTL). CD 56 samples were taken using an extendable grab sample rod, which holds the bottle directly to ensure no accidental contamination. Lake samples were taken 8-12" below the water surface at a geo-located position to develop an accurate representation of the lake conditions. The phosphorus samples were delivered to MVTL in New Ulm and analyzed for both Total and Ortho phosphorus concentrations.

B - Nitrogen
Nitrogen data was collected similar to the phosphorus data; using grab samples at the CD 56 collection site, and below surface samples at the lake sites. The nitrate samples were analyzed for nitrate-nitrite.

C – Chlorophyll A
Chlorophyll-a samples were collected at the Crystal Lake sites using the below surface sample method. Chlorophyll measurement is an indicator of algal development and activity within the lake system, and can typically be related to Secchi depth measurements. Collected samples were stored in an opaque plastic or amber glass bottles to prevent any additional development or breakdown of the chlorophyll within the sample until analysis.

D – Temperature and Dissolved Oxygen
Temperature and dissolved oxygen (DO) data was collected using a YSI Professional Plus multi-parameter meter with a YSI Quattro multi-parameter probe. This setup allows instant calibration to ensure data accuracy and records data to verify field notes.

E – Secchi Depth
The Secchi disk is a flat, circular object lowered into the lake to measure water transparency. The depth at which the disk is no longer visible is taken as a measure of the transparency of the water. This measure, known as the Secchi depth, is related to water turbidity. A summary of sample analysis and methods is shown below Table 4.2.

Table 4.2 – Sample Method Data

Analyte	Sample Quantity	Sample Container	Preservative	Holding Time	Analytical Method
Chlorophyll a	1 L	Amber glass	Cool to 4°C	4 H†	SM* 10200 H
Total Phosphorus	500 mL	Plastic	H_2SO_4 to pH <2, Cool to 4°C	28 D	EPA 365.1 Rev 2.0
Ortho- Phosphorus	500 mL	Plastic	Cool to 4°C	2 D	EPA 365.1 Rev 2.0
Nitrate + Nitrite	250 mL	Plastic	H_2SO_4 to pH <2, Cool to 4°C	28 D	EPA 353.2 Rev 2.0
Total Suspended Solid	500 mL	Plastic	Cool to 4°C	7 D	USGS I-3765-85

†May be stored on ice in the dark for up to 48 hrs prior to analysis, otherwise, filter within 48 hrs and store frozen at ≤ -20

4.3 - Data Summary

Water quality data from CD 56 was collected and analyzed during the Phase II Crystal Loon Mills Clean Water Partnership (CWP) project. One rain/stage gauge collection site and one sampling site were utilized.

The CD 56 rain/stage gauge collection site was located at County Road 20 (CR 20). The sampling site was located on CD 56 at County Road 9 (CR 9). Stage data was continuously recorded with an ultrasonic transducer and rain gauge data was collected via a Texas Instruments rainfall gauge with all data downloaded to a data logger. The sites are shown on figure 4.3.

All water quality samples were taken at this site from the middle of the ditch where the channel is deepest. Flow data and water quality samples were used to calculate flow weighted means for nutrients entering Crystal Lake.

Figure 4.3 – CD 56 Sample sites
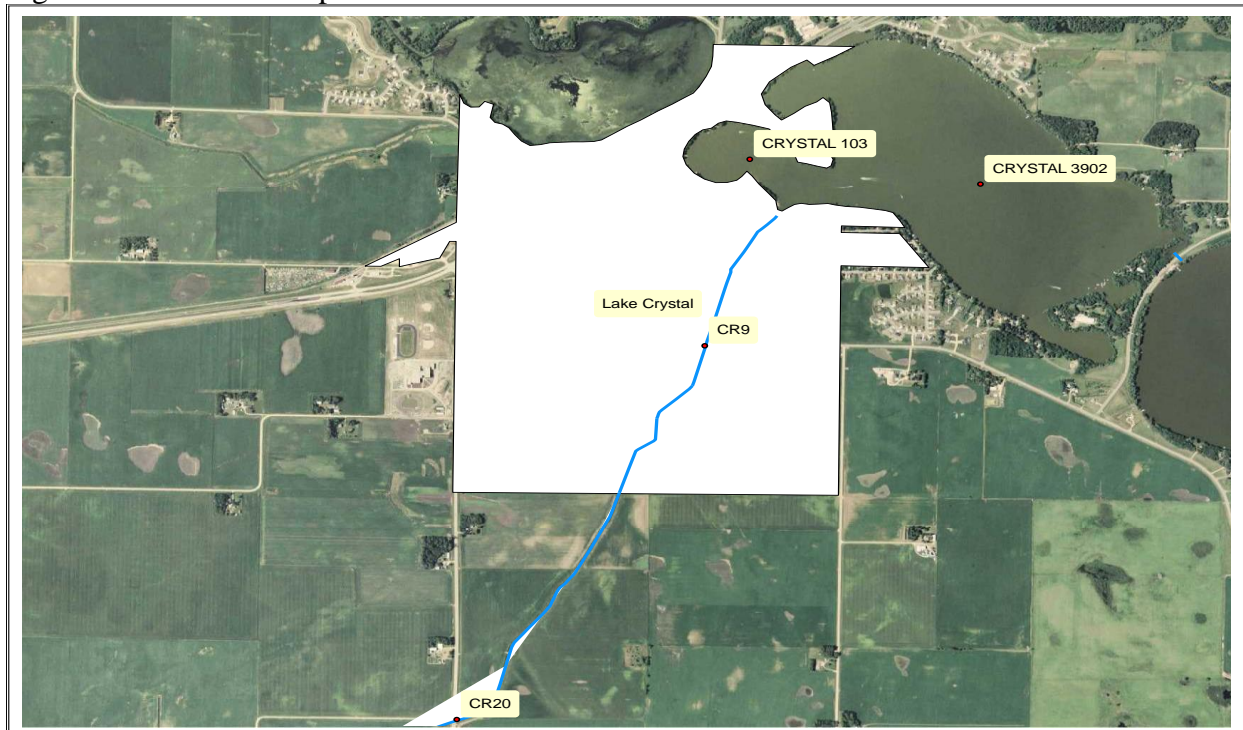
A.   County Ditch 56

Stage gauge data was collected every 3 minutes, averaged, and compiled for every 15 minutes. Both stream and rain gauge data were collected using a CR-510 data logger. Water quality samples were taken every 10-14 days during baseflow conditions, as well as during rain/storm events through the 2007-2009 monitoring seasons.

Transparency tube readings, weather and field condition notes were recorded at sample collection. Water quality samples were sent to Minnesota Valley Testing Laboratories (MVTL) for analysis.

Twenty, twenty-five and eighteen samples were taken during 2007, 2008 and 2009 sampling seasons. Below is a water quality summary for CD 56 (Tables 4.3- A through E).

Table 4.3A. 2007 County Ditch 56 water quality data summation.

2007	TSS (mg/L)	Turbidity (NTU)	E. coli (cfu)	Nitrate (mg/L)	TP (mg/L)	PO4 (mg/L)	% PO4	TSVS (mg/L)	T-tube (cm)	TKN (mg/L)
Average	22.80	20.94	1072.78	8.09	0.232	0.172	72.61%	6.45	45.46	1.88
Max	84	68	3900	13.8	0.681	0.534	89.62%	22	60	2.6
Min	2	3	108.1	3	0.06	0.03	50.00%	1	15	1
# of samples taken	20	17	11	20	20	20	20	20	14	11

Table 4.3B. 2008 County Ditch 56 water quality data summation.

2008	TSS (mg/L)	Turbidity (NTU)	E. coli (cfu)	Nitrate (mg/L)	TP (mg/L)	PO4 (mg/L)	% PO4	TSVS (mg/L)	T-tube (cm)	TKN (mg/L)
Average	99.64	63.36	1359.24	10.63	0.217	0.148	66.90%	18.36	35.39	2.19
Max	1380	440	14136	16.4	0.827	0.796	99.62%	172	60	3.4
Min	1	3	9.7	4.18	0.049	0.028	30.93%	1	1.5	1.3
# of samples taken	25	22	26	25	25	25	25	22	23	11

Table 4.3C. 2009 County Ditch 56 water quality data summation.

2009	TSS (mg/L)	Turbidity (NTU)	E. coli (cfu)	Nitrate (mg/L)	TP (mg/L)	PO4 (mg/L)	% PO4	TSVS (mg/L)	T-tube (cm)	TKN (mg/L)
Average	9.71	8.39	307.68	3.34	0.204	0.171	80.01%	3.17	51.58	1.52
Max	49	36	2419.6	12.2	0.47	0.393	98.38%	11	60	2
Min	1	1	2	0.45	0.043	0.014	32.56%	1	17	1
# of samples taken	17	18	18	18	18	18	18	18	18	10

Table 4.3D 2007-2009 County Ditch 56 water quality data summation.

Overall 2007-2009	TSS (mg/L)	Turbidity (NTU)	E. coli (cfu)	Nitrate (mg/L)	TP (mg/L)	PO4 (mg/L)	% PO4	TSVS (mg/L)	T-tube (cm)	TKN (mg/L)
Average	50.19	33.35	957.80	7.74	0.218	0.162	72.46%	9.83	43.25	1.88
Max	1380	440	14136	16.4	0.827	0.796	99.62%	172	60	3.4
Min	1	1	2	0.45	0.043	0.014	30.93%	1	1.5	1
# of samples taken	62	57	55	63	63	63	63	60	55	32

Table 4.3E provides a summary of estimated nutrient and sediment loading and flow weighted mean concentrations (FWMC) in CD 56 during the CWP phase I diagnostic study (1995 & 1996) and the CWP Phase II implementation project (2007-2009). These values were calculated using the FLUX Model, a computer program designed by the U.S. Army Engineer Waterways Experimental Station. FLUX is used to estimate the load of nutrients or other water quality constituents passing a location over a given period of time.

The table also provides the runoff, in inches, during the monitoring period for each of the CWP project years. Runoff is calculated by taking the total flow volume divided by the area of the watershed. The data indicate that the greatest runoff occurred in 1995 with 14.81" and the least in 2009 with only 1.18". 1996, 2007 and 2008 all had similar overall runoff values, although the timing of the runoff varied (most of the 2007 runoff occurred in late summer and fall).

The FWMC data in table 4.3E is calculated by dividing the total constituent load by the total flow volume. This provides a flow weighted concentration for each constituent during the monitoring period. These data indicate TSS values have remained fairly stable ranging from 54 mg/l in 1995 to 8 mg/l in 2009. These values are somewhat low when compared with other small

ditch watersheds monitored for water quality in south-central Minnesota. This is likely explained by the flat topography of the ditch watershed and the sandier soils which are not transported as easily as silts and clays. The highest concentrations of TSS occurred during and following storm runoff. Overland runoff into open tile intakes and ditch side inlets are likely the sources of these short lived, but high TSS concentration spikes during storm events.

TP FWMC's in CD 56 have been elevated each of the years monitored. It should be noted that the 1995 and 1996 flows and loads are estimated due to problems with backwater. For the model, the 1995 and 2009 data were not used, as they were not representative of normal yearly flow values. TP values are consistently 2 to 3 times the water quality standard of 0.090 mg/l that would apply to the receiving water, Crystal Lake. The component of TP that is most readily available to algae is PO4. Comparison of TP and PO4 indicate the majority of phosphorus in CD 56 is in the PO4 form. These data, combined with the TSS data, indicate that soil erosion is not the dominant source of phosphorus loading in CD 56.

The majority of phosphorus is in the dissolved form, a large fraction of which is likely bioavailable upon entering the lake. Land use upstream of CR9 is predominately row crop agriculture (corn and soybean) much of which is drained by subsurface tile. It is likely that the majority of the water in the ditch originates from a combination of groundwater and tile outlet flow. Research suggests that subsurface tile without open intakes can be a significant source of phosphorus (mostly PO4) in soils that contain high phosphorus concentrations (Sims et al, 1998). It is possible that tile drainage and related soil characteristics are contributing to the elevated PO4 measured in the ditch. Nutrient management must continue to be addressed in the CD 56 watershed. Soil testing and precision application of fertilizers which result in a net reduction of phosphorus into the watershed is critical.

Table 4.3 E. CD 56 – 1995, 1996, 2007-2009 Monitoring Season FWMC and Loads

Year	1995*	1996*	2007	2008	2009
Monitoring Period*	3/24 - 11/30	6/5-10/30	3/28 - 10/26	5/2 - 10/22	3/22 - 10/25
Runoff (inches)	14.81	5.61	4.63	4.83	1.18
Nitrate FWMC (mg/L)	11.4	9.9	9.9	10.3	4.2
Nitrate Load (Kg)	160,082	52,534	43,614	46,971	4,655
TP FWMC (mg/L)	0.213	0.336	0.265	0.193	0.198
TP Load (Kg)	2,989	1,786	1,163	881	222
PO4 FWMC (mg/L)	0.127	0.213	0.193	0.120	0.170
PO4 Load (Kg)	1,778	1,134	845	550	190
PO4/TP	59%	63%	73%	62%	86%

*1995 and 1996 estimated. Potential backwater and flow monitor issues may exist.

B.   Crystal Lake

Crystal Lake Total Maximum Daily Load Study (TMDL) staff began collecting bi-monthly water quality samples on May 15, 2008 and concluded sampling September 30, 2009. Samples were collected as 'elbow depth' surface grab samples. One under ice winter sample was taken for all sampling sites across Crystal, Loon, and Mills Lakes.

A total of eleven open water samples were taken in 2008. One winter sample in February, and twelve open water samples were collected in 2009. Samples were collected at two sites each on Crystal and Loon Lakes and one site on Mills Lake. The Crystal Lake site, 'Crystal 103', was located in the southwest bay, off the public swimming beach, and 'Crystal 3902' was located at the approximate center of the lake at its deepest point. All standards refer to the shallow lake standards for the Western Corn Belt Plains Ecoregion (WCBP).

Total phosphorus – During the 2008 sampling season, total phosphorus concentrations exceeded the lake standard of 90 parts per billion (ppb) in all months except May and June. Total phosphorus levels spiked in the 2009 winter sample. This increase was more than likely due to the lake becoming anoxic from bacterial decomposition, releasing phosphorus from the sediments. Phosphorus levels remained above the WCBP standard when sampling resumed in March 2009, continuing to rise, reaching a concentration of 525.0 ppb on July 14, 2009. After peaking, phosphorus concentrations began to decrease until sampling ended on September 24, 2009, with levels still above the standard. Throughout the TMDL study, Crystal Lake had an average total phosphorus concentration of 226 ppb, approximately two and half times the WCBP standard of 90 ppb, with 83 percent of the samples in exceedance.

Chlorophyll-a – Chlorophyll-a concentrations exceeded the standard of 30 ppb for 70 percent of the samples during both the 2008 and 2009 sampling seasons. Concentrations remained below the WCBP standard until late-June, exceeding the standard once water temperatures became adequate to produce algal blooms. This trend was seen in both the 2008 and 2009 sampling seasons. Overall chlorophyll-a concentrations averaged 70.3 ppb, approximately 2.3 times above the WCBP standard during the study period.

Secchi disk transparency – Secchi disk transparencies met the standard of 0.7m or greater during May and early-June of 2008 and did not meet standards for the remainder of the 2008 sample season. This relationship is inversely correlated with the increase in chlorophyll-a concentrations in the same time period. During the 2009 sampling season only one sample (May 11th, 2009) met the WCBP standard. Overall, 83 percent of samples exceeded the WCBP standard with an average Secchi disk transparency of 0.5m, 1.4 times greater than the WCBP standard for the monitored period.

Figure 4.3A - Average TP, Chl-a, and Secchi data
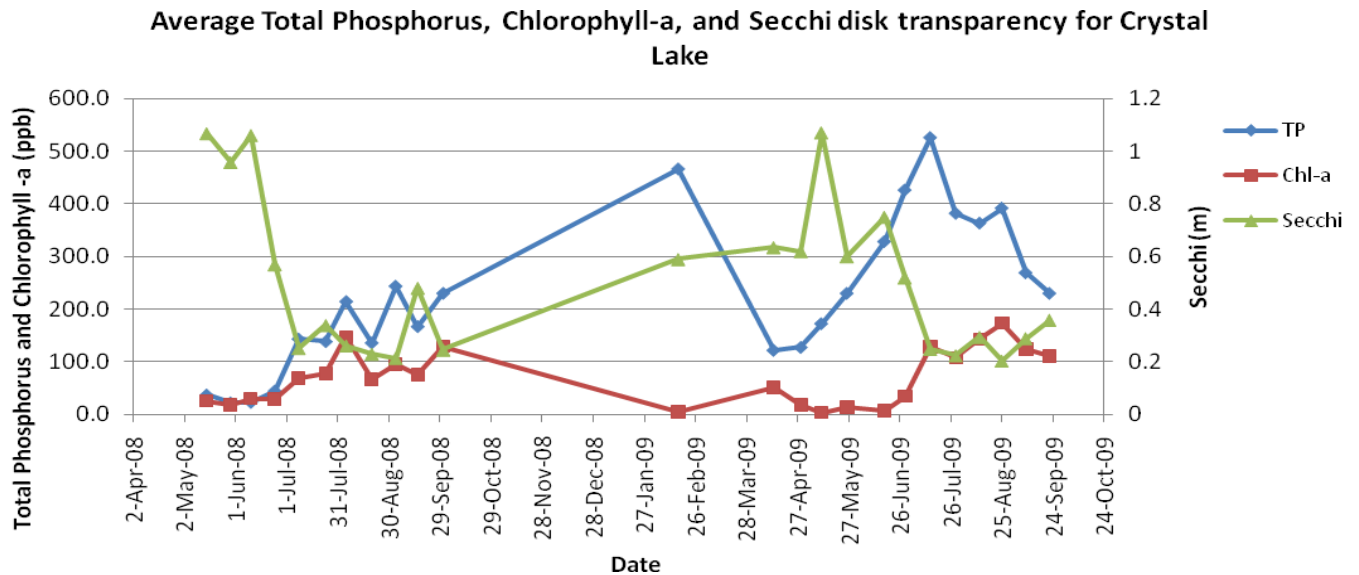
Figure 1. Average total phosphorus (TP), chlorophyll-a (chl-a) and Secchi disk transparency for Crystal Lake. Total phosphorus and chlorophyll-a are recorded as parts per billion (ppb) and Secchi disk transparency is recorded in meters (m).

Based on all information collected through TMDL monitoring, using the mean values of the data, the TSI value was calculated at 72, placing the lake in the hypereutrophic category.

Figure 4.3B - Carlson Trophic Status Index with Crystal Lake values
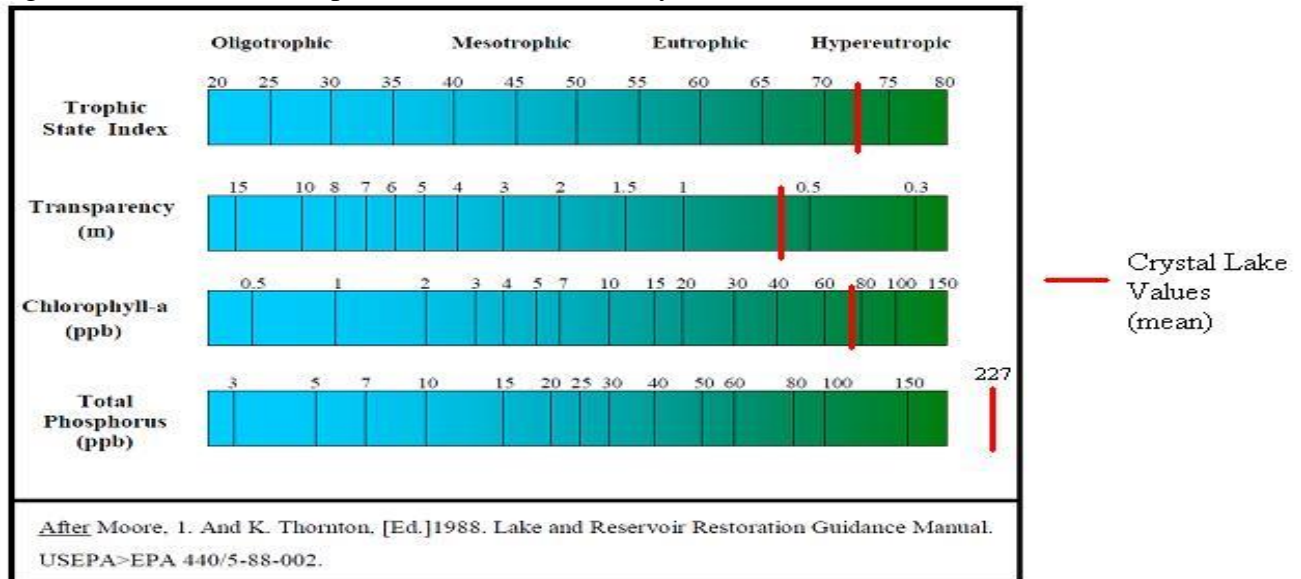
4.4 – Watershed Data Analysis/Methods

For the purposes of this TMDL, three models were used to analyze various factors impacting Crystal Lake. In order to accurately use the models, investigation of the contributing watersheds was needed to calculate loading data.

The following watersheds were used for assessments: Mills Lake Watershed, Loon Lake Watershed, CD 56 Watershed, City of Lake Crystal Watershed, and the Crystal Lake watershed (Figure 4.4A).

Figure 4.4A - Contributing watersheds
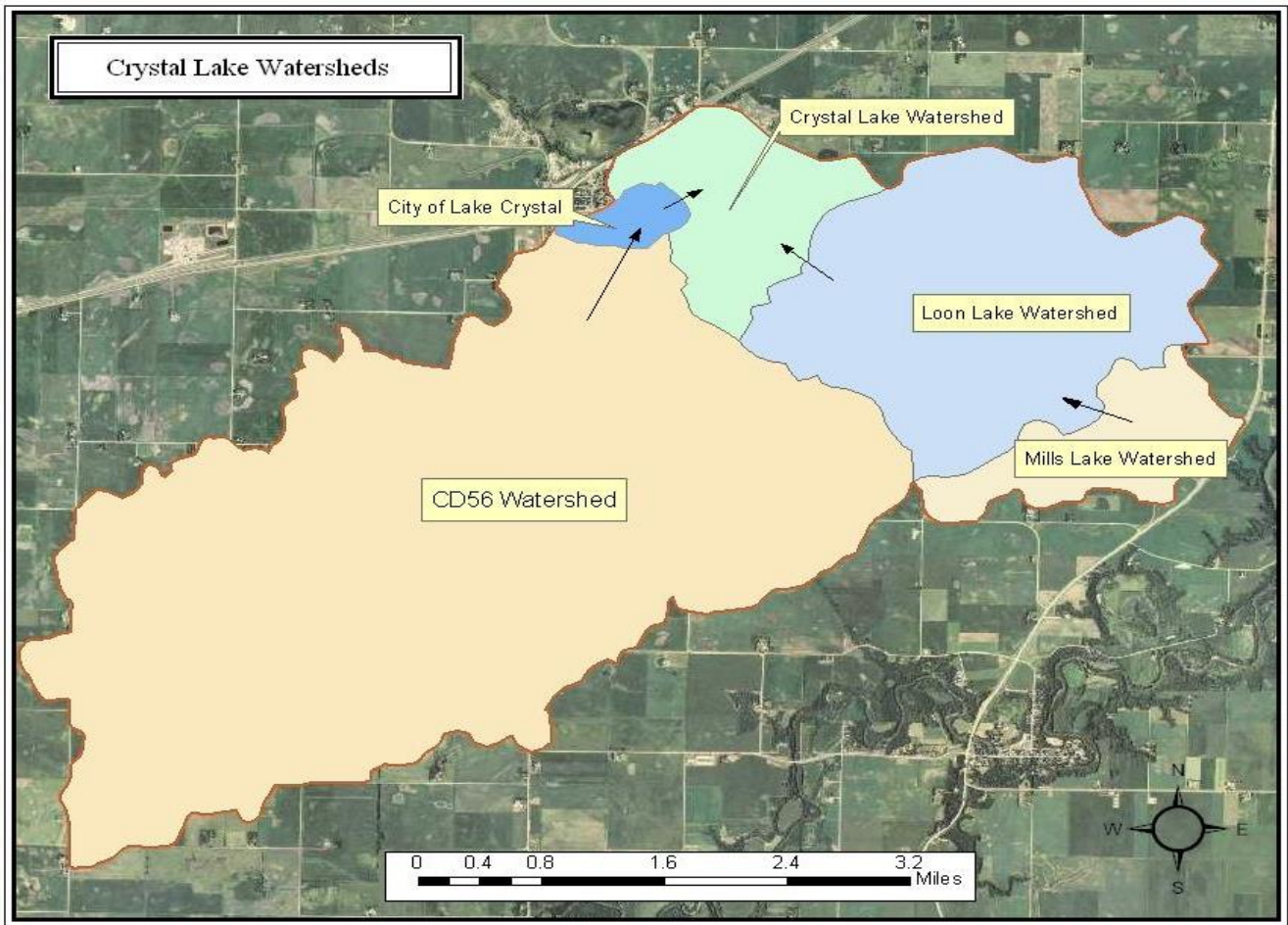
As shown in the schematic, the watersheds feed into one another, increasing the contributing areas until the total watershed is accounted for (Figure 4.4B).

Figure 4.4B – Schematic of watersheds
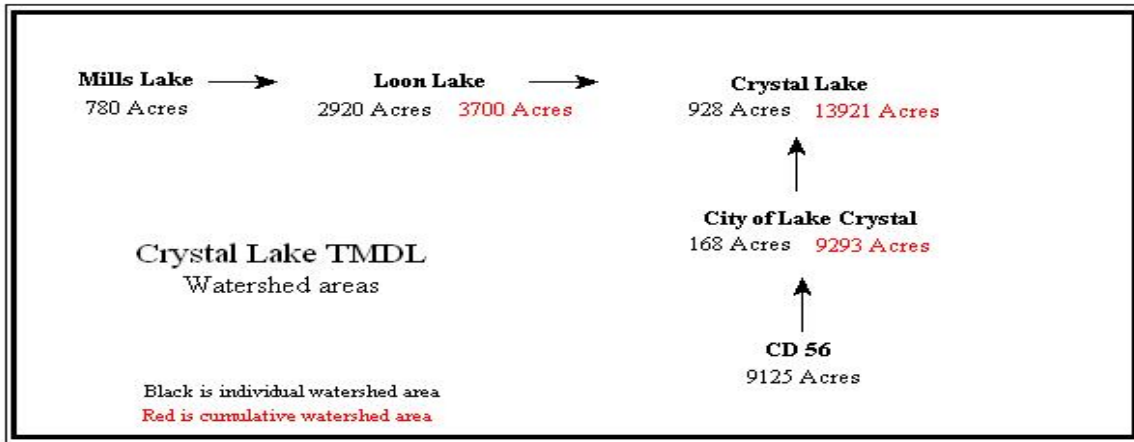
As discussed in the "Lake TMDL Protocol and Submittal Requirements" developed by the MPCA, three models are used to evaluate the data. These models examine the available data and help to determine if additional analysis is required. Starting with a "Level I Assessment", Lake Crystal was evaluated using the MINLEAP model. Based on the results, additional "Level II Assessments" and "Level III Assessments" were necessary using additional models. Model descriptions are included below along with initial results.

4.5 - MINLEAP model

Developed by Bruce Wilson and Dr. William Walker Jr., the "Minnesota Lake Eutrophication Analysis Procedure" or MINLEAP, is a simple modeling method used to estimate loading levels and lake response based on specific lake data when compared to reference lakes within the same eco region.

This model is useful because it allows the comparison between the predicted phosphorus, chlorophyll-a and Secchi depths to the actual, observed data. This comparison provides a quick method of comparing expected parameters based on location and reference lakes in the area, to actual loading levels based on the sample results.

This information can be used to perform a cursory comparison and calculation based on the reductions necessary to meet the standards. Similarly, the model can be calibrated to calculate the necessary loading to predict the same values as the observed values. Using information such as ecoregion, lake morphometry, and lakeshed area, MINLEAP will estimate in-lake total phosphorus, Chlorophyll-A levels, and average Secchi depth.

The MINLEAP model (Wilson and Walker, 1989) uses the Canfield Bachmann equation (Canfield and Bachmann, 1981) to predict hydrologic and phosphorus dynamics based on watershed, lake morphometry and ecoregion. Tables 4.5A-4.5C show the MINLEAP predictions based on Crystal Lake's characteristics.

Model Results

Table 4.5A. MINLEAP predicted phosphorus load and hydrology.

Average Total Phosphorus Inflow (µg/L)	Total Phosphorus Load (kg/yr)	Phosphorus Retention Coefficient	Lake Outflow (hm3/yr)	Residence Time (yr)	Areal Water Load (m/yr)
606	4,106	0.68	6.77	0.5	4.37

The MINLEAP model was used to predict in-lake water chemistry for Crystal Lake based on the predicted phosphorus and hydrologic dynamics. Based on these factors, MINLEAP predicted greater water quality than what has been observed in Crystal Lake (Table 4.5B). A t-test with an absolute value greater than 2.0 indicates a statistically significant difference between the observed and predicted values. Observed total phosphorus, chlorophyll-a and Secchi disk transparency were not significantly different than the predicted values.

Based on the initial modeling run, a lake located in the WCB with Crystal Lake's morphometry and contributing watershed is predicted to have a lower TP value and a higher Chl-a value than observed. It should be noted that the model does predict that the TP levels found in the lake will be greater than the recommended standards, and the lake is predicted to be hyper-eutrophic. This is likely due to the large size of the watershed feeding the lake system. MINLEAP uses published runoff values to calculate average values for land use within the eco region, and run off coefficients to predict what is likely entering the system

Table 4.5B. MINLEAP water quality predictions versus observed conditions.

Variable	Observed	Predicted	T-Test
Total Phosphorus (µg/L)	230	197	0.42
Chlorophyll-a (µg/L)	94	147.7	-0.68
Secchi disk (m)	0.4	0.4	-0.15

Carlson's Trophic Status Index (TSI) values are calculated to place observed in-lake conditions in the context of the trophic status of ecoregion reference lakes. Crystal Lake exceeded ecoregion TSI values for each parameter. Crystal Lake can be classified as hypereutrophic.

Table 4.5C. Crystal Lake TSI values.

Total Phosphorus TSI	Chlorophyll-a TSI	Secchi TSI	Average TSI
83	76	74	77

The default "stream phosphorus (ppb)" value for the WCP is 570. In order to calibrate the model and have the predicted TP values equal the observed TP values, the Stream phosphorus value needs to be increased to 913. This model does not allow adjustment of the specific land use values within the watershed. Also, by adjusting the Stream phosphorus value the calculated chlorophyll -a values continue to diverge from the observed values. By adjusting the Stream phosphorus value to 913, we see the observed values matching the predicted TP values. The value of this model run is to serve as a rough estimate of the total TP load that would be required to see the inlake TP observed in the course of the study.

With the model, it is important to compare the quality of the performance based on several variables. While the model has been demonstrated to perform well in the Northern Lake/Forest and Northern/Central Hardwood forest areas, it does not perform as well in the Western Corn Belt plains and Northern Glaciated Plains. Also, lakes exhibiting high levels of internal loading or nutrient cycling do not perform as well as other lake systems. Internal loading is suspected of being a major contributor to the total TP load to Crystal Lake. Due to this fact, additional modeling was performed in the Crystal Lake watershed.

4.6 - Reckhow -Simpson Model

Named after the models creators, the Reckhow-Simpson model is used to estimate lake water quality by modeling phosphorus loading through estimates of precipitation, runoff and evaporation within the lake system. This model provides a basis for calculating nutrient budgets through a combination of runoff and phosphorus export coefficients based on land use and land use area within the watershed.

By comparing lakes within the eco region, the model uses general information about soils, land use, climate, and geomorphology to calculate total phosphorus (TP) loading, as well as predict phosphorus loading and chlorophyll-a levels.

The Reckhow-Simpson model (Reckhow and Simpson, 1980) uses the Canfield Bachmann equation to predict in-lake total phosphorus concentration, chlorophyll-a concentration and Secchi disk transparency using land cover information specific to the lake watershed. The modeler can specify a range of phosphorus export coefficients to apply to the different land covers as well as climatological, runoff and morphometry characteristics of the lake of interest. The Reckhow-Simpson model accounts for phosphorus loads from septics through resident estimates and soil retention coefficients. It also can provide estimates of loading from livestock based on the number of animal units of each type.

The Crystal Lake watershed was broken down into the following five land cover categories based on the 2010 National Agricultural Statistics Service (NASS) coverage:

Table 4.6A. Land cover areas and associated phosphorus export coefficients for Crystal Lake.

	Area (ha)	P export coefficient (kg/ha)	Range considered for P export coefficient (kg/ha)
Forest	60.2	0.12	0.1-0.15
Cultivated	3,956.3	0.4	0.2-0.8
Urban	555.4	1	0.5-1.25
Wetland/Open Water	654.5	0.1	0.1
Pasture/Open	217.1	0.3	0.2-0.4

This model allows individual run off coefficient values to be adjusted, allowing the model the flexibility to more accurately assess the unique factors within a watershed. Each run off coefficient value has a low, medium, and high value. By adjusting these values, the model can be adjusted to investigate how different factors can influence loading. Within the model, the user

must specify the average precipitation in the watershed, as well as the measured runoff in the area. The precipitation data was gathered from the Minnesota Climatology Working Group through the NOAA website. Runoff data included in the model was based on an area average, and then compared to actual flow, precipitation, and runoff data calculated within the Crystal Lake watershed.

An average water runoff value of 0.13 m was used based on Figure 5 in Heiskary and Wilson (1994). This value is also very close to the average runoff estimated from CD 56 (0.12997 m/yr) during the monitoring years of 1996, 2007 and 2008. The thirty year average precipitation (0.765 m) and average evaporation (0.99 m) were calculated using data from the University of Minnesota's Climatology Lab and the University of Minnesota's Southern Research and Outreach Center respectively. Using these values and the phosphorus export ranges above, the Reckhow-Simpson model predicts the following water quality conditions for Crystal Lake:

Table 4.6B. Reckhow-Simpson in-lake predictions for low, medium and high phosphorus export coefficients.

	Observed lake conditions	Predicted lake conditions (low P export)	Predicted lake conditions (medium P export)	Predicted lake conditions (high P export)
Total Phosphorus (µg/L)	230	82	129	191
Chlorophyll-a (µg/L)	94.05	41.1	79.7	141.4
Sechhi transparency (m)	0.382	0.9	0.6	0.4
Total phosphorus TSI	83	68	74	80
Chlorophhyll-a TSI	75	67	74	79
Secchi transparency TSI	74	62	67	73

Table 4.6C illustrates the total phosphorus flux variability associated with each land cover depending on the assumed phosphorus export coefficient.

Table 4.6C. Phosphorus load variability associated with different phosphorus export coefficients.

Land Cover	Kg P/yr – low P export coefficient	Kg P/yr – medium P export coefficient	Kg P/yr – high P export coefficient
Forest	6	7	9
Cultivated	791	1583	3165
Urban	278	555	694
Wetland/Open Water	65	65	65
Pasture/Open	43	65	87
Precipitation	47	47	78
Onsite septics	57	57	57
Total P flux	1,287	2,379	4,155

Some field scale studies indicate higher phosphorus export coefficients can occur under certain circumstances (Harmel, et al., 2008). For example, a rainfall simulation study on cropland found TP runoff rates ranging from 0.1 to 1.7 kg/ha TP as a function of different swine manure and fertilizer practices (Daverede et al., 2004).

The low to high estimates shown above try to capture the variability by showing the broadest range of likely possibilities. However, the upper end loading estimates are likely higher than what would be seen averaged across an entire watershed. Due to the inherent variability of phosphorus loading, land cover loading rates need to be considered in relative rather than absolute terms. Therefore, it was determined to use the medium phosphorus export coefficients and loads associated with each land cover.

Even under the high phosphorus export scenario the model predicts greater water quality than was observed. This suggests that to achieve an in-lake phosphorus concentration matching the observed there is a phosphorus source for which we have not accounted.

The Reckhow-Simpson model allows the modeler to input livestock information specific to the lake watershed to estimate the amount of livestock-associated phosphorus produced in the watershed, and an estimate of the phosphorus delivery from livestock. Assuming a range of kilograms of phosphorus produced by each animal type per year, the following mass of phosphorus is produced annually in the Crystal Lake watershed (Table 9).

Table 4.6D. Phosphorus production associated with livestock in Crystal Lake watershed.

Livestock Type	Animal Units	Total kg phosphorus produced (Low)	Total kg phosphorus produced (Medium)	Total kg phosphorus produced (High)
Swine	720	648	1,152	2,736
Horses	49	147	245	382.2
Total	769	795	1,397	3,118

These values represent an estimate of the phosphorus produced by livestock in the watershed, not the amount that is delivered to the lake. If we assume the medium phosphorus production estimate of 1,397 kg/yr and 5% delivery, an additional 70 kg of phosphorus enters Crystal Lake every year. Adding this amount of phosphorus to the lake model results in the following in-lake predicted values:

Table 4.6E. Predicted in-lake water quality incorporating delivered livestock phosphorus.

	Observed lake conditions	Predicted lake conditions (medium P export)
Total Phosphorus (µg/L)	230	132
Chlorophyll-a (µg/L)	94.05	82.5
Secchi transparency (m)	0.382	0.6
Total phosphorus TSI	83	75
Chlorophhyll-a TSI	75	74
Secchi transparency TSI	74	67

The addition of livestock phosphorus load increases the predicted lake phosphorus concentration, but still not to the observed condition. Internal loading might account for some of the additional phosphorus load required to reach the observed in–lake concentration (Hoverson, 2008; Welch and Cooke, 1995).

4.7 BATHTUB Model

BATHTUB is a model developed by William Walker while working for the US Army Corp of Engineers Waterways Experimental Station. This model has been widely used to model nutrient balance calculations within a steady-state, spatially segmented hydraulic network by calculating advective and diffusive transport, and nutrient sedimentation dynamics within the system. This data can be used to develop a eutrophication model and nutrient budget for a multiple basin reservoir system.

BATHTUB is designed to handle simultaneous modeling/analysis for connected or segmented reservoirs or basins, such as the Crystal Loon Mills lake chain. Using this simultaneous modeling method can help ensure accurate representation of specific processes occurring in linked systems. The modeling process is primarily used to perform diagnostic analysis of the current conditions of the basin, or to predict impact of potential changes within the system.

BATHTUB generates output in various formats, as appropriate for specific applications, as well as calculating confidence levels by performing error analysis based on all water quality inputs as well as any limitations of the model itself. Eutrophication-related water quality conditions (expressed in terms of total phosphorus, total nitrogen, chlorophyll-*a,* transparency, organic nitrogen, ortho-phosphorus, and hypolimnetic oxygen depletion rate) are predicted using empirical relationships previously developed and tested for reservoir applications (Walker 1985).

The BATHTUB model allows continuous calibration by checking against predicted nutrient loading versus the actual nutrient loading data collected through the grab samples. The data can be calibrated by reviewing individual data points, or all data points in a global calibration, as well as changing individual factors such as levels of internal loading or nutrient residence time.

The set up within the BATHTUB model requires that all areas contributing to the lake be designated as "segments" or "tributaries". Segments can be used if the lake has connected areas that cannot be spatially separated due to the nature of flows within the system. For the purposes of the TMDL, while the lakes are connected, each was modeled as an individual lake with outflows and loading predicted into the next lake in the chain. The outflow from the lake was then modeled as a tributary to the next lake system. Depending on the conditions and location of the lake, the number of tributaries ranges from one to four. Using multiple tributaries also allowed the model to use runoff coefficients and runoff data to model nonpoint source data, as well as measured flow and loading data from the ditch system. This allowed comparison of suspected nonpoint influence, since it was possible to compare the predicted nonpoint loading to calculate loading from sample data within the same area.

Six "tributaries" were identified in the Crystal Lake model (Figure 4.7A). The CD 56 watershed as a monitored inflow was considered the first tributary. Phosphorus loading from the CD 56 watershed was estimated from 1996, 2007 and 2008 measured flow (4.8 hm^3/yr) and phosphorus

concentration data (average flow weighted mean concentration = 0.2655 mg/L). Livestock sources of phosphorus as a point source were considered the second tributary. A flow rate of 0.01 hm^3/yr and a concentration of 7,000 ppb were applied. These values do not reflect actual conditions, but they force the model to deliver the 70 kg P/yr that was estimated from the Reckhow-Simpson model.

Onsite septic systems as a point source were considered the third tributary. Phosphorus loading from septics was estimated from the Reckhow-Simpson model. A flow rate of 0.01 hm^3/yr and a phosphorus concentration of 5,700 ppb were applied. As with the livestock "tributary" these values likely do not reflect actual conditions. However, they force the BATHTUB model to deliver the 57 kg P/yr that was estimated in the Reckhow-Simpson model. Loon Lake outflow as a monitored inflow was considered the fourth tributary. Flow from Loon Lake (0.6 hm^3/yr) was estimated using BATHTUB and phosphorus load was estimated based on 2006-2009 in-lake total phosphorus concentration (133 ppb).

The subwatershed that is composed primarily of the city of Lake Crystal was considered the fifth tributary and treated as a non-point source. Land cover was divided into the categories of forest, cultivated, urban, wetland/open water and pasture/open. The phosphorus export coefficients from the Reckhow-Simpson model were converted from kg/ha to ppb and applied to the BATHTUB model to estimate the phosphorus load from the landuse in this tributary. Finally, the subwatershed directly surrounding Crystal Lake was considered the sixth tributary and treated as a non-point source. It should be noted that this tributary also included part of the city of Lake Crystal. Once again, the phosphorus export coefficients from the Reckhow-Simpson model were converted from kg/ha to ppb and applied to the BATHTUB model to estimate the phosphorus load from the landuse in this tributary

Figure 4.7A - BATHTUB methods

41
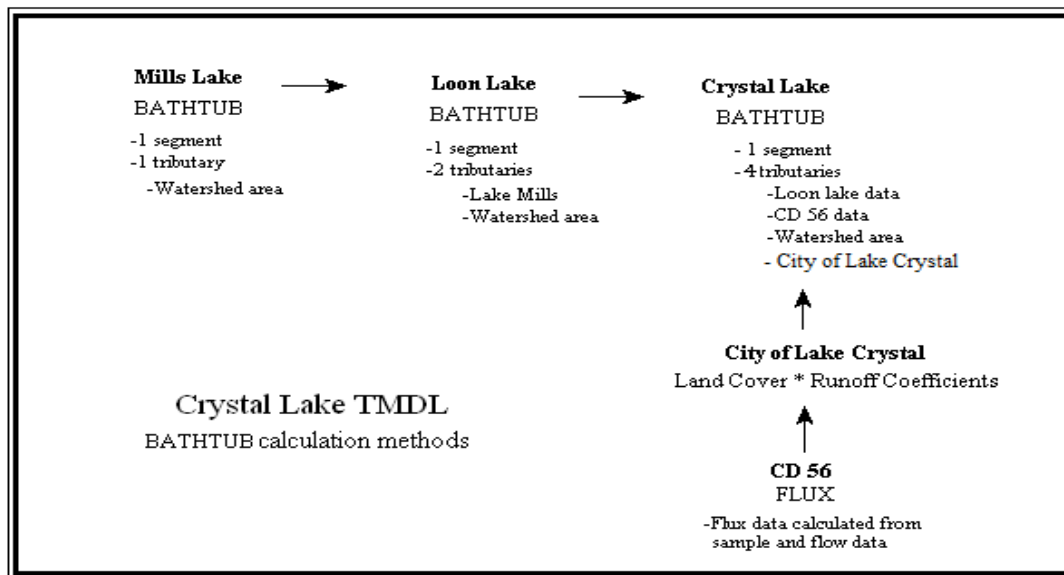
Model Results

Table 4.7A. BATHTUB water quality predictions versus observed conditions.

	Observed lake conditions	Predicted lake conditions (first order P model)	Predicted lake conditions (Canfield-Bachmann, Lakes P model)
Total Phosphorus (µg/L)	230	198	116
Chlorophyll-a (µg/L)	94.05	62	49
Sechhi transparency (m)	0.382	0.3	0.5

The following model options provided the best agreement with observed water quality conditions:
   a. Conservative substances – Not computed
   b. P balance – Several models were tested. The First Order option yielded the best agreement with the observed in-lake phosphorus concentration. The Canfield Bachmann Lakes model yielded a prediction that was significantly different from the observed. See the discussion below.
   c. N balance – not computed
   d. Chlorophyll-a – The option of phosphorus, Light, T (default option) yielded the best agreement with the observed in-lake chl-a concentration.
   e. Transparency – The VS Total phosphorus option yielded the best agreement with the observed average Secchi depth.
   f. Dispersion – Fischer numeric (default)
   g. P calibration - Decay rates (default)
   h. N calibration – Decay rates (default)
   i. Error analysis – Model and data (default); used estimates of coefficient of variation of the mean for observed data.
   j. Availability factors – Ignore (default)
   k. Mass balance tables – Use estimated concentrations (default)

The First Order and Canfield Bachmann model predictions underestimate the observed lake conditions, indicating that there is a phosphorus dynamic for which we are not accounting. Of the three models, BATHTUB relies most heavily on actual monitored data and as such should do the best job at estimating the external phosphorus load. Therefore, the discrepancy between predicted and observed is likely the result of in-lake processes.

It should be noted that while the data indicate internal processes are contributing to in-lake phosphorus concentrations, external sources of phosphorus will need to be reduced to attain long-term improvements to Crystal Lake water quality.

Several internal processes could be contributing to Crystal Lake's elevated phosphorus concentrations. Bioturbation, wind and reduced phosphorus sedimentation could each impact phosphorus levels in the lake. Anaerobic release of phosphorus is likely not a major contributor to summer phosphorus concentrations as Crystal Lake is shallow and does not stratify. Winter anaerobic conditions could be occurring, though the lake is equipped with an aeration system to avoid winter fish kills.

To model internal processes in BATHTUB, the phosphorus sedimentation coefficient can be reduced. The default BATHTUB phosphorus sedimentation coefficient of 1.0 can be adjusted to reduce sedimentation and increase in-lake phosphorus. The First Order model and the Canfield Bachmann Lakes model require different phosphorus sedimentation coefficients to approximate the observed conditions. Reducing the coefficient to 0.63 within the First Order model and to 0.22 in the Canfield Bachmann Lakes model results in the following in-lake water quality predictions:

Table 4.7B. Predicted water quality with reduction of phosphorus sedimentation coefficient.

	Observed lake conditions	Predicted lake conditions (First Order model)	Predicted lake conditions (Canfield Bachmann lakes model)
Total Phosphorus (µg/L)	230	230	231
Chlorophyll-a (µg/L)	94.05	65	65
Sechhi transparency (m)	0.382	0.3	0.3

The internal load can also be modified within the model to approximate the in-lake phosphorus concentration. The First Order model and the Canfield Bachmann Lakes model require different amounts of internal phosphorus load to approximate observed conditions. An internal load of 0.5 mg/m^2 day within the First Order model and 5.25 mg/m^2 day within the Canfield Bachmann lakes model results in the following in-lake water quality predictions:

Table 4.7C. Predicted water quality with additional internal phosphorus load.

	Observed lake conditions	Predicted lake conditions (First Order model)	Predicted lake conditions (Canfield Bachmann lakes model)
Total Phosphorus (µg/L)	230	230	230
Chlorophyll-a (µg/L)	94.05	65	65
Sechhi transparency (m)	0.382	0.3	0.3

The goal of this exercise is not to quantify the internal load or the reduced sedimentation coefficient. Rather it illustrates the relative importance of internal processes in Crystal Lake with respect to the observed water quality. A moderate to large amount of internal load would be required to produce the observed lake conditions and conversely a moderate to large reduction in the sedimentation coefficient would be required to do the same. A combination of internal load and reduced sedimentation are likely contributing to the in-lake phosphorus concentrations in Crystal Lake. Quantifying the contribution of each would require additional data not available at this time.

It is clear from the initial model run results that the First Order and Canfield Bachmann Lakes options provide very different predictions for in-lake phosphorus concentrations and require different degrees of calibration to approximate observed conditions. At first glance, it would appear the First Order model more closely represents the phosphorus dynamics of the Crystal Lake watershed. The First Order prediction is not significantly different from the observed in-lake phosphorus value and less internal load would be required to approximate the observed water quality. The relative importance of external loading in this scenario is supported by high measured phosphorus concentrations entering Crystal Lake. However, under this scenario it is possible that internal load is being underestimated. The First Order model is a simple linear model that assumes lake phosphorus concentration is proportional to phosphorus load. The First Order model assumes a constant sedimentation coefficient that does not change based on phosphorus load. Therefore, the First Order model is more sensitive to increased phosphorus loading and does not require as much internal load to calibrate to the observed. The highest in-lake concentration measured during the time of the TMDL study (0.531 mg/L) was taken during winter, suggesting a significant phosphorus release from bottom sediments was taking place and the First Order modeled load very likely or is too low. The Canfield Bachmann Lakes model, developed from a database of over 700 natural and artificial lakes, is a more sophisticated lake model as the sedimentation coefficient increases as phosphorus load increases. As a result, lake phosphorus concentration is not simply proportional to phosphorus load and much more internal load was required to calibrate the model to the observed. However, the internal load required in this instance was beyond typical shallow lake estimates (0 – 4 mg P m^{-2}d^{-1} from Hoverson, 2008 and Nurnberg, 1984) and is very likely higher than the actual internal load. Based on this uncertainty and best professional judgment, both models were used to estimate the phosphorus load capacity of Crystal Lake by using the average of the loads that calibrated each model respectively.

Loads within the BATHTUB model were modified to approximate the phosphorus water quality standard of < 90 ppb total phosphorus (Table 4.7D). In developing the lake nutrient standards for Minnesota lakes (Minn.Rule 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (Heiskary and Wilson, 2008). Clear relationships were established between the causal factor total phosphorus and the response variables chlorophyll-a and Secchi disk. Based on these relationships it is expected that by meeting the phosphorus target of 90 µg/L for Crystal Lake the chlorophyll-a and Secchi standards (30 µg/L and 0.7 m, respectively) will likewise be met.

Table 4.7D. Model to Phosphorus Standard

	Observed lake conditions	Lake conditions modeled to TP standard	Load Capacity – First Order model	Load Capacity – Canfield Bachmann lakes model	Daily Load Capacity- Average of First Order and Canfield Bachmann models
Total Phosphorus	230 (µg/L)	90 (µg/L)	791.2 kg P/yr	1,208.9 kg P/yr	6.04lbs/day

In order to provide for a 10% margin of safety (MOS), the total maximum annual phosphorus load was reduced by 10% yielding an annual maximum load of 712.1 kgP/yr for the First Order model and 1,088 kgP/yr for the Canfield Bachmann lakes model. Based on the uncertainty discussed above, the Total Maximum Daily Load will be based on the midpoint of the two model estimates. Annual and daily load capacities are shown in Table 4.7E.

Table 4.7E. Annual and Daily load calculations

	Annual Load Capacity (kg/yr)	Annual Load Capacity (lbs/yr)	Daily Load Capacity (kg/day)	Daily Load Capacity (lbs/day)
First Order Model	712.1	1,569.9	1.95	4.3
Canfield Bachmann Lakes Model	1,088	2,398.6	2.98	6.57
Total Maximum Load – midpoint of First Order and Canfield Bachmann models	900.1	1,984.4	2.47	5.44

Section 5.0 – TMDL Allocation

The TMDL process establishes the allowable loading of pollutants for a waterbody based on the point and nonpoint pollution sources, natural background conditions, and in-stream water quality conditions. In general terms, the process can be described by the following equation:

$$\textbf{TMDL} = \textbf{LC} = \sum \textbf{WLA} + \sum \textbf{LA} + \textbf{MOS}$$

Where:

LC = loading capacity, or the maximum amount of loading a water body can receive without violating water quality standards;

WLA = Waste load allocation, or the portion of the TMDL allocated to existing or future point sources;

LA = Load allocation, or the amount of the TMDL allocated to existing or future nonpoint sources;

MOS = margin of safety, or an accounting of uncertainty about the relationship between pollutant loads and the receiving water quality;

Within the WLA, LA, and MOS, there are additional categories and values taken into account.

5.1 – Waste Load Allocation

The waste load allocation is the sum of all the permitted discharges within the lake watershed. All permitted sources are designed to not exceed the nutrient standards due to permit limits, but must be considered when calculating total loading within a system.

The WLA includes three subcategories: municipalities subject to MS4 NPDES permit requirements; municipal wastewater treatment and industrial, non-MS4 wastewater treatment facilities; and construction and industrial stormwater (NPDES).

Municipalities subject to MS4 NPDES permit requirements - The development of urban areas have led to drainage alteration with impervious surfaces and varying volumes of storm water being delivered to streams, rivers and ditch systems. Municipalities of a certain size or density, or located in a sensitive area are subject to Municipal Separate Storm Sewer Systems (MS4) rules (Minnesota Rules, Chapter 7090), which limits the amount of discharge from stormwater within the area. These MS4 values are calculated for the TMDL by reviewing the developed area within the watershed, permits are broken down into the three categories:

1   **Mandatory MS4s**: MS4s in urbanized areas as defined by the 2000 Census are required to obtain a NPDES/SDS stormwater permit. An "urbanized area" is defined as a land area comprising one or more places ("central places") and the adjacent densely settled surrounding area ("urban fringe") that together have a residential population of at least 50,000 and a density of at least 1,000 people per square mile. The definition also includes any other public storm sewer system located fully or partially within an urbanized area.

2.   **Designated MS4s**: MS4s outside of urbanized areas that have been designated by the MPCA for permit coverage under Minn. R. ch 7090 are required to obtain a NPDES/SDS stormwater permit. MS4s designated by rule are cities and townships with a population of at least 10,000; and cities and townships

with a population of at least 5,000 and discharging or the potential to discharge to valuable or polluted waters. These designated MS4s are required to obtain permit coverage by February 15, 2007.

3. **Petition MS4s:** MS4s that are designated through the petition process under Minn. R. ch. 7090 are required to obtain a NPDES/SDS stormwater permit. The public can petition the Commissioner for the designation of an MS4 based on the designation criteria established in the rules.

Lake Crystal is not considered an MS4 community under any of these conditions, and therefore has no WLA loading under the MS4 category.

Municipal Wastewater Treatment and Industrial Wastewater– All wastewater treatment facilities (Waste Water Treatment Plants or Water Treatment Plants) and industrial facilities with permitted nutrient limits are reviewed. The permitted value is calculated by taking the maximum allowable discharge amount and then calculating the total discharge based on the design flow of the facility. To ensure an accurate calculation, the discharge type and duration of the facility is considered.

For wastewater treatment facilities with pond systems the discharge values are calculated based on their permitted discharge volume and the permitted concentration limit. While the discharge is calculated as a daily volume, a pond system discharges on specified days during the year (April 1 through June 15 and September 15 through December 15).

The WWTP for Lake Crystal is outside of the Crystal Lake watershed, and all other contributing watersheds in the project area, therefore has no WLA for this TMDL.

Construction and Industrial Stormwater (NPDES) – All construction and industrial stormwater permit holders are listed in the MPCA's DELTA database. A permit is required for any construction activities disturbing: one acre or more of soil; less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre; or less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources.

Although stormwater runoff at construction sites that do not have adequate runoff controls can be significant sources of sediment and nutrients on a per acre basis (MPCA Stormwater web page, 2006), MPCA records show that the number of projects per year are relatively small. A review of permits over a 10 year period only revealed 4 construction projects requiring a permit. In order to avoid a zero allocation for construction, we will use a 1% estimate, assuming that no more than 1% of the total watershed (approximately 130 acres) will ever be permitted/under construction at one time. The construction stormwater is then considered 1% of the total loading capacity

Within each of the watersheds all permitted facilities are listed and mapped within the area. The majority of permitted facilities within many of the watersheds are permitted feedlot or animal confinement facilities, which are permitted at zero nutrient or flow discharges, and therefore have no loading.

For the purposes of the TMDL, the WLA includes the following:

∑**WLA** = NPDES Permitted MS4 discharges (0.00) + NPDES Construction stormwater discharges (0.054 lbs/day or 1%)

∑**WLA= 0.05 lbs/day**

While no permitted nutrient sources exist in the basin (with the exception of construction stormwater), it is important that the allocation exists to account for the potential for businesses and industry to develop within the watershed. If the WLA is set to zero, then any developing businesses would be forced to use credits or nutrient trading to offset any discharges and meet the TMDL requirements. However, any new business or industry would also be required to meet discharge standards within the TMDL values. Due to the relatively small area of the total watershed, it is likely that any new industry would discharge outside of the Crystal Lake watershed.

5.2 – Load allocation
The load allocation (LA) is the portion of the total loading capacity assigned to nonpoint and natural background sources of nutrient loading. While substantial research has been conducted to estimate the amount of nutrient contribution from different nonpoint or natural sources, allocations in this report do not subdivide the LA. There are several reasons for this. First, current research is not sufficient to precisely define either nonpoint or natural background sources especially with the influence of the ditch system and sources of nutrients. Secondly, sub-division of the LA is not required by the EPA. Finally, discussions on which nonpoint or natural background sources should be considered, and how they should be addressed will be included in the implementation process.

The LA is composed of several different sources which are listed below:

A - Natural Background
When addressing the natural background loading levels within a TMDL study, the EPA offers the following guidance:

> Natural or background inputs of nitrogen and phosphorus in stream and river systems will contribute to increased nutrient concentrations. Typically, such sources can be estimated from regional reference streams. Reference sites are relatively undisturbed by human influences or represent least-impaired conditions; their levels of nitrogen and phosphorus reflect background loading from stream erosion, wild animal wastes, leaf fall and other natural or background processes. If possible, reference streams should be located in similar geophysical and hydrologic watersheds, having similar stream morphology and stream order. A wide variety of state and local agencies may collect information about reference streams. Without site-specific or regional reference stream information, literature values may be used to estimate background sources.

The *Lakes Nutrient TMDL Protocol and Submittal Requirements* makes the following statement:

> Natural background load is a portion of the watershed loading and internal loading, and should be defined as precisely as possible. This will range from having paleolimnologic data (as derived from sediment cores) for the TMDL lake to using ecoregion ranges for lakes of a similar type.

Existing methods, such as core data or diatom reconstruction, could potentially define a general value for natural background in the watershed but determining a specific percentage that would be an accurate and defensible value or calculation method within an individual watershed is difficult. Impacts within the watersheds could include unique stressors, such as elevation changes, channel alteration, upland management practices and other factors which lead to differing rates of natural and/or accelerated nutrient loading.

During the development of the Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria, the study sought out and carefully identified "ecoregion reference lakes", which were used within the development of the standards applied within this TMDL. This study included diatom/TP reconstruction, and other recommended methods. The reference ecoregion data prepared in the report are used to identify and examine the suspected natural loading levels.

For the purposes of the TMDL, it was decided that a numerical value or percentage attributed to natural background is not required by the EPA as a submittal requirement, and a specific value would not be defensible or ultimately beneficial to the final TMDL project. The load allocation within this TMDL is a combination of all nonpoint sources, including natural background. Future implementation planning will consider ongoing research and theories of related source contributions to the nutrient impairments including the levels of natural background.

B – CD 56 loading/Watershed loading
County Ditch 56 has been monitored though several projects, including the Clean Water Partnership (phase I Diagnostic and II implementation) and the TMDL. Loading data was developed through use of FLUX software. This program calculated loading based on recorded flow and sample data. Data was reviewed from 1995, 1996, 2007, 2008 and 2009. The flow and sample data from 1995 and 2005 were not used for the models, due to the years having non-representative flow and loading levels, and potential errors due to back water from the lake at the monitoring site. The 1996, 2007 and 2008 data was then averaged together. The 1995 and 2009 data was not included due to the data not be a "normal" flow year.

For the purposes of the TMDL, CD 56 is listed as a monitored inflow within the models. Data on the ditch is considered nonpoint source due to the loading which comes from diffuse sources within the CD 56 watershed. No specific allocation is given to the ditch. It should be noted that at times the loading values for the ditch have been higher than the calculated TMDL value. Because of these circumstances CD 56 and its surrounding watershed should be high priorities in any implementation efforts in helping the lake meet the TMDL value.

C - Internal loading/Bioturbation

In addition to nutrient loading from external sources, internal loading (nutrient resuspension/recycling from the bottom sediments) of phosphorus is likely a large source of the nutrients for Lake Crystal. All of the models used indicated that internal phosphorus loading has been demonstrated to be an important aspect of the total loading within the system. Internal phosphorus load is a self-enhancing process that fertilizes water systems (Nurnberg and Peters, 1984).

When compared to nutrients suspended in the waters column, phosphorus is more concentrated in the sediments than in the water due to settling and fixing by aquatic vegetation. Phosphorus can be released from the sediments through a number of processes, such as diffusion, anoxic conditions, wind and wave action, lake system exchange, and bioturbation from bottom feeding fish. The presence of benthic fish (bottom feeders) has been shown to contribute nutrients to the water column (NALMS, 1988). Nutrients are released as the fish feed and digest food from the bottom of the lake. Crystal Lakes' high populations of white sucker's, carp, and bullheads can contribute to the resuspension of sediments (DNR fisheries survey, 2006).

Internal loading values were estimated by calibrating to the observed in-lake phosphorus concentration. Daily internal load estimates range from 1.7 to 17.9 lbs P/day depending on the model. Treatment of internal loading will impact short term water quality, but reduction of external phosphorus loading sources will lead to long term improvements. Maintaining any internal loading reductions is only possible by addressing and limiting external sources.

D - Urban and residential sources

Untreated stormwater runoff has the potential to contribute nutrients to Crystal Lake. Stormwater can transport sediment, fertilizers, vehicle fluids/chemicals, leaves and grass clippings. Many of these materials can enter the lake system, break down, and release additional nutrients.

Since the city of Lake Crystal is not a regulated MS4 community, NPDES permit requirements regarding stormwater discharges do not apply. Stormwater loading was calculated using the area of developed spaces, and multiplying them by the run of coefficients and average precipitation values. The Reckhow-Simpson and BATHTUB models each calculate the total amount of loading differently. Reckhow-Simpson uses areas classified as urban and calculates predicted values using a range of values from .5 to 1.25 kg/ha while BATHTUB allows customizing of the runoff coefficient.

E - Failing SSTS

Subsurface Sewage Treatment Systems (SSTS), septic systems and/or "straight pipe systems", around Lake Crystal are another potential source of nutrients. Leeching of septage (partially treated sewage) from noncompliant systems may be considerable under a variety of conditions, providing nutrients in the form of ortho-phosphorus, which is more readily available for uptake and use by algae.

Proactive implementation and rule enforcement within Blue Earth County has significantly reduced the number of failing or straight pipe SSTS within the watershed. Nutrient input from

septic systems is minimal relative to other sources to Lake Crystal but needs consideration in the loading scenarios. Continued implementation at the county level will further reduce this potential nutrient input and will be a targeted source within the implementation plan.

SSTS and straight pipe contributions were utilized in modeling efforts but will not be accounted for directly in the TMDL nutrient budget. Any discharge from a straight pipe or noncompliant septic system is illegal, and as such is not given a load allocation value.

F - Atmospheric Loading
Additional loading can result from trace levels of phosphorus carried by precipitation. This type of phosphorus enters the lake via direct input (rain falling on the lake surface) or transported via overland stormwater flow.

The additional levels of phosphorus carried through stormwater from the precipitation are difficult to quantify. Best efforts have been made to calculate the loading based on runoff coefficients found in literature. The levels of atmospheric deposition vary based on the quantities of rainfall and climate conditions in an area, considering both wet and dry deposition rates. These levels are discussed in the MPCA report, "Detailed Assessment of Phosphorus Sources to Minnesota Watersheds" (Barr Engineering, 2004).

For the purposes of this TMDL, the rate is estimated to be 30 mg/m^2-year. Based on the calculated deposition rates, atmospheric loading is a small portion of the overall nutrient load, and potentially insignificant when compared to the external and internal loading sources. It is also important to note that the value, even if small, is important to consider in the overall budget, especially when this loading source is not possible to control. Based on the estimated rate, the total loading value from atmospheric loading is 102 lbs/year, or .28 lbs/day.

$\sum$**LA** = nonpoint sources as listed above. No specific allocations for each area.

$\sum$**LA= 5.39 lbs/day**

5.3 Margin of Safety

Margin of Safety, MOS, accounts for uncertainty within the calculation methods, sample data, or the allocations which will result in attainment of water quality standards. Figure 5.3 lists the approaches and considerations when addressing the MOS.

Figure 5.3

Type of Margin of Safety	Approaches
Explicit	• Set numeric targets at more conservative levels than analytical results indicate • Add a safety factor to pollutant loading estimates • Do not allocate part of available loading capacity; reserve for MOS
Implicit	• Conservative assumptions in derivation of numeric targets • Conservative assumptions when developing numeric model applications • Conservative assumptions when analyzing prospective feasibility of practices and restoration activities.

Flow and loading estimates from the primary conduit of phosphorus to Crystal Lake (CD 56) were based on monitoring data taken over multiple years. Phosphorus load estimates from other sources were based on published regional phosphorus export coefficients and actual monitoring data (Loon Lake). The MPCA believes the modeled phosphorus loads accurately represent conditions present in the Crystal Lake Watershed. The use of a 10% MOS was based on best professional judgment and accounts for environmental variability in pollutant loading, variability in water quality data, calibration and validation processes of modeling efforts, uncertainty in modeling outputs, and conservative assumptions made during the modeling efforts.

5.4 – Total TMDL and summary

In summary, the TMDL value is calculated at the following:

TMDL = LC = $\sum$WLA + $\sum$LA + MOS

LC – MOS = 6.04lbs/day – 0.60 lbs/day = 5.44 lbs/day

 $\sum$WLA = 0.05 lbs/day [NPDESvalues (0.00) + Construction stormwater (0.054 lbs/day or 1%)]

 $\sum$LA = 5.39 lbs/day [nonpoint sources as listed above. No specific allocations for each area.]

 MOS = 0.60 lbs/day

5.5 – Necessary Reductions:

While not required within the context of the TMDL, it is helpful to look at loading reductions necessary to meet the standards. The topic of necessary reductions considers nonpoint inputs and high levels of loading through both internal and external sources. The total volume of phosphorus loading that would allow the lake to meet the standards is 1,984.1 lbs/year or 5.44lbs/day. BATHTUB estimates phosphorus loading to Crystal Lake ranges between 4,458.4 to 10,385.9 lbs/year (12.2 to 28.4 lbs/day) depending on the model.

Recorded loading values from CD 56 range from 1,940 to 3,936 lbs/year (using the 1996, 2007 and 2008 as the average flow years) depending on flow volume throughout the year. This value can't be divided into a daily value since specific loading is based on several climatic factors. However, for the purposes of discussion, the loading from CD 56 ranged from 98% to 198% of the calculated total loading capacity depending on flow conditions.
The estimated internal load based on calibration of the BATHTUB model was approximately 1.71 to 17.9 lbs/day (First Order and Canfield Bachmann lakes models respectively). This value makes up 31% to 329% of the daily loading capacity. Internal loading must be greatly reduced if significant water quality improvements are to be made.

To calibrate the BATHTUB model to the in-lake phosphorus standard, the phosphorus concentration within CD 56 was reduced from 265.5 ppb to 68 ppb (First Order model) and 155 ppb (Canfield Bachmann lakes model). Reducing the load from a single tributary was the simplest way to model the effects of phosphorus load reduction on the lake. This is not intended to suggest that all reductions must come from the CD 56 watershed. Improvements to Crystal Lake water quality will require phosphorus reductions from all of its sources. Completely removing internal loading from the lake system is not possible, meaning that limiting the levels of internal and external loading is likely the best option of addressing nutrient loading. By adjusting the urban and agricultural runoff values, different levels of internal loading may be entered, depending on the decreases in other categories.

Ultimately, the decisions on what areas should be targeted for reductions will be based on the discussion during the development of the implementation plan. Additional modeling may be done at that time to determine what areas to reduce based on what is deemed feasible and practical by the technical advisory team. Any significant reduction in loading within the watershed will require a significant and likely aggressive implementation to achieve the reduction necessary to meet the TMDL values.

Section 6.0 – Implementation Activities

6.1 – Best management practices
In order to improve water quality, reduce the frequency of algae blooms, increase transparency and decrease nutrient concentration within Crystal Lake, a reduction in both the in-lake phosphorus cycling and nutrient inflow is necessary. This will require a suite of practices across all land uses.

An implementation strategy will be developed following EPA approval of this TMDL report. The strategy will provide a list of practices and goals created through an active stakeholder process to ensure the needs of the community are met. The development of a strategy for implementation planning and action is essential. Input from all interests should to be engaged in the process of developing the overall strategy and implementation plan. To achieve results, the plan, targets, and goals must be acceptable to the community within the watershed if the community is to act as the principal agent for progress.

Along with a list of practices and methods to deal with the impairment, a well designed targeting procedure also needs to be developed. Areas should be targeted based on factors such as slope, soil type, land cover, and distance to the water body, to ensure that the implementation activities will yield the maximum benefit for the minimum cost.

Counties, with BWSR assistance, have developed water plans focusing on concerns with local water quality issues. These chapters should be referenced and utilized when developing the implementation strategy, especially when dealing with target areas or local goals.

Implementation activities can be completed using existing conservation programs and rules established by state, county, or local ordinances. Existing rules/programs include USDA programs such as CRP, CREP, RIM, and EQIP, DNR programs, and county or local ordinances concerning shoreland, ditches, setbacks and riparian areas.

Best Management Practices (BMPs) are designed by the local and regional groups, or agencies (such as a SWCD), and used as a means for improving agricultural or urban discharges. The majority of these practices are modeled on researched, field-tested designs and implemented at the individual field scale to ensure proper function in the areas where they are installed

A - Urban BMPs:
Additional BMP and implementation activity should focus on urban and stormwater issues. Stormwater can have serious consequences on the quality of lakes, streams and rivers if it is not treated or managed. Often associated with impervious areas and urban development, stormwater often contains oil, chemicals, excess phosphorus, toxic metals, litter, and potentially disease-causing organisms and bacteria.

Because of the potential impact of stormwater, the MPCA, BWSR, and many local government units have developed rules, programs and suggestions when dealing with stormwater. For example, the MPCA covers construction and industrial stormwater under the NPDES permit program with the following language:

> Construction Stormwater:
> Construction storm water activities are considered in compliance with provisions of the TMDL if they obtain a Construction General Permit under the NPDES program and properly select, install and maintain all BMPs required under the permit, including any applicable additional BMPs required in Appendix A of the Construction General Permit for discharges to impaired waters, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

Industrial Stormwater:
Industrial stormwater activities are considered in compliance with provisions of the TMDL if they obtain an industrial stormwater general permit or general Sand and Gravel Permit (MNG49) under the NPDES program and properly select, install and maintain all BMPs required under the permit.

Additional work has been done through the development of the "Minnesota Stormwater Manual" which details the effects of stormwater, and lists several alternative methods of stormwater design, BMPs, and other options.

Educational materials and programs including the DNRs "Restore your shore" should be promoted and used. Demonstration sites can prove that a natural shore can not only have a positive effect on the lake itself, but can also be aesthetically pleasing and help control erosion and wildlife issues.

Lawn fertilizers can be a source of both nitrogen and phosphorus. They are not recommended for use around lakes. Per Minnesota Law 18C.60 (2006), Minnesota Statutes state that all fertilizers containing phosphorus were banned from use on lawns in Minnesota, with the exception if soils can be proven to be phosphorus deficient (by way of a soil test) or in the establishment of a new lawn.

A buffer of unfertilized natural vegetation should be maintained along the shoreline to help control erosion as well as trap some of the nutrients that may run off lawns and into the lake. Grass clippings and leaves should be removed before they end up in the lake where they are a source of nutrients and organic matter.

Additionally, urban practices such as plunge pools and retrofitting stormwater systems with traps can be an effective way of reducing nutrient loading. Plunge pools are already in use for portions of Lake Crystal.

B - Rural BMPs:
Best management practices have been used in agriculture for several decades to greatly reduce levels of soil erosion and transport. Traditional BMP funding comes through various government organizations to landowners in rural, agricultural settings but can also be funded and installed by individual landowners without government support. Federal guidance for agricultural BMPs is available from the Natural Resource Conservation Service (NRCS) in the Field Office Technical Guide (FOTG). The FOTG is available online, or from your local NRCS office. These guides are often county specific, and offer guidance on designs that would be suited to the area.

Since many BMPs are related to erosion and water quality they can assist in reducing the nutrient loading. These BMPs (with NRCS program code numbers) include, but are not limited to:

Conservation Cover (327),Conservation Crop, Rotation (328), Contour Farming (330), Contour Strip Cropping (585), Cover Crop (340), Critical Area Planting (340), Cross Wind Strip-cropping (589B),Cross Wind Trap Strip (589), Dike (356), Diversion (362), Filter Strip (393), Grade Stabilization Structure (410), Grassed Waterway (412), Heavy Use Area Protection (561),

Lined Waterway or Outlet (468), Mulching (484), Residue Management programs, Riparian Forest Buffer (391), Riparian Herbaceous Cover (390), Roof Runoff Management (558), Runoff Management System (570), Sediment Basin (558), Stream Channel Stabilization (584), Stream Habitat Improvement and Management (395), Structure for Water Control (587), Terrace (600), Vegetative buffers (601), Wetland Creation (658), Wetland Enhancement (659) and Wetland Restoration (657).

Additional practices and projects utilized within the ditch system should be considered. Practices that promote water and nutrient retention, including the two-stage ditch system, may be beneficial to the lake system. A two-stage ditch can provide drainage and improved ecological function, reducing nutrient loading and costs of ditch cleaning and maintenance.

C - In lake management
Due to the levels of nutrient coming from internal loading, in lake treatments of phosphorus may be necessary. Alum and other treatments may be beneficial once external sources have been reduced. They can lessen the internal nutrient cycling by binding and settling available phosphorus, creating a layer on the lake bottom that may help reduce nutrient cycling. While beneficial, this is not a permanent solution, and substantial cost is associated with each treatment method used.

Biological control of fish species is also important in reducing nutrient cycling. Rough fish and other bottom feeders can cause nutrient release through regular feeding activities. Controlling fish population is very difficult, especially in a chain of lakes. Treatments such as rotenone can be used to reclaim the lake, but will cause the existing fish community to collapse. These treatments can be controversial and should be handled by the DNR after discussion with area residents and stakeholders.

Shoreline areas on the land and into the shallow water provide essential habitat for fish and wildlife that live in or near Minnesota lakes. Overdeveloped shorelines cannot support the fish, wildlife, and clean water that are associated with natural undeveloped lakes. Shoreline habitat consists of aquatic plants, woody plants, and natural lake bottom soils. Plants in the water and at the water's edge provide habitat, prevent erosion, and absorb excess nutrients. Shrubs, trees, and woody debris such as fallen trees or limbs provide good habitat both above and below the water and should be left in place. By leaving a buffer strip of natural vegetation along the shoreline, property owners can reduce erosion, help maintain water quality, and provide habitat and travel corridors for wildlife (MNDNR).

It is important to restate that while focusing on the internal nutrient cycling through various treatment options would likely result in improved water quality, it is also important to deal with external nutrient loading. By not addressing the external loading, the effectiveness of any in-lake treatment would be limited. Over time, internal load will subside if external loading is controlled through implementation activities.

6.2 - Effectiveness monitoring/Monitoring plan

Monitoring related to TMDLs should include at least three components, subject to available resources. In order to effectively track progress, monitoring plans should include tracking the adoption of implementation activities, monitoring the effectiveness of individual and/or sets of implementation measures, and resource monitoring for evaluating impairment.

Data from water quality monitoring programs enables water quality condition assessment and creates a long-term data set to track progress toward water quality goals. BMPs implemented by local units of government will be tracked through BWSR's e-Link system. Water quality monitoring programs will continue to collect and analyze data in the Crystal Lake Watershed as part of *Minnesota's Water Quality Monitoring Strategy* (MPCA 2011). Data needs are considered by each program and additional monitoring is implemented when deemed necessary and feasible. These monitoring programs are summarized below:

Intensive Watershed Monitoring (MPCA 2012a)
This data provides a periodic but intensive "snapshot" of water quality throughout the watershed. This program collects water quality and biological data at roughly 100 stream and 50 lake monitoring stations across the watershed in 1 to 2 years, every 10 years. To measure pollutants across the watershed the MPCA will re-visit and re-assess the watershed, as well as have capacity to visit new sites in areas with BMP implementation activity. This first round of this work will be completed in the Minnesota River-Mankato Watershed in 2018.

Clean Water Act Section 319 Grants
Within the CWA, the Nonpoint Source (NPS) Management Program was introduced in 1987 as Section 319. Under Section 319, federal grant money is distributed to states, territories and tribes. These grants can be applied for under criteria established by the MPCA. Typically the focus of these projects includes technical and financial assistance, outreach and education, and project implementation and evaluation.

Citizen Stream Monitoring Program (CSMP)
The Citizen Stream-Monitoring Program is a monitoring network composed entirely of volunteers trained and assisted by the MPCA staff. Started in 1998, the programs now have more than 400 volunteers and close to 700 sites across the state. These volunteers assist in determining the condition of Minnesota streams by expanding our water-quality monitoring network. Anyone interested can participate in this basic, centrally administered and interpreted stream monitoring programs. Increased stream monitoring helps identify problems, develop strategies and prioritize activities for improving water quality, and tracks progress toward improvement.

Section 7.0 – Reasonable Assurance

A TMDL needs to provide reasonable assurance that water quality targets will be achieved through the specified combination of point and nonpoint source reductions reflected in the LAs and WLAs. According to EPA guidance (EPA 2002b), "When a TMDL is developed for waters impaired by both point and NPSs, and the WLA is based on an assumption that nonpoint-source load reductions will occur ... the TMDL should provide reasonable assurances that nonpoint-source control measures will achieve expected load reductions in order for the TMDL to be approvable. This information is necessary for the EPA to determine that the TMDL, including the LA and WLAs, has been established at a level necessary to achieve water quality standards". In the Crystal Lake watershed considerable reductions in NPS are required.

The MPCA will adopt portions of the Chesapeake Bay Reasonable Assurance framework, with some modifications as follows:

- Evaluate existing programmatic, funding, and technical capacity to implement watershed strategies.
- Identify gaps in current programs, funding, and local capacity to achieve the needed controls.
- Build program capacity for short-term and long-term goals. Demonstrate increased implementation and/or pollutant reductions.
- Commit to track/monitor/assess and report progress at set regular times.

The phosphorus impairment in this TMDL will not include reductions to point sources since there are no permitted MS4s in the Crystal Lake watershed or permitted wastewater treatment facilities. The construction and industrial stormwater contributions are minor sources of phosphorus to Crystal Lake and reductions in their WLAs will not help to accomplish the goals of the TMDL.

Additional requirements could be implemented if nonpoint source targets are not met and will focus on NPSs themselves. They could take the form of:

- Review of statewide nonpoint source control programs and policies by state agencies and their implementation by local agencies.
- Requirements to comply with existing nonpoint source authorities, including but not limited to:
  - o 50-foot buffer required for the shore impact zone of streams classified as protected waters (Minn. Stat. § 103F.201) for agricultural land uses
  - o Protecting highly erodible land within the 300-foot shoreland district (Minn. Stat. § 103F.201)
  - o Buffers on public drainage ditches (Minn. Stat. § 103E.021)
  - o Excessive soil loss statute (Minn. Stat. § 103F.415)
  - o Nuisance nonpoint source pollution (Minn. R. 7050.0210, subp. 2)
  - o Other measures that may be identified in the future WRAPS Report or the One Watershed One Plan

The targeting of BMPs and ongoing research to pinpoint phosphorus sources and measure the effectiveness of nonpoint source remediation measures will provide some assurance of achieving the LA of this TMDL. In addition, inter-agency work groups formed to direct the state's Clean Water Fund will help to ensure that nonpoint source load reductions will be addressed. These groups have developed guidance related to monitoring, implementation, research, and identification of measures and outcomes. Within this framework of implementation, reasonable assurance will be provided with regard to NPS through commitments of funding, watershed planning, and use of existing regulatory authorities. The CWLA (2006) provided the MPCA authority and direction for carrying out section 303(d) of the Clean Water Act, in addition to one-time funding to initiate a comprehensive 10-year process of assessment and TMDL development in Minnesota.

In November 2008, Minnesotans voted in support of the Clean Water, Land and Legacy Amendment to the state constitution. Through this historic vote, about $5.5 billion will be dedicated to the protection of water and land over the next 25 years. One third of the annual proceeds from sales tax revenue, an estimated $80 to $90 million, will be devoted to a Clean Water Fund to protect, enhance and restore water quality of lakes, rivers, streams, and groundwater. The Amendment specifies that this funding must supplement and not replace traditional funding. Approximately two-thirds of the annual proceeds will be earmarked for water quality protection and restoration.

Reasonable assurance for permitted sources such as construction and industrial stormwater is provided primarily via compliance with the respective NPDES permit programs, which have been described in section 5.1. Point sources were not identified as a primary source of TP in the Crystal Lake watershed.

In order for Crystal Lake to meet water quality standards, the majority of pollutant reductions will need to come from NPS contributors. With a lack of existing state and federal regulations for NPS and the monetary incentives for practices that can degrade water quality including agricultural drainage and surface runoff, major contributions of nutrients and increased flows will continue throughout the watershed. State and local agencies will need to work with landowners to identify priority areas for BMPs and practices that will help reduce nutrient runoff, as well as streambank and overland erosion. Agencies, organizations, local units of governments, and citizens alike need to recognize that resigning waters to an impaired condition is not acceptable. Some of these efforts are well underway as a locally led group has formed to focus on finding solutions for improving the water quality of Crystal Lake. Their efforts have led to increased dialogue between the urban and rural residents, native plantings and innovative in-lake treatment approaches. In addition, the Crystal Lake watershed will be included in the Minnesota River – Mankato Watershed Restoration and Protection Strategies Document (WRAPS). The WRAPS document will reflect 10-year targets and water quality goals as determined by the Crystal Lake TMDL with strategies to accomplish the targets and goals. The strategies identified and developed by the WRAPS workshop team will be used to calculate the adoption rates needed to meet the pollutant/stressor 10-year targets. This information is most relevant for local planning efforts including the specific strategies, actions, and responsibilities for BMP implementation.

To best assure that NPS reductions are achieved, a large emphasis will be placed on citizen engagement, where the citizens and communities that hold the power to improve water quality conditions are involved in discussions and decision-making. The watershed's citizens and communities will need to voluntarily adopt the practices at the necessary scale and rates to achieve water quality goals. In addition to citizen engagement, several government programs have been created to support a political and social infrastructure that aims to increase the adoption of strategies that will improve watershed conditions. Selection of sites for BMP implementation will be led by local units of government, local citizen groups, county Soil and Water Conservation Districts (SWCDs), county planning and zoning with guidance and support from multiple state agencies (MPCA, BWSR, DNR, MDA, MDH). One example of a program is the Minnesota Agricultural Water Quality Certification Program (AWQCP), which provides regulatory security and incentives to landowners who adopt conservation practices. Additional financial programs include the Clean Water Act Section 319 grant programs, Board of Water and Soil Resources (BWSR) implementation funding, and Natural Resources Conservation Service (NRCS) incentive programs. Programs and activities are also occurring at the local government level, where county staff, commissioners, and residents work together to address water quality issues.

Section 8.0 – Public Participation

Public participation and involvement are important in the successful design, review, and implementation of a TMDL study. For this reason, the Crystal Lake TMDL project worked closely with a broad array of county, state and citizen groups and organizations.

To address the broad interests that would be involved in the project, the technical advisory team was composed of various representatives of stakeholders groups to help ensure that all groups would remain up to date and able to raise concerns and/or opinions as necessary.

The Technical group included state, federal and local government employees, research groups and projects, and joint powers boards. Agencies on the mailing and contact lists include SWCD, MPCA, BWSR, MSU, DNR, County Employees, CSMP volunteers, and concerned citizens.

The technical committee was updated bi-monthly on the progress of the project during the duration of the Phase II Clean Water Partnership.

Due to changes in staff though out the project, public updates and involvement were less than originally hoped. However, the goals of the TMDL work plan and requirements regarding public notification were met through press releases and meetings, along with additional opportunities made available to any member interested in being involved with the project.

> TMDL Advisory Team discussed project in conjunction with CWP project meetings. These meetings were held during bi-monthly during the life of the project.
> Meeting Dates: 1/14/08, 2/19/08, 3/19/08, 4/21/08, 5/22/08, 8/20/08, 10/31/08, 3/16/09, 5/29/09, 8/19/09, 10/16/09, and 12/16/09.

> Organized & hosted public/stakeholder open house meetings (Lake Crystal, 10/13/08); the Technical Advisory Team is under development, with the majority of the team coming from the existing CWP team with the potential of additions to the team of additional interested parties or organizations.

> 6/17/2009 – The TMDL was discussed during the lakeshore owners workshop.

> 8-29-2010 - Meeting with Minnesota Department of Natural Resources to discuss the TMDL, and the potential of partnering with project in the future.

Public Notice

An opportunity for public comment on the draft TMDL report was provided via public notice in the State Register from August 27th, 2012 through September 26th, 2012. There were 6 comment letters and 2 contested case hearing requests received and responded to as a result of the public comment period.

Section 9.0 – References

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Section 10.0 – Appendices

Appendix 1 – General Demographic information – Lake Crystal

Appendix 2 – Soils information

Appendix 3 – Land use classification definitions

Appendix 1 – General Demographic information – Lake Crystal

As of the census of 2000, there were 2,420 people, 940 households, and 652 families residing in the city. The population density was 1,361.3 people per square mile (524.9/km²). There were 973 housing units at an average density of 547.3/sq mi (211.1/km²). The racial makeup of the city was 97.98% White, 0.29% African American, 0.45% Native American, 0.29% Asian, 0.04% Pacific Islander, 0.45% from other races, and 0.50% from two or more races. Hispanic or Latino of any race were 0.74% of the population.

There were 940 households out of which 34.8% had children under the age of 18 living with them, 57.8% were married couples living together, 8.3% had a female householder with no husband present, and 30.6% were non-families. 26.4% of all households were made up of individuals and 14.8% had someone living alone who was 65 years of age or older. The average household size was 2.52 and the average family size was 3.05.

In the city the population was spread out with 27.4% under the age of 18, 7.9% from 18 to 24, 28.3% from 25 to 44, 18.9% from 45 to 64, and 17.4% who were 65 years of age or older. The median age was 35 years. For every 100 females there were 97.2 males.

The median income for a household in the city was $39,912, and the median income for a family was $47,143. Males had a median income of $31,970 versus $21,548 for females. The per capita income for the city was $17,454. About 4.5% of families and 5.4% of the population were below the poverty line, including 6.8% of those under age 18 and 8.2% of those age 65 or over.

People Quick Facts Blue Earth County Minnesota
http://quickfacts.census.gov/qfd/states/27/27013.html

Appendix 2 – Soils information
Top 5 soils (by area) in the Watershed.
Soil area information collected through GIS analysis
Soil description information collected through the NRCS "Web Soil Survey"

Dassel loam (11.41% of watershed) – The Dassel series consists of very poorly drained soils in depressions on glacial lake deltas and outwash plains. The 183 Dassel loam category is specifically a very poorly drained soil, typically 3-15 acres. The soil is naturally wet, and requires drainage to be used for row crop agriculture

Fieldon loam (10.25% of watershed) - This soil type typically is found in 3 – 30 acres flats on the depressional and outwash plains and stream deltas. Though a sandy soil, it is naturally wet and also required drainage to be used for agricultural practices. Under prolonged dry conditions, the soil has been known to become droughty. The sandy nature of the soil makes it susceptible to collapse.

Darfur loam (7.25% of watershed) – Typically found on glacial lake plain deltas and a few shallow drainage areas, this soils is typically 3-30 acres. With little slope (typically less than 2%) this soil type is naturally wet and also requires drainage for agricultural use.

Clarion loam, 2 to 6 percent slopes (6.91% of watershed) – This subset of the Clarion series is usually found in the gently rolling or hilled areas near the peak or rises on the hills. This is soil type is well suited for agriculture, as long as erosion is controlled on the sloping areas.

Litchfield loamy fine sand, 1 to 3 percent slopes (6.46% of watershed) – This type of sandy soils is typically found in the flat areas, usually accompanied by Dickinson, Estherville and Darfur soils types. Because of the mellow, texture it drains easily, but does not retain high levels of natural fertility. Because of this, fertilizers (and occasionally irrigation) are commonly used to increase soil productivity. This soils is subject to high levels of wind and water erosion if left unprotected.

Crystal Lake Watershed
Blue Earth County, Minnesota
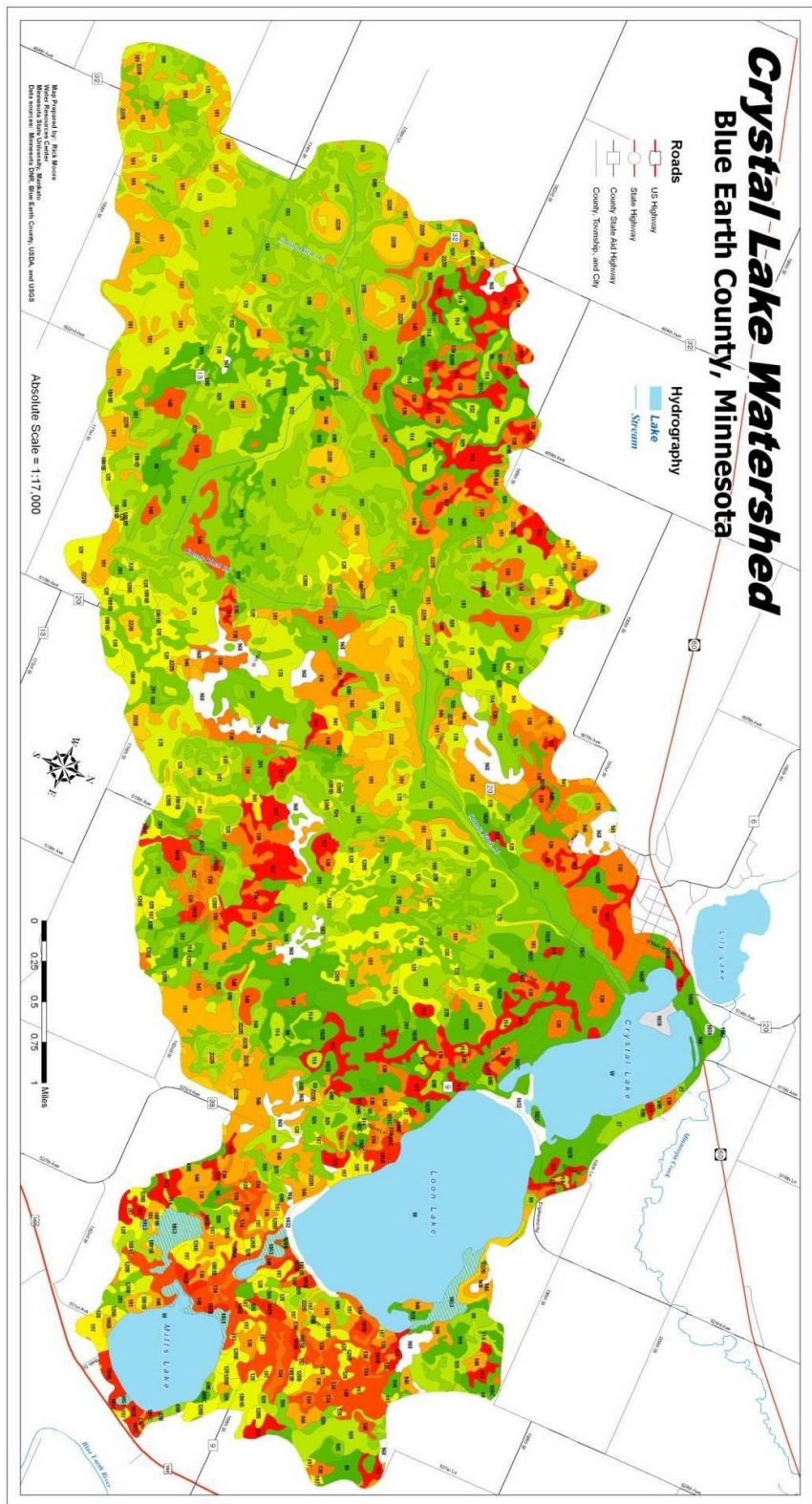
Appendix 3 – Land use classification definitions
The Land use definitions used within this TMDL are taken from the 2009 National
Agricultural Statistics Service (NASS). The NASS land cover data is developed by the
United States Department of Agriculture, and uses a combination of NASS specific land
covers and information developed by the National Land Cover Dataset (NLCD). The
NASS land cover breaks agricultural areas into specific crop or cover types in addition to
the Typical NLCD classifications. The NASS definitions are as follows:

Value	Classification
1	Corn
5	Soybeans
12	Sweet Corn
23	Spring Wheat
24	Winter Wheat
37	Other Hays
41	Sugarbeets
53	Peas
62	Pasture/Grass
111	NLCD - Open Water
121	NLCD - Developed/Open Space
122	NLCD - Developed/Low Intensity
	NLCD - Developed/Medium
123	Intensit
	NLCD - Developed/High
124	Intensity
131	NLCD - Barren
141	NLCD - Deciduous Forest
171	NLCD - Grassland Herbaceous
181	NLCD - Pasture/Hay
190	NLCD - Woody Wetlands
195	NLCD - Herbaceous Wetlands

NLCD classifications are then altered by placing a "1" in front of the typical numeric
classification. For example, 11 – open water becomes 111 – open water, and 21 – Low
intensity development becomes 121 – Low Intensity development. The NLCD
classifications are as follows:
Water - All areas of open water or permanent ice/snow cover.
11. Open Water - All areas of open water; typically 25 percent or greater cover of water (per
pixel).

12. Perennial Ice/Snow - All areas characterized by year-long cover of ice and/or snow.

**Developed - Areas characterized by a high percentage (30 percent or greater) of constructed
materials (e.g. asphalt, concrete, buildings, etc).**
21. Low Intensity Residential - Includes areas with a mixture of constructed materials and
vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account

for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.

22. High Intensity Residential - Includes highly developed areas where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80 to100 percent of the cover.

23. Commercial/Industrial/Transportation - Includes infrastructure (e.g. roads, railroads, etc.) and all highly developed areas not classified as High Intensity Residential.

Barren - Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation present regardless of its inherent ability to support life. Vegetation, if present, is more widely spaced and scrubby than that in the "green" vegetated categories; lichen cover may be extensive.

31. Bare Rock/Sand/Clay - Perennially barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, beaches, and other accumulations of earthen material.

32. Quarries/Strip Mines/Gravel Pits - Areas of extractive mining activities with significant surface expression.

33. Transitional - Areas of sparse vegetative cover (less than 25 percent of cover) that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.).

Forested Upland - Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25-100 percent of the cover.

41. Deciduous Forest - Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.

42. Evergreen Forest - Areas dominated by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.

43. Mixed Forest - Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.

Shrubland - Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall, with individuals or clumps not touching to interlocking. Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included.

51. Shrubland - Areas dominated by shrubs; shrub canopy accounts for 25-100 percent of the cover. Shrub cover is generally greater than 25 percent when tree cover is less than 25 percent. Shrub cover may be less than 25 percent in cases when the cover of other life forms (e.g. herbaceous or tree) is less than 25 percent and shrubs cover exceeds the cover of the other life forms.

Non-natural Woody - Areas dominated by non-natural woody vegetation; non-natural woody vegetative canopy accounts for 25-100 percent of the cover. The non-natural woody classification is subject to the availability of sufficient ancillary data to differentiate non-natural woody vegetation from natural woody vegetation.

61. Orchards/Vineyards/Other - Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals.

Herbaceous Upland - Upland areas characterized by natural or semi-natural herbaceous vegetation; herbaceous vegetation accounts for 75-100 percent of the cover.

71. Grasslands/Herbaceous - Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing.

Planted/Cultivated - Areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber; or is maintained in developed settings for specific purposes. Herbaceous vegetation accounts for 75-100 percent of the cover.

81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.

82. Row Crops - Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.

83. Small Grains - Areas used for the production of graminoid crops such as wheat, barley, oats, and rice.

84. Fallow - Areas used for the production of crops that are temporarily barren or with sparse vegetative cover as a result of being tilled in a management practice that incorporates prescribed alternation between cropping and tillage.

85. Urban/Recreational Grasses - Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Wetlands - Areas where the soil or substrate is periodically saturated with or covered with water as defined by Cowardin et al.

91. Woody Wetlands - Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

92. Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.