Upper Watershed TMDL Studies for Clearwater River Watershed District

Part I
Lake Nutrient TMDLs
for Clear Lake
Lake Betsy
Union Lake
Scott Lake
Lake Louisa
Lake Marie

Part II
Bacterial TMDL
for Clearwater River:
CD 44 to Lake Betsy

CRWD

Wenck

Prepared for

Clearwater River Watershed District

FINAL
November 2009

wq-iw8-10e

Clearwater River Watershed District

Lake Nutrient TMDLs for:
Clear Lake
Lake Betsy
Scott Lake
Union Lake
Lake Louisa
Lake Marie

Part I

Prepared by:

WENCK ASSOCIATES, INC.
1800 Pioneer Creek Center
P.O. Box 249
Maple Plain, Minnesota 55359-0249
(763) 479-4200

November 2009

Overall Table of Contents

Overall TMDL Summary Table

Part 1: Lake Nutrient TMDL – Summary Table		
EPA/MPCA Required Elements	**Summary**	**TMDL Report Section**
Location	The Upper Mississippi St. Cloud area HUC 07010203. More specifically, the upper portion of the Clearwater River Watershed District, in Stearns and Meeker Counties, Minnesota.	***Part 1***, Section 3: Figures 3.1, 3.2 and 3.3
303(3) Listing Information	Clear Lake 47-0095 Lake Betsy 47-0042 Union Lake 86-0298 Scott Lake 86-0297 Lake Louisa 86-0282 Lake Marie 73-0014 Lake Louisa was the first of the above lakes to be added to the 303(d) list in 2002. The remaining five lakes included in this report, Clear Lake, Lake Betsy, Union Lake, Scott Lake and Lake Marie, were added to the 303(d) list in 2008. All of the six lakes addressed in this report are included on the 303(d) list due to excess nutrient concentrations impairing aquatic recreation, as set forth in Minnesota Rules 7050.0150. The TMDL for Lake Louisa was prioritized to start in 2004 and be completed by 2009. The TMDL for Lake Betsy was prioritized to start in 2008 and be completed by 2012. The remaining four lakes, Clear Lake, Union Lake, Scott Lake and Lake Marie, were all prioritized to start in 2008 and be completed in 2013.	***Part 1,*** Section 2
Applicable Water Quality Standards/ Numeric Targets	Criteria set forth in Minn. R. 7050.0150 (3) and (5). The numeric target for five of the six lakes discussed herein: Lake Betsy, Scott Lake, Union Lake, and Lake Louisa is a total phosphorus concentration of 40 µg/L or less. The numeric target for Clear Lake and Lake Marie is a total phosphorus concentration of 60 µg/L.	***Part 1,*** Section 2

Overall TMDL Summary Table

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<tr><td>Loading Capacity (expressed as daily load)</td><td>The loading capacity is the total maximum daily load for each of these conditions. The critical condition for these lakes is the summer growing season. The loading capacity is set forth in Table 7.2.

Total maximum daily total phosphorus load (lb/day)
Clear Lake 3.4 (1,250 lb/yr)
Lake Betsy 7.9 (2,868 lb/yr)
Union Lake 1.6 (572 lb/yr)
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<tr><td>Wasteload Allocation</td><td>There are no individual permitted sources in the watershed allowed to discharge to surface waters. The Wasteload Allocation represents the WWTPs which operate using land application, cluster systems which discharge to drainfields, potential future systems that have been evaluated for the area, and the NPDES Construction Permit. All but the NPDES permit have WLA of 0, as the MPCA has rejected requests to discharge to area lakes in the past.
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<tr><th>Source</th><th>Permit #</th><th>Gross WLA (lb P/day)</th></tr>
<tr><td>NPDES Construction</td><td>MNR100001</td><td>0.41 (total)</td></tr>
<tr><td>City of Fairhaven- Future</td><td>NA</td><td>0</td></tr>
<tr><td>Clearwater River Watershed District :</td><td></td><td>0</td></tr>
<tr><td>❖ Rest-a-While Shores</td><td>09-17550</td><td>0</td></tr>
<tr><td>❖ Wandering Ponds</td><td>09-20199</td><td>0</td></tr>
<tr><td>❖ Lake Louisa Hills</td><td>Pending</td><td>0</td></tr>
<tr><td>❖ Future Regional System</td><td>NA</td><td>0</td></tr>
<tr><td>City of South Haven WWTP</td><td>MN006461</td><td>0</td></tr>
<tr><td>City of Kimball WWTP</td><td>MN005264</td><td>0</td></tr>
<tr><td>City Watkins WWTP</td><td>MN0051365</td><td>0</td></tr>
</table></td><td></td></tr>
</table>

Overall TMDL Summary Table

Part 1: Lake Nutrient TMDL – Summary Table			
EPA/MPCA Required Elements	**Summary**		**TMDL Report Section**
Load Allocation	The portion of the loading capacity allocated to existing non-permitted sources.		***Part 1,*** Section 7, Tables 7.2 and 7.3
	Source	**Load Allocation (lb/day)**	
	Atmospheric and Groundwater	Clear Lake 0.99 Lake Betsy 0.56 Union Lake 0.47 Scott Lake 0.54 Lake Louisa 2.45 Lake Marie 2.42	
	Internal Load	Clear Lake 0.06 Lake Betsy 0.97 Union Lake 0.20 Scott Lake 0.16 Lake Louisa 1.73 Lake Marie 0.65	
	Watershed Loads (including upstream lakes)	Clear Lake 2.35 Lake Betsy 6.24 Union Lake 0.88 Scott Lake 6.17 Lake Louisa 4.75 Lake Marie 9.30	
	Septic Systems	Scott Lake 0 Lake Louisa 0 Lake Marie 0 Clear Lake 0 Lake Betsy 0 Union Lake 0	
Margin of Safety	The Margin of Safety is implicit in each TMDL due to the conservative assumptions of the model and the proposed iterative nutrient reduction strategy with monitoring.		***Part 1,*** Section 7.4
Seasonal Variation	Seasonal variation is accounted for by developing targets for the summer critical period where the frequency and severity of nuisance algal growth is greatest. Although the critical period is the summer, lakes are not sensitive to short-term changes but rather respond to long-term changes in annual load.		***Part 1,*** Section 7.3

Overall TMDL Summary Table

Part 1: Lake Nutrient TMDL – Summary Table		
EPA/MPCA Required Elements	**Summary**	**TMDL Report Section**
Reasonable Assurance	Reasonable assurance is provided by the cooperative efforts of the Clearwater River Watershed District, a watershed based organization with statutory responsibility to protect and improve water quality in the water resources in the Clearwater River watershed in which these lakes are located.	***Part 1,*** Section 10
Monitoring	The Clearwater River Watershed District monitors lakes water quality for district lakes on a rotating basis annually through its baseline monitoring program which it started in 1981. Through this program the CRWD also measures watershed loads and hydrology annually. The CRWD will continue this annual baseline program and add monitoring as recommended in section 11.	***Part 1,*** Section 11, Appendix D
Implementation	This TMDL sets forth a proposed implementation framework and load reduction strategies. The final implementation plan is part of a program to address all TMDLs within the Clearwater River Watershed District. Strategies will be refined annually as new monitoring data and evaluation indicates. The estimated cost of implementation is $7.6 million over 10 years.	***Part 1,*** Section 9
Public Participation	Public Comment period: Meeting location: Comments received:	***Part 1,*** Section 8

Overall TMDL Summary Table

<table>
<tr><th colspan="3">Part 2: Bacterial TMDL – Summary Table</th></tr>
<tr><th>EPA/MPCA Required Elements</th><th>Summary</th><th>TMDL Report Section</th></tr>
<tr><td>Location</td><td>Upper portion of the Clearwater River Watershed District, in Stearns and Meeker Counties Minnesota in the Upper Mississippi River Basin.</td><td>Part 2, Section 2</td></tr>
<tr><td>303(3) Listing Information</td><td>Clearwater River, CD44 to Lake Betsy 07010203-549. The original listing was for 07010203-502, Clear Lake to Lake Betsy. The reach was subsequently split into 549 and 550. The listed portion to which this TMDL study applies is 549.

The Clearwater River was added to the 303(d) list in 2002 due to excess bacteria concentrations which impair aquatic recreation, per Minnesota Rules 7050.0150. The TMDL for Clearwater River was prioritized to start in 2004 and be completed by 2009.</td><td>Part 2, Section 1</td></tr>
<tr><td>Applicable Water Quality Standards/ Numeric Targets</td><td>Criteria set forth in Minn. R. 7050.0222 (4). The numeric target for the reach is in terms of E. Coli: Concentrations shall not exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies between April 1 and October 31.</td><td>Part 2, Section 3</td></tr>
<tr><td>Loading Capacity (expressed as monthly geometric mean)</td><td>The loading capacity, the total maximum daily load expressed as a monthly geometric mean per MPCA submittal requirements. The loading capacity is provided across five flow regimes:

<table>
<tr><th>Reach</th><th>Critical Condition</th><th>Waste Load (10^9 org)</th><th>Load (10^9 org)</th><th>Margin of Safety (10^9 org)</th><th>TMDL (10^9 org)</th></tr>
<tr><td rowspan="5">Clearwater River</td><td>High Flow</td><td>0</td><td>237.9</td><td>91.75</td><td>329.65</td></tr>
<tr><td>Wet</td><td>0</td><td>63.25</td><td>61.22</td><td>124.47</td></tr>
<tr><td>Mid-Range</td><td>0</td><td>28.74</td><td>9.77</td><td>38.51</td></tr>
<tr><td>Dry</td><td>0</td><td>3.10</td><td>9.21</td><td>12.32</td></tr>
<tr><td>Low Flow</td><td>0</td><td>0.02</td><td>1.51</td><td>1.54</td></tr>
</table></td><td>Part 2, Section 5</td></tr>
</table>

Overall TMDL Summary Table

Part 2: Bacterial TMDL – Summary Table				
EPA/MPCA Required Elements	**Summary**			**TMDL Report Section**
Wasteload Allocation	There are no individual permitted sources in the watershed allowed to discharge to surface waters. The Wasteload Allocation represents the WWTPs which operate using land application; potential future systems that have been evaluated for the area; and the NPDES Construction Permit. All have a WLA of 0, as the MPCA has rejected requests to discharge to area lakes in the past.			***Part 2,*** Section 5
	Source	**Permit #**	**Gross WLA (organisms/ month)**	
	NPDES Construction	MNR100001	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 storm water requirements if they are more restrictive than requirements of the State General Permit.	
	Clearwater River Watershed District Future Systems	NA	0	
	City Watkins WWTP	MN0051365	0	

Overall TMDL Summary Table

<table>
<tr><th colspan="8">Part 2: Bacterial TMDL – Summary Table</th></tr>
<tr><th>EPA/MPCA Required Elements</th><th colspan="6">Summary</th><th>TMDL Report Section</th></tr>
<tr><td rowspan="11">Load Allocation</td><td colspan="6">The portion of the loading capacity allocated to existing non-permitted sources. Proportional loads were derived by using the determined percentage contribution of each source. Wet condition proportions were applied to the High Flow and Wet flow regimes, dry condition proportions were applied to Dry and Low Flow flow regimes and the average of wet and dry condition proportions were applied to the Average flow condition.</td><td rowspan="11">Part 2, Section 5</td></tr>
<tr><th rowspan="2">Source</th><th colspan="5">Load Allocation (org/month 10^9)</th></tr>
<tr><th>High Flow</th><th>Wet</th><th>Avg.</th><th>Dry</th><th>Low Flow</th></tr>
<tr><td>Septic Systems (SSTS)</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Urban Runoff</td><td>0.142</td><td>0.03</td><td>0.009</td><td>0</td><td>0</td></tr>
<tr><td>Riparian Livestock</td><td>87.74</td><td>23.33</td><td>12.01</td><td>1.45</td><td>0.014</td></tr>
<tr><td>Applied Manure</td><td>149.81</td><td>39.83</td><td>16.69</td><td>1.65</td><td>0.016</td></tr>
<tr><td>Incorporated Manure</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Wildlife</td><td>0.02</td><td>0.006</td><td>0.004</td><td>0.001</td><td>0.000006</td></tr>
<tr><td>Total</td><td>237.9</td><td>63.2</td><td>28.7</td><td>3.10</td><td>0.03</td></tr>
<tr><td colspan="6" style="display:none"></td></tr>
<tr><td>Margin of Safety</td><td colspan="6">The Margin of Safety is both an implicit (conservative assumptions and adaptive management) and explicit (quantified variability across the flow regime). The explicit MOS is the difference between the median and minimum flow value in each of the defined flow regimes. This accounts for the variation in flow for each flow regime.</td><td>Part 2, Section 5.3</td></tr>
<tr><td>Seasonal Variation</td><td colspan="6">Seasonal variation is accounted for by assumptions in the loading potential, use of a load duration curve to set TMDLs over seasonal flow regimes, and in the linkages between sources and in-stream bacteria concentrations. The in-stream data used to link sources to in-stream concentrations represents an appropriate range of seasonal and annual variations in flow and conditions. Load reduction strategies in the implementation plan are based on the relationships developed using these data.</td><td>Part 2, Section 5.4</td></tr>
</table>

Overall TMDL Summary Table

Part 2: Bacterial TMDL – Summary Table		
EPA/MPCA Required Elements	**Summary**	**TMDL Report Section**
Reasonable Assurance	Reasonable assurance is provided by the cooperative efforts of the Clearwater River Watershed District, a watershed based organization with statutory responsibility to protect and improve water quality in the water resources in the Clearwater River watershed which contains the listed reach and its tributary watershed.	***Part 2,*** Section 7
Monitoring	The Clearwater River Watershed District monitors water quality and flow in the listed reach annually through its baseline monitoring program which it started in 1981. The CRWD will continue this annual baseline program and add monitoring as recommended in Section 8.	***Part 2,*** Section 8
Implementation	This TMDL sets forth a proposed implementation framework and load reduction strategies. The final implementation plan is part of a program to address all TMDLs within the Clearwater River Watershed District. Strategies will be refined annually as new monitoring data and evaluation indicates. The estimated cost of implementation is $7.6 million over 10 years.	***Part 2,*** Section 9
Public Participation	Public Comment period: Meeting location: Comments received:	***Part 2,*** Section 6

Overall Executive Summary
(April 20, 2009)

Section 303(d) of the Federal Clean Water Act (CWA) requires the Minnesota Pollution Control Agency (MPCA) to identify water bodies that do not meet water quality standards and to develop total maximum daily pollutant loads for those water bodies. A total maximum daily load (TMDL) is the amount of a pollutant that a water body can assimilate without exceeding the established water quality standard for that pollutant. Through a TMDL, pollutant loads are allocated to point and non-point sources within the watershed that discharge to the water body.

The Clearwater River Watershed District (CRWD) has reduced nutrient and sediment loads in the watershed through watershed best management practices (BMPs) and capital projects improving water quality reducing concentrations many watershed lakes and the Clearwater River by an order of magnitude. However, some 303(d) impairments remain. This upper watershed-wide TMDL study was prepared by Wenck Associates, Inc. (Wenck) for the CRWD and addresses:

- Six lake nutrient impairments,
- A stream bacteria impairment.

The total drainage area of the sub-watersheds draining to the impaired portion of the Clearwater River and Chain of Lakes is approximately 93 square miles. The progression of lakes in the Clearwater River Chain of Lakes System from upstream to downstream is Clear Lake, Lake Betsy, Union Lake, Scott Lake, Lake Louisa and Lake Marie. The 10-mile reach of the Clearwater River (river miles 35.0 to 25.0) impaired for bacteria lies between Clear Lake and Lake Betsy.

The impairments in this watershed were addressed together because the tributary watersheds for the impairments overlap. This means that the implementation plans to address each of the impairments and meet the TMDLs set forth in this report will also overlap. (Figure E1). Table E.1 lists the impairments.

Figure E.1 Impairments Addressed in this Report and Tributary Watershed

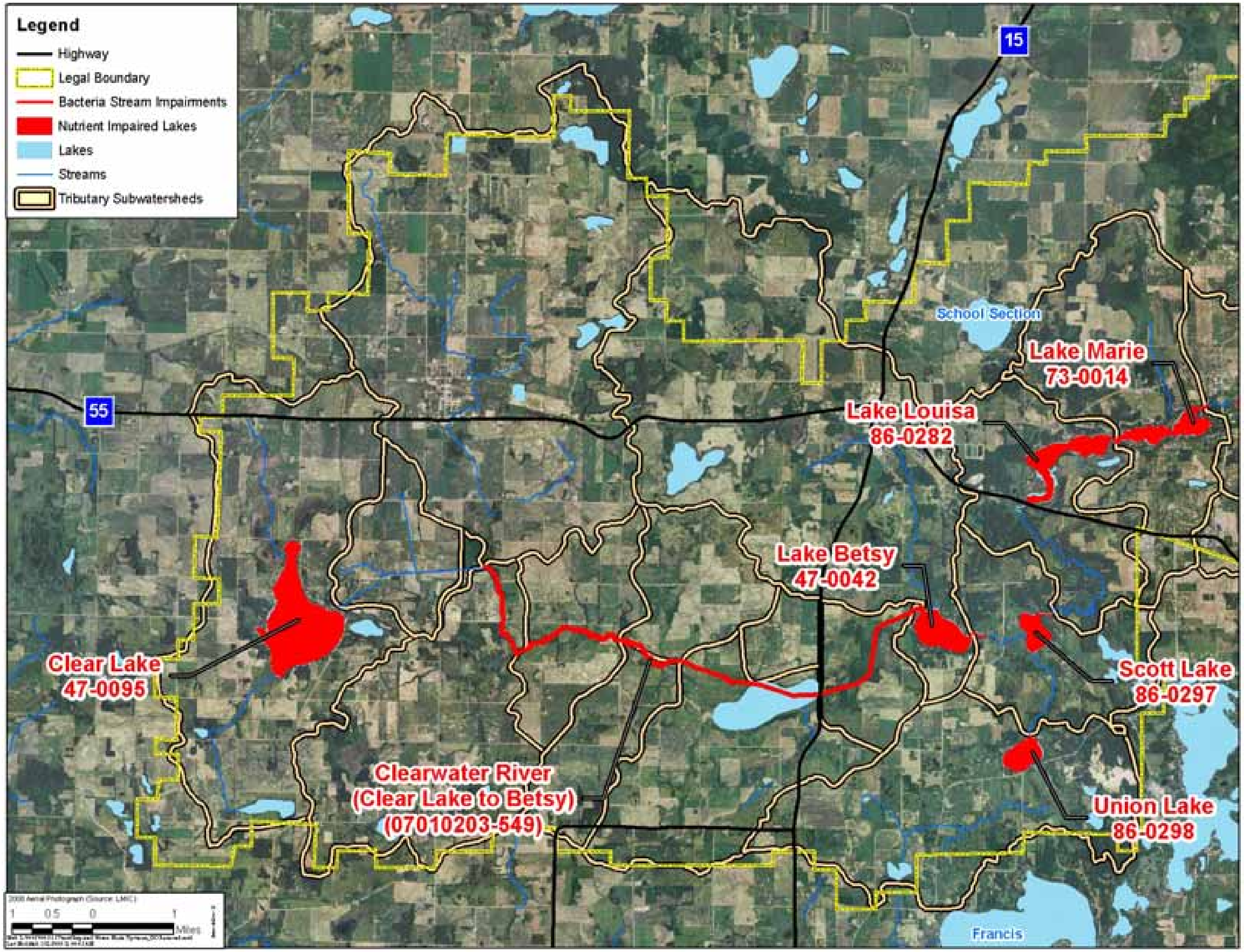


Table E.1 Impairments Addressed in this Report

Water Body	Impairment	Report Location
Clear Lake (47-0095)	Excess nutrient concentration impairing aquatic recreation	Part 1
Lake Betsy (47-0042)	Excess nutrient concentration impairing aquatic recreation	Part 1
Union Lake (86-0298)	Excess nutrient concentration impairing aquatic recreation	Part 1
Scott Lake (86-0297)	Excess nutrient concentration impairing aquatic recreation	Part 1
Lake Louisa (86-0282)	Excess nutrient concentration impairing aquatic recreation	Part 1
Lake Marie (73-0014)	Excess nutrient concentration impairing aquatic recreation	Part 1
Clearwater River: CD44 to Lake Betsy (07010203-549)	Excess bacterial concentrations impairing aquatic recreation	Part 2

The Clearwater River and the Clearwater River Chain of Lakes are the predominant water features in the District. The six lakes and one 10-mile stream reach addressed in this report comprise the upper portion of the Clearwater River Watershed District, Clearwater River and the Clearwater River Chain of Lakes.

The goal of this TMDL is to quantify the pollutant reductions needed for these impaired waters to meet State water quality standards. To address the nutrient loads in the lakes, the nature of this chain system makes it imperative to achieve a nutrient load reduction in the Clearwater River, as well as an appropriate load reduction in each lake upstream of the next. This riverine system with overlapping watersheds is at the heart of why the TMDL was completed holistically instead of piecemeal.

Addressing the impairments at once was a cost effective and time efficient method to get a watershed-wide implementation plan to address all the impairments in the upper portion of the watershed. Further, the lack of point sources in the watershed will require load reductions to come strictly through watershed management. The CRWD is the LGU charged with managing the watershed and as such it makes sense for them to conduct the studies at once.

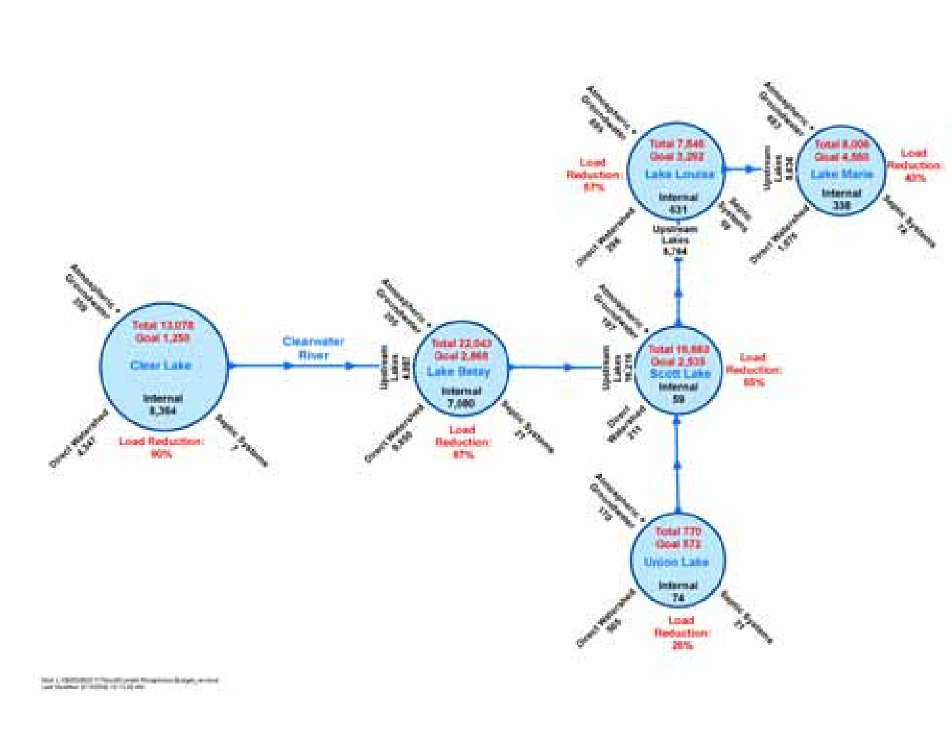
The report for the lake nutrient impairments and the stream bacteria impairments were submitted as stand alone documents for ease of review for the MPCA and stakeholders.

The data collected for these studies are presented in the Data Appendix—Part 3 of this report. Other data used in setting these TMDLs are available in STORET.

<u>Lake Nutrients</u>

Load Allocations to meet State standards indicate that average nutrient load reductions for the six lakes ranging from 26% to 90% are required to meet standards under average precipitation conditions. Internal load management and reduction of phosphorus from watershed runoff will both be required to meet phosphorus load reduction goals. Figure E.2 shows the schematic flow diagram of the system, phosphorus load sources, and the overall phosphorus load reduction to meet standards.

Figure E.2 Flow Diagram and Phosphorus Budget (Phosphorus values are in pounds phosphorus per average year, schematic, not to scale)



<u>Clearwater River Bacteria</u>

Required load reductions in terms of fecal coliform to meet *E. coli* standards range from 35 to 92 % in the listed reach. Based on the linkage analysis, the primary implementation strategies will focus on riparian pasture management and agricultural BMPs.

Clearwater River Dissolved Oxygen

The Clearwater River reach from CD44 to Lake Betsy (Reach 07010203-549) is also listed as impaired for Dissolved Oxygen (DO). A DO TMLD study was conducted simultaneously with the Bacteria TMDL study. Analysis of the data, modeling of the results and source identification in the DO TMDL study revealed that the majority of the listed reach is not impaired for DO. The one portion of the reach that is impaired for DO is due to the river flowing though a wetland with very high sediment oxygen demand within the wetland. This leads to very low DO concentrations within the wetland and the discharge of low DO water to the Clearwater River. This is a natural occurrence in wetlands and not the result of alteration of the river or the contributing watershed. As a result the DO portion of the study was removed from this TMDL report. The MPCA Delisting Committee is process of reviewing this section of the Clearwater River based on the completed TMDL study results.

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TABLES

FIGURES

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APPENDICES

Acronyms

Agency	Minnesota Pollution Control Agency
BOD	Biochemical Oxygen Demand
CAFO	Confined Animal Feeding Operation
Carlson TSI	Carlson Trophic Status Index
CBOD	Carbonaceous BOD
CBOD-5	5-Day Biochemical Oxygen Demand
CBOD-20	20-Day Biochemical Oxygen Demand
CBOD-u	Ultimate Biochemical Oxygen Demand
CFR	Code of Federal Regulations
cfs	cubic feet per second
CFU/100 mL	colony forming units per 100 milliliters
COLA	Chain of Lakes Association (for the Clearwater Chain)
CWA	Clear Water Act
CRWD	Clearwater River Watershed District
District	Clearwater River Watershed District
DO	Dissolved oxygen
EPA	Environmental Protection Agency
Lbs	Pounds
MDNR	Minnesota Department of Natural Resources
µg/L	micrograms per liter
mg/L	milligrams per liter
mi^2	square miles
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
NCHF	North Central Hardwood Forest
NO_2/ NO_3-N	Nitrate/ Nitrite- Nitrogen
NPS	non-point source
QA	Quality Assurance
QC	Quality Control
SOD	Sediment Oxygen Demand
STORET	EPA's "STOrage and RETrevial" System
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total phosphorus
TSS	Total Suspended Solids
USGS	United States Geological Survey
WWTP	Wastewater Treatment Plant
USDA	United States Department of Agriculture

TMDL Summary Table

TMDL Summary Table		
EPA/MPCA Required Elements	**Summary**	**TMDL Report Section**
Location	Upper portion of the Clearwater River Watershed District, in Stearns and Meeker Counties Minnesota in the Upper Mississippi River Basin.	Section 3: Figures 3.1, 3.2 and 3.3
303(3) Listing Information	Clear Lake 47-0095 Lake Betsy 47-0042 Union Lake 86-0298 Scott Lake 86-0297 Lake Louisa 86-0282 Lake Marie 73-0014 Lake Louisa was the first of the above lakes to be added to the 303(d) list in 2002. The remaining five lakes included in this report, Clear Lake, Lake Betsy, Union Lake, Scott Lake and Lake Marie, were added to the 303(d) list in 2008. All of the six lakes addressed in this report are included on the 303(d) list due to excess nutrient concentrations impairing aquatic recreation, as set forth in Minnesota Rules 7050.0150. The TMDL for Lake Louisa was prioritized to start in 2004 and be completed by 2009. The TMDL for Lake Betsy was prioritized to start in 2008 and be completed by 2012. The remaining four lakes, Clear Lake, Union Lake, Scott Lake and Lake Marie, were all prioritized to start in 2008 and be completed in 2013.	Section 2
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City of Fairhaven- Future

Clearwater River Watershed District :
❖ Rest-a-While Shores
❖ Wandering Ponds
❖ Lake Louisa Hills
❖ Future Regional System

City of South Haven WWTP

City of Kimball WWTP

City Watkins WWTP</td><td>MNR100001

NA

09-17550
09-20199
Pending
NA

MN006461

MN005264

MN0051365</td><td>0.41 (total)

0

0

0
0
0
0

0

0

0</td></tr>
</table>

TMDL Summary Table

<table>
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Scott Lake 6.17
Lake Louisa 4.75
Lake Marie 9.30</td></tr>
<tr><td>Septic Systems</td><td>Scott Lake 0
Lake Louisa 0
Lake Marie 0
Clear Lake 0
Lake Betsy 0
Union Lake 0</td></tr>
<tr><td>Margin of Safety</td><td colspan="2">The Margin of Safety is implicit in each TMDL due to the conservative assumptions of the model and the proposed iterative nutrient reduction strategy with monitoring.</td><td>Section 7.4</td></tr>
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Implementation	This TMDL sets forth a proposed implementation framework and load reduction strategies. The final implementation plan is part of a program to address all TMDLs within the Clearwater River Watershed District. Strategies will be refined annually as new monitoring data and evaluation indicates. The estimated cost of implementation for all the TMDLs addressed in the upper watershed is $7.6 million over 10 years.	Section 9
Public Participation	Public Comment period: Meeting location: Comments received:	Section 8

Executive Summary

Section 303(d) of the Federal Clean Water Act (CWA) requires the Minnesota Pollution Control Agency (MPCA) to identify water bodies that do not meet water quality standards and to develop total maximum daily pollutant loads for those water bodies. A total maximum daily load (TMDL) is the amount of a pollutant that a water body can assimilate without exceeding the established water quality standard for that pollutant. Through a TMDL, pollutant loads are allocated to point and non-point sources within the watershed that discharge to the water body.

This TMDL study prepared by Wenck Associates, Inc. (Wenck) for the Clearwater River Watershed District (CRWD), addresses nutrient impairments for six lakes comprising the upper portion of the Clearwater River Chain of Lakes located within the Clearwater River Watershed District: Clear Lake (47-0095); Lake Betsy (47-0042); Union Lake (86-0298); Scott Lake (86-0297); Lake Louisa (86-0282); and Lake Marie (73-0014). The goal of this TMDL is to quantify the pollutant reductions needed for these lakes to meet State water quality standards for nutrients.

Load Allocations to meet State standards indicate that average nutrient load reductions for the six lakes ranging from 26% to 90% are required to meet standards under average precipitation conditions. Internal load management and reduction of phosphorus from watershed runoff will both be required to meet load reduction goals.

1.0 Introduction

1.1 PURPOSE

This TMDL study addresses nutrient impairments in a chain of six lakes on the Clearwater River. Listed from upstream to downstream locations, the lakes addressed in this TMDL are Clear Lake, Lake Betsy, Union Lake, Scott Lake, Lake Louisa, and Lake Marie. The goal of this TMDL is to quantify the pollutant reductions needed to meet State water quality standards for nutrients in the six listed lakes. The nutrient TMDLs for these six lakes are being established in accordance with section 303(d) of the Clean Water Act, because the State of Minnesota has determined waters in Clear Lake, Lake Betsy, Union Lake, Scott Lake, Lake Louisa, and Lake Marie exceed the State established standards for nutrients.

This TMDL provides waste load allocations (WLAs) and load allocations (LAs) for Clear Lake, Lake Betsy, Union Lake, Scott Lake, Lake Louisa, and Lake Marie. Based on the current State standard for nutrients, the TMDL establishes a numeric target of 40 µg/L total phosphorus concentration for deep lakes in the Northern Lakes and Forests ecoregion and 60 µg/L total phosphorus concentration for shallow lakes in the Northern Lakes and Forests ecoregion. The numeric target for Lake Betsy, Union Lake, Scott Lake and Lake Louisa is 40 µg/L; the numeric target for Clear Lake and Lake Marie is 60 µg/L.

1.2 PROBLEM IDENTIFICATION

The six lakes addressed in this TMDL are within the CRWD. The 168 square mile CRWD covers parts of eight townships including Luxemburg, Forest Prairie, Forest City, Maine Prairie, Kingston, Fairhaven, Southside and French Lake across parts of Meeker, Stearns and Wright Counties. Lake Louisa (DNR# 86-0282) was first placed on the on the State of Minnesota's 303(d) list of impaired waters in 2002. The remaining five lakes, Clear Lake (DNR# 47-0095), Lake Betsy (DNR# 47-0042), Union Lake (DNR# 86-0298), Scott Lake (DNR# 86-0282) and Lake Marie (DNR# 73-0014), were placed on the 2008 State of Minnesota's 303(d) list of impaired waters. All of the six lakes addressed in this TMDL were identified for impairment of aquatic recreation (e.g., swimming). Water quality does not meet state standards for nutrient concentrations.

2.0 Target Identification and Determination of Endpoints

2.1 IMPAIRED WATERS

The first of the six lakes to be added to the 303(d) impaired waters list for Minnesota was Lake Louisa in 2002. The remaining five lakes, Clear Lake, Lake Betsy, Union Lake, Scott Lake and Lake Marie were added to the 303(d) impaired water list in 2008. All six lakes are impaired by excess nutrient concentrations, which inhibit aquatic recreation. The MPCA's projected schedule for TMDL completions, as indicated on the 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. The Lake Louisa TMDL project was scheduled to be completed in 2009, and the Lake Betsy TMDL project is scheduled to be completed in 2012. The TMDL projects for Clear Lake, Union Lake, Scott Lake and Lake Marie are scheduled to be completed in 2013. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the water body; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

2.2 MINNESOTA WATER QUALITY STANDARDS AND ENDPOINTS

2.2.1 State of Minnesota Standards

Minnesota's standards for nutrients limit the quantity of nutrients which may enter waters. Minnesota's standards at the time of listing (Minnesota Rules 7050.0150(3)) stated that in all Class 2 waters of the State (i.e., "…waters…which do or may support fish, other aquatic life, bathing, boating, or other recreational purposes…") "…there shall be no material increase in undesirable slime growths or aquatic plants including algae…" In accordance with Minnesota Rules 7050.0150(5), to evaluate whether a water body is in an impaired condition the MPCA developed "numeric translators" for the narrative standard for purposes of determining which lakes should be included in the section 303(d) list as being impaired for nutrients. The numeric translators established numeric thresholds for phosphorus, chlorophyll-a, and clarity as measured by Secchi depth. Table 2.1 lists the thresholds for listing lakes on the 303(d) list of impaired waters in Minnesota that were in place when these lakes were listed.

Table 2.1. Trophic status thresholds for determination of use support for lakes

305(b) Designation	Full Support			Partial support to Potential Non-Support			
303(d) Designation	Not Listed			Review	Listed		
Ecoregion	TP Range (ppb)	Chl-a (ppb)	Secchi (m)	TP Range (ppb)	TP (ppb)	Chl-a (ppb)	Secchi (m)
Northern Lakes and Forests	<30	<10	>1.6	30-35	>35	>12	<1.4
(Carlson's TSI)	(<53)	(<53)	(<53)	(53-56)	(>56)	(>56)	(>56)
North Central Hardwood Forests	<40	<14	>1.4	40-45	>45	>18	<1.1
(Carlson's TSI)	(<57)	(<57)	(<57)	(57-59)	(>59)	(>59)	(>59)
Western Cornbelt Plains and Northern Glaciated Plains	<70	<24	>1.0	70-90	>90	>32	<0.7
(Carlson's TSI)	(<66)	(<61)	(<61)	(66-69)	(>69)	(>65)	(>65)

TSI= Carlson trophic state index; Chl-a= chlorophyll-a; ppb= parts per billion or µg/L; m=meters

2.2.2 Endpoint Used in this TMDL

The numeric target used to list these lakes was the numeric translator threshold phosphorus standard for Class 2B waters in the North Central Hardwood Forest ecoregion (40 µg/L) prior to adoption of new standards in 2008 (Table 2.1). Under the new standards, Clear Lake and Lake Marie are considered shallow lakes with a numeric target of 60 µg/L. Lake Betsy, Union Lake, Scott Lake, Lake Louisa and Lake Marie would be considered deep lakes with a numeric target of 40 µg/L. Therefore, this TMDL presents load and wasteload allocations and estimated load reductions assuming an endpoint of 40 µg/L for Lake Betsy, Union Lake, Scott Lake and Lake Louisa and an endpoint of 60 µg/L for Clear Lake and Lake Marie.

The numeric standards for chlorophyll-a and Secchi depth are 14 µg/L and 1.4 meters, respectively for Lake Betsy, Union Lake, Scott Lake and Lake Louisa. The numeric standards for chlorophyll-a and Secchi depth are 20 µg/L and 1.0 meters, respectively for Clear Lake and Lake Marie (Table 2.2).

Table 2.2. Numeric targets for Lakes in the North Central Hardwood Forest and Western Corn Belt Plain Ecoregions.

Parameters	Ecoregions			
	North Central Hardwood Forest		Western Corn Belt Plains	
	Shallow [1]	Deep	Shallow [1]	Deep
Phosphorus Concentration (µg/L)	60	40	90	65
Chlorophyll-a Concentration (µg/L)	20	14	30	22
Secchi disk transparency (m)	>1	>1.4	>0.7	>0.9

[1] Shallow lakes are defined as lakes with a maximum depth of 15 feet or a less, or with 80% or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (littoral zone).

2.3 PRE-SETTLEMENT CONDITIONS

Another consideration when evaluating nutrient loads to lakes is the natural background load. Ultimately, the background load represents the load the lake would be expected to receive under natural, undisturbed conditions. This load can be determined using ecoregion pre-settlement nutrient concentrations as determined by diatom fossil reconstruction. Diatom inferred total phosphorus concentrations are presented in Table 2.3.

Table 2.3. Pre-settlement total phosphorus concentrations based on water quality reconstructions from fossil diatoms.

Parameters	Ecoregions			
	North Central Hardwood Forest		Western Corn Belt Plains	
	Shallow [1]	Deep	Shallow [1]	Deep
Phosphorus Concentration (µg/L)	47	26	89	56

(MPCA 2002). All are the concentration at the 75th percentile.

1. Shallow lakes are defined as lakes with a maximum depth of 15 feet or a less, or with 80% or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (littoral zone).

Based on the diatom fossils, pre-settlement concentrations were approximately 26 µg/L for deep lakes in the North Central Hardwood Forests ecoregion. Another benchmark that may be useful in determining goals and load reductions are expected stream concentrations under natural or undisturbed conditions. Table 2.4 provides data from minimally impacted streams.

Table 2.4. Interquartile range of summer mean concentrations by ecoregion for minimally impacted streams in Minnesota.

Region	Total Phosphorus (µg/L)		
	25th Percentile	50th Percentile	75th Percentile
North Central Hardwood Forest	70	100	170

(McCollor and Heiskary 1993)

Existing flow-weighted mean total phosphorus concentrations in the Clearwater River upstream of Lake Betsy have ranged from 130 to 510 µg/L since 1998, with an average of 261 µg/L over that period.

3.0 Watershed and Lake Characterization

3.1 LAKE AND WATERSHED CONDITIONS

The Clearwater River Watershed District is a predominantly agricultural 168-square mile watershed in central Minnesota (Figure 3.1). The Clearwater River and the Clearwater River Chain of Lakes are the predominant water features in the District. The lakes addressed in this report comprise the upper portion of the Clearwater River Chain of Lakes. The total drainage area of the sub-watersheds draining to the Chain of Lakes is approximately 93 square miles. The progression of lakes in the Clearwater River Chain of Lakes from upstream to downstream is Clear Lake, Lake Betsy, Union Lake, Scott Lake, Lake Louisa and Lake Marie. A description of watershed and physical lake characteristics is presented for each lake.

3.1.1 Clear Lake

Clear Lake is the first of the Clearwater River Chain of Lakes and is located at headwaters of the Clearwater River. The Clear Lake watershed covers 6,801 acres and is located within Forest Prairie Township in Meeker County, Minnesota. Clear Lake is a 515-acre basin with an average depth of nine feet and a maximum depth of 17 feet (Table 3.1). The littoral zone covers 463 acres or approximately 90 percent of the basin. The littoral zone is that portion of the lake that is less than 15 feet in depth, and is where the majority of the aquatic plants grow. Clear Lake meets the definition of a shallow lake. There are three un-named tributaries that flow into Clear Lake, two from the north and one from the south. The outlet channel of Clear Lake forms the headwaters of the Clearwater River.

3.1.2 Lake Betsy

Lake Betsy is the second of the Clearwater River Chain of Lakes, located downstream of Clear Lake and upstream of Scott Lake. The Lake Betsy watershed covers 43,788 acres that includes the Clear Lake sub-watershed and is located within Luxemburg, Forest Prairie, Forest City, Maine Prairie and Kingston Townships in Meeker and Stearns Counties, Minnesota. The municipalities of Watkins and Kimball are located within the Lake Betsy watershed. Lake Betsy is an 83-acre basin with an average depth of ten feet and a maximum depth of 23 feet (Table 3.1). The littoral zone covers 54 acres or approximately 68 percent of the basin. There are two inflow tributaries into Lake Betsy including Willow Creek, which enters the lake from the north and the main stem of the Clearwater River which enters the lake from the west. The outlet of Lake Betsy is the main stem of the Clearwater River, which exits the northeast corner of the basin and continues flowing east to Scott Lake.

3.1.3 Union Lake

Union Lake is not located along the main stem of the Clearwater River, but is tributary to the third lake in the chain, Scott Lake, via an unnamed tributary. The Union Lake watershed covers 4,741 acres and is located within Kingston, Southside and French Lake Townships in Meeker and Wright Counties, Minnesota. Union Lake is a 92-acre basin with an average depth of 18 feet and a maximum depth of 35 feet (Table 3.1). The littoral zone covers 29 acres or approximately 32 percent of the basin. There are no defined inflow tributaries into Union Lake. The outlet of Union Lake is an un-named perennial stream that exits the north end of the lake and flows north towards Scott Lake.

3.1.4 Scott Lake

Scott Lake is the third of the Clearwater River Chain of Lakes, located downstream of Lake Betsy and Union Lake and upstream of Lake Louisa. The Scott Lake watershed covers 51,003 acres including approximately 2,473 acres of direct sub-watershed and the upstream watersheds of Clear Lake, Lake Betsy and Union Lake. The Scott Lake watershed is located within Luxemburg, Forest Prairie, Forest City, Maine Prairie, Kingston, Southside and French Lake Townships in Meeker, Stearns and Wright Counties, Minnesota. The municipalities of Watkins and Kimball are located within the Scott Lake watershed. Scott Lake is a 148-acre basin with an average depth of 12 feet and a maximum depth of 29 feet (Table 3.1). The littoral zone covers 88 acres or approximately 60 percent of the basin. There are two inflow tributaries into Scott Lake including an un-named tributary that enters the south end of the lake and the main stem of the Clearwater River which enters the lake from the west. The outlet of Scott Lake is the main stem of the Clearwater River, which exits the northeast corner of the basin and continues flowing east to Lake Louisa.

3.1.5 Lake Louisa

Lake Louisa is downstream of Scott Lake and its outlet is the upstream end of Lake Marie. The Lake Louisa watershed covers 53,881 acres including approximately 2,878 acres of direct sub-watershed and the upstream watersheds of Clear Lake, Lake Betsy, Union Lake, and Scott Lake. The Lake Louisa watershed is located within Luxemburg, Forest Prairie, Forest City, Maine Prairie, Kingston, Southside, French Lake and Fairhaven Townships in Meeker, Stearns and Wright Counties, Minnesota. The municipalities of Watkins and Kimball are located within the Lake Louisa watershed. Lake Louisa is a 193-acre basin with an average depth of 12 feet and a maximum depth of 44 feet (Table 3.1). The littoral zone covers 125 acres or approximately 65 percent of the basin. The main stem of the Clearwater River is the main inflow tributary into Lake Louisa. The outlet of Lake Louisa is the channel connecting the lake to Lake Marie.

3.1.6 Lake Marie

Lake Marie is the sixth of the Clearwater River Chain of Lakes, located at the downstream end of the study area. The Lake Marie watershed covers 59,836 acres including approximately 4112 acres of direct sub-watershed and the upstream watersheds of Clear Lake, Lake Betsy, Union Lake, Scott Lake, Lake Louisa and School Section Lake. The Lake Marie watershed is located within Luxemburg, Forest Prairie, Forest City, Maine Prairie, Kingston, Southside, French Lake and Fairhaven Townships in Meeker, Stearns and Wright Counties, Minnesota. The municipalities of Watkins, Kimball and South Haven are located within the Lake Louisa watershed. Lake Marie is a 140-acre basin with an average depth of 8 feet and a maximum depth of 36 feet (Table 3.1). The littoral zone covers 119 acres or approximately 85 percent of the basin. The Lake Louisa outlet channel forms the inflow channel of into Lake Marie. The natural outlet of Lake Marie is the main stem of the Clearwater River which exits the northeast corner of the basin and continues flowing east.

Table 3.1 Morphometric characteristics for the six lakes in the Clearwater River Chain of Lakes

Parameter	Clear Lake	Lake Betsy	Union Lake	Scott Lake	Lake Louisa	Lake Marie
Surface Area (ac)	515	83	92	148	193	140
Average Depth (ft)	9	10	18	12	12	8
Maximum Depth (ft)	17	23	35	29	44	36
Volume (ac-ft)	4,504	833	1,700	1,791	2,232	1,085
Average Residence Time (days)	686	33	291	12	17	24
Littoral Area (ac)	463	54	29	88	125	119
Watershed (ac)	6,801	43,789	4,741	51,003	53,881	59,837

3.2 LAND USE

The Clearwater River watershed is comprised mainly of agricultural land uses. The National Agriculture Statistics Services (NASS) 2006 cropland data layer was used to determine land use within the Chain of Lakes sub-watersheds. This data is an appropriate data set for large agricultural watersheds as the use categories within the data set are more specific in describing agriculture uses, such as separately classifying corn, soybeans and alfalfa. Other categories in the data set are more general such as urban, wetlands or woodlands. These uses comprise smaller percentages of the total watershed draining to each lake, making the more general categories appropriate when estimating watershed loads. The land use data for each lake watershed is presented in Table 3.2. Overall, corn is the most frequent land use covering 14,329 acres or 24 percent of the 59,836 acres of the Chain of Lakes watersheds. Woodlands and soybeans were the next most frequent land uses each covering slightly more than 10,000 acres or 17 percent of the total watershed. Grasslands and pasture covered 9,678 acres or 16 percent of the total watershed area. Other significant land uses within the overall Chain of Lakes watershed include urban (10.6 %), wetlands (7.7 %), open water (3%) and alfalfa (3%).

The land use types for each lake watershed are displayed in Table 3.2. The watershed tributary to downstream lakes includes the drainage area for the upstream lakes. For Lake Betsy, Scott

Lake, Lake Louisa and Lake Marie the land use totals include the direct sub-watershed as well as the contributing watersheds of the upstream lakes. Similar to the trend for the overall watershed, corn was the dominate land use for most of the individual lake watersheds. This is mainly due to the large number of acres in corn production in the Lake Betsy watershed which then contributes to the watersheds of the remaining downstream lakes. The one exception is Union Lake which is located in the south-central portion of the Chain of Lakes watershed and does not have other lakes that contribute to its' watershed. The dominant land use in the Union Lake watershed is woodlands, followed by grass/pasture. Corn is the third most abundant land use in the Union Lake watershed.

Table 3.2 2006 NASS land use for the Clearwater River Chain of Lakes watersheds (acres)

Land Use	Clear Lake	Lake Betsy	Union Lake	Scott Lake	Lake Louisa	Lake Marie
Corn	1,854.9	12,330.5	716.5	13,130.6	13,329.8	14,329.1
Soybeans	1,414.0	9,060.1	247.5	9,325.1	9,384.4	10,220.0
Alfalfa	152.1	1,568.7	82.5	1,651.3	1,651.3	1,658.7
Grass/Pasture	544.0	5,600.9	1,145.2	7,651.0	8,308.8	9,677.7
Woodland	633.2	5,139.1	1,222.9	7,473.8	8,837.7	10,411.0
Barren	0.0	0.0	26.0	26.0	26.0	26.0
Urban/Developed	800.0	4,987.0	416.1	5,528.3	5,810.1	6,352.4
Water	654.7	1,199.5	131.8	1,501.5	1,707.1	2,046.3
Wetlands	724.7	3,728.5	646.1	4,432.3	4,502.2	4,632.1
Other Crops**	23.7	174.7	106.3	283.2	323.5	483.6
TOTAL	6,801.3	43,789.1	4,741.0	5,1003.2	53,880.9	59,836.9

** : Other Crops includes spring wheat, winter wheat, peas, oats and rye.

3.3 LAKE DESCRIPTIONS

The Clearwater River Chain of Lakes is characterized by its recreational use, fish populations and health, aquatic plants, and shoreline habitat and conditions. A summary of these characteristics for each of the lakes within the Chain can be found in Table 3.3. A more detailed description of each of the lake characteristics is found in the text that follows.

3.3.1 Recreational Uses

The Clearwater River Chain of Lakes provides a variety of recreational uses, including fishing and boating. Table 3.3 provides a summary of the lake characteristics for each of the lakes in the Clearwater River Chain of Lakes. Lake Betsy, Scott Lake and Lake Louisa do not have public access. Lake Betsy and Lake Louisa, however, can be accessed via the Clearwater River and Lake Marie respectively. Union Lake and Lake Marie each have one public access. The Lake Marie public access is located in Fairhaven Mill County Park, which has a picnic area and shoreline fishing. Clear Lake has two public accesses, one DNR owned access at the north end of the lake, and one new access at the south end of the lake in the county park. Clear Lake County Park is 34.4 acres and has a picnic area and shelter, fishing pier, boat landing, and hiking trails.

Table 3.3 Lake Characterization for Clearwater River Chain of Lakes

Lake Name	Clear Lake	Lake Betsy	Union Lake	Scott Lake	Lake Louisa	Lake Marie
Public Boat Access	2	via Clearwater River	1	None	via Lake Marie	1
Most Recent Fish Survey	2003	2002	2002	1997	2005	2005
Primarily Managed Fish Species	Bluegill, Largemouth bass, Walleye	Black crappie, Northern pike	Bluegill, Largemouth bass, Northern pike	Black crappie, Northern pike	Largemouth bass, Northern pike	Largemouth bass, Northern pike
Fish Stocking	Walleye 2005	Walleye 1992	Walleye 1989	Walleye 1992	N/A	N/A
Rough Fish	Black bullhead Carp	Black bullhead Carp	Black bullhead Carp	Black bullhead Carp	Black bullhead Carp	Black bullhead Carp
Fish Kill Frequency	Infrequent partial winter kills (2001)	N/A	N/A	Infrequent partial winter kills	N/A	N/A
Most Recent Vegetation Survey	July 2007	July 2007	July 2007	August 1997	August 2005	August 2005
Exotic Vegetation	CLPW	CLPW	CLPW	CLPW	CLPW	CLPW
Shoreline Development	90% Heavy	50% Moderate	60% Moderate	10% Light	50% Moderate	85% Heavy
DNR Lake Classification	RD	RD	RD	NE	GD	RD

Figure 3.1 Location Map

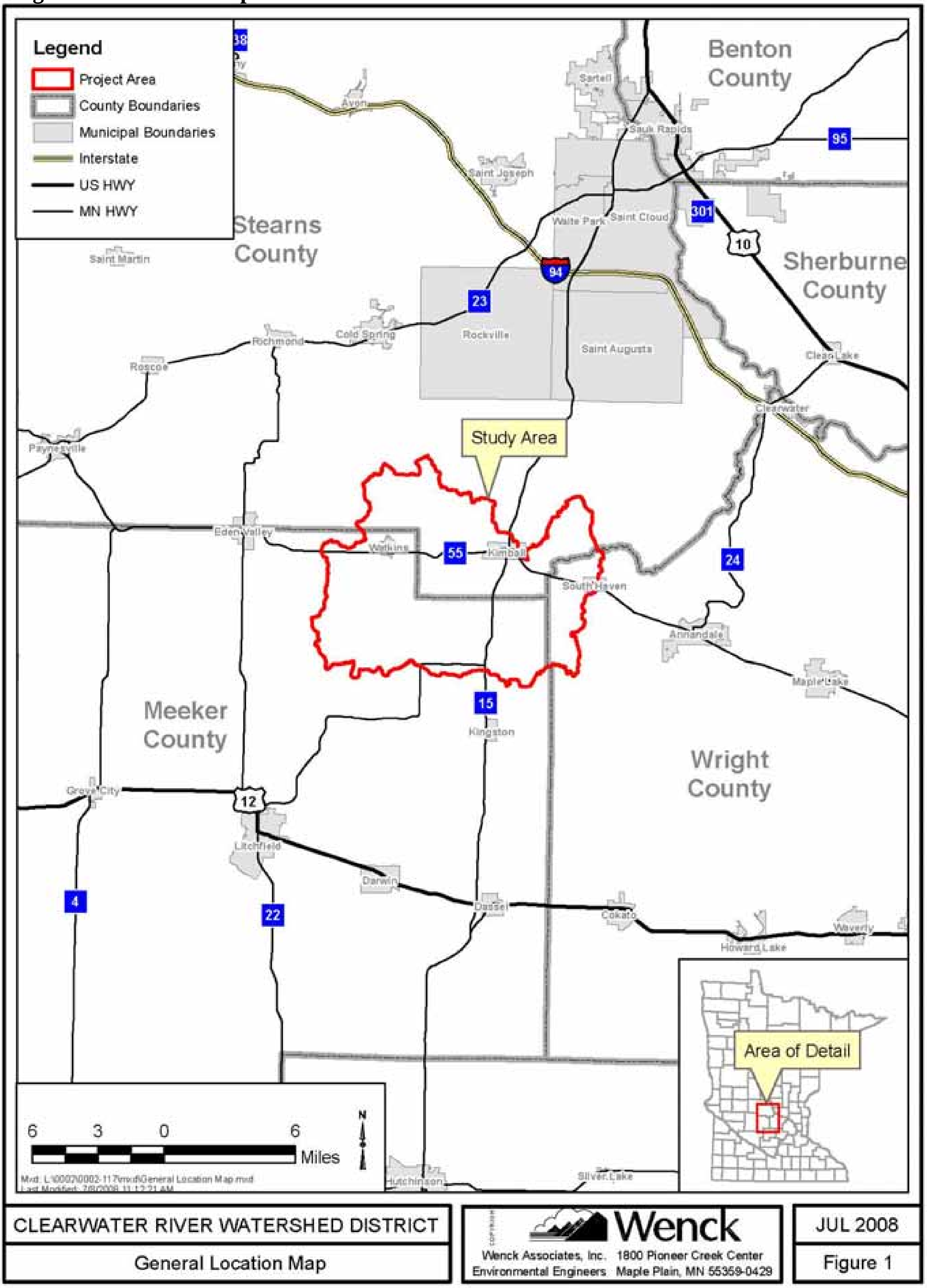


Figure 3.2 Impaired Lakes

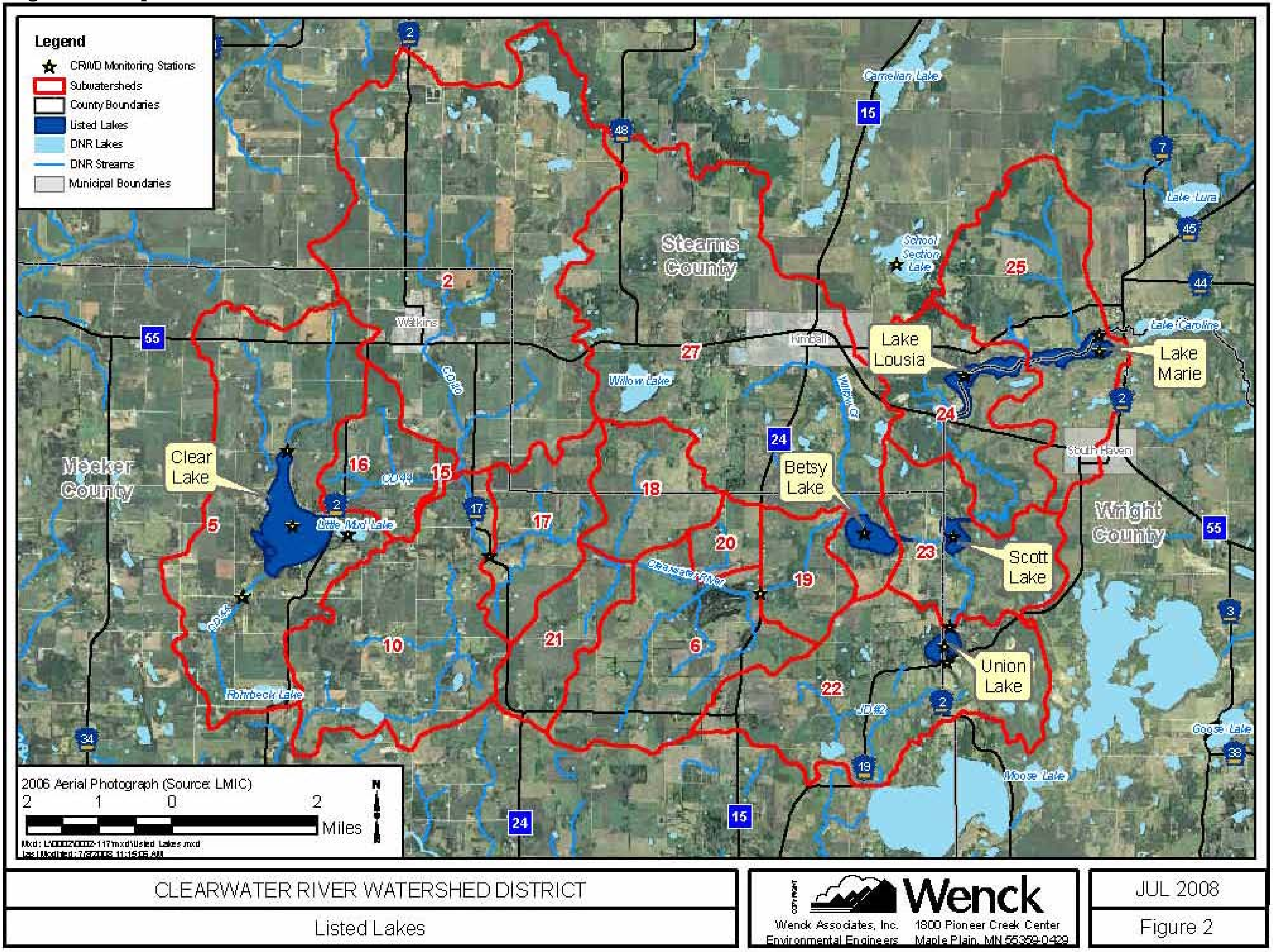


Figure 3.3 General Drainage System

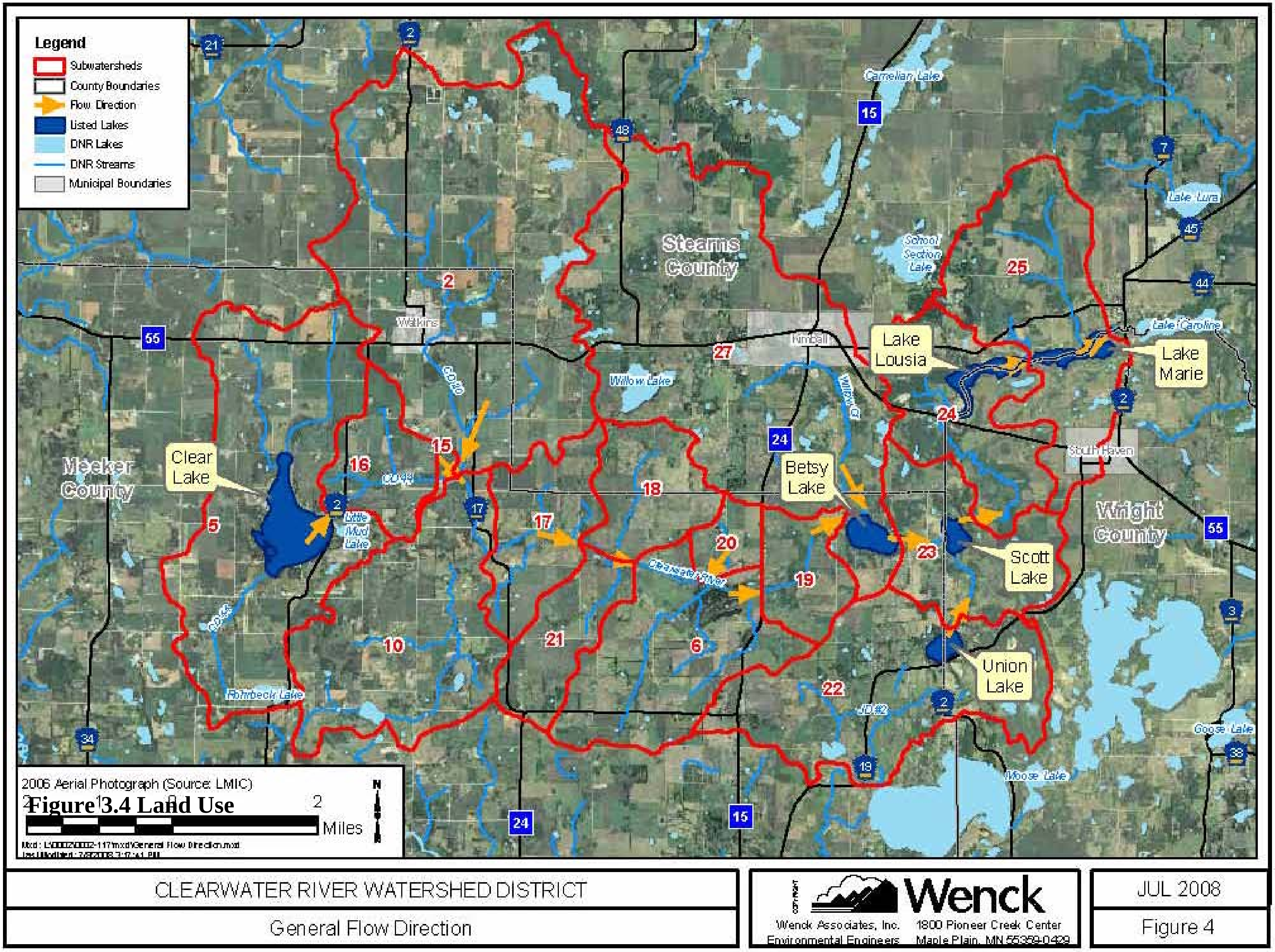
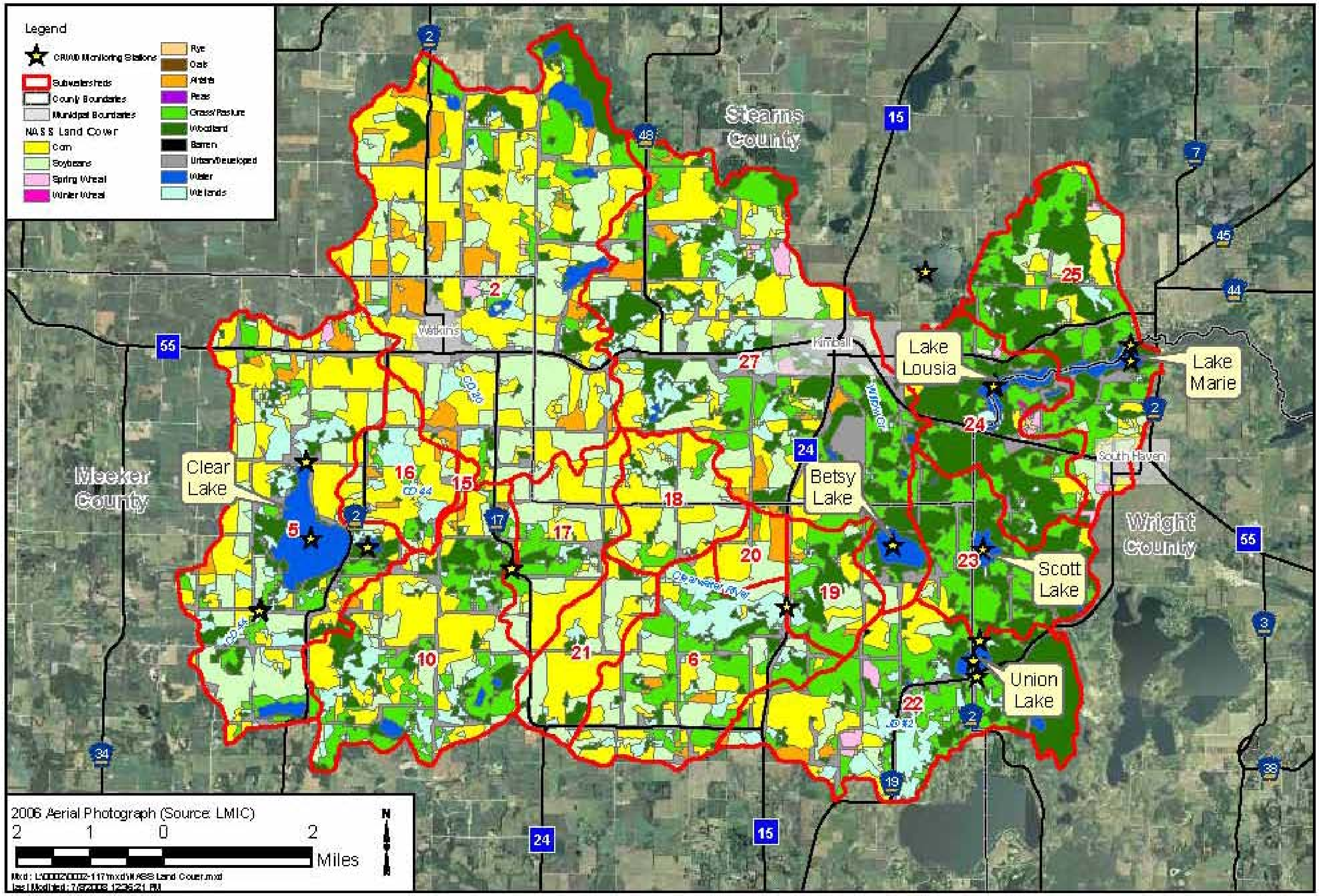


Figure 3.4 Land Use



CLEARWATER RIVER WATERSHED DISTRICT

NASS Land Cover

Wenck

Wenck Associates, Inc. Environmental Engineers

1800 Pioneer Creek Center Maple Plain, MN 55359-0429

JUL 2008

Figure 3

3.3.2 Fish Community

Fish surveys have been completed by the Minnesota Department of Natural Resources (DNR) for each of the lakes in the Clearwater River Chain of Lakes. All of the lakes have been surveyed within the last six years with the exception of Scott Lake, which according to DNR area fisheries managers, no longer has much DNR management activity on it due to the lack of public access. Scott Lake was last surveyed in 1997 for both fish and vegetation.

The Clearwater River Chain of Lakes is managed for largemouth bass and northern pike. Clear Lake is also managed for bluegill and walleye. Lake Betsy is managed for black crappie and northern pike.

Fish stocking has not occurred recently in the Chain of Lakes with the exception of Clear Lake, which was last stocked with walleye fingerling in 2005. Prior to that Clear Lake was stocked with walleye in 2003, 2001 and 2000. Other lakes in the Chain of Lakes have not been stocked since 1992. Lake Louisa and Lake Marie have never been stocked.

Common carp have both direct and indirect effects on aquatic environments. Carp uproot aquatic macrophytes during feeding and spawning that re-suspends bottom sediments and nutrients. These activities can lead to increased nutrients in the water column ultimately resulting in increased nuisance algal blooms. Residents report significant populations of carp and other rough fish, such as black bullhead present in Clearwater River Chain of Lakes.

A carp trap is located upstream of Lake Louisa, from which 69,000 lbs of rough fish were harvested between 1998 and 2002. Fish kills occur when dissolved oxygen (DO) levels are so low that fish begin to die from the lack of oxygen. Fish kills commonly occur during the summer or winter. Summer kills are the result of high productivity (algae and macrophyte) that eventually senesce, and are subsequently broken down by bacteria. The breakdown by bacteria demands oxygen, which depletes DO in the water column. These conditions can result in a summer fish kill. Winter fish kills are the result of snow-covered ice that shades out photosynthesis under the ice. These conditions, coupled with a high sediment oxygen demand can deplete the DO under the ice and result in a fish kill. Fish kills are not common in the Clearwater River Chain of Lakes. Clear Lake experienced a partial winter fish kill in 2001, but has not had one in recent years. Scott Lake has also experienced infrequent, partial winter fish kills, but has not had one for many years.

3.3.3 Aquatic Plants

Aquatic plants are beneficial to lake ecosystems providing spawning and cover for fish, habitat for macroinvertebrates, refuge for prey, and stabilization of sediments. However, in excess they limit recreation activities such as boating and swimming and reduce aesthetic value. Excess nutrients in lakes can lead to non-native, invasive aquatic plants taking over a lake. Some exotics can lead to special problems in lakes. For example, Eurasian watermilfoil can reduce plant biodiversity in a lake because it grows in great densities and outcompetes all the other plants. Ultimately, this can lead to a shift in the fish community because these high densities favor panfish over larger game fish. Species such as curly leaf pondweed can cause very specific problems by changing the dynamics of internal phosphorus loading. All in all, there is a delicate balance within the aquatic plant community in any lake ecosystem.

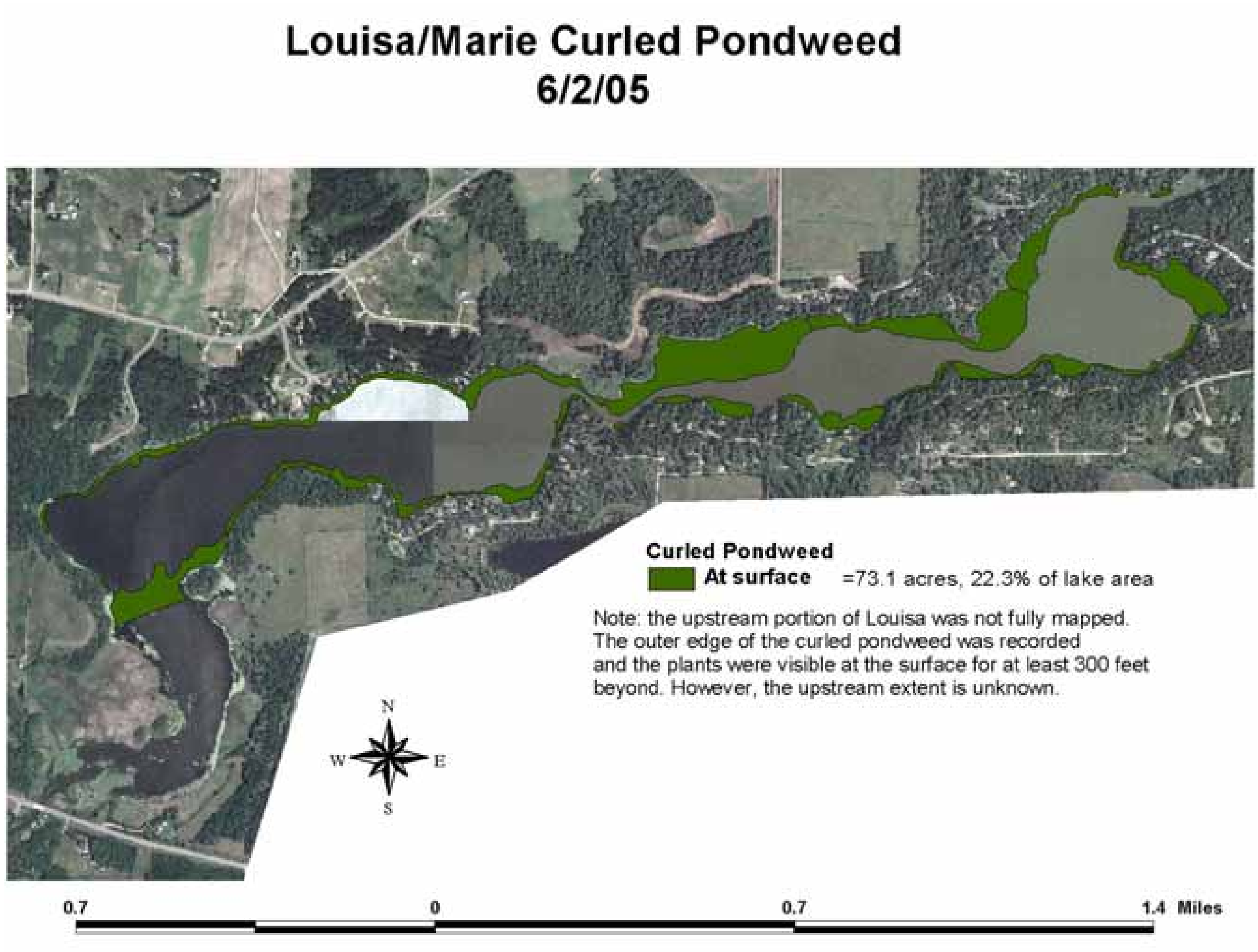
In 2005, the Minnesota DNR collected aquatic plant survey data from Lake Louisa and Lake Marie. The DNR also collected aquatic plant survey data from Clear Lake, Lake Betsy, and Union Lake in 2007. Aquatic plant survey data has not been collected from Scott Lake since 1997. Curly-leaf pondweed has been observed throughout the Clearwater River Chain of Lakes. Eurasian water milfoil has not been found in the Chain of Lakes during aquatic plant surveys.

DNR aquatic plant surveys conducted for Clear Lake indicate that the emergent species, Broad-leaved cattail is common in the lake. The submerged species, Sago pondweed also had a high percentage of occurrence during transect surveys. Curly-leaf pondweed and coontail were also found in this lake. The most common submerged species found in Lake Betsy during transect surveys were coontail and Curly-leaf pondweed. Survey results for Union Lake indicate that Broad-leaved cattail and coontail are common for this waterbody. Curly-leaf pondweed was also found in Union Lake.

Based on DNR aquatic plant surveys, the most common submergent vegetation found in Lake Louisa was coontail. Curly-leaf pondweed was abundant on the northwest side of the lake and found along almost the entire shoreline of the lake in the shallow areas. The southwest bay of the lake at the inlet of the Clearwater River is home to an abundance of emergent white waterlily. Modeling indicates that this vast shallow area dominated by emergent vegetation at the inlet to Lake Louisa may act like a filter to trap particulate phosphorus as it enters the lake from the Clearwater River. Residents of Lake Louisa have at times expressed interest in dredging this shallow area out because of an accumulation of sediment.

Lake Marie has an abundance of both waterlily and Curly-leaf pondweed, especially in the north and western areas of the lake. DNR Fisheries mapped the areas of Lake Louisa and Marie Lake to show the areas that curly leaf pondweed is most abundant (Figure 3.4).

Figure 3.5 Extent of Curly Leaf Pondweed in Lakes Louisa and Marie (source: DNR)



3.3.4 Shoreline Habitat Condition

The shoreline areas are defined as the areas adjacent to the lakes edge with hydrophytic vegetation and water up to 1.5 feet deep or a water table within 1.5 feet from the surface. Shoreline areas should not be confused with shoreland areas which are defined as 1,000 feet upland from the ordinary high water level (OHWL). Natural shorelines provide water quality treatment, wildlife habitat, and increased biodiversity of plants and aquatic organisms. Natural shoreline areas also provide aesthetic values and important habitat to fisheries including spawning areas and refugia.

Vegetated shorelines provide numerous benefits to both lakeshore owners and lake users including improved water quality, increased biodiversity, important habitat for both aquatic and terrestrial animals, and stabilizing erosion resulting in reduced maintenance of the shoreline. Identifying projects where natural shoreline habitats can be restored or protected will enhance the overall lake ecosystem.

The littoral zone is defined as that portion of the lake that is less than 15 feet in depth and is where the majority of the aquatic plants are found. The littoral zone of the lake also provides the essential spawning habitat for most warm water fishes (e.g. bass, walleye, and panfish). Lakes within the Chain of Lakes range from a low of 31 percent littoral in Union Lake to a high of 90 percent littoral in Clear Lake. The definition of a shallow lake is any lake that has a maximum depth of 15 feet or less or a lake that is 80 percent or more littoral. Based on this criteria, Clear Lake (90% littoral) and Lake Marie (85% littoral) would be considered shallow lakes while Scott Lake, Union Lake, Lake Marie and Lake Betsy would be considered deep lakes with littoral areas comprise less than 65 percent of the lake in each instance.

Limited data are available on shoreline conditions, as no shoreline condition surveys have been performed on the Chain of Lakes. Aerial photos and some ground observations indicate that Clear Lake and Lake Marie are the most heavily developed with single family residential homes and cabins, which typically feature turf lawns and little native vegetation. Both of these lakes are classified as recreational development (RD) by the DNR. Lake Betsy, Union Lake, and Lake Louisa all have moderate shoreline development with a mix of single family homes and cabins along with areas of wetlands and undeveloped shorelines. Scott Lake is the least developed with little to no development along its shoreline, much remains in native vegetation and wildlife habitat. The DNR classifies this lake as natural environment (NE).

4.0 Nutrient Source Assessment

4.1 INTRODUCTION

Understanding the sources of nutrients to a lake is a key component in developing a TMDL for lake nutrients. In this section, we provide a brief description of the potential sources of phosphorus to the lake.

4.2 PERMITTED SOURCES

Permitted sources can range from industrial effluent to municipal wastewater treatment plants. There are no known wastewater treatment plant (WWTP) effluent discharges in the watershed. The Cities of South Haven, Watkins and Kimball operate wastewater treatment plants within the watershed, however these municipalities use land application to treat their waste water and are not permitted to discharge to surface waters. Additionally the majority of spray irrigation fields used currently are not within the watersheds tributary to the impaired lakes, and the MPCA has rejected attempts by area WWTPs to discharge to area lakes. As such, these systems are likely not sources of nutrients to impaired waters.

The City of Fairhaven is also located within the watersheds tributary to Lakes Louisa and Marie. This city does not operate a WWTP currently and homes in the area are believed to be on ISTS.

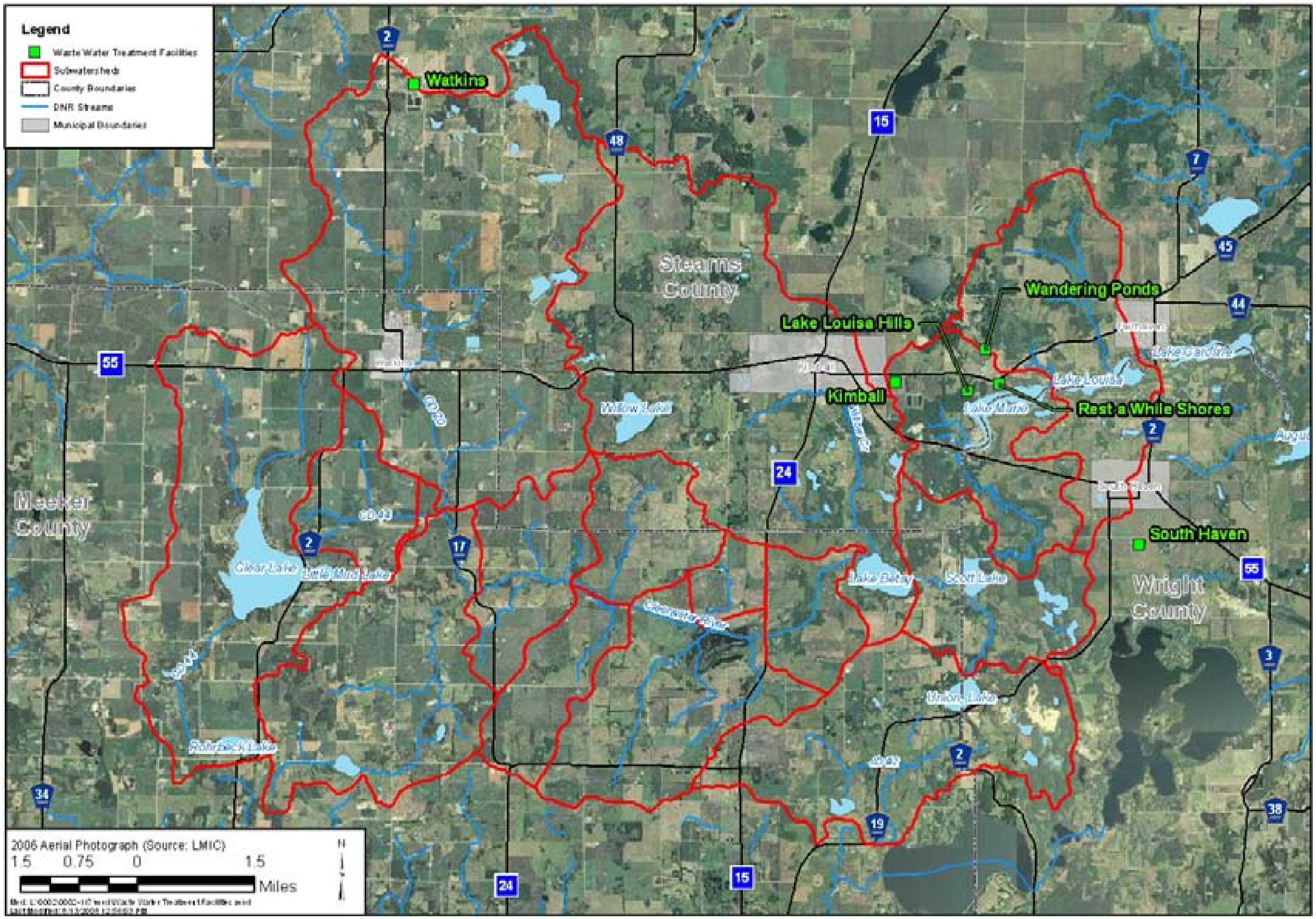
In efforts to improve the water quality of District lakes and stream, the CRWD has issued a report on Master Sanitary Sewer Planning for the area (Wenck 2001), and has installed several cluster wastewater systems which operate on septic systems that discharge to drain fields. The fact of the study indicates the potential for a future regional system to treat wastewater in the area. Such a regional system would likely serve the areas of Lakes Louisa and Marie.

All permitted and potential waste water treatment facilities in the watersheds tributary to the listed waters are listed in Table 4.1, the locations are shown in Figure 4.1.

Table 4.1 Summary Waste Water Treatment Plants by Municipality

Permit Holder/ System	Waste Water Treatment Method
City of Fairhaven	ISTS (Potential future)
City of Kimball	Land Application (SDS Permit)
City of Watkins	Land Application (SDS Permit)
City of South Haven	Land Application (SDS Permit)
CRWD- Regional	Master System (Potential)
CRWD- Rest-a-While Shores	Cluster System *
CRWD- Wandering Ponds	Cluster System *
CRWD- Lake Louisa Hills	Pending Cluster System *

Figure 4.1 WWTP and Land Application Sites Relative to Impaired Waters



Though the National Pollution Discharge Elimination System (NPDES) Phase II issues permits for small municipal separate storm sewer systems (MS4), none of the three municipalities (Watkins, Kimball and South Haven) in the watershed tributary to these lakes operates under an NDPES MS4 permit.

No other permitted sources are present in the Clearwater River Chain of Lakes Watershed.

4.3 NON-PERMITTED SOURCES

The non-permitted sources of nutrients include:

- In-lake nutrient cycling,
- Clearwater River, Upper Lakes & Wetlands which is comprised of drainage from
    - Agricultural land uses
    - Urban land uses and
    - Residential land uses
- Local (Direct) watershed,
    - Agricultural land uses
    - Urban land uses and
    - Residential land use
- Septic systems,
- Atmospheric loads and
- Ambient groundwater inflows

These sources are assessed in the sections that follow.

4.3.1 In-Lake Nutrient Cycling

In-lake nutrient cycling is an important component of the whole lake nutrient budget. Phosphorus builds up in lake-bottom sediments due to increases in phosphorus load export from the tributary watershed. Monitoring done through the Clearwater Chain of Lakes Restoration in 1983 showed that 168,000 lbs of phosphorus load in the Clearwater River upstream of Lake Betsy (Hickok and Associates, 1983). This was the highest value reported through annual monitoring, however typical TP loads upstream of Lake Betsy ranged from 22,000 lbs annually in the early 1990's down to below the goal for Clearwater Lake of 5,000 lbs more recently (the goal for Clearwater Lake was set as part of the 1980 Clearwater Chain of Lakes Restoration project.

The 1983 report also reported phosphorus retention values for Lakes Betsy and Scott: 0.11 (19,000 lbs of the 170,300 lbs of TP retained), and for Lakes Louisa and Marie: 0.28 (42,000 lbs of the 151,900 lb TP load was retained in Lakes Louisa and Marie).

Phosphorus accumulated in the lake sediments released under specific conditions is called internal loading. Internal loading can be a result of sediment anoxia where poorly bound phosphorus is released into the water column in a form readily available for phytoplankton production.

Internal loading can also result from sediment resuspension that may result form rough fish activity or prop wash from boat activity. Additionally, curly leaf pondweed can increase internal loading because it senesces and releases phosphorus during the summer growing season (late June to early July).

4.3.2 The Clearwater River/ Upper Lakes and Wetlands

The six lakes addressed in this study are part of a flow-through Chain of Lakes on the Clearwater River. As such, the dominant loading to each lake is often from the upstream water feature. Conversely, where lakes are present in series the upstream lakes also work to buffer the effects of upstream nutrient loads.

Working downstream to upstream, Lake Louisa is the dominant upstream nutrient source to Lake Marie, the Clearwater River and Scott Lake are tributary to Lake Louisa, Lakes Betsy and Union are tributary to Scott Lake, and the Clearwater River is tributary to Lake Betsy. Clear Lake is at the upstream end of the system with only a direct tributary watershed.

The nutrient loads in the upstream lakes and the Clearwater River originate from the dominant land uses within the upstream watersheds. Nutrient loads from upstream lakes are also increasingly the result of internal lake loading within the upstream lakes.

Model boundary conditions were set to reflect the impact of these upstream waters. Boundary conditions were set where upstream monitoring data is available to more accurately represent the system. Understanding this flow-through configuration, the modeled boundary conditions and their impact on model predictions and phosphorus budgets is critical to putting the model in the context of the TMDL. Assumptions are made to incorporate additional Margin of Safety. Boundary condition assumption for each model is tabulated in Table 4.2.

Table 4.2 Upstream Model Boundary Condition

Lake	Upstream Water Body/ Model Boundary Condition
Clear Lake	--
Lake Betsy	Clearwater River (CR 28.2)
Scott Lake	Lake Betsy & Union Lake
Union Lake	--
Lake Louisa	CR 19.8
Lake Marie	Lake Louisa

4.3.3 Local (Direct) Watershed

As described above, the six lakes addressed in this study are part of a flow-through Chain of Lakes on the Clearwater River and as such the upstream water body (and its tributary watershed) is often a dominant source of phosphorus in the nutrient budget for a given lake. In the context of the TMDL study, the local watershed is the direct drainage area to the lake not also tributary to the upstream boundary condition lake or river station. Dominant nutrient sources in the watershed tend to be dominant land uses which are summarized in Table 3.2.

4.3.4 Septic Systems

Most homes ringing the six lakes addressed in this study are served exclusively by individual sewage treatment systems (ISTS). The major exception is Clear Lake: the Clear Lake Association reports that septic systems for all but 7 homes on Clear Lake were abandoned and waste water was routed to the Watkins sewage treatment system. This occurred in 2001. The number of homes on septic systems by lake is summarized for lake in Table 4.3

Table 4.3 Number of homes served by ISTS

Lake	Estimated Septic Systems (# of homes)
Clear Lake	7
Lake Betsy	20
Scott Lake	0
Union Lake	20
Lake Louisa	56
Lake Marie	70

The soils in the CRWD in the vicinity of Lakes Louisa and Marie are sandy. High phosphorus loading from ISTS is possible in sandy soils even when systems are largely compliant. Failure rates were assumed to be 25%. This assumption of 25% failure rates is conservative in the context of the TMDL and protective of lake water quality. Minimizing the potential load reductions to be gained from ISTS maximizes the load reductions required of other areas. In any case, eliminating loads from ISTS is an important element of TMDL implementation, but the load allocation and does not overly rely on them to meet standards.

4.3.5 Atmospheric Deposition

The atmosphere delivers phosphorus to water and land surfaces both in precipitation and in so-called “dryfall” (dust particles that are suspended by winds and later deposited). As such atmospheric inputs must be accounted for in development of a nutrient budget, though they are generally very small direct inputs to the lake surface and are impossible to control.

4.3.6 Ambient Groundwater Inflows

The Clearwater Chain of Lakes lies within the Anoka Sand Plain and is therefore subject to significant groundwater interaction. The hydrologic atlas, “Water Resources of the Mississippi and Sauk Rivers Watershed, Central Minnesota” (Helgesen et al., 1975; U.S Geological Survey HA-534), includes the Clearwater River watershed and contains a water table map indicating that groundwater from the Sand Plain aquifer discharges to Clearwater River generally – as expected for a significant stream- and to the lakes along it. Because groundwater typically contains phosphorus: the statewide median TP concentration for surficial glacial aquifers is 56 μg/L (MPCA, 1999), it can be a component of the overall nutrient load to a given lake.

5.0 Assessment of Water Quality Data

The District first conducted diagnostic monitoring through the 1980 Chain of Lakes Improvement project. Since then, the Clearwater River Watershed District has collected water quality data annually to document trends. Lakes are sampled annually on a rotating basis; data are summarized in the CRWD annual water quality monitoring reports published most (Wenck 1985- 2007). Historical TP, Secchi and Chlorohpyll- a data for each lake, as well as stream loading data is presented in Appendix A. Annual average TP concentrations are compared to standards for shallow lakes (Figure 5.1) and deep lakes (Figures 5. 2). Recent typical annual average TP concentrations are compared with lake standards in Table 5.1

Figure 5.1 Average In-lake TP Concentrations for Shallow Impaired Lakes

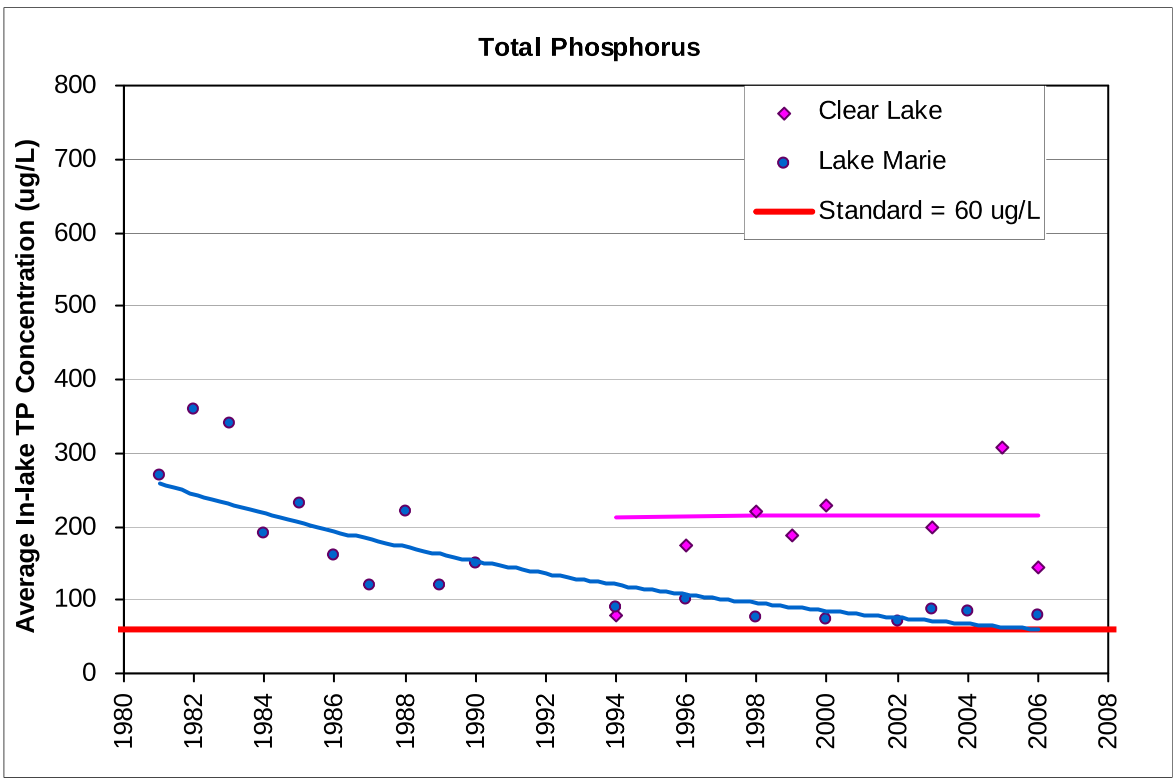


Figure 5.2 Average In-lake TP Concentrations for Deep Impaired Lakes

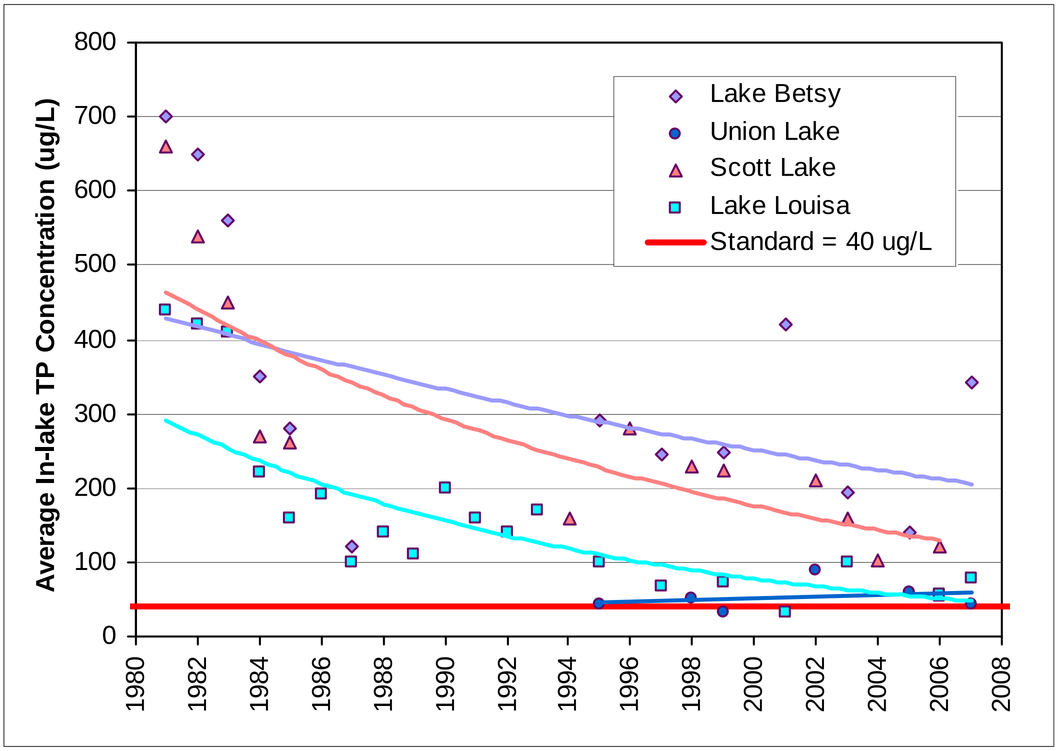


Table 5.1 Recent Typical Annual Average TP Concentrations Compared to Numeric Targets

Lake	TP (µg/L)		Chlorophyll-a (µg/L)		Secchi Depth (ft)	
	Target	Recent	Target	Recent	Target	Recent
Clear Lake	60	143-307	20	60-134	3.3	1.0-3.6
Lake Betsy	40	140-420	14	4-170	4.6	1.6-3.6
Scott Lake	40	103-230	14	51-141	4.6	2.0-2.6
Union Lake	40	30-88	14	7-39	4.6	3.3-7.5
Lake Louisa	40	33-100	14	5-79	4.6	3.0-3.6
Lake Marie	60	70-87	20	13-81	3.3	3.6-7.5

Data was collected on Lake Louisa and the Clearwater River upstream of Lake Betsy through this TMDL study and published in Phase I and Phase II Reports (Wenck 2003, and Wenck 2007). Relevant conclusions are repeated herein. Streams are sampled annually in three locations, with supplemental monitoring throughout the watershed. Synoptic stream surveys, as well as bi-weekly sampling were conducted for Phase II of this TMDL. These data are also summarized in Phase I and Phase II TMDL Reports (Wenck 2004, and Wenck 2007). This section summarizes current water quality conditions in each lake using all available data.

5.1 CLEAR LAKE

District monitoring for Clear Lake began in 1981 with the Clearwater Chain of Lakes Restoration Project. Summer average total phosphorus concentrations in Clear Lake ranged from 80 in 1994 to 307 µg/L in 2005. Average in-lake concentrations exceed the state standard, 60 µg/L for shallow lakes. Recent sample years represent mostly dry to average precipitation conditions with the exception of 1994, which was a wet year and in-lake P concentrations were the lowest measured (80µg/L). Recent typical in-lake P concentrations are about 200 µg/L.

Summer average chlorophyll-a concentrations ranged from 4 µg/L in 1983 to 134 µg/L in 2000. The lowest chlorophyll-a concentrations are observed during very wet years, even though in-lake phosphorus concentrations remain high during those years pointing to the importance of flushing of this lake in preventing nuisance algae blooms.

That said, nuisance algae blooms are common in Clear Lake. Typical recent chlorophyll-a concentrations are about 60 µg/L. Observed Secchi-depth readings have ranged from >1 foot in 1989 to greater than 7 feet in 1983. The typical recent Secchi depth is 2.9 feet.

In-lake water quality in Clear Lake has declined relative to monitoring conducted in the early 1980's. Until 2001, all the Clear Lakeshore homes were on private septic systems. In 2001, the homes were connected to the Watkins Wastewater treatment system and the individual sewage treatment systems presumably went offline. Historic loads from septic systems likely represented a growing load to the lake as systems aged and subsequently failed. Though lake shore owners report improvements in water quality since 2001, and a reduction in algae blooms, such an improvement is not immediately reflected in recent water quality data. This is possibly due to a residual load in the lake shore soils, internal loading from historic loads, or curly leaf pond weed. Residents report an increasing density of the invasive species.

Tributary stream monitoring was conducted in 1982, 1983, and again in 2006: 1983 was a very wet year, 2006 was dry compared to average conditions. In 1983, watershed loads to Clear Lake were calculated: 12,400 lbs, which translates into flow-weighted average watershed concentrations ranging from 320 µg/L at the northwest tributary, 420 µg/L at the southwest tributary and 670 µg/L at the northeast tributary. The tributaries were dry in 2006 except for early spring, and sampling results showed a concentration of 121 µg/L on the northeast tributary and 67 µg/L on the southwest tributary during high flow and 818 µg/L during very low flow (almost stagnant conditions).

5.2 LAKE BETSY

District water quality monitoring in Lake Betsy began in 1981. Over the entire monitoring period there has been a wide range of observed average growing season total phosphorus concentrations from a low of 120 to a high of 700 µg/L. Recent typical TP values range from 140 to 420 µg/L. Data trends indicate an overall decrease in phosphorus levels from early monitoring (Appendix A).

Observed in lake chlorophyll-a concentrations have also varied widely in Lake Betsy with some years below the State standard of 14 µg/L and other years greatly exceeding the standard. The general trend of all collected chlorophyll-a data for Lake Betsy indicate a slight increase in chlorophyll-a levels (Appendix A). Increased chlorophyll-a concentrations in recent years may correlate with decreasing TP concentrations in that previously, the system may have been light-limited resulting in very low chlorophyll-a concentrations. As TP concentrations decline, nuisance algal blooms may continue to increase until TP loading goals are attained. Secchi depth has varied form 7.8 feet to 1.5 feet with recent typical values of about 3 feet.

Nutrient and sediment loads from the Clearwater River to Lake Betsy are measured annually just upstream of the inflow at County Road 15. Loads at this station have ranged from 168,000 in 1983 to just 530 lbs in 2000, a very dry year. Loads represent in-stream concentrations ranging from 900 µg/L to 130 µg/L, with recent typical concentrations 130 and 291 µg/L. Willow Creek, also tributary to Lake Betsy was monitored in the early 1980's and again more recently in 2002 to track bacteria sources in the watershed. Typical Willow Creek inflows were in the range of 120 to 240 µg/L, with higher concentrations in the spring, 520 µg/L.

5.3 UNION LAKE

District monitoring in Union Lake began in 1995. Summer average total phosphorus concentrations in Union Lake have ranged from 31 to 88 µg/L during that time. Although these phosphorus levels typically exceed the State standard of 40 µg/L, the levels in Union Lake are lower than those found in other lakes in the Chain of Lakes. Union Lake is located in the south central portion of the overall Chain of Lakes watershed and has no contributing upstream lakes and a relatively small contributing watershed. The outlet to Union is a tributary stream that flows north into Scott Lake.

Chlorophyll-a values observed in Union Lake have ranged from 7 to 39 µg/L. Both TP and chlorophyll-a concentrations show a flat trend. The Secchi depth readings have ranged from 3.3 to 5.9 feet, meeting the State standard of in all but 1 year.

Tributary inflow to Union Lake was sampled in 2002 and concentrations ranged from 150 to 180 µg/L.

5.4 SCOTT LAKE

District monitoring for Scott Lake began in 1981. Summer average total phosphorus concentrations in Scott Lake ranged from 103 to 660 µg/L. The range and variation of observed total phosphorus concentrations in Scott Lake is similar to that of Lake Betsy, directly upstream of Scott Lake. Concentrations observed in these lakes are generally higher than other lakes within the chain and are closely correlated (R^2=0.97). This is due to their close proximity and the dominance of the Clearwater River as a source of phosphorus to both lakes.

Both lakes show a decreasing trend in average summer levels of phosphorus (Appendix A) which correlate strongly with the decrease in total phosphorus loads in the Clearwater River upstream of Lake Betsy. Both lakes have large tributary watershed areas relative to lake area, and very small residence times.

Chlorophyll-a concentrations have varied greatly during the overall monitoring period of record from a low of 3 to a high of 223 µg/L. The overall trend of chlorophyll-a concentrations shows an increase over the entire period of record but concentrations have remained relatively stable over the last 10 years (Appendix A). During the first two years of District monitoring in 1981 and 1982, observed Secchi depths were are their greatest, exceeding the State standard of 4.6 ft. Since that time Secchi depth measurements have always been less than the state standard. In the last 10 years Secchi depth values have been very stable in Scott Lake, with observed values virtually unchanged from 1998 through 2006 (Appendix A).

5.5 LAKE LOUISA

The CRWD has monitored Lake Louisa on an almost annual basis since 1981. Summer average total phosphorus concentrations in Lake Louisa ranged from 33 to 440 µg/L. Since 1995 in-lake total phosphorus concentrations have remained relatively stable and the overall historical trend exhibits a decrease in total phosphorus concentrations asymptotically approaching the state standard.

The Clearwater River is tributary to Lake Louisa downstream of Scott Lake, and as such in-lake TP concentrations in Lake Louisa are correlated with Scott Lake concentrations (R^2=0.86), which coupled with the short residence time points to the strong influence of the Clearwater River on in-lake water quality. Data also indicate that the Clearwater River between Scott Lake and Lake Louisa and in particular a large shallow area of Lake Louisa at the inlet provide significant assimilative capacity for upstream nutrients and act as a buffer for Lake Louisa against upstream nutrient loads.

Observed chlorophyll-a concentrations have ranged from 4 to 101 µg/L and have exceeded the state standard in the majority of the monitoring years. The overall historical trend in chlorophyll-a in Lake Louisa reveals a very slight increase in observed concentrations (Appendix A). Over the last ten years chlorophyll-a concentrations have remained fairly stable. Secchi depth values in Lake Louisa exhibit a very slight decrease over the entire monitoring period of record. However, over the last 10+ years Secchi depth values have been very stable, with observed values virtually unchanged from 1995 through 2007 (Appendix A).

Historical and current efforts to improve water quality in Lake Louisa have been successful as shown by improved water quality since 1981. The dominant mechanism of water quality improvement was likely the reduction of phosphorus loads in the Clearwater River gained through capital improvement projects and watershed best management practices. Rough fish removal is an important element of past and current lake management. The Chain of Lakes Association (COLA) implements removals rough fish through a trap at Highway 55 at the upstream end of the lake. Table 5.2 shows the pounds of fish removed annually.

Table 5.2 Rough Fish Removal from the Upper Clearwater Chain of Lakes

Year	Rough Fish Removed (lbs)
1984-1988 (1)	206,400
1998	1,000
1999	1,000
2000	30,000
2001	30,000
2002(2)	7,000
2003(2)	0
2004	20,000
2005	0
2006	800
2007	0
2008 (to date)	14,000

(1) Removal after 1999 was performed at the fish trap on Highway 55 upstream of Lake Louisa
(2) High water limited trapping in these years

Aerators were operated in Lakes Louisa, Marie and Augusta between 1985 and 1995. They were not replaced after equipment failure in 1995.

5.6 LAKE MARIE

District monitoring in Lake Marie began in 1981 and similar to Lake Louisa, the lake has been monitored on an almost annual basis since that time. Lake Marie is connected by a short channel to Lake Louis, which lies directly upstream. The Lake outflow is the Fairhaven Dam at which flow was continuously monitored by the MPCA between summer 2005 and 2007.

Summer average total phosphorus concentrations in Lake Marie ranged from 70 to 360 µg/L. Although total phosphorus concentrations have typically exceeded the State standard, the trend shows a decrease in the average phosphorus levels approaching the state standard.

Chlorophyll-a concentrations in Lake Marie have ranged from 4 to 153 µg/L and have typically exceeded the State standard of 14 µg/L. Trends in chlorophyll-a data indicate relatively consistent levels since monitoring began 1981. Secchi depth measurements in Lake Marie have also remained relatively constant over the monitoring period of record. Comparison of average observed Secchi depth readings across all years reveals a slight improvement in water clarity over time, with slight improvements each year since 1996. Water clarity values in Lake Marie have exceed the state standard of 4.6 feet twice in the last ten years.

Efforts to manage internal loads mirror those described for Lake Louisa in terms of rough fish removal, and aerators.

6.0 Linking Water Quality Target and Sources

A lake nutrient budget can be used to identify and prioritize management strategies to improve water quality. Additionally lake response models can be developed to understand how lake nutrient concentrations respond to changes in nutrient loads. Through this knowledge, managers can make decisions about how to allocate lake restoration dollars and efforts and quantify the effects of such efforts.

6.1 SELECTION OF MODELS AND TOOLS

The original scope of this TMDL Study included only Lake Louisa and the Clearwater River bacteria and dissolved oxygen (DO) impairments between Clear Lake and Lake Betsy. The river impairments are addressed in two separate reports (Wenck 2008). Data was collected in 2006 support these TMDLs. Data was collected to characterize watershed contributions to the impaired reach of the Clearwater River and to calibrate a BATHTUB model of Lake Louisa. There is also a large historical data base (runoff, precipitation, in-lake water quality, and watershed loads) available through the CRWD's annual monitoring program.

Clear Lake, Lake Betsy, Scott Lake, Union Lake and Lake Marie located directly upstream and downstream of Lake Louisa on the Clearwater River were added to the impaired waters list for nutrients in 2008. The technical advisory group for the TMDL study recognized that the significant overlap in the watersheds tributary to these lakes and the large existing data set presented an opportunity to address the TMDLs for all these at once. The choice to set the TMDLs on a watershed basis recognizes both significant influence of the Clearwater River and watershed loads in all these lakes, and the need to ensure that addressing impairments in Lake Louisa and the Clearwater River will go far enough to address impairments in other impaired watershed lakes. This allows for an implementation plan for the entire upper watershed rather than several disjointed plans.

Available data was the basis for the modeling selections. All lake response modeling was conducted using model equations extracted from BATHTUB. The models are calibrated to available data collected since 1998, focusing on the most recent data available. The partitioned loads from 2001-2007 were averaged to yield the current phosphorus budget for an average year representing both current watershed conditions relevant to TP export, and a range of wet, dry and average years.

Watershed phosphorus loads were calculated using primarily measured water quality and watershed runoff. Literature values were used where watershed data were not available. Runoff volumes across the watershed are based on historical stream flow gauging at long-term monitoring stations and more recently from continuous flow records collected at Fairhaven Dam for this TMDL study.

Literature values were derived using the unit area load method. The potential range of phosphorus loads were quantified based on watershed land cover, slopes, soil types and delivery potential derived from the SWAT interface. Literature values for phosphorus export were taken from EPA 440/5-80-011, "Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients".

6.2 CURRENT PHOSPHORUS BUDGET COMPONENTS

The current phosphorus load contributions from each potential source was developed using the modeling and collected data described above. For each lake the phosphorus load contributions were partitioned into six contributing components:

1. Atmospheric load,
2. Septic systems,
3. Ambient groundwater,
4. Direct watershed runoff
5. The Clearwater River and upstream lakes,
6. Internal phosphorus cycling.

The following is a brief description of the budget components and how these values were developed.

6.2.1 Atmospheric Load

The atmosphere delivers phosphorus to water and land surfaces both in precipitation and in so-called "dryfall" (dust particles that are suspended by winds and later deposited). A recent statewide study of phosphorus sources commissioned by the MPCA (Barr, 2004 updated in 2007) gives the following atmospheric load data for the upper Mississippi River watershed (Table 6.1):

Table 6.1 Atmospheric Deposition of P

Deposition Component	[kg/ha/yr]	[lb/ac/yr]
Low-Precipitation P Deposition	0.08	0.07
Average-Precipitation P Deposition	0.10	0.09
High-Precipitation P Deposition	0.12	0.11
Dry P Deposition	0.17	0.16
Dry-Year Total P Deposition	0.25	0.23
Average-year Total P Deposition	0.27	0.24
Wet-year Total P Deposition	0.29	0.27

Deposition rates were applied to the area of each lake surface based on annual precipitation for dry (< 25 inches), average, and wet precipitation years (>38 inches). The atmospheric load typically comprises a small percentage of the total load for each lake.

6.2.2 Septic Systems

A review of county parcel information was conducted to determine the amount of lake homes and residents along the shoreline of each lake. Residents comprise both part-time and year-round residents. Local knowledge of the watershed was also applied to determine an accurate number of lake homes utilizing septic systems on Clear Lake where all but 7 lake shore homes were connected to the City of Watkins sewer and waste water treatment system in 2001. Additionally, it is known that there is no public access and no lake shore homes along the shore of Scott Lake.

The total septic load to each lake was calculated by multiplying the number of homes around the lake assuming four persons per home and a total phosphorus load of 4.2 pounds of phosphorus per system per year. The total phosphorus septic load to the lake was then determined by multiplying the total septic load by an assumed failure rate of 25 percent. For example, for Clear Lake there are 7 homes on septic systems. Based on the above assumptions the septic load to the lake would be calculated as follows:

(7 systems)*(4.2 lbs TP/yr per system)*(25% failure rate) = Septic Load to Lake

6.2.3 Ambient Groundwater

Regional studies show that the Clearwater River Chain of Lakes, situated in the Anoka Sand Plain, is subject to groundwater interaction (Helgesen et al., 1975). A water table map indicates that groundwater from the Sand Plain aquifer discharges to Clearwater River generally – as expected for a significant stream, and to the lakes that comprise the Chain of Lakes. Measured base flows in the Clearwater River support this conclusion.

The specific rate of groundwater inflow to each of the listed lakes was calculated using regional values for hydraulic conductivity for the Anoka Sand Plain, hydraulic gradient from the regional hydraulic atlas and Darcy's Law. Resulting phosphorus loads can then be calculated based on calculated inflow using the statewide median TP concentration for surficial glacial aquifers of 56 ug/L (MPCA, 1999).

6.2.4 Direct Watershed Runoff

The direct sub-watershed is defined as the portion of the upstream load not tributary to another water body. The boundary condition for each lake was the upstream lake or monitoring station for which measured data was available. This reduces the uncertainty of watershed loading estimates takes into account the nutrient removal in upstream lakes. The remaining tributary watershed is considered "direct" watershed runoff.

Phosphorus loads from the direct sub-watershed to each lake were based on direct measurement of water quality and watershed runoff where available. Measured watershed runoff and land use based literature concentrations were used otherwise. Watershed TP export was derived from EPA 440/5-80-011, "Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients".

6.2.5 Clearwater River and Upstream Lakes

All the lakes addressed in the report are on or tributary to the Clearwater River. Flow from the Clearwater River and/or upstream lake plays a significant role in the nutrient and water balance for four of these lakes. Lake Betsy, Scott Lake, Lake Marie and Lake Louisa all receive water and therefore nutrients from contributing upstream lakes and the Clearwater River. Conversely, these lakes also act as a buffer to the downstream lakes by trapping nutrients.

Traditional watershed TP export values were not appropriate to characterize watershed export from upstream of these lakes, and water quality data was available for the upstream lake or monitoring station, so the upstream lake or stream station functioned as the boundary condition for each lake model.

Because CRWD measures lake water quality on a rotating basis, in-lake data from the lake directly upstream (paired data) was not available for all years. Paired data sets were available for 2 to 4 years for each lake. Because of the short residence time of the lakes and the dominance of the Clearwater River, paired data sets provided the best quantifications of upstream loads to most lakes, and as such were used for model calibration.

When paired data were not available, the load from upstream lakes was calculated based on data collected further upstream given the strong relationships between water quality at different locations along the Clearwater River. Strong correlations are not surprising given the relative locations of the lakes and river monitoring stations (Figures 6.1). Examples of these correlations are shown in Figure 6.2 and 6.3.

Figure 6.1 Relative Location of CR 28.2, Lake Betsy and Scott Lake

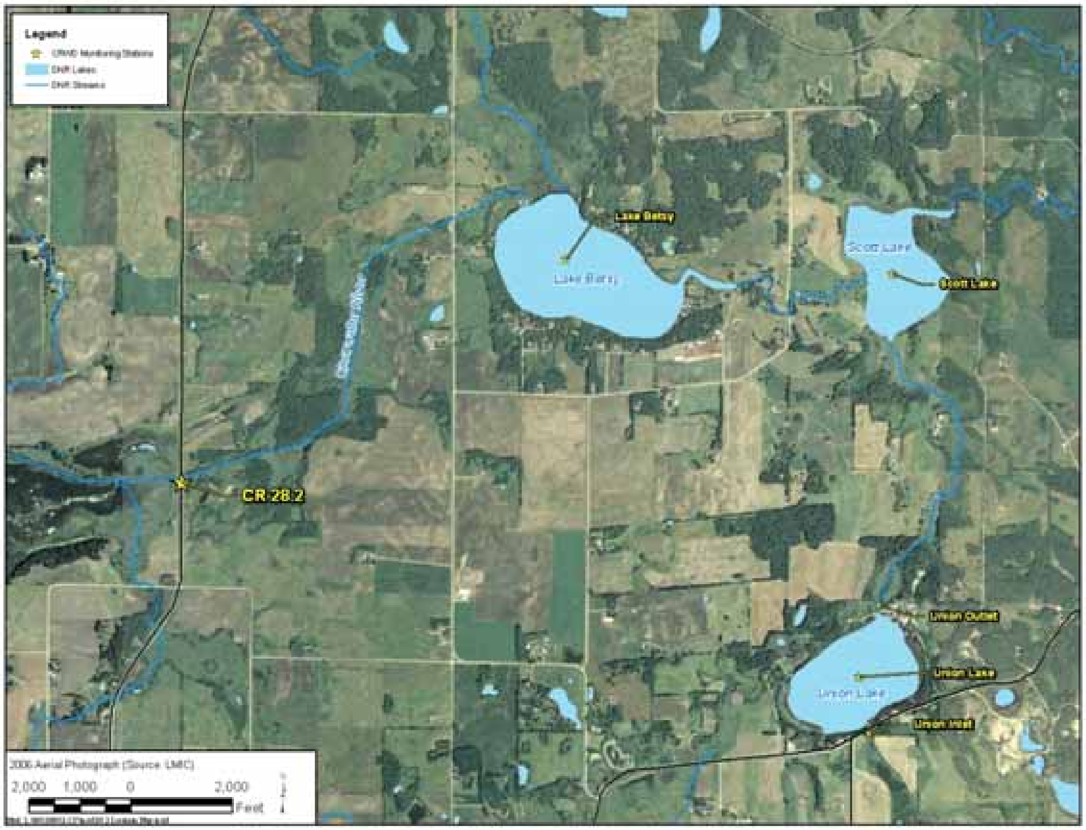
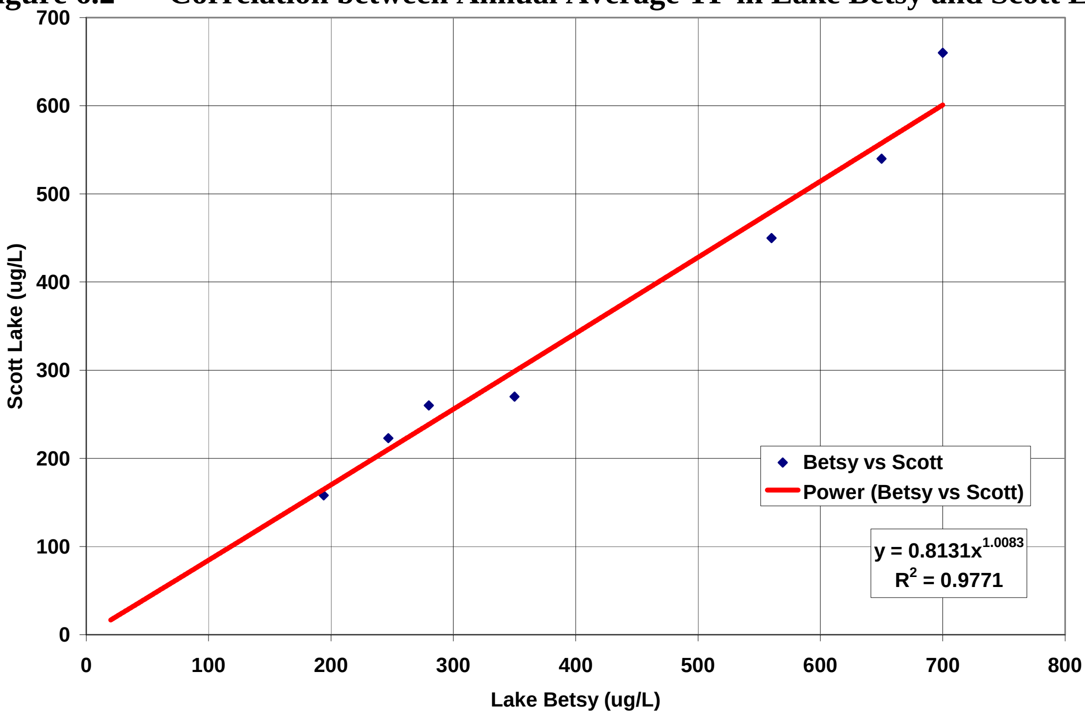


Figure 6.2 Correlation between Annual Average TP in Lake Betsy and Scott Lake



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6.2.6 Internal Phosphorus Cycling

Internal phosphorus cycling has been shown to be an important element in lake nutrient budgets. High phosphorus concentrations in all six lakes indicate that internal loading may be significant. Two methods were used to quantify internal nutrient cycling in CRWD lakes depending on the level of available data for each lake.

The anoxic factor (Nurnberg 2004), which estimates the period where anoxic conditions exist over the sediments, was used in conjunction with literature values for release rates to quantify internal loading. The anoxic factor is estimated from the dissolved oxygen profiles collected in each lake. The anoxic factor is expressed in days but is normalized over the area of the lake. The anoxic factor can then be calculated as the number of anoxic days multiplied by the area of anoxia, divided by the total lake area.

Internal phosphorus loads were estimated for Lakes Louisa and Marie in 1983 using bell jars placed over sediment. Average sediment release rates were 2.58 mg/m^2/ day under aerobic conditions and 4.45 mg/m^2/day under anaerobic conditions. A follow up study in 2003 conducted by Wenck Associates quantified the sediments' phosphorus content in Lakes Louisa and Marie and estimated release rates between 6 and 18 mg/m^2/day.

6.3 CURRENT PHOSPHORUS BUDGET

A current phosphorus budget quantifying the relative contributions from each potential sources was developed using the models and data described above. Data from 2001 to 2007 were used to develop the phosphorus budgets for each lake for an average year because these data represent current relevant watershed conditions that influence TP export as well as a range of wet and dry conditions. Table 6.2 shows the range of TP and runoff measured for the averaging period. For comparison, average precipitation in this area is 29.6 inches.

Table 6.2 Precipitation and Runoff 2001-2007

Year	Annual Precipitation (inches)
2001	31.3
2002	40.6
2003	23.0
2004	33.1
2005	36.9
2006	23.4
2007	27.2
Average	30.8

The phosphorus budget derived from the water quality modeling is shown in Table 6.3, the modeling summary is included as Appendix B.

Table 6.3 Current Annual Phosphorus Budget (lbs/ yr)

	Total	Direct Watershed	Upstream Lakes	Septic Systems	Atmospheric + Groundwater	Internal
Clear Lake	13,078	4,347	-	7	359	8,364
Lake Betsy	22,043	9,850	4,887	21	205	7,080
Union Lake	770	505	-	21	170	74
Scott Lake	16,683	211	16,216	-	197	59
Lake Louisa	7,646	296	5,764	59	895	631
Lake Marie	8,006	1,076	5,636	74	883	338

Partitioning between internal and external loads is difficult with small data sets. The nutrient budget suggests that while internal loads are significant and must be addressed to meet water quality goals, the dominant source of phosphorus to the impaired lakes is the Clearwater River and the resulting water quality in upstream lakes.

6.4 WATER QUALITY RESPONSE MODELING

The BATHTUB model was developed using measured runoff volumes. Measured water quality data was used where available. Land use based literature values for unit area loads were used in the absence of literature values, and compared to measured water quality for subwatersheds with similar land use to narrow the predicted export ranges. No calibration factors were used in the modeling.

6.5 FIT OF THE MODELS

Though empirical models can give us an estimate of annual loading. The model fit reasonably well compared to annual average lake water quality data, differences between observed and predicted average in-lake concentrations were generally within the reported standard deviations for annual average TP for a given year. Given the short residence times of these lakes, on the order of days during spring and early summer high flow, the models represent a reasonable fit to the available data (Appendix B).

Further, after extensive evaluation of load allocations based on the range of calibration data, significant differences in the modeled watershed loads or load allocations to different sources do not change the implementation planning discussed in Section 9 of this report. Watershed loads will require significant reductions to meet standards, and internal loads will require management in all but Union and Scott Lake. Internal load management is strongly recommended to add to the Margin of Safety (MOS) in Lake Louisa given that upstream load reduction targets are aggressive and may not be achievable with current available technologies. Since internal load management is ongoing through carp management, it should continue and the lake associations should consider curly leaf pond weed control additionally.

6.6 CONCLUSION

Clear Lake:

- In 2001, all but 7 of the existing ISTSs for lake shore homes were removed and sewage from the homes was subsequently routed to the City of Watkins WWTP. This resulted in a ~100 lb TP reduction to the lake.
- A sedimentation pond was also installed on both the north and the south end of the lake.
- Residents have reported improved water quality though annual average TP data has not yet reflected the improvements. The lake may still be responding to these changes and may not be in equilibrium, and this maybe affecting the fit of the model in recent years.
- Regardless of model fit, it is clear that both watershed and internal load reductions are required to meet water quality goals.

Lake Betsy:

- Water quality in Lake Betsy is dominated by loads from the Clearwater River. The short residence time of this lake means that water quality in the lake during the early spring and summer months is essentially the same as in the river.
- Historically high TP loads in the Clearwater River appear to have induced high internal loads in Lake Betsy.
- In 2 of the last 5 years, annual average water quality in Lake Betsy has been *worse* than flow-weighted mean concentrations in the Clearwater River upstream of Lake Betsy. This indicates that though the lake is still trapping some particulate P, the effects of internal loading may begin to negate positive effects on downstream water bodies.
- Significant P reductions in watershed runoff and internal loading are required for this lake to meet state standards.

Union Lake:

- Union Lake has a small tributary watershed relatively good water quality as compared downstream Scott Lake.
- Watershed loads appear to be the only necessary reduction for this lake to meet its water quality goal.

Scott Lake:

- Scott Lake, directly downstream of both Lake Betsy and Union Lake is highly dominated by the inflow from Lake Betsy.
- Controlling loads from Lake Betsy is the key to meeting state water quality standards in Scott Lake.

Lakes Louisa & Marie:

- The Clearwater River and the large area of emergent vegetation at the upstream end of Lake Louisa have a significant assimilative capacity for TP and act as a buffer improving downstream water quality.
- Though direct watershed load reductions are necessary to meet standards, improving water quality in the Clearwater River and upstream lakes will have the biggest impact on water quality in these lakes.
- Because upstream watershed TP load reduction goals are aggressive and may not be achievable with existing technologies, management of internal loads is strongly recommended.

7.0 TMDL Allocation

7.1 LOAD AND WASTELOAD ALLOCATION

Nutrient loads in this TMDL are set for phosphorus, since this is typically the limiting nutrient for nuisance aquatic plants. This TMDL is written to solve the TMDL equation for a numeric target of 40 µg/L of total phosphorus for Lake Betsy, Lake Scott, Union Lake and Lake Louisa and a target of 60 µg/L and Clear Lake and Lake Marie.

7.1.1 Allocation Approach

There are no known wasteloads in the watersheds tributary to the listed lakes. The permitted WWTPs in the Clearwater River Watershed District listed in Table 7.1 all operate as spray irrigation systems. As such there are no permitted wastewater treatment plant effluent discharges in this portion of the Clearwater River Watershed District. It is unlikely that these WWTPs are a phosphorus source the impaired waters and therefore they have been included in the TMDL equation with a wasteload allocation of 0. If in the future it is determined that these discharges are a phosphorus source, then this discharger will be assigned a wasteload allocation.

Table 7.1 WWTPs in the Clearwater River Watershed District Tributary to Listed Waters Addressed in this Report.

Permit Holder/ System	Waste Water Treatment Method
City of Fairhaven	ISTS (Potential future)
City of Kimball	Land Application (SDS Permit)
City of Watkins	Land Application (SDS Permit)
City of South Haven	Land Application (SDS Permit)
CRWD- Regional	Master System (Potential)
CRWD- Rest-a-While Shores	Cluster System *
CRWD- Wandering Ponds	Cluster System *
CRWD- Lake Louisa Hills	Pending Cluster System *

The Load Allocation must be divided among existing sources, save those that are not permitted under state law. Discharge from septic systems, for example, is not allowed by law and therefore the load allocation for septic systems is zero. Relative proportions allocated to each source are based on reductions that can reasonably be achieved through Best Management Practices as discussed in the implementation section of the report.

7.1.2 Critical Conditions

The critical condition for lakes is the summer growing season. Minnesota lakes typically demonstrate the impacts of excessive nutrients during the summer recreation season (June 1 to September 30) including excessive algal blooms and fish kills. Lake goals have focused on summer-mean total phosphorus, Secchi transparency and chlorophyll-a concentrations. These parameters have been linked to user perception (Heiskary and Wilson 2005). Consequently, the lake response models have focused on the summer growing season as the critical condition. Additionally, these lakes tend of have relatively short residence times as they are flow through lakes on a river chain, and therefore respond to summer growing season loads.

7.1.3 Allocations

The loading capacity is the total maximum daily load. The daily load and wasteload allocations for the average conditions for each lake are shown in Table 7.2

Table 7.2 Total Phosphorus Load Allocations Expressed as Daily Loads

Lake	Total Phosphorus TMDL (lbs/day)	Waste Load Allocation (lbs/ day)	Load Allocation (lbs/day)	Margin of Safety
Clear Lake	3.42	0.03	3.39	Implicit
Lake Betsy	7.85	0.08	7.77	Implicit
Union Lake	1.57	0.02	1.55	Implicit
Scott Lake	6.94	0.07	6.87	Implicit
Lake Louisa	9.01	0.09	8.92	Implicit
Lake Marie	12.48	0.12	12.36	Implicit

T:\0002\117\Lake Response Modeling\Goal\[Goal LRModel (Clear-Betsy-Union-Scott-Louisa-Marie).xls]RptTbls

Load allocations by source for each lake are provided in Table 7.3. No reduction in atmospheric loading is targeted because this source is impossible to control on a local basis. The remaining load reductions were applied based on our understanding of the lakes, efficacy of proposed implementation strategies, as well as the model from the output.

Table 7.3 Partitioned Total Phosphorus Load Allocations Expressed as Daily Loads

Lake	Phosphours TMDL	Direct Watershed	Upstream Lakes	Septic Systems	Atmospheric + Groundwater	Internal
Clear Lake	3.4	2.3	0.0	0.0	1.0	0.1
Lake Betsy	7.9	4.2	2.0	0.0	0.6	1.0
Union Lake	1.6	0.9	0.0	0.0	0.5	0.2
Scott Lake	6.9	0.5	5.7	0.0	0.5	0.2
Lake Louisa	9.0	0.6	4.1	0.0	2.5	1.7
Lake Marie	12.5	1.3	7.9	0.0	2.4	0.6

T:\0002\117\Lake Response Modeling\Goal\[Goal LRModel (Clear-Betsy-Union-Scott-Louisa-Marie).xls]Goal Summary

Annual total maximum loads are provided in Tables 7.4 and 7.5. The values in Tables 7.2 and 7.3 are calculated from annual loads dividing by 365.25 days per year (to account for leap year). The loading capacity provided in Tables 7.4 and 7.5 are based on average model predicted results for the years in which lake water quality data was available during the recent 7 year period which represents both wet and dry conditions.

Table 7.4 Total Phosphorus Load Allocations Expressed as Annual Loads

Lake	Total Phosphorus TMDL (lbs/yr)	Waste Load Allocation (lbs/ yr)	Load Allocation (lbs/yr)	Margin of Safety
Clear Lake	1,250	12	1,237	Implicit
Lake Betsy	2,868	29	2,840	Implicit
Union Lake	572	6	566	Implicit
Scott Lake	2,535	25	2,509	Implicit
Lake Louisa	3,292	33	3,259	Implicit
Lake Marie	4,560	46	4,514	Implicit

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Table 7.5 Partitioned Total Phosphorus Load Allocations Expressed as Annual Loads

Lake	Phosphours TMDL (lbs/yr)	Direct Watershed	Upstream Lakes	Septic Systems	Atmospheric + Groundwater	Internal
Clear Lake	1,250	857	0	0	359	21
Lake Betsy	2,868	1547	733	0	205	354
Union Lake	572	323	0	0	170	74
Scott Lake	2,535	185	2068	0	197	59
Lake Louisa	3,292	233	1499	0	895	631
Lake Marie	4,560	492	2902	0	883	236

T:\0002\117\Lake Response Modeling\Goal\[Goal LRModel (Clear-Betsy-Union-Scott-Louisa-Marie).xls]Goal Summary

7.2 RATIONAL FOR LOAD AND WASTELOAD ALLOCATIONS

The TMDL presented here is developed to be protective of the aquatic recreation beneficial uses in lakes.

7.2.1 Modeled Historic Loads

Using the Canfield-Bachmann equation, historic loads and load reductions were calculated for each of the six impaired lakes. These calculations provide some insight into the assimilative capacity of the lakes under historical conditions as well as over time. Additionally, these results provide a sense for the level of effort necessary to achieve the TMDL and whether that TMDL will be protective of the water quality standard.

7.3 SEASONAL AND ANNUAL VARIATION

The daily load reduction targets in this TMDL are calculated from the current phosphorus budget for each lake. The budget is an average of several years of monitoring data, 2001-2007, and includes both wet years and dry years to account for annual variation.

The BMPs to address excess loads to the lakes will be designed for average conditions; however, the performance will be protective of all conditions. For example, a stormwater pond designed for average conditions may not perform at design standards for wet years; however the assimilative capacity of the lake increases in wet years due to increased flushing. Programmatic BMP targets such as areal coverage for buffer strips are finite and can be increased to be protective in all conditions. However, the implementation of this BMP is largely based on willing participation from land owners and will be recommended to the maximum possible extent in any case. Additionally, in dry years the watershed load will be naturally lower allowing internal loading to comprise a larger portion of the overall phosphorus budget. Consequently, averaging across several modeled years addresses annual variability in lake loading.

Seasonal variation is accounted for through the use of annual loads and developing targets for the summer period where the frequency and severity of nuisance algal growth will be the greatest. Although the critical period is the summer, lakes are not sensitive to short term changes in water quality, rather lakes respond to long-term changes such as changes in the annual load. Therefore the seasonal variation is accounted for in annual loads. Additionally by setting the TMDL to meet targets established for the most critical period (summer), the TMDL will inherently be protective of water quality during all other seasons.

7.4 MARGIN OF SAFETY

A Margin of Safety has been incorporated into this TMDL by using conservative assumptions in terms of the modeling and implementation planning. These were used to account for an inherently imperfect understanding of the lake system and to ultimately ensure that the nutrient reduction strategy is protective of the water quality standard. Further, phased implementation and monitoring allow for adaptive management.

7.5 RESERVE CAPACITY/ FUTURE GROWTH

Comprehensive plans for the portions of Stearns, Wright and Meeker Counties within Clearwater River Watershed District show that highest projected growth rates will center in existing urban areas, along lake shores and highway corridors. Significant development is not anticipated, but many of the areas in which growth is projected are tributary to impaired waters in the CRWD, and to the lakes addressed in this study specifically.

Load reduction targets to meet water quality goals are already aggressive, and so reserve capacity is just not available given the current phosphorus budgets and required load reductions. As the result, planned developments must be undertaken to avoid increasing phosphorus loads to lakes over existing conditions, and to decrease phosphorus loads where possible. The phosphorus load reductions required to meet water quality goals make stormwater BMPs and low impact development in these growth areas necessary. It will be one of the most cost effective methods to limit watershed phosphorus loads. Further, there are no planned WWTP expansions in the area at this time, and it is unlikely given current MPCA policy and citizen sentiment that any WWTP would be permitted for an expansion of that expansion meant discharges to area lakes. The 1981 Chain of Lakes Restoration Project was specifically designed to eliminate WWTP discharges from area lakes.

This means that reserve capacity for growth is essentially zero with respect to phosphorus, in that nutrient export will need to decline with development instead of increasing. This does not mean no growth, it simply means growth must be accomplished without increasing phosphorus loads to impaired waters. We have the design tools to accomplish this, what is needed is the regulatory framework and intergovernmental coordination in terms of development review and design standards. Recommendations to that end are incorporated in the implementation plan.

This is in line with, and no more stringent than existing state statutes prohibiting the degradation of Minnesota waters.

8.0 Public Participation

The CRWD sees public participation as critical to the process of implementing the TMDL to meet water quality standards. The public participation efforts for this TMDL study are summarized below. The work described below is collective for all the on-going TMDL studies in the CRWD.

8.1 TECHNICAL ADVISORY COMMITTEE

This TMDL study has proceeded in Phases: Phase I was a review of existing data, Phase II was collection of data to fill gaps, and Phase III is setting the load allocation. The decision to proceed in phases was made to ensure that the most efficient and technically sound path was taken towards completion of the TMDL. Workplans and reports from each phase received review and approval from the Technical Advisory Committee comprised of the MPCA technical staff in the Brainerd/Baxter and St. Paul offices, the CRWD, and the project consultant. This group met formally only once at the Brainerd/ Baxter office, but was effectively coordinated by the MPCA project manager Margaret Leach throughout the project.

8.2 STAKEHOLDER MEETINGS

Since the beginning of the TMDL process in 2003 District Administrator Merle Anderson has actively sought engagement from and communication with city, county, township, lake association, and individuals alike. His efforts took the form of attendance of the regular meetings of these groups, calls to group leaders, organizing special meetings of these groups for the purpose of making presentations, and preparation of materials for distribution (Appendix C). Presentations are available on the CRWD web site.

Administrator Anderson updated the members of these groups on the status of the TMDL and provided information on the cause of the impairments and on their roles in the conceptual implementation plan. The goal of these efforts was to leverage existing regulatory framework, and relationships to generate support for TMDL implementation efforts. Using existing governmental programs and services for TMDL implementation should provide a significant cost savings and efficiency.

This work on the part of Administrator Anderson is part of the ongoing tradition of the CRWD to work with other government agencies and provide them with the support they need to protect water resources. Specific examples of this work in the recent past are listed:

- CRWD funded municipal stormwater studies for the Cities of Annandale, Kimball and Watkins wherein several opportunities for stormwater improvements were identified.
- CRWD funded design of a road pavement project in Maine Prairie Township to ensure protection of the near-by School Section Lake.
- Development review and comment for major cities and counties.
- CRWD offers additional incentives for riparian buffers, rain gardens and CRP on top of what is offered by other government agencies.

8.3 PUBLIC MEETINGS

Additionally, seven public meetings have been held to date. At each stakeholder meeting, the District Administrator and project consultant updated the stakeholders on the status of the TMDL and provided information on the cause of the impairment and on conceptual implementation plans.

Five of the six lakes addressed herein were not included in the early efforts with respect to this TMDL study. Clear Lake, Lake Betsy, Union Lake, Scott Lake and Lake Marie were added to the 303(d) list in 2008. Prior to the April 16, 2008 meeting, only Lake Louisa and Lake Marie were discussed (Lake Marie was discussed because the same group represents Lake's Louisa and Marie, and meeting the load reduction for Lake Louisa will implicitly reach the goal set for Lake Marie). The results of the public participation meetings are summarized below:

December 17, 2003 in Annandale

Watershed District Managers, the District Administrator, the MPCA Project Manager, and the Wenck Project Manager presented information about the TMDL process and the Clearwater River and Lake Louisa TMDL Project specifically. A question and answer session followed the presentation. County Soil and Water Conservation District Representatives from Wright, Meeker and Stearns Counties were invited, along with representatives from the Cities of Kimball and Watkins. Citizen advisory group members were also invited. Wright and Meeker County representatives attended.

December 17, 2003 in Annandale

The Wenck Project Manager presented information about the TMDL process and the Clearwater River and Lake Louisa TMDL Project specifically. An analysis of existing data was presented. A question and answer session followed the presentation. County Soil and Water Conservation District Representatives from Wright, Meeker and Stearns Counties were invited, along with representatives from the Cities of Kimball and Watkins. Citizen advisory group members, and lake associations were also invited. A Meeker County representative attended, along with members of the Citizen Advisory Group, and Clearwater Lake Association.

March 16, 2004 in Watkins

An additional meeting was held to solicit additional stakeholder involvement. The Wenck Project Manager presented information about the TMDL process and the Clearwater River and Lake Louisa TMDL Project specifically. An analysis of existing data was presented. A question and answer session followed the presentation.

Meeting invitations and a letter describing the TMDL Project were sent to resident's homes. County Soil and Water Conservation District Representatives from Wright, Meeker and Stearns Counties, as well as representatives from the Cities of Kimball and Watkins were invited. Citizen advisory group members and lake associations were invited. The goal of the meeting was to establish a representative stakeholder group. These representative stakeholders met two more times.

July 15, 2007 Clearwater Chain of Lakes Association, Lake Louisa Working Group

District Administrator Merle Anderson met with members of the Clearwater Chain of Lakes Association (CCOLA) to spark interest in a Lake Louisa working group. This group of citizens heard a summary of the TMDL process and progress and agreed to discuss the Lake Louisa TMDL with residents to encourage interest and participation.

August 6, 2007, Clearwater Chain of Lakes Association, Lake Louisa Working Group

District Administrator Merle Anderson and Project Engineer Rebecca Kluckhohn met with 16 members of the Clearwater Chain of Lakes Association (CCOLA). This group is comprised of Lake Louisa and Lake Marie residents concerned with upstream water quality. Each resident expressed concern about the perceived deterioration of water quality in the entire Chain of Lakes. Most residents had moved to the area since the major improvements in water quality in the 1980s as the result of the Clearwater Chain of Lakes Improvement Project. Residents speculated that many septic systems around the lakes needed replacement, but that costs would be prohibitive for several residents. Residents also expressed concerns about livestock allowed to graze in and near the lakes and the Clearwater River.

August 10, 2007, Clear Lake Citizenship Dinner

The CRWD's 6th Annual Citizenship Dinner was held at the Sportsman's Center at Clear Lake. Residents in the area of Clear Lake, the upstream boundary of the listed reach of the Clearwater River addressed in this report. Manager Anderson and District Engineer Norm Wenck listened to residents and answered questions about water quality in Clear Lake.

October 3, 2007, Meeting with the Chain of Lakes Association

A meeting with the Chain of Lakes Association to go over Phase II Report and answer questions. Provided discussion topics for their next meeting.

April 16, 2008, Public Meeting

A public meeting to present the findings of the TMDL studies was held April 16, 2008 at Annandale Middle School. Representatives from all areas impacted by the TMDLs, including a representative of residents of Lake Betsy, Union Lake and Scott Lake, two members of the Clear Lake Association, and members of the Chain of Lakes Association representing Lakes Louisa and Marie. The CRWD District Administrator, project consultant, MPCA project manager and Communication coordinator were also present to answer questions about the TMDL process and outcome.

August 2, 2008, CRWD Summer Tour

CRWD hosted a tour for 81 watershed residents to view watershed projects including rain gardens, buffers, sedimentation basins, fish migration barriers. Implementation of TMDLs were discussed.

9.0 Implementation

9.1 IMPLEMENTATION FRAMEWORK

Implementing TMDLs within the CRWD will be a collaborative effort between state and local government, and individuals led by the CRWD. To meet water quality standards CRWD will leverage existing regulatory framework, and relationships to generate support for TMDL implementation efforts, providing technical support, funding, coordination and facilitation when needed. Efficiency and cost savings are realized by using existing governmental programs and services for TMDL implementation to the maximum extent possible.

9.1.1 Clearwater River Watershed District

The mission of the Clearwater River Watershed District is to promote, preserve and protect water resources within the boundaries of the District in order to maintain property values and quality of life as authorized by MS103D. To this end, the Districts Comprehensive Plan approved July 23, 2003, documents the District's goals, existing policies and proposed actions. One of the Districts stated goals is to bring all of CRWD surface water into compliance with state water quality standards, through the TMDL process.

Because the primary goal and mission of the CRWD is in line with the goal of TMDL implementation, many of the implementation strategies are extensions of existing CRWD programs and projects and can be funded using existing CRWD budgets. However, funding will be necessary. The recommended implementation plan to meet lake water quality goals and associated cost is described in the following section.

9.1.2 Counties, Cities, Townships, Lake Associations

Partnerships with counties, cities, townships and lake associations are one mechanism through which the CRWD protects and improves water quality. The CRWD will continue its strong tradition of partnering with state and local government to protect and improve water resources and to bring waters within the CRWD into compliance with State standards.

9.1.3 MPCA

The CRWD recognizes that public funding to set and implement TMDLs is limited, and therefore understands that leveraging matching funds as well as utilizing existing programs will be the most cost efficient and effective way to implement TMDLs within the CRWD. The CRWD does project a potential need for about 50% cost-share support from the MPCA or other sources in the implementation phase of the TMDL process.

9.2 REDUCTION STRATEGIES

9.2.1 Annual Load Reductions

The focus in implementation will be on reduction the annual phosphorus loads to the lake through structural and non-structural Best Management Practices. The TMDL established for each lake is shown in Section 7 of this report (Table 7.2, and allocated between sources in Table 7.3). Table 9.1 shows load reductions by source for each lake.

Table 9.1 Load Reductions by Source

	Total	Direct Watershed	Upstream Lakes	Septic Systems	Atmospheric + Groundwater	Internal
Clear Lake	90%	80%	NA	100%	0%	100%
Lake Betsy	87%	84%	85%	100%	0%	95%
Union Lake	26%	36%	NA	100%	0%	0%
Scott Lake	85%	12%	87%	NA	0%	0%
Lake Louisa	57%	21%	74%	100%	0%	0%
Lake Marie	43%	54%	48%	100%	0%	30%

T:\0002\117\Lake Response Modeling\Goal\[AVG LRModel (Clear-Betsy-Union-Scott-Louisa-Marie).xls]Summary

No reductions in atmospheric or groundwater loading are targeted because these sources are not readily controllable. The remaining load reductions were applied based on our understanding of the lakes and surrounding watersheds as well as output from the model.

9.2.2 Actions

A conceptual implementation plan for reducing phosphorus loads to the six impaired lakes is presented below (Table 9.2). Strategies are recommended based on their relative cost and effectiveness given the current level of understanding of the sources and in-lake processes. Recommendations take into account findings from stakeholder participation. Cost share breakdown is expected to be 50% from the state and federal funds, 25% from the individual, and 25% from watershed budgets.

The implementation plan pulls from existing CRWD studies and project proposals to reduce watershed phosphorus loads. Two such studies are the Watkins and Kimball Areas Stormwater Management Studies (Wenck 2003 and 2006).

Table 9.2 Conceptual Implementation Plan and Costs

Practice	TMDL	Unit Cost	Units	Note	Qty	Cost
Promote Ag BMPs (Conservation Tilling)	Nutrient, DO	$50,000	ls		1	$50,000
Replace Tile Intakes w/ Filters	Nutrient, DO, Bacteria	$500	per intake	*evaluate limestone/steel wool filter intakes to increase P removal	400	$200,000
Tile Intake Buffers	Nutrient, DO, Bacteria	$100	per intake		300	$30,000
Buffer Tributaries	Nutrient, DO, Bacteria	$350	ac		300	$105,000
Buffer Stream Banks	Nutrient, DO, Bacteria	$350	ac		200	$70,000
Tile Discharge Management	Nutrient, DO, Bacteria	$130,000	ls	* Inventory, FS, design construct	1	$130,000
Riparian Pasture/ Grazing Management Grants, Pasture Renovation, Manure Management	Nutrient, DO, Bacteria	$10,000	ea		100	$1,000,000
Street Sweeping						
Kimball	Nutrient, DO, Bacteria	$40	per curb mile	* high efficiency, 25 curb miles for 15 years	25	$30,000
South Haven	Nutrient	$40	per curb mile	* high efficiency, 5 curb miles for 15 years	5	$6,000
Fairhaven	Nutrient	$40	per curb mile	* high efficiency, 5 curb miles for 15 years	5	$6,000
Watkins	Nutrient	$40	per curb mile	* high efficiency, 15 curb miles for 15 years	15	$18,000
Lakeshore Septic Upgrade Grants	Nutrient	$7,500	ea	All impaired lakes on the chain	130	$975,000
Lake shore restoration grants (Shore land Erosion)	Nutrient	$300	ea	*grants	300	$90,000
Shallow Lakes Management Plans for Marie and Clear Lakes	Nutrient	$15,000	ea		2	$30,000
Carp Control	Nutrient	$25,000	average per year per lake	*Fish trap already installed at Louisa	40	$1,000,000
Lake Aeration	Nutrient			*3 existing aerators		$600,000
Curly Leaf Pondweed Control	Nutrient			*Lake association cost in some cases		$200,000
Kingston Wetland Maintenance and Enhancement, Potentially aeration	Nutrient, DO			Need Feasibility Study		$350,000
Lake Betsy Hypolimnetic Withdrawal & Land Application	Nutrient			Need Feasibility Study		$500,000
South Haven Stormwater Enhancement	Nutrient, DO, Bacteria					$75,000
City of Kimball Stormwater Enhancement Per 2004 Kimball Area Stormwater Management Study	Nutrient, DO, Bacteria					$500,000
City of Watkins Stormwater Enhancement per 2006 Watkins Area Stormwater Management Study	Nutrient, DO, Bacteria					$800,000
Public Outreach	Nutrient, DO, Bacteria	$10,000	per year		10	$100,000
Implementation Project Management and Administration	Nutrient, DO, Bacteria	$30,000	per year		10	$300,000
Implementation Performance Monitoring, Recommendations for Adaptive Management	Nutrient, DO, Bacteria	$25,000	per year		10	$250,000
Implementation Engineering	Nutrient, DO, Bacteria	$15,000	per year		10	$150,000
T:\0002\117\[TMDL Implementation_Report.xls]November 2009					**TOTAL:**	**$7,565,000**

10.0 Reasonable Assurance

When establishing a TMDL, reasonable assurances must be provided by demonstrating the ability to reach and maintain water quality endpoints. Several factors control reasonable assurance, including a thorough knowledge of the ability to implement BMPs as well as the overall effectiveness of the selected BMPs. This TMDL establishes load reduction goals in the upper Clearwater River Watershed District to reduce nutrient loads to the impaired lakes.

TMDL implementation will be implemented on an iterative basis so that implementation course corrections based on annual monitoring and reevaluation can adjust the strategies to meet the standards.

11.0 Monitoring

The CRWD measures lake water quality annually on a rotating basis. Precipitation, stream flow, stream water quality, and nutrient and sediment loads at three long-term monitoring stations are also measured and reported annually in the Districts Annual Monitoring Reports. This monitoring program described in detail in Appendix D will continue, and is generally sufficient to track significant water quality trends, assess progress towards goals and make adjustments towards adaptive management.

In addition to the Annual Monitoring Program, the CRWD sometimes implements special monitoring to track success of individual projects, or to investigate specific water quality concerns. Supplemental monitoring of this nature is expected throughout the course of TMDL implementation. The following recommendations are made to supplement the annual monitoring plan (note that some of these items are in reference to other TMDL studies ongoing in the CRWD):

- Assess special monitoring needs annually based on implementation projects, report findings the Annual Monitoring Report.
- Add *e.* coli to the parameter list for stream water quality samples to assess progress towards meeting bacteria TMDL. Consider adding two sampling stations along the impaired reach. This will require close coordination of District sampling technician to ensure holding times are met.
- Install a continuous pressure transducer at the watershed outlet and midpoint to measure flows and annual runoff.
- Increase sampling frequency for CR 28.2 and upper watershed lakes (Betsy, Scott, Union, Louisa and Marie). Add 3-5 more events per year during high flows to better characterize the lake response to TP loads from the Clearwater River. Weekly stream sampling, and bi-weekly lake monitoring for these lakes are recommended.
- At the start of the TMDL implementation, and every 5 years thereafter, sample all lakes in the Clearwater River Chain of Lakes in one year on a bi-weekly basis to provide a District-wide look at lake water quality. This is not imperative for large scale trend tracking, but it provides model calibration data to further evaluate the impact of upstream lakes on downstream lakes and may provide additional insight into implementation strategies.
- Increase frequency of lake DO and temperature profiles to better characterize anoxic factor. Sediment samples to quantify P release rates are recommended for Clear Lake, Scott and Betsy.

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Part II: Bacterial TMDL

Clearwater River: CD 44 to Lake Betsy

Bacterial TMDL for the Clearwater River: Clear Lake to Lake Betsy

Part II

Wenck File #0002-117

Prepared for:

CLEARWATER RIVER WATERSHED DISTRICT
PO Box 481
Annandale, Minnesota 55302-0481
(320) 274-3935

FINAL
November 2009

Prepared by:

WENCK ASSOCIATES, INC.
1800 Pioneer Creek Center
P.O. Box 249
Maple Plain, Minnesota 55359-0249
(763) 479-4200

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APPENDICES

TMDL Summary Table

TMDL Summary Table		
EPA/MPCA Required Elements	**Summary**	**TMDL Report Section**
Location	Upper portion of the Clearwater River Watershed District, in Stearns and Meeker Counties Minnesota in the Upper Mississippi River Basin.	Section 2
303(3) Listing Information	Clearwater River, Clear Lake to Lake Betsy 07010203-502 The Clearwater River was added to the 303(d) list in 2002 due to excess bacteria concentrations which impair aquatic recreation, per Minnesota Rules 7050.0150. The TMDL for Clearwater River was prioritized to start in 2004 and be completed by 2009.	Section 1
Applicable Water Quality Standards/ Numeric Targets	Criteria set forth in Minn. R. 7050.0222 (4). The numeric target for the reach is in terms of *E. Coli:* Concentrations shall not exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies between April 1 and October 31.	Section 3
Loading Capacity (expressed as monthly geometric mean)	The loading capacity, the total maximum daily load expressed as a monthly geometric mean per MPCA submittal requirements. The loading capacity is provided across five flow regimes:	Section 5

Reach	Critical Condition	Waste Load (10^9 org)	Load (10^9 org)	Margin of Safety (10^9 org)	TMDL (10^9 org)
Clearwater River	High Flow	0	237.9	91.75	329.65
	Wet	0	63.25	61.22	124.47
	Mid-Range	0	28.74	9.77	38.51
	Dry	0	3.10	9.21	12.32
	Low Flow	0	0.02	1.51	1.54

<table>
<tr><th colspan="5">TMDL Summary Table</th></tr>
<tr><th>EPA/MPCA Required Elements</th><th colspan="3">Summary</th><th>TMDL Report Section</th></tr>
<tr><td rowspan="5">Wasteload Allocation</td><td colspan="3">There are no permitted sources in the watershed allowed to discharge to surface waters. The Wasteload Allocation represents the WWTPs which operate using land application; potential future systems that have been evaluated for the area; and the NPDES Construction Permit. All have a WLA of 0, as the MPCA has rejected requests to discharge to area lakes in the past.</td><td rowspan="5">Section 5</td></tr>
<tr><td>Source</td><td>Permit #</td><td>Gross WLA (organisms/ month)</td></tr>
<tr><td>NPDES Construction</td><td>MNR100001</td><td>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 storm water requirements if they are more restrictive than requirements of the State General Permit.</td></tr>
<tr><td>Clearwater River Watershed District Future Systems</td><td>NA</td><td>0</td></tr>
<tr><td>City Watkins WWTP</td><td>MN0051365</td><td>0</td></tr>
</table>

TMDL Summary Table		
EPA/MPCA Required Elements	**Summary**	**TMDL Report Section**
Load Allocation	The portion of the loading capacity allocated to existing non-permitted sources. Proportional loads were derived by using the determined percentage contribution of each source. Wet condition proportions were applied to the High Flow and Wet flow regimes, dry condition proportions were applied to Dry and Low Flow flow regimes and the average of wet and dry condition proportions were applied to the Average flow condition.	Section 5

Source	Load Allocation (org/month 10^9)				
	High Flow	**Wet**	**Avg.**	**Dry**	**Low Flow**
Septic Systems (SSTS)	0	0	0	0	0
Urban Runoff	0.142	0.03	0.009	0	0
Riparian Livestock	87.74	23.33	12.01	1.45	0.014
Applied Manure	149.81	39.83	16.69	1.65	0.016
Incorporated Manure	0	0	0	0	0
Wildlife	0.02	0.006	0.004	0.001	0.000006
Total	237.9	63.2	28.7	3.10	0.03

Margin of Safety	The Margin of Safety is both an implicit (conservative assumptions and adaptive management) and explicit (quantified variability across the flow regime). The explicit MOS is the difference between the median and minimum flow value in each of the defined flow regimes. This accounts for the variation in flow for each flow regime.	Section 5.3
Seasonal Variation	Seasonal variation is accounted for by assumptions in the loading potential, use of a load duration curve to set TMDLs over seasonal flow regimes, and in the linkages between sources and in-stream bacteria concentrations. The in-stream data used to link sources to in-stream concentrations represents an appropriate range of seasonal and annual variations in flow and conditions. Load reduction strategies in the implementation plan are based on the relationships developed using these data.	Section 5.4

TMDL Summary Table		
EPA/MPCA Required Elements	**Summary**	**TMDL Report Section**
Reasonable Assurance	Reasonable assurance is provided by the cooperative efforts of the Clearwater River Watershed District, a watershed based organization with statutory responsibility to protect and improve water quality in the water resources in the Clearwater River watershed which contains the listed reach and its tributary watershed.	Section 7
Monitoring	The Clearwater River Watershed District monitors water quality and flow in the listed reach annually through its baseline monitoring program which it started in 1981. The CRWD will continue this annual baseline program and add monitoring as recommended in Section 8.	Section 8
Implementation	This TMDL sets forth a proposed implementation framework and load reduction strategies. The final implementation plan is part of a program to address all TMDLs within the Clearwater River Watershed District. Strategies will be refined annually as new monitoring data and evaluation indicates. The estimated cost of implementation for all the TMDLs addressed in the upper watershed is $7.6 million over 10 years.	Section 9
Public Participation	Public Comment period: Meeting location: Comments received:	Section 6

1.0 Executive Summary

The MPCA found that the Clearwater River between Clear Lake and Lake Betsy, reach ID 07010203-502 located in Meeker County, Minnesota, is impaired and does not meet Minnesota water quality standards for pathogen indicator bacteria. This reach was placed on the 303(d) list in 2004 because monitoring data have revealed that fecal coliform (FC) concentrations (a class of bacteria which is a good indicator of the potential presence of pathogens) at times exceed 2,000 colony forming units per 100 milliliters (CFU/100 mL), and/or the geometric mean FC of at least 5 samples collected within a calendar month across several years of monitoring data at times exceeds 200 CFU/100 mL. This could pose a risk to swimmers and limit other recreational uses.

Section 303(d) of the Clean Water Act requires states to set Total Maximum Daily Loads (TMDLs) for impaired waters and determine load reductions needed to achieve standards. This report presents the pathogen indicator bacteria TMDL for the Clearwater River between Clear Lake and Lake Betsy. The goal of this TMDL is to develop and execute an implementation plan with sufficient BMPs to achieve the necessary load reductions to achieve the State standard for bacteria indicators.

Though fecal coliform is the pathogen indicator bacteria used to list this reach, and comprises the available pathogen indicator data set for the reach, Minnesota recently switched from fecal coliform to *E. coli*, a sub-group of fecal coliform, as the regulated pathogen indicator bacteria. The equivalent *E. coli* concentration for the 200 CFU/ 100 mL FC chronic standard is 126 CFU/ 100 mL *E. Coli*. The equivalent *E. coli* concentration for the 2,000 CFU/ 100 mL FC accute standard is 1,260 CFU/ 100 mL *E. Coli*.

This TMDL study began in 2003, well in advance of the rules change. As such, the available data, the linkages between in-stream bacteria concentrations and sources, and the discussion of load reduction are all in terms of fecal coliform, but the formal TMDL is presented in terms of *E. Coli*. It is valid to use FC data to set a TMDL for *E. Coli* due to the strong empirical relationship between FC and *E. Coli* concentrations as documented in Minnesota streams (MPCA 2007).

Required load reductions in terms of fecal coliform to meet *E. Coli* standards range from 35 to 92 % in the listed reach. Based on the linkage analysis, the primary implementation strategies will focus on riparian pasture management and other agricultural BMPs.

.

2.0 Background

2.1 WATERSHED DESCRIPTION

The Clearwater River Watershed District is a predominantly agricultural 168-square mile watershed in central Minnesota (Figure 2.1). The Clearwater River and the Clearwater River Chain of Lakes are the predominant water features in the District. From upstream to downstream the Chain of Lakes includes Clear Lake, Lake Betsy, Union Lake, Scott Lake, Lake Louisa, Lake Marie, Caroline Lake, Lake Augusta, Pleasant Lake, Cedar Lake and Clearwater Lake.

The CRWD has been proactive in the protection and improvement of water quality and has made considerable improvements in water quality throughout the District. However, monitoring data has shown that a 9.7-mile stretch of Clearwater River between Clear Lake and Lake Betsy (ID 07010203-502) does not meet water quality standards for fecal coliforms. The impaired reach and its tributary watershed are shown in Figure 2.2.

Figure 2.1. Clearwater River Watershed Location Map

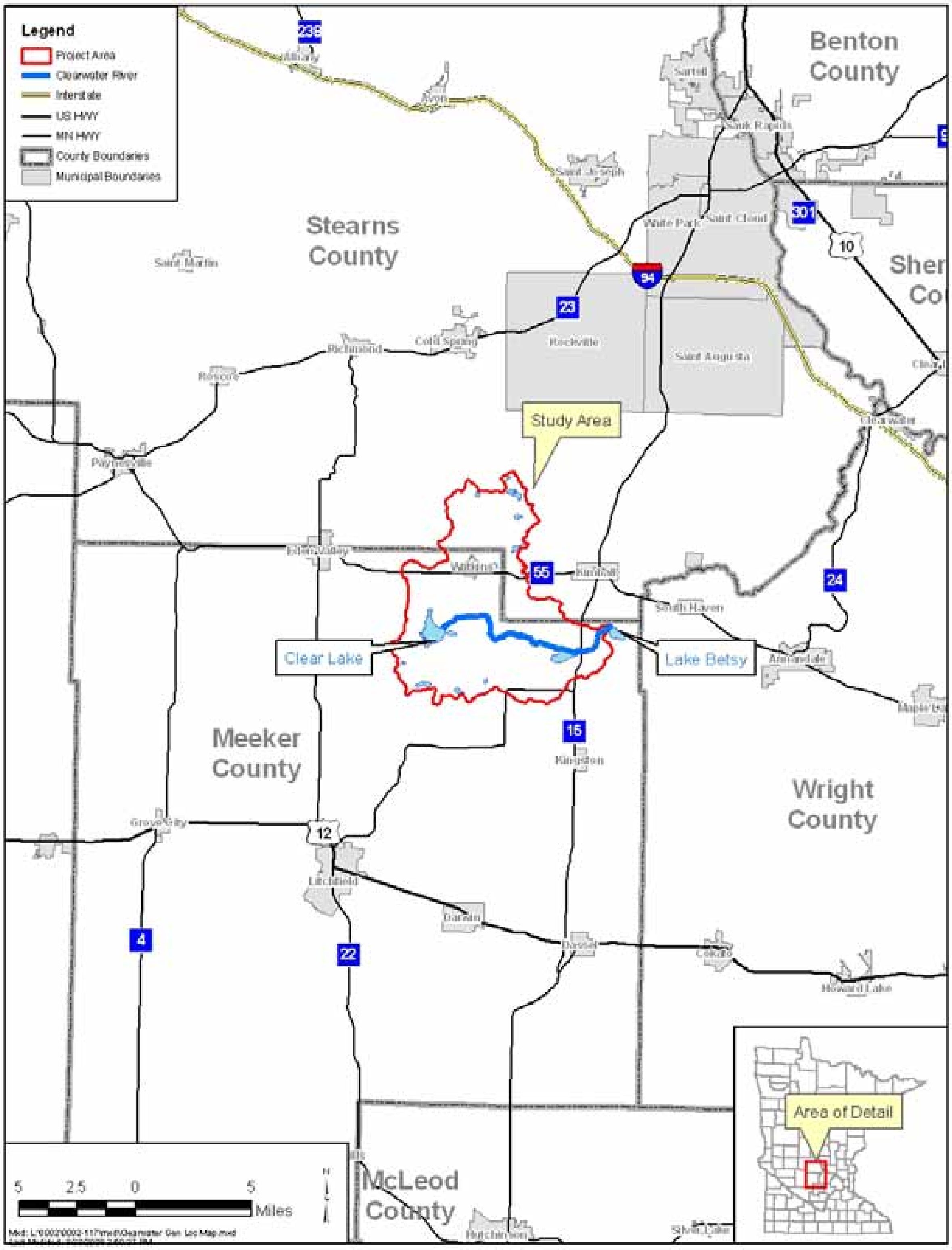
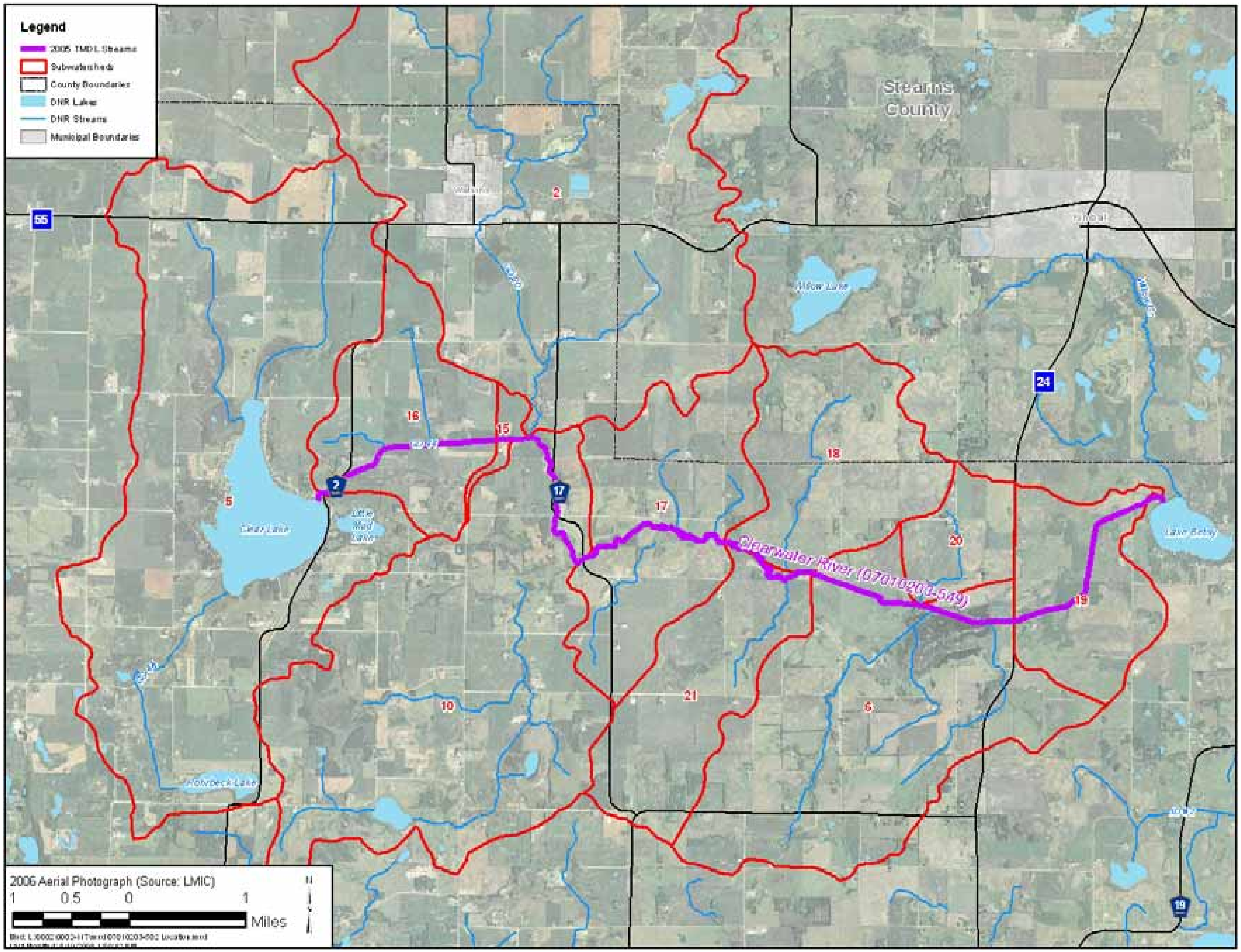


Figure 2.2. Clearwater River, Listed Reach from Clear Lake to Lake Betsy and Tributary Watershed



2.2 LAND USE

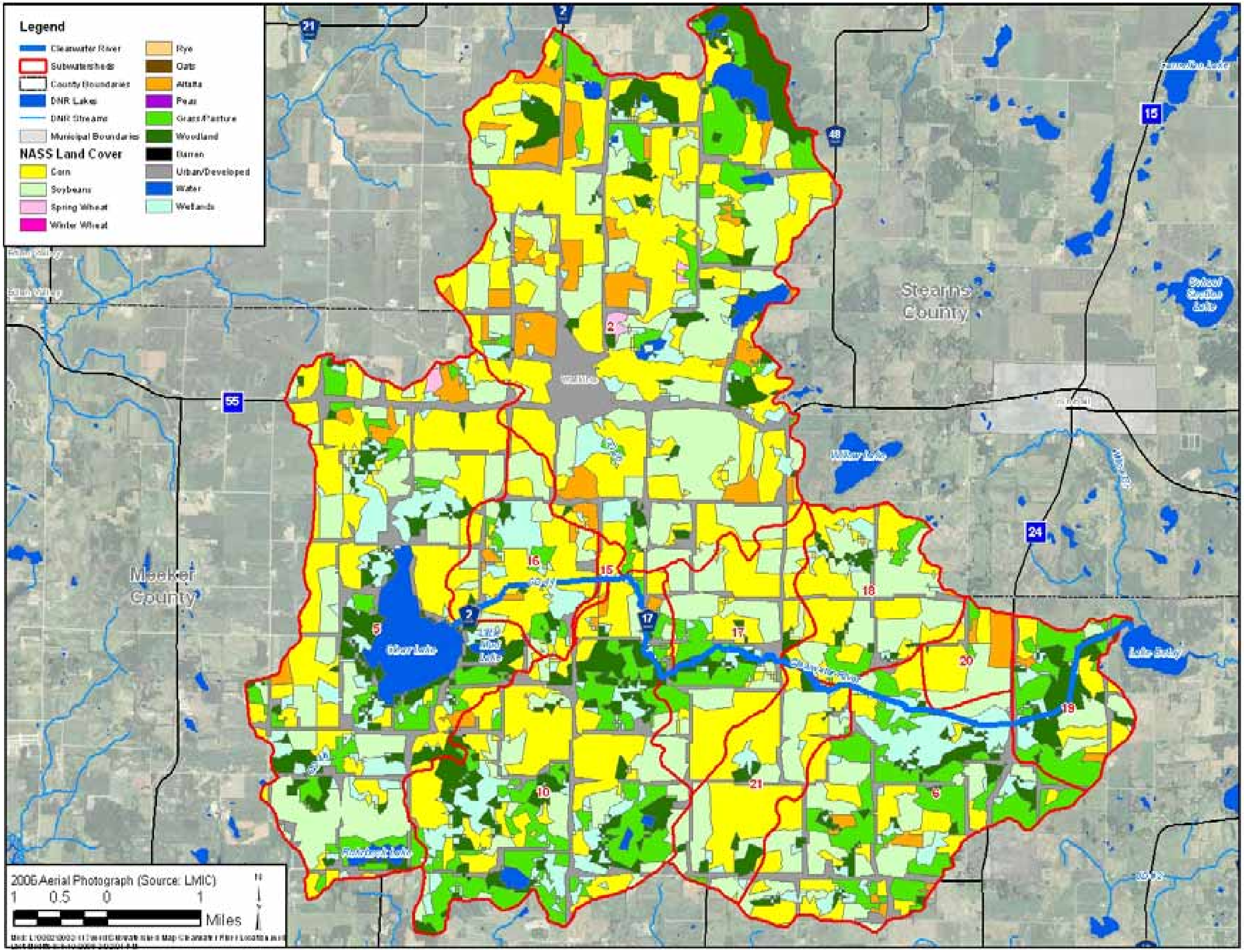
The Clearwater River watershed is comprised mainly of agricultural land uses. The National Agriculture Statistics Services (NASS) 2006 cropland data layer was used to determine land use within the sub-watersheds tributary to the listed reach. This data is an appropriate data set for large agricultural watersheds as the use categories within the data set are more specific in describing agriculture uses, such as separately classifying corn, soybeans and alfalfa. Other categories in the data set are more general such as urban, wetlands or woodlands.

The sub-watersheds that contribute to the TMDL for the Clearwater River reach between Clear Lake and Lake Betsy are listed in Table 2.1. The land use data for each of these sub-watersheds is shown in Figure 2.3. Overall, corn is the most frequent land use covering 10,601 acres or 31.3 percent of the 33,875 acres of the area within the sub-watersheds between Clear Lake and Lake Betsy. Soybeans were the next most frequent land use, covering almost 7,700 acres or 22.7 percent of the total area. Grasslands and pasture (12%), woodland (9%), urban/developed (10%), and wetlands (8%) range between about 3,000 and 4,000 acres each.

Table 2.1 Land Use in the Sub-watersheds Tributary to the Listed Reach of the Clearwater River.

Landuse	Total (ac)	Percent
Corn	10,601.34	31.29%
Soybeans	7,665.40	22.63%
Spring Wheat	73.37	0.22%
Alfalfa	1,269.44	3.75%
Peas	0.49	0.00%
Grass/Pasture	3,932.62	11.61%
Woodland	3,002.73	8.86%
Urban/Developed	3,516.33	10.38%
Water	1,000.65	2.95%
Wetlands	2,813.19	8.30%
Total (acres)	33,875.55	100.00%

Figure 2.3 Land Use in the Sub-watersheds Tributary to the Listed Reach of the Clearwater River



2.3 STREAM PHYSICAL CHARACTERISTICS

The Clearwater River between Clear Lake and Lake Betsy extends between CR 35.3 in the upstream end at Clear Lake and CR 25.6 at Lake Betsy (Figure 2.4). The channel in this 9.7 mile reach can be broken into three distinct sections based on channel characteristics such as slope, morphometry, channel bed and riparian land use. Table 2.2 summarizes the stream characteristics for each reach.

In the 1.7-mile upstream segment of the Clearwater River between Clear Lake and CR 33.6 the slope is 0. The channel is primarily ditched in this segment, sometimes draining large wetland complexes. The riparian land use is primarily pasture, wetland and agriculture (primarily grass pasture and row crop, see Section 2.2, see also Phase II Report Appendix H for Field Survey Results).

The next reach between CR 33.6 and CR 29.0 is steeper; in fact the maximum slope of 33 ft/ mile occurs between CR 33.6 and CR 31.8. Downstream of this, the slope ranges from 5 to 10 ft/ river mile. The portion of the river between CR 33.6 and CR 29.0 is more sinuous, the sediments are generally coarser. The channel in this segment is mostly flanked by a woody riparian buffer consisting of trees and grasses.

Between CR 29.0 and CR 25.0 the river is ditched through large wetlands. The first of these wetlands is the Kingston wetland located between CR 29.0 and CR 27.2. In 1985 a CRWD project diverted low flow streamflow from the main ditched channel and around to the edges of the Kingston wetland allowing stream flow to filter back into the channel through the wetland. The project was one of several in the 1980 Clearwater River Chain of Lakes Restoration; an effort that reduced total phosphorus and sediment loading in the Clearwater River and downstream lakes by an order of magnitude.

Downstream of CR 25.6, the slope of the river is small, and in fact there is backflow from Lake Betsy into the Clearwater River from time to time.

A navigable document with photos of the stream, assessment of the sediments, and riparian cover are presented in a spatial framework in Phase II Report, Appendix H (Wenck 2007).

Figure 2.4 Monitoring Stations in the Clearwater River between Clear Lake and Lake Betsy

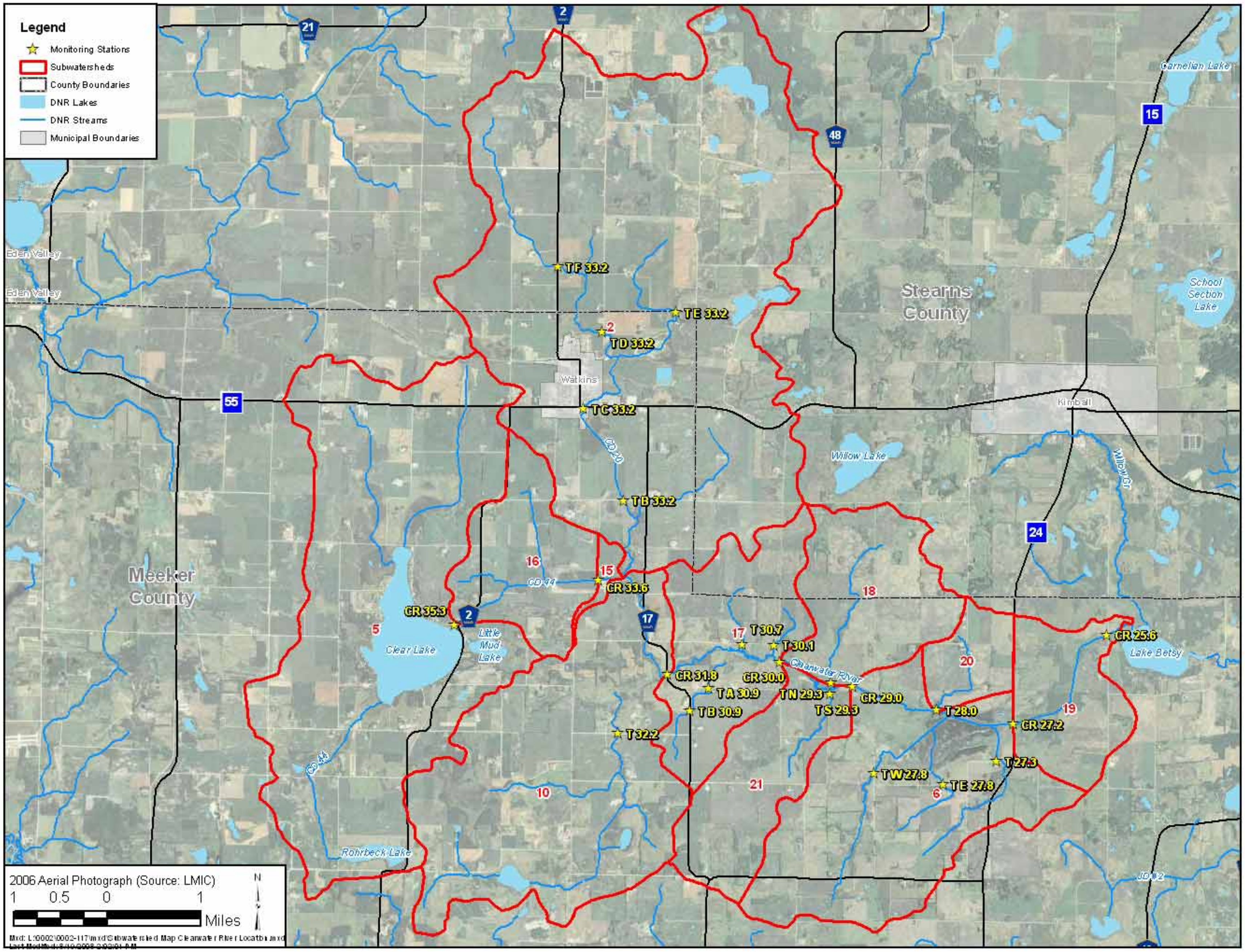


Table 2.2 Stream Characteristics of the Clearwater River between Clear Lake and Lake Betsy

River Mile	Drainage Area (acres)	Elevation (ft NGVD)	Slope (ft/ mile)	Stream Width (ft)	Tree Canopy	Sediment Description	Description
CR 35.3	6,801	1,129	--	12	Mowed turf grass riparian, 75% upstream, 25% downstream	gravel and cobbles, medium to coarse sand	Clear Lake Outlet
CR 33.6	8,214	1,129	0	12	20% upstream, 100% downstream	medium to coarse sandy clay upstream; coarser sand, some gravel and cobble.	Straight narrow ditch with steep banks upstream, flowing through agricultural land. Downstream, channel has more meanders and is heavily forested. Channel widens and sediment is coarser graied.
CR 31.8	23,679	1,070	33	14	75% in the area	Fine to medium sand, layers of gravel, some cobble and boulders	Meandering channel, undercut banks, braided, sediment deposits
CR 30.0	25,602	1,060	6	14	100% upstream, 90% downstream	clean medium to coarse sand, organic material at surface	Meandering channel, undercut banks, braided, sediment deposits
CR 29.0	28,633	1,050	10	18	60% upstream, 90% downstream	Medium to coarse sand, some gravel	Meandering channel, undercut banks, braided, sediment deposits, Kingston Wetland downstream
CR 27.2	32,704	1,040	6	43	10% upstream, 60% downstream	Wetland soils, organic muck	County Road 15, ditched and dredged channel
CR 25.6	33,877	1,032	5	35	90% upstream, 20% downstream	Sandy edges, organic muck	Ditched, straight channel with undercut banks. Forested banks upstream. Cow pasture on the northbank downstream.
CR 25.0	33,976	1,032	0	--			Lake Betsy Inlet

T:\ 0002\75_TMDL Ph2\Report\[Rpt Outline.xls]Table4.1

2.4 FIELD MONITORING

Field monitoring for the Clearwater River between Clear Lake and Lake Betsy bacteria TMDL was conducted between August 2005 and October 2006. Field data collection was conducted to determine the spatial and temporal extent of the bacteria impairments on the Clearwater River and to quantify the sources. The TMDL study included a field survey, bi-weekly water quality sampling as well as synoptic surveys, continuous and discrete flow measurements, passive sampling for optical brighteners, and a time of travel study. The findings of this study are presented in the Phase II Report (Wenck 2007).

The CRWD also collected bacteria data through special monitoring between 1999 and 2002 to track bacteria sources in the watershed. These data are summarized in the Phase I Report (Wenck 2004).

Data were collected during wet and dry weather and over a range of flow conditions. The findings of these studies that are relevant to the TMDL are summarized in the sections that follow.

2.5 WATER QUALITY

Table 2.3 compares water quality in the Clearwater River in 2005 and 2006 to that of minimally impacted streams in the North Central Hardwood Forest Ecoregion.

Table 2.3 Water Quality in the Clearwater River and Minimally Impacted Streams of the North Central Hardwood Forest Ecoregion

	Water Quality of Minimally Impacted Streams in NCHF, Annual 1970-1992*				2005-2006 Clearwater River, Clear Lake to Lake Betsy			
Parameter	Mean	SD	MAX	MIN	Mean	SD	MAX	MIN
Conductivity (µmhos/cm)	298	83	840	40	826	262	1,716	442
pH (SU)	8.1	0.3	8.9	7.2	7.7	0.8	9.0	5.6
TSS (mg/L)	13.7	22.5	330	0.5	20	51	387	2
Ammonia-N (mg/L)	0.2	0.2	1.3	0.02	0.1	0.1	0.6	0.1
NO2+NO3 (mg/L)	0.16	0.15	0.65	0.01	3.7	6.6	48	0.20
TP (mg/L)	0.13	0.15	1.6	0.01	0.21	0.13	0.72	0.04
Fecal Coliform (#/100mL)	920	3,277	27,000	4	621	12,609	60,000	10
BOD5 (mg/L)	2.7	2.1	17	0.3	2.9	1.3	7.0	2.0

*McCollar & Heiskary, 1993

T:\0002\75_TMDL Ph2\Report\[RAK FINAL DATA.xls]Table 4.2

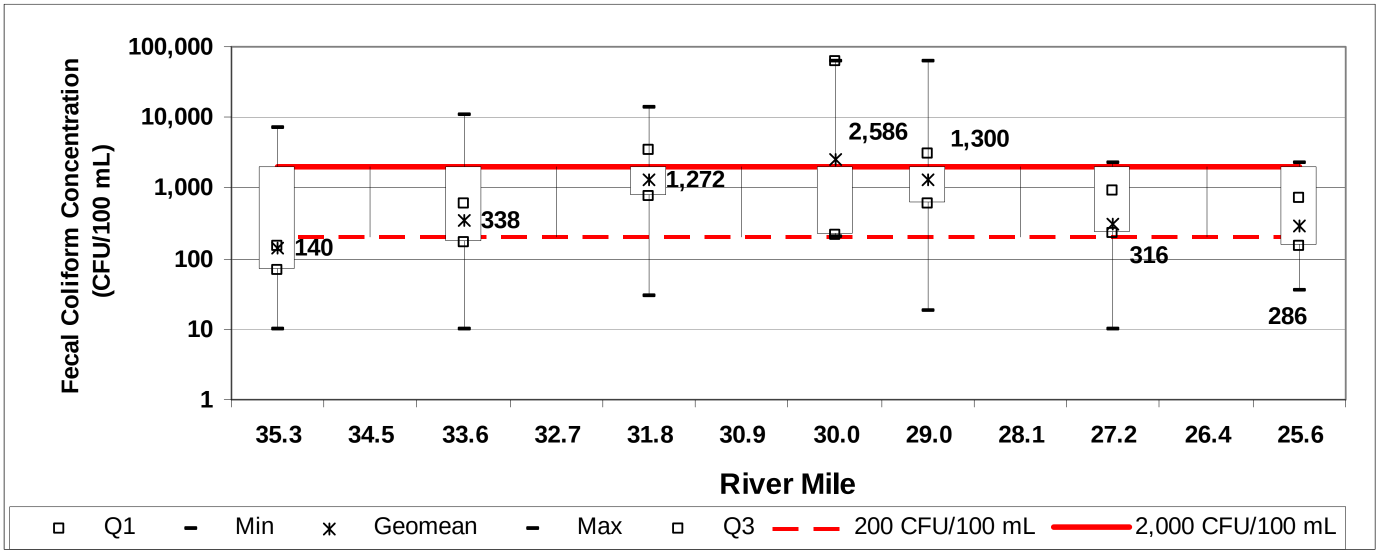
The most striking differences between 2005 and 2006 Clearwater River means and Ecoregion means are conductivity, NO2 +NO3, TSS, and total phosphorus. These values are consistent with a stream impacted by anthropogenic activities.

The high mean conductivity in the Clearwater River relative to the mean conductivity measured in minimally impacted streams in the ecoregion further indicates that the stream has a groundwater contribution in this reach.

The chemical characteristics of the flow in the listed reach of the Clearwater River along with the dominant land use in the tributary watershed point to agricultural uses as the primary source of impairment, though all sources require consideration. Concentrations of NO2+NO3 are an order of magnitude higher in the Clearwater River compared to those of minimally impacted streams; NO2+ NO3 is a key component of agricultural runoff because of its use as fertilizer. Nitrogen fertilizers may be over-applied in cultivated areas leading to high concentrations in waters with agricultural watersheds. In further support of this conclusion, 55% of the land area tributary to the listed reach is row crops.

Geomean fecal coliform concentrations were lowest, 140 cfu/ 100mL, at the upstream boundary of the listed reach of the Clearwater River. Concentrations increased steadily downstream and were highest between CR 31.8 and CR 29.0 with concentrations of 1,272 cfu/ 100mL and 1,300 cfu/ 100mL respectively (the peak value of 2,586 cfu/ 100mL represents two sample events). Figure 2.5 shows the longitudinal geometric mean, minimum, maximum and log standard deviation of data collected during bacteria TMDL monitoring.

Figure 2.5 Longitudinal Fecal Coliform Bacteria Concentrations in the Clearwater River



The bacteria impairment impacts the entire reach, but appears to be highest in the central portion of the river. This finding provides important insight as to the optimal locations within the tributary watershed to implement the recommended load reduction strategies.

The load reductions required to meet the State water quality standards for bacteria range from 35 to 92 percent across the listed reach of the Clearwater River (Figure 2.5). These load reductions are based on fecal coliform bacteria data that was collected during the Clearwater River Bacteria TMDL study. The current state standard is for *E. Coli*. Empirical relationships between fecal coliform and *E.Coli* in Minnesota suggest that reductions set for fecal coliform can be appropriately applied to meet *E. Coli* standards.

3.0 Applicable Water Quality Standards and Numeric Targets

This Clearwater River reach is classified as a Class 2B, 3C, 4a, 4B, 5 and 6 water and is protected for aquatic life (warm and cool water fisheries and associated biota) and recreation (all water recreation activities including bathing). The Minnesota standard for class 2B waters is as follows:

Minn. R. ch. 7050.0222 subp. 4, *E. Coli* water quality standard for class 2B and 2C waters states that *E. coli* shall not exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples in any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies between April 1 and October 31.

Endpoint *E. coli* concentrations were determined to be the State water quality standard of a monthly geometric mean of 126 cfu/ 100 ml and no value exceeding 1,260 cfu/ 100 ml for the period of April 1 through October 31. However, the focus of this TMDL is on the "chronic" standard of 126 cfu/ 100 ml. It is believed that achieving the necessary reductions to meet the chronic standard will also reduce the exceedances of the acute standard (MPCA 2002).

This standard, current as of 2008, represents a change from the historic use of fecal coliform as a regulated pathogen indicator. Because the change is recent, the in-stream water quality data available for this TMDL study was fecal coliform, not *E. Coli.* The fecal coliform data was used to link watershed sources of bacteria to in-stream bacteria concentrations and to determine effective load reduction strategies. The *E. Coli* standard was determined to be as protective as the fecal coliform standard, and load reductions that are applicable to fecal coliform will result in similar load reductions to E. Coli bacteria (MPCA 2007).

For reference, the historical fecal coliform standards were as follows: that Fecal Coliform shall not exceed 200 organisms per 100 milliliters as a geometric mean of not less than five samples in any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 2,000 organisms per 100 milliliters. The standard applies between April 1 and October 31.

4.0 Source Assessment

An assessment of sources of bacteria in the watershed is discussed in this section. The sources are non-point source in nature; there are no known point sources within the entire tributary watershed of the Clearwater River listed for bacteria impairment. Bacteria sources in the watershed tributary to the listed reach of the Clearwater River include livestock and associated land practices including feedlots and pasturing, crop farming and associated land uses including drain tiles, runoff from the City of Watkins, septic systems, pets, and natural wildlife sources.

Though the applicable water quality standards and numeric targets identified are for *E. Coli*, the source assessment was completed using available fecal coliform data. Sources are evaluated and linked to in-stream water quality based on the fecal coliform data, even though the standard is for *E. Coli*. The linkage is possible due to the strong empirical relationship between E. Coli and fecal coliform concentrations in Minnesota streams (MPCA 2007). Future sampling will be for *E. Coli.*

The number of fecal coliform samples collected in 2005 and 2006 exceeding the former fecal coliform chronic and acute standards (200 and 2,000 CFU/ 100 mL respectively) is compared to channel flow and runoff conditions in the main stem (Table 4.1) and in main stem plus tributaries (Table 4.2).

Table 4.1 2005 and 2006 Fecal Coliform Samples Exceeding 200 CFU/100 mL and 2,000 CFU/100 mL and Associated Channel Conditions (Main Stem)

Main Stem Bacteria Samples Collected in 2005 and 2006 (CFU/ 100 mL)						
	Number of samples (n)	Accute Exceedance, n >2,000	Chronic Exceedance, 200<n <2,000	No Exceedance, n<200	Downstream Flow (cfs)	Conditions (1)
08/15/05	4	0	3	1	0.4	Dry
04/18/06	8	0	2	6	29.3	Dry
05/30/06	7	1	3	3	11.1	Dry
06/15/06	7	0	3	4	3.8	Dry
07/12/06	5	3	2	0	0.5	Dry
06/28/06	7	0	5	2	3	Moderate
07/26/06	4	1	2	1	1.1	Moderate
09/26/05	9	5	4	0	10.9	Wet
08/23/06	2	2	0	0	0.3	Wet
09/25/06	6	5	1	0	7.6	Wet
10/05/06	6	0	6	0	6.3	Wet

T:\0002\117\Revised TMDL Reports\[Bacti LInk_2.xls]Bact 2
(1) Dry= more than 5 days since last precipitation event;
Moderate= 4 or 5 days since last precipitation event
Wet= 1, 2, or 3 days since last precipiation event

Table 4.2 2005 and 2006 Fecal Coliform Samples Exceeding 200 CFU/100 mL and 2,000 CFU/100 mL and Associated Channel Conditions (Main Stem & Tributaries)

Main Stem & Tributary Bacteria Samples Collected in 2005 and 2006 (CFU/ 100 mL)						
	Number of samples (n)	Accute Exceedance, n >2,000	Chronic Exceedance, 200<n <2,000	No Exceedance, n<200	Downstream Flow (cfs)	Conditions (1)
08/15/05	9	0	5	4	0.4	Dry
04/18/06	23	0	3	20	29.3	Dry
05/30/06	9	1	5	3	11.1	Dry
06/15/06	9	1	4	4	3.8	Dry
07/12/06	5	3	2	0	0.5	Dry
06/28/06	9	0	6	3	3	Moderate
07/26/06	4	1	2	1	1.1	Moderate
09/26/05	22	12	10	0	10.9	Wet
08/23/06	2	2	0	0	0.3	Wet
09/25/06	7	5	2	0	7.6	Wet
10/05/06	7	1	6	0	6.3	Wet

T:\0002\117\Revised TMDL Reports\[Bacti LInk_2.xls]Bact 2
(1) Dry= more than 5 days since last precipitation event;
Moderate= 4 or 5 days since last precipitation event
Wet= 1, 2, or 3 days since last precipiation event

In the main stem of the Clearwater River, 71% of the acute bacteria exceedances occurred within three days of a precipitation event (See Table 4.1 column 3 for source: the number of acute exceedances that occurred in the wet weather n=12 from the 3rd column in the table, over the total, n=17, is 71%). This is consistent with historical data that showed 77% and 83% of fecal coliform samples exceeding 2,000 CFU/ 100 mL at CR 33.0 and CR 28.2 respectively occurred within 3 days of a precipitation event. Wet weather exceedances point to a multiplicity of sources.

Acute exceedances in dry weather are highly correlated to the presence of livestock in the streams, though also occurred in wet weather. Chronic exceedances occur in both wet and dry weather.

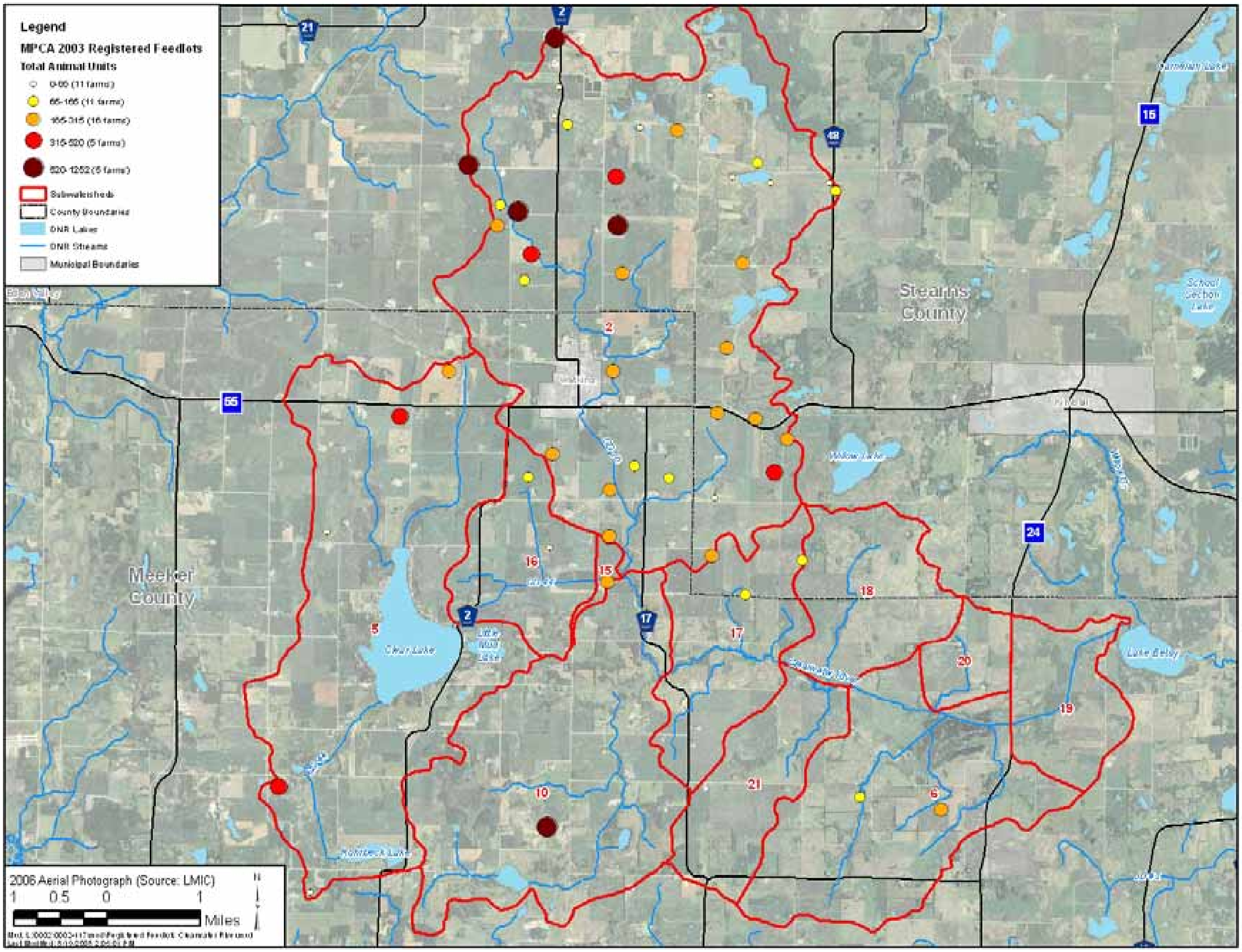
4.1 SOURCE DESCRIPTIONS AND RESULTS

4.1.1 Livestock

Livestock sources include several categories such as feedlots, overgrazed pastures, surface application of manure and incorporated manure. Registered feedlot operations and their associated animal units within the watershed are presented in Figure 4.1. In the Clearwater River, fecal coliform concentrations in excess of 60,000 CFU/ 100 mL during dry weather conditions in 2005 and 2006 were primarily observed in areas with riparian livestock pastures where livestock were observed during sampling events to have unrestricted, continuous access to the stream.

Observation of livestock management practices of the watershed would suggest that livestock has access to the stream frequently enough in some areas such that it contributes to the impairment at a level that requires action.

Figure 4.1 Registered Feedlots in the Watershed Tributary to the Listed Reach of the Clearwater River between Clear Lake and Lake Betsy



4.1.2 Crop Farming

Corn and soy bean rotation are the primary row crops in the watershed tributary to the portion of the Clearwater River between Clear Lake and Lake Betsy. The high in-stream concentrations of NO2 + NO3 indicate that crop farming is a source of nutrients, bacteria and oxygen demand to the stream. Organic and ammonia nitrogen in animal waste also contributes to NO_2 + NO_3 through the process of nitrification. In areas where surface manure is applied to crop fields, open tile inlets can serve as a transport mechanism to deliver bacteria to the Clearwater River and its tributaries.

4.1.3 Surface Manure Application

Manure from animal feedlots is applied to the landscape through one of two methods, surface application or liquid incorporation. Large hog or dairy feedlot operations typically have a liquid manure pit and these operations use liquid incorporation to apply manure. However, there are very few of these large feedlot operations within the Clearwater River watershed between Clear Lake and Lake Betsy. The vast majority of feedlot operations in the listed portion of the watershed are small to medium sized beef, dairy and hog operations. These farms surface apply manure, typically starting in mid to late fall after harvesting is complete with surface manure applications continuing through the winter. Surface applied manure is worked into the soil with agriculture tillage equipment, which may take place immediately after application but may be delayed until the spring immediately prior to planting. To account for the varied application, it was assumed that 20% of incorporated manure spreading occurred in the spring with the remaining 80% occurring in the fall. Some of the exceedances of the bacteria standard observed between 1992 and 2003 coincide with periods of land application which may indicate land application does contribute to the bacteria impairment. Land application is conducted in the manner described in this paragraph, though specific application rates are not available.

4.1.4 Septic Systems (SSTS) and Human Waste

Failing or nonconforming septic systems can be an important source of fecal coliform bacteria especially during dry periods when these sources continue to discharge and runoff driven sources are not active. No homes, and therefore no septic systems, are located close enough to the Clearwater River to be a source of bacteria to the Clearwater River in the impaired reach. The absence of optical brighteners, a major component of residential wastewater, in the Clearwater River indicates that direct discharge of SSTS to tile lines is not an issue in this reach.

Wastewater from the City of Watkins and most of the homes ringing Clear Lake are routed to the WWTP at Watkins and land-applied north of the City outside of the area tributary to Clearwater River and is therefore not a source for bacteria presently.

Seven homes on the southeast portion of Clear Lake are not connected to the sanitary sewer in this area and are reported to be using SSTS. Treated wastewater from these homes likely infiltrates via groundwater to Clear Lake. These homes are not a likely source of bacteria to the Clearwater River for two reasons. First, the systems are reported to be compliant, which means no detectable FC within 50 feet of system, and second, any bacteria that does make it to the lake is dispersed in the large volume of lake water and is not a concentrated source of bacteria to the river downstream. This is further supported by the absence of high bacteria concentrations at the outlet of Clear Lake, and the absence of optical brighteners in the Clearwater River. Note: The Clearwater River was sampled for optical brighteners, a major component of household wastewater and therefore an indicator of the presence of household wastewater, during Phase II. No optical brighteners were detected results and sampling methods are summarized in Appendix I of the Phase II Report.

4.1.5 Wildlife

The DNR area wildlife manager, Mr. Fred Bengston, stationed in Sauk Rapids, was interviewed regarding wildlife populations in the CRWD. A 2007 DNR assessment of whitetail deer indicated populations were 8.0 deer/ square mile in the western portion of the watershed near the listed reach of the Clearwater River (Minnesota DNR, 2007). Breeding populations of waterfowl were estimated based on a 2007 Waterfowl Breeding Population Survey (Minnesota DNR, 2007). The study found 5.1 ducks and 3.3 Canada geese per square mile in areas with similar wetland densities as the Clearwater River watershed. Since the population assessment documents breeding populations, it is representative of spring and early summer populations of waterfowl. As juveniles reach maturity, the population densities increase towards late summer and fall until migration (Minnesota DNR 2007).

Mr. Bengston indicated that while wildlife populations were considered moderate to high throughout the watershed, wildlife populations were not concentrated in areas along the Clearwater River corridor that would allow them to contribute significantly to high bacteria concentrations in the Clearwater River. In short, the pathways to transport the bacteria from the producer (the animal) to the impaired water are not significant, and therefore the bacterial loading from wildlife is not expected to be significant.

4.1.6 Urban Stormwater Runoff

Untreated urban stormwater has demonstrated fecal coliform concentrations as high as, or higher than grazed pasture runoff, cropland runoff, and feedlot runoff (USEPA 2001, Bannerman et al. 1993, 1996). There is relatively little urban area in the portion of the Clearwater River watershed listed for bacteria impairment, with urban and developed lands comprising approximately 10 percent of the total area. Consequently, urban stormwater is a relatively small proportion of fecal coliform load in this watershed.

One urban area, Watkins, lies within the watershed tributary to the Clearwater River between Clear Lake and Lake Betsy. The City of Kimball lies within the CRWD, however it is located within a subwatershed that drains into Lake Betsy via Willow Creek which enters the lake downstream of the listed reach of the Clearwater River. Therefore runoff from the City of Kimball is not a contributing source of bacteria considered in this TMDL.

Watkins storm water enters the Clearwater River via County Ditch 20, between monitoring stations at CR 33.8 and CR 31.8. Flows in the upper portion of the Clearwater River are largely comprised of flow from this tributary area. A bacteria population in excess of the upper detection limit, >60,000 CFU/ 100 mL, was observed in the Watkins tributary (sample location

TB 33.2) during the wet weather synoptic survey, the concentration was only 45 CFU/ 100 mL during the dry weather synoptic survey.

4.2 LINKING WATER QUALITY TARGETS AND SOURCES

A key aspect of a TMDL is the linkage between the pollutant sources and the selected water quality target or instream loads. Establishment of this linkage provides for the quantification of the assimilative capacity of the stream while still supporting State water quality standards. This linkage allows for loads or load reductions to be allocated among the sources that will ultimately result in the water body meeting standards. The linkages can be obtained through intensive modeling or through the use of qualitative assumptions backed by a sound understanding of pollutant dynamics in the watershed. Both techniques require significant professional judgment and selection of terms based on assumptions. However, intensive modeling assumptions are often complex and difficult to explain to local stakeholders. Alternatively, the utilization of qualitative assumptions can be clearly explained to those who they may affect the most. The qualitative assumptions can be tested through statistical analysis of a rigorous data set and a thorough understanding of pollutant source practices and dynamics.

4.3 SELECTION OF MODEL AND TOOLS

The TMDL was set using the load duration approach. Flow data from the District long term monitoring station located at river mile 28.2 (CR 28.2) was used in conjunction with the *E. Coli* standard to develop the TMDL. The District began collecting discrete flow measurements at the CR 28.2 monitoring station in 1981. Typical monitoring years included collecting monthly flow measurements during the months when the river was flowing (i.e. no ice cover), generally ranging from the months of March through September for most years. Additional flow measurements were collected on a more frequent basis during the synoptic surveys and water quality monitoring to support the TMDL study on the Clearwater River. A total of 211 discrete flow measurements were available over the period of record for the CR 28.2 monitoring site.

The discrete flow measurements from CR 28.2 were compared to continuous flow measurements collected downstream at the Fairhaven Dam monitoring station, which is also downstream of the listed reach. A comparison of the two flow data sets revealed that the shape of the flow duration curves for the CR 28.2 and Fairhaven Dam was similar, even though there are considerably more data points available for the Fairhaven Dam monitoring station. The additional data points from a continuous dataset do produce a smoother flow curve and also flatten out the high and low ends of the flow curve. However, using the discrete flow measurement provides a conservative measure for setting the TMDL, especially at the critical low flow conditions. The lower flows recorded for the low flow condition from the discrete flow measurements would allow for a smaller bacteria load when setting the TMDL to meet the water quality standard as compared to using the continuous dataset from the Fairhaven Dam site. Based on the these described factors it was determined that the discrete flow measurements from the CR 28.2 monitoring site, which is located within the listed reach of the Clearwater River, was an appropriate flow data set to use in setting the bacteria TMDL.

The load duration curve approach begins by ranking all of the recorded flows over time to determine a percentage of the time specific flow levels are exceeded. These flow values are then multiplied by the State standard for *E. Coli*, of 126 org/100 ml, to determine the allowable bacteria load across all flow regimes. The allowable loads are calculated as the total number of organisms/month of *E. Coli* bacteria that can be delivered to the river that will result in a concentration meeting the State standard. The calculated monthly loads are plotted as a continuous curve on a logarithmic scale which displays the bacteria load at the state standard across all flow regimes.

To develop the linkage between watershed sources and water quality targets, we used the approach developed for the Southeast Minnesota Regional Fecal Coliform TMDL (MPCA 2002). This approach entails a two-step process that identifies the amount of fecal coliform potentially available for runoff and links these quantified sources to the streams through a runoff potential. This approach is ultimately based on two sets of clearly defined assumptions: 1) The amount of fecal coliform available for runoff from each source and 2) the potential for that fecal coliform to reach surface waters under wet and dry conditions. These analyses will result in a partitioning of the stream load among the sources based on the proportions available for delivery from the watershed and the potential for that source to reach surface waters.

4.4 FECAL COLIFORM AVAILABLE FOR RUNOFF

The first set of assumptions divides the fecal coliform produced in the watershed into several source areas such as surface applied manure (Table 4.3). It is important to note that this process assumes that all fecal coliform produced in the watershed, remains in the watershed. For example, while all dairy cow manure is potentially available for runoff, 7% is assumed to be in riparian pastures while 93% is assumed to be applied to the watershed surface. Additionally, the assumptions identify the portion of the load available seasonally and the quantity that may be available. For example, it was assumed that 10% of cat and dog waste in urban areas was improperly managed. These assumptions are gross and are intended to represent average conditions in the watershed (MPCA 2002).

The assumptions were first developed as a part of the Southeast Regional TMDL (MPCA 2002; Mulla et al 2001) and then adjusted based on local knowledge of the watershed and input from the Meeker County FSA office to reflect current practices and conditions in the contributing watershed.

Table 4.3. Assumptions Used to Estimate the Amount of Available Coliform Production Available for Potential Runoff or Discharge into the Clearwater River and its Tributaries

Category	Source	Assumption
	Riparian Livestock	7% of Dairy 17% of Beef Manure 59% of Swine Manure 100% Horse Manure
	Surface Applied Manure	93% of Dairy Manure 83% of Beef Manure 100% of Poultry Manure 41% Swine Manure; 20% of this manure applied in Spring 80% of this manure applied in Fall
	Incorporated Manure	0% of Dairy Manure 0% of Swine Manure
Human	Failing Septic Systems and Unsewered Communities	All waste from failing septic systems and unsewered communities
Wildlife	Deer	All fecal matter produced by deer in basin
	Geese	All fecal matter produced by geese in basin
	Other Wildlife	The equivalent of all fecal matter produced by deer and geese in basin
Urban Stormwater Runoff	Improperly Managed Waste from Dogs and Cats	10% of waste produced by estimated number of dogs and cats in basin

Estimated daily fecal coliform potentially available for runoff are shown in Table 4.4. The daily fecal coliform production estimates for each animal unit or individual were based on literature values (MPCA 2002).

Table 4.4. Estimated Monthly Fecal Coliform Available During Runoff Events

Category	Source	Animal Units or Individuals Derived from Tables*	Fecal Coliform Organisms Produced Per Unit Per Month (10^9)**	Total Fecal Coliform Available (10^9)	Total Fecal Coliform Available by Source (10^9)
	Riparian Livestock	587.7 Dairy Animal Units	2190	1,290,000	4,090,000
		582.5 Beef Animal Units	3960	2,310,000	
		204 Swine Animal Units	2440	497,000	
		20 Horse Animal Units	12.8	256	
		0 Poultry Animals Units	1030	0	
	Surface Applied Manure***	7374.6 Dairy Animal Units	2190	16,162,800	27,900,000
		2887.5 Beef Animal Units	3960	11,426,400	
		140 Swine Animal units	2440	340,928	
		0 Horse Animal Units	12.8	0	
		2.25 Poultry Animal Units	1030	2,328	
Human	Failing Septic Systems and Unsewered Communities	931 People	60.9	56,700	56,700
Wildlife	Deer	423 Deer	15.2	6,440	12,900
	Geese	172 Geese	0.317	54.5	
	Other Wildlife	Equivalent of Deer	15.2	6,440	
Urban Stormwater	Improperly Managed Waste from Dogs and Cats	891 Dogs and Cats	152	135,000	135,000
Total					32,194,600

* Example –Dairy Animal Units in Basin x 1% on Overgrazed Pasture in Riparian Areas = Animal Units
** Derived from literature values in Mulla et. Al (2001), USEPA (2001), and Alderisio and DeLuca (1999)

4.4.1 Fecal Coliform Delivery Potential

The second set of assumptions provides information on the potential for the previously quantified source areas to reach surface waters. Developing the delivery potential for each source is based on assigning risk values on a scale of 1-5 (1= very low risk and 5 = very high risk). These risk assignments are then translated into delivery percentages where a very low potential delivers one percent, low potential is two percent, moderate is four percent, high is six percent, and very high is eight percent. (Table 4.5; Mulla et al. 2001).

These numbers were based on those used in the Southeast Minnesota Regional Bacteria TMDL (MPCA 2002) and adjusted based on land use and local practices to reflect conditions in the watershed tributary to this listed reach. Additionally, these assumptions are divided into wet weather conditions and dry weather conditions to differentiate between those sources that are precipitation driven versus those which are not dependent on precipitation. The assumed dry weather sources are septic systems, riparian livestock in pastures with direct access to the streams, and wildlife. Surface applied manure has been excluded as a dry weather source of bacteria in other TMDL studies. However, based on the agricultural conditions in the Clearwater River watershed it was determined that surface applied manure would be included as a dry weather source but be assigned the lowest delivery potential.

Each of the delivery potentials is presented seasonally, however no seasonal difference in the delivery from the source was assumed. Seasonality was accounted for in the amount available for wash off due to seasonal differences in application practices. Septic system delivery potential was not doubled here to reflect some of the variability in assessing failing septic systems. Some septic systems are considered failing due to interaction with the water table, but do not have a direct connection to surface waters. The delivery potential remains high though, due to the extensive drain tiling in the region.

Table 4.5. Assumed Fecal Coliform Delivery Potential

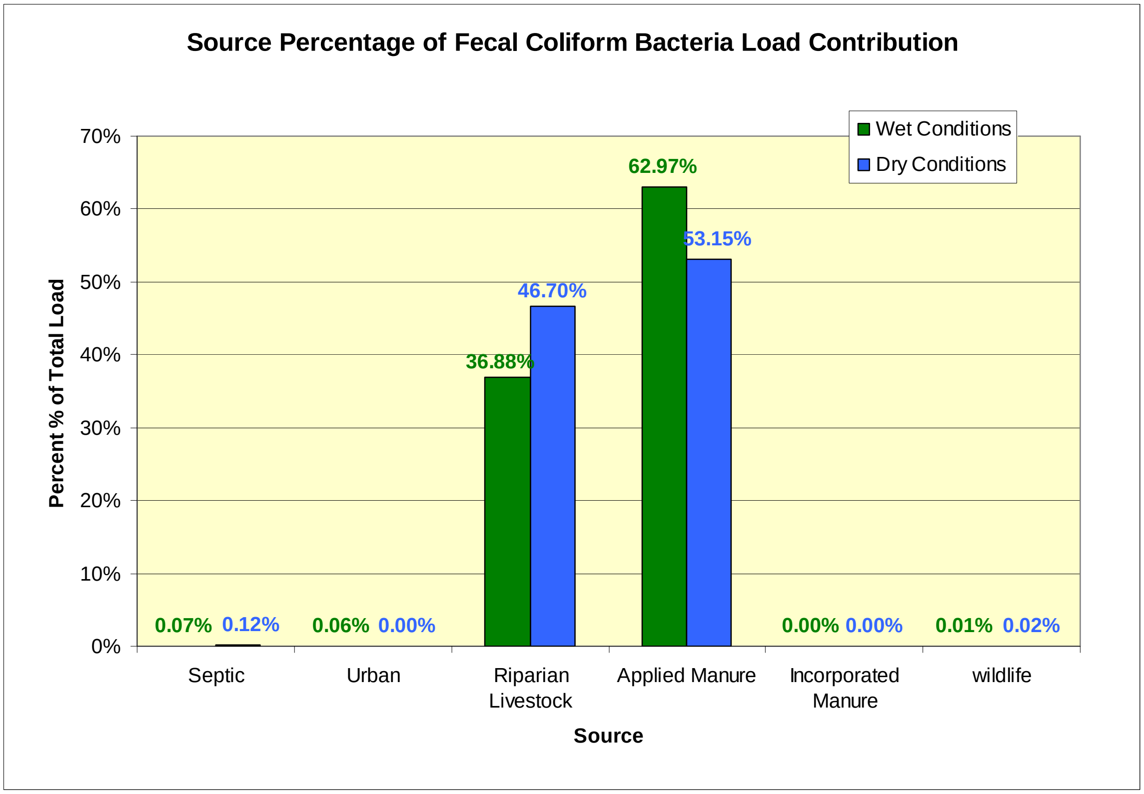
Source	**Estimated Delivery Potential**	
	Wet Conditions	**Dry Conditions**
Riparian Livestock	Very High (8%)	High (6%)
Surface Applied Manure	Low (2%)	Very Low (1%)
Failing Septic Systems	Moderate (4%)	Moderate (4%)
Unsewered Communities	Very Low (1%)	Very Low (1%)
Deer	Very Low (1%)	Very Low (1%)
Geese	Moderate (4%)	Moderate (4%)
Other Wildlife	Very Low (1%)	Very Low (1%)
Urban Stormwater Runoff	Moderate (4%)	N/A

4.4.2 Estimated Source Load Proportions

Current load proportions were estimated by multiplying the delivery potential by the amount of fecal coliform available for runoff. Seasonal load proportions are presented in Figure 4.2 for the Clearwater River. Both wet and dry weather loads were dominated by contributions from riparian livestock and surface applied manure. During both flow conditions surface applied manure comprises the largest portion of the load and riparian livestock are the next largest contributor. However, under wet conditions the percentage difference between the two sources is much greater than the difference during dry conditions.

Failing septic systems, urban runoff and wildlife contribute a low portion of the total bacteria load in the watershed under both wet and dry conditions.

Figure 4.2: Wet and Dry Seasonal Load Proportions for the Clearwater River from Clear Lake to Lake Betsy

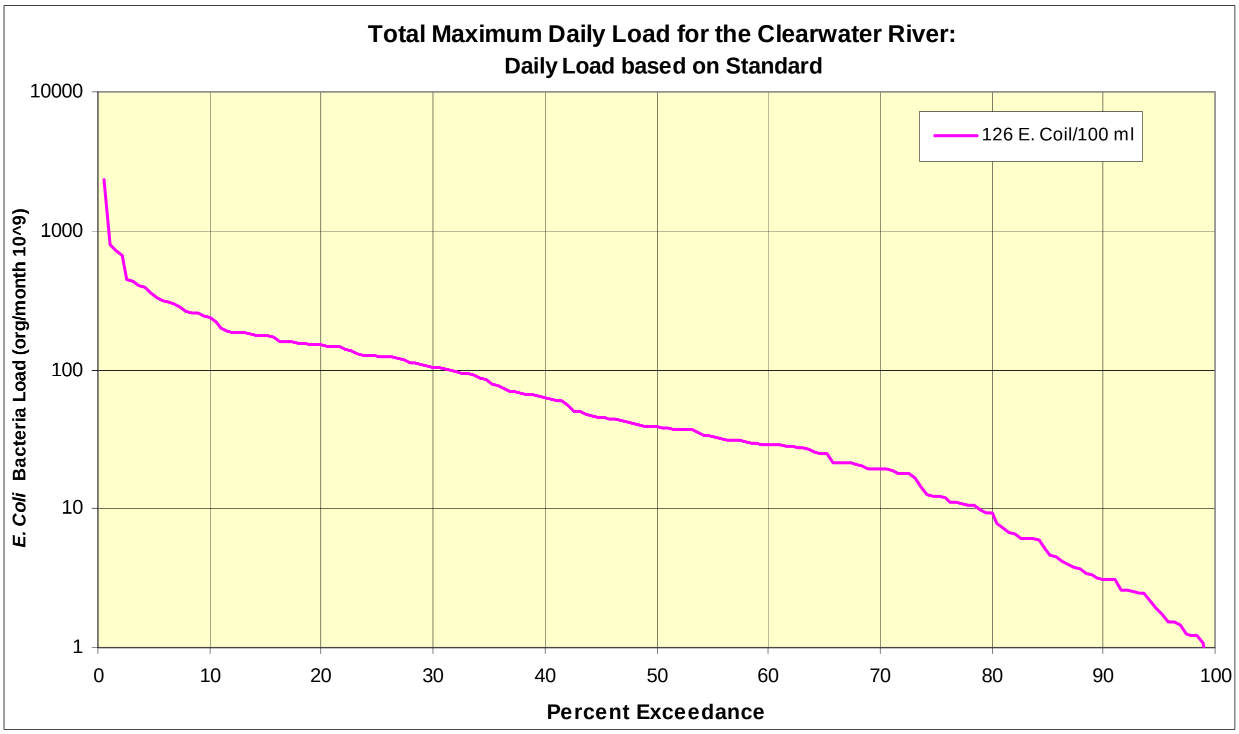


5.0 TMDL

5.1 LOADING CAPACITY

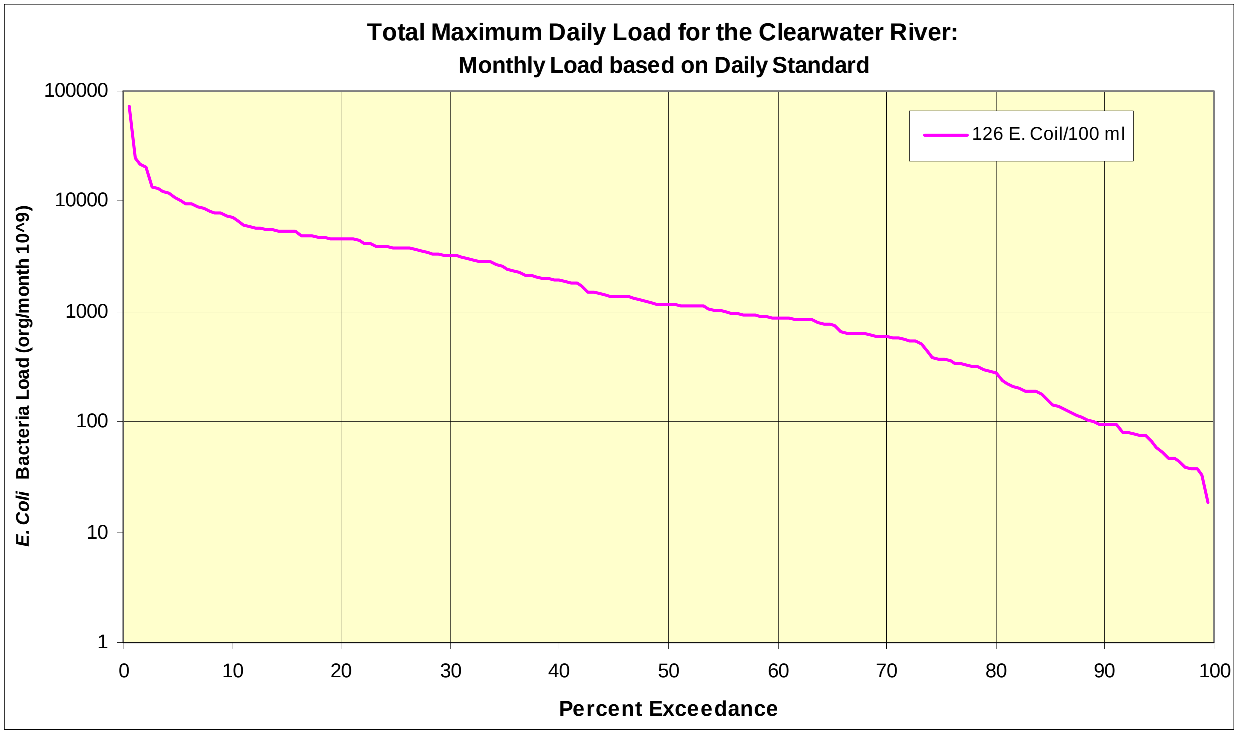
Because *E. Coli* is primarily a nonpoint source issue in the Clearwater River watershed, it is inappropriate to define the TMDL as a single number since the TMDL is entirely dependent upon the daily flow and concentration, which is highly dynamic. To this effect, the TMDL is represented by an allowable load across all flow conditions as is demonstrated in Figure 5.1 for daily loads and 5.2 for monthly loads. To determine acceptable loads under the critical flow regimes, chronic standard concentrations were multiplied by the flow at each interval.

Figure 5.1 The Total Maximum Daily Load Across Flow Exceedances for the Listed Segment of the Clearwater River. Concentrations Represent Total Daily Load Based on Standard of 126 *E. Coli*/100 ml.



Data used to calculate the load duration curve was from 1981 through 2007. This graph represents the allowable load while meeting the State standard. Development of the flow duration curve is documented in Appendix A.

Figure 5.2 The Total Maximum Daily Load Across Flow Exceedances for the Listed Segment of the Clearwater River. Concentrations Represent Total Monthly Load Based on Daily Standard of 126 *E. Coli*/100 ml.



To develop the TMDL equation, the seasonal mean discharge was calculated for each of five flow conditions. These data were then multiplied by the standard of 126 *E.Coli*/100 ml to establish the TMDL (Table 5.1). The MOS was established using all existing watershed data to quantify uncertainty in the data. The MOS portion of the TMDL is the difference between the median and the minimum concentrations for each flow condition. For example, in the Clearwater River, the TMDL for the daily load under the wet condition is 124.47×10^9. The *E. Coli* bacteria concentration for the minimum flow under the wet condition is 61.12×10^9 which is set to the MOS for this flow condition. The load allocation assigned for the high flow is the remaining load after the MOS is subtracted from the TMDL using the following calculation:

TMDL – MOS = LA
or
124.47×10^9 *E. Coli* – 61.22×10^9 *E. Coli* = 63.25×10^9 *E. Coli*

Under this scenario the allocation is 51 percent of the TMDL load at 126 *E. Coli*/100 ml and the MOS is the remaining load. The TMDL Loads for both daily loads and monthly loads based on 126 *E. Coli* /100ml daily standard are provided in Table 5.1 and 5.2, respectively

Table 5.1 The TMDL Expressed as Daily Loading Capacity of *E. Coli* in the Clearwater River from CD 44 to Lake Betsy.

Reach	Critical Condition	Wasteload Allocation* (10^9 org)	Load Allocation (10^9 org)	Margin of Safety (10^9 org)	TMDL (10^9 org)
Clearwater River	High Flow	0	237.9	91.75	329.65
	Wet	0	63.25	61.22	124.47
	Mid-Range	0	28.74	9.77	38.51
	Dry	0	3.10	9.21	12.32
	Low Flow	0	0.03	1.51	1.54

* There are no point discharges from industries, municipalities or waste water treatment plants or individually permitted sources within the watershed. As a result the waste load allocation is zero under all flow conditions.

Table 5.2 The TMDL Expressed as Monthly Loading Capacity of *E. Coli* in the Clearwater River from CD 44 to Lake Betsy.

Reach	Critical Condition	Wasteload Allocation* (10^9 org)	Load Allocation (10^9 org)	Margin of Safety (10^9 org)	TMDL (10^9 org)
Clearwater River	High Flow	0	7,241.8	2,792.8	10,034.6
	Wet	0	1,925.3	1,863.4	3,788.8
	Mid-Range	0	874.9	297.3	1,172.3
	Dry	0	94.72	280.4	375.1
	Low Flow	0	0.9	46.0	46.9

* There are no point discharges from industries, municipalities or waste water treatment plants or individually permitted sources within the watershed. As a result the waste load allocation is zero under all flow conditions.

5.2 RATIONALE FOR LOAD AND WASTELOAD ALLOCATIONS

Section 4 of this report documented gross estimates of the fecal coliform contribution from several sources in the watersheds. In contrast, Section 5 evaluates actual water quality data from the streams against the standard in the development of the TMDL, allocations, and percent reductions needed to meet the standard. While estimates of fecal coliform contributions are derived from literature values and knowledge of the land practices, actual fecal coliform or *E. Coli* data is based on field monitoring.

Load and wasteload allocations were based on thorough watershed wide monitoring of fecal coliform from April 1 through October 31. This robust data set provided for a thorough seasonal evaluation of loads and consequently the magnitude of the exceedances and reductions needed to meet the standard.
Linkages to sources were developed through a thorough accounting of fecal coliform produced in the watershed and assumptions regarding the potential for these sources to reach surface

waters. Based on this accounting, load reductions can be targeted to those sources contributing the greatest amount of fecal coliform under both wet and dry conditions. These linkages provide a framework for targeting source areas that are contributing during both wet and dry conditions.

5.3 MARGIN OF SAFETY (MOS)

The margin of safety is established to account for variability and lack of knowledge in the relationship between load and wasteload allocations and water quality. This margin of safety can be established through explicit quantification of variability or through implicit conservative assumptions in the analysis. In this TMDL, both an implicit (conservative assumptions and adaptive management) and explicit (quantified variability across the flow regime) margin of safety has been used. The MOS is the difference between the median and minimum flow value in each of the defined flow regimes. This accounts for the variation in flow for each flow regime.

5.4 SEASONAL VARIATION

Seasonal variation was addressed in both the accounting of fecal coliform sources and in the analysis of stream concentration data. Fecal coliform sources potentially available for runoff were varied seasonally to reflect the seasonality of practices in manure application and handling. For example, it was assumed that 20% of surface applied manure was applied (or available) in the spring, 20% in the summer, and 60% in the fall. Additionally, load and wasteload allocations were varied seasonally to reflect changes in stream loads and concentrations among seasons. The winter season is not included because the standard is for April 1 through October 31.

5.5 ANNUAL VARIABILITY

To address annual variability in the TMDL, precipitation patterns during the monitoring season were compared to average precipitation patterns for the watershed. Area-weighted average precipitation is 29.6 inches for the watershed as measured at the long term Citizen Precipitation Records throughout the District. Monitoring for the TMDL occurred in 2005 and 2006 where annual precipitation was 36.9 and 23.4 inches respectively. Additionally, CRWD added bacteria (fecal coliform) to their annual monitoring program in 1999-2002 to track bacteria sources in the watershed. Precipitation in Watkins in 1999 to 2000 ranged from 22.1 to 37.5 inches annually.

Data were collected in wet, average and dry years, and samples were collected in wet weather, dry weather, high flow and low flow and are representative of conditions in the watershed. Therefore the load reductions required are representative of typical conditions in the watershed.

Annual variability is further addressed in the implementation plan as load reduction strategies function across a range of weather conditions. For example, the primary load reduction strategy: riparian pasture management, will function regardless of annual variability.

5.6 FUTURE GROWTH

The population and land use practices within the listed portion of the Clearwater River watershed are not anticipated to change significantly. The City of Watkins is the only urban area that contributes directly to the listed portion of the Clearwater River. The City of Kimball is located in a sub-watershed that drains to the Clearwater River just below the listed reach, but is presented here to quantify general growth patterns expected in the area. The population within the City of Watkins in 2000 was 880 residents (Table 5.2).

Based on estimates received from the City of Watkins, the State of Minnesota Demographer estimates the 2008 population at approximately 950. This represents approximately eight percent growth since the year 2000. The 2000 population census data from the US Census Bureau reveals that the rural population in the listed watershed was 1077 residents and the population of the City of Kimball was 635 residents.

Stearns County has recently completed its 2030 Comprehensive plan. Based on the plan, growth in Stearns County has been approximately six percent since the year 2000. The plan also estimates the population in the county in 2030, with an estimated growth rate of approximately 25 percent. However, the majority of growth in Stearns County is anticipated to be with the growth corridor along I-94, near the City of St. Cloud. The rural areas in Stearns County are anticipated to grow less, in the range of five to ten percent. Additionally the City of Watkins and Kimball anticipate similar growth over the next 10 to 20 years to that which has occurred over the last 20 years, which is approximately five to ten percent.

Growth within the urban areas of Watkins will result in bacteria from humans being treated at waste water treatment plants that do not contribute to the listed reach of the Clearwater River, as it is currently land applied. However, the Watkins WWTP was still given a WLA of 0 as discussed in later sections to account for future growth.

Growth in the rural areas of the watershed will result in the instillation of new SSTS systems to treat bacteria, since straight pipe septic systems are illegal. New SSTS systems will effectively treat bacteria and will not contribute to the bacteria load in the watershed. Changes in the human population should not change the load allocations provided in this TMDL. Additionally, loads from septic systems are not allowed under current law and it is unlikely that future sources will be permitted to discharge into the listed reach. Consequently no provisions for changes in human population have been identified in this TMDL.

Table 5.2 Population Growth Estimates for Urban Areas in the Clearwater River Watershed

Urban Populations 2000	2000	2008 (estimated)	Percent Change
Watkins	880	950	+8%
Rural Population	1077	1142	+6%
Kimball*	635	673	+6%

* : The City of Kimball is located is a subwatershed that drains to the Clearwater River just below the listed reach.

The major source of fecal coliform in the watershed is livestock. Based on information from the Meeker County SWCD, animal units have remained stable in recent years within the county and the watershed. One trend in the watershed has been the smaller family farms in the county discontinuing livestock farming to focus on crop farming. Some new large feedlot operations may occur in the future within the watershed. However, livestock facilities and practices are heavily scrutinized and often are permitted, especially in the case of new or expanding operations. Consequently, changes in animal numbers, practices, or facility size and type, will be associated with permits and mitigation practices to minimize export of fecal coliform.

As a result of this close scrutiny, potential increases in fecal coliform from livestock practices in the watershed should be mitigated. Based on the lack of projected population growth or development in the watershed it is likely that the existing agricultural practices in the watershed will continue in their current manner. A provision for an increase in livestock in the watersheds is not necessary at this time.

6.0 Public Participation

The CRWD sees public participation as critical to the process of implementing the TMDL to meet water quality standards. The public participation efforts for this TMDL study are summarized below. The work described below is collective for all the on-going TMDL studies in the CRWD.

6.1 TECHNICAL ADVISORY COMMITTEE

This TMDL study has proceeded in Phases: Phase I was a review of existing data, Phase II was collection of data to fill gaps, and Phase III is setting the load allocation. The decision to proceed in phases was made to ensure that the most efficient and technically sound path was taken towards completion of the TMDL. Workplans and reports from each phase received review and approval from the Technical Advisory Committee comprised of the MPCA technical staff in the Brainerd/Baxter and St. Paul offices, the CRWD, and the project consultant. This group met formally only once at the Brainerd/ Baxter office, but was effectively coordinated by the MPCA project manager Margaret Leach throughout the project.

6.2 STAKEHOLDER MEETINGS

Since the beginning of the TMDL process in 2003 District Administrator Merle Anderson has actively sought engagement from and communication with city, county, township, lake association, and individuals alike. His efforts took the form of attendance of the regular meetings of these groups, calls to group leaders, organizing special meetings of these groups for the purpose of making presentations, and preparation of materials for distribution (Appendix C). Presentations are available on the CRWD web site.

Administrator Anderson updated the members of these groups on the status of the TMDL and provided information on the cause of the impairments and on their roles in the conceptual implementation plan. The goal of these efforts was to leverage existing regulatory framework, and relationships to generate support for TMDL implementation efforts. Using existing governmental programs and services for TMDL implementation should provide a significant cost savings and efficiency.

This work on the part of Administrator Anderson is part of the ongoing tradition of the CRWD to work with other government agencies and provide them with the support they need to protect water resources. Specific examples of this work in the recent past are listed:

- CRWD funded municipal stormwater studies for the Cities of Annandale, Kimball and Watkins wherein several opportunities for stormwater improvements were identified.
- CRWD funded design of a road pavement project in Maine Prairie Township to ensure protection of the near-by School Section Lake.
- Development review and comment for major cities and counties.
- CRWD offers additional incentives for riparian buffers, rain gardens and CRP on top of what is offered by other government agencies.

6.3 PUBLIC MEETINGS

Additionally, seven public meetings have been held to date. At each stakeholder meeting, the District Administrator and project consultant updated the stakeholders on the status of the TMDL and provided information on the cause of the impairment and on conceptual implementation plans.

Five of the six lakes addressed herein were not included in the early efforts with respect to this TMDL study. Clear Lake, Lake Betsy, Union Lake, Scott Lake and Lake Marie were added to the 303(d) list in 2008. It was determined that it was best to address all the impaired waters in the upper watershed at once because the system was a flow-through chain of lakes and the implementation areas overlap providing costs savings to address them at once. Prior to the April 16, 2008 meeting, only Lake Louisa and Lake Marie were discussed (Lake Marie was discussed because the same group represents Lakes Louisa and Marie, and meeting the load reduction for Lake Louisa will implicitly reach the goal set for Lake Marie). The results of the public participation meetings are summarized below:

December 17, 2003 in Annandale

Watershed District Managers, the District Administrator, the MPCA Project Manager, and the Wenck Project Manager presented information about the TMDL process and the Clearwater River and Lake Louisa TMDL Project specifically. A question and answer session followed the presentation. County Soil and Water Conservation District Representatives from Wright, Meeker and Stearns Counties were invited, along with representatives from the Cities of Kimball and Watkins. Citizen advisory group members were also invited. Wright and Meeker County representatives attended.

February 18, 2003 in Annandale

The Wenck Project Manager presented information about the TMDL process and the Clearwater River and Lake Louisa TMDL Project specifically. An analysis of existing data was presented. A question and answer session followed the presentation. County Soil and Water Conservation District Representatives from Wright, Meeker and Stearns Counties were invited, along with representatives from the Cities of Kimball and Watkins. Citizen advisory group members, and lake associations were also invited. A Meeker County representative attended, along with members of the Citizen Advisory Group, and Clearwater Lake Association.

March 16, 2004 in Watkins

An additional meeting was held to solicit additional stakeholder involvement. The Wenck Project Manager presented information about the TMDL process and the Clearwater River and Lake Louisa TMDL Project specifically. An analysis of existing data was presented. A question and answer session followed the presentation.

Meeting invitations and a letter describing the TMDL Project were sent to resident's homes. County Soil and Water Conservation District Representatives from Wright, Meeker and Stearns Counties, as well as representatives from the Cities of Kimball and Watkins were invited. Citizen advisory group members and lake associations were invited. The goal of the meeting was to establish a representative stakeholder group. These representative stakeholders met two more times.

July 15, 2007 Clearwater Chain of Lakes Association, Lake Louisa Working Group

District Administrator Merle Anderson met with members of the Clearwater Chain of Lakes Association (CCOLA) to spark interest in a Lake Louisa working group. This group of citizens heard a summary of the TMDL process and progress and agreed to discuss the Lake Louisa TMDL with residents to encourage interest and participation.

August 6, 2007, Clearwater Chain of Lakes Association, Lake Louisa Working Group

District Administrator Merle Anderson and Project Engineer Rebecca Kluckhohn met with 16 members of the Clearwater Chain of Lakes Association (CCOLA). This group is comprised of Lake Louisa and Lake Marie residents concerned with upstream water quality. Each resident expressed concern about the perceived deterioration of water quality in the entire Chain of Lakes. Most residents had moved to the area since the major improvements in water quality in the 1980s as the result of the Clearwater Chain of Lakes Improvement Project. Residents speculated that many septic systems around the lakes needed replacement, but that costs would be prohibitive for several residents. Residents also expressed concerns about livestock allowed to graze in and near the lakes and the Clearwater River.

August 10, 2007, Clear Lake Citizenship Dinner

The CRWD's 6^{th} Annual Citizenship Dinner was held at the Sportsman's Center at Clear Lake. Residents in the area of Clear Lake, the upstream boundary of the listed reach of the Clearwater River were addressed in this report. Manager Anderson and District Engineer Norm Wenck listened to residents and answered questions about water quality in Clear Lake.

October 3, 2007, Meeting with the Chain of Lakes Association

A meeting with the Chain of Lakes Association to go over Phase II Report and answer questions. Provided discussion topics for their next meeting.

April 16, 2008, Public Meeting

A public meeting to present the findings of the TMDL studies was held April 16, 2008 at Annandale Middle School. Representatives from all areas impacted by the TMDLs attended the meeting, including a representative of residents of Lake Betsy, Union Lake and Scott Lake, two members of the Clear Lake Association, and members of the Chain of Lakes Association representing Lakes Louisa and Marie. The CRWD District Administrator, project consultant, MPCA project manager and Communication coordinator were also present to answer questions about the TMDL process and outcome.

August 2, 2008, CRWD Summer Tour

CRWD hosted a tour for 81 watershed residents to view watershed projects including rain gardens, buffers, sedimentation basins, fish migration barriers. Implementation of TMDLs was discussed.

7.0 Reasonable Assurance

When establishing a TMDL, reasonable assurances must be provided demonstrating the ability to reach and maintain water quality endpoints. Several factors control reasonable assurances including a thorough knowledge of the ability to implement BMPs as well as the overall effectiveness of the BMPs. Clearwater River Watershed District is positioned to implement the TMDL and ultimately achieve water quality standards.

The Clearwater River Watershed District is the water management authority for the Clearwater River and its tributary watershed. The CRWD is uniquely qualified through its knowledge of the watershed to implement corrective actions to achieve TMDL goals.

Several of the implementation strategies are already part of the District's existing programs to improve water quality such as education, grants for pasture management, riparian buffers, and rain gardens, assistance to municipal partners for stormwater management, follow up water quality monitoring. The District's stable framework of existing programs provides funding for TMDL Implementation each year.

8.0 Monitoring Plan

The CRWD measures lake water quality, precipitation, stream flow, stream water quality, and nutrient and sediment loads at three long-term monitoring stations and reports results annually. This monitoring program described in detail in Appendix B will continue, and is generally sufficient to track significant water quality trends, assess progress towards goals and make adjustments towards adaptive management.

In addition to the Annual Monitoring Program, the CRWD sometimes implements special monitoring to track success of individual projects, or to investigate specific water quality concerns. Supplemental monitoring of this nature is expected throughout the course of TMDL implementation. The following recommendations are made to supplement the annual monitoring plan (note that some of these items are in reference to other TMDL studies ongoing in the CRWD):

- Assess special monitoring needs annually based on implementation projects, report findings in the Annual Monitoring Report.
- Add *E.* Coli to the parameter list for stream water quality samples to assess progress towards meeting bacteria TMDL. Consider adding two sampling stations along the impaired reach of the Clearwater River. This will require close coordination of District sampling technician to ensure holding times are met.
- Install a continuous pressure transducer at the watershed outlet and midpoint to measure flows and annual runoff.
- Increase sampling frequency for CR 28.2 to better characterize early spring flows and loads.

9.0 Implementation

9.1 IMPLEMENTATION FRAMEWORK

Implementing TMDLs within the CRWD will be a collaborative effort between state and local government, and individuals led by the CRWD. To meet water quality standards CRWD will leverage existing regulatory framework, and relationships to generate support for TMDL implementation efforts, providing technical support, funding, coordination and facilitation when needed. Efficiency and cost savings are realized by using existing governmental programs and services for TMDL implementation to the maximum extent possible.

9.1.1 Clearwater River Watershed District

The mission of the Clearwater River Watershed District is to promote, preserve and protect water resources within the boundaries of the District in order to maintain property values and quality of life as authorized by MS103D. To this end, the District's Comprehensive Plan approved July 23, 2003, documents the District's goals, existing policies and proposed actions. One of the District's stated goals is to bring all of CRWD surface water into compliance with state water quality standards, through the TMDL process.

Because the primary goal and mission of the CRWD is in line with the goal of TMDL implementation, many of the implementation strategies are extensions of existing CRWD programs and projects and can be funded using existing CRWD budgets. However, funding support will be necessary. The recommended implementation plan to meet lake water quality goals and associated cost is described in the following section.

9.1.2 Counties, Cities, Townships, Lake Associations

Partnerships with counties, cities, townships and lake associations are one mechanism through which the CRWD protects and improves water quality. The CRWD will continue its strong tradition of partnering with state and local government to protect and improve water resources and to bring waters within the CRWD into compliance with State standards.

9.1.3 MPCA/ BWSR

The CRWD recognizes that public funding to set and implement TMDLs is limited, and therefore understands that leveraging matching funds as well as utilizing existing programs will be the most cost efficient and effective way to implement TMDLs within the CRWD. The CRWD has projected a potential need for about 50% cost-share support from the MPCA, Board of Water and Soil Resources (BWSR) or other sources in the implementation phase of the TMDL process.

9.2 REDUCTION STRATEGIES

The findings of this study indicate that the dominant bacteria sources to the Clearwater River are from riparian livestock and applied manure. While bacteria load reductions from all sources will be necessary, load reductions from these sources will be the most effective towards meeting water quality goals. To that end, the TMDL implementation plan for bacteria relies on three main strategies and is based on the findings of this study.

1. Riparian pasture management
2. Manure application BMPs
3. Reduction of delivery potential from applied manure

The CRWD's existing programs provide the framework for implementation, but they will require additional funding to reach the level of implementation required to meet state standards.

Existing CRWD programs are typically aimed at phosphorus load reduction, however since the delivery mechanisms for phosphorus and bacteria to surface waters are often the same, the same programs work for both impairments. Current CRWD phosphorus reduction programs that also target bacteria are described, along with the additional work that will be needed to meet state water quality standards:

1. CRWD provides incentives for shoreline and farm buffers including rain gardens, and tile intake buffers. The farm buffers provide an additional incentive to farmers who enroll land in CRP. County Soil conservation Districts provide technical assistance for buffer installation. The CRWD will expand this program and focus heavily in subwatersheds tributary to the listed reach.
2. Animal feedlot upgrade incentives and pasture management plan grants. In a recent example of this program, the CRWD awarded a land owner a grant for construction to prevent grazing animals from entering the Clearwater River. This program should be expanded to include a study to identify parcels for upgrade and approach land owners with incentives and education. Activities should be focused in the subwatersheds tributary to the listed reach.
3. CRWD works collaboratively with cities, counties and townships to provide funds for stormwater management. The Watkins Area Stormwater Management Study funded by the CRWD is an example of such collaboration. The study identified several options for stormwater management in advance of development in the area.
4. The CRWD's education and outreach is extensive as documented in the public involvement section. The success of the programs listed above hinges on participation which is fueled by education. This program should be extended providing a CRWD staff person devoted to TMDL implementation.

The conceptual implementation plan to reduce bacteria concentrations in the Clearwater River is presented below (Table 9.1). Strategies are recommended based on their relative cost and effectiveness given the current level of understanding of the sources of bacteria in the watershed and their delivery potential. Recommendations take into account findings from stakeholder participation. Cost share breakdown is expected to be 50% from the state and federal funds, 25% from the individual, and 25% from watershed budgets. The estimated total cost of implementation over 10 years is $7.6 million dollars. The strategies below represent reductions to non-point source bacteria loads from urban, residential, lakeshore and agricultural sources.

Given the severe nutrient and bacteria load reductions required across the watershed, stakeholders in the entire drainage area will be required to participate in load reduction BMPs. Further, stakeholder participation hinges on both stakeholder willingness to participate, and on the equal application of BMPs. For example one group cannot be perceived as bearing the load of this project disproportionally. These factors, plus technical feasibility and effectiveness will guide BMP targeting. The TMDL seeks not to disenfranchise stakeholders at the outset recognizing the potentially catastrophic effects of doing so on meeting goals.

Table 9.1 Conceptual Implementation Plan and Costs

Practice	TMDL	Unit Cost	Units	Note	Qty	Cost
Promote Ag BMPs (Conservation Tilling)	Nutrient, DO	$50,000	ls		1	$50,000
Replace Tile Intakes w/ Filters	Nutrient, DO, Bacteria	$500	per intake	*evaluate limestone/steel wool filter intakes to increase P removal	400	$200,000
Tile Intake Buffers	Nutrient, DO, Bacteria	$100	per intake		300	$30,000
Buffer Tributaries	Nutrient, DO, Bacteria	$350	ac		300	$105,000
Buffer Stream Banks	Nutrient, DO, Bacteria	$350	ac		200	$70,000
Tile Discharge Management	Nutrient, DO, Bacteria	$130,000	ls	* Inventory, FS, design construct	1	$130,000
Riparian Pasture/ Grazing Management Grants, Pasture Renovation, Manure Management	Nutrient, DO, Bacteria	$10,000	ea		100	$1,000,000
Street Sweeping						
Kimball	Nutrient, DO, Bacteria	$40	per curb mile	* high efficiency, 25 curb miles for 15 years	25	$30,000
South Haven	Nutrient	$40	per curb mile	* high efficiency, 5 curb miles for 15 years	5	$6,000
Fairhaven	Nutrient	$40	per curb mile	* high efficiency, 5 curb miles for 15 years	5	$6,000
Watkins	Nutrient	$40	per curb mile	* high efficiency, 15 curb miles for 15 years	15	$18,000
Lakeshore Septic Upgrade Grants	Nutrient	$7,500	ea	All impaired lakes on the chain	130	$975,000
Lake shore restoration grants (Shore land Erosion)	Nutrient	$300	ea	*grants	300	$90,000
Shallow Lakes Management Plans for Marie and Clear Lakes	Nutrient	$15,000	ea		2	$30,000
Carp Control	Nutrient	$25,000	average per year per lake	*Fish trap already installed at Louisa	40	$1,000,000
Lake Aeration	Nutrient			*3 existing aerators		$600,000
Curly Leaf Pondweed Control	Nutrient			*Lake association cost in some cases		$200,000
Kingston Wetland Maintenance and Enhancement, Potentially aeration	Nutrient, DO			Need Feasibility Study		$350,000
Lake Betsy Hypolimnetic Withdrawal & Land Application	Nutrient			Need Feasibility Study		$500,000
South Haven Stormwater Enhancement	Nutrient, DO, Bacteria					$75,000
City of Kimball Stormwater Enhancement Per 2004 Kimball Area Stormwater Management Study	Nutrient, DO, Bacteria					$500,000
City of Watkins Stormwater Enhancement per 2006 Watkins Area Stormwater Management Study	Nutrient, DO, Bacteria					$800,000
Public Outreach	Nutrient, DO, Bacteria	$10,000	per year		10	$100,000
Implementation Project Management and Administration	Nutrient, DO, Bacteria	$30,000	per year		10	$300,000
Implementation Performance Monitoring, Recommendations for Adaptive Management	Nutrient, DO, Bacteria	$25,000	per year		10	$250,000
Implementation Engineering	Nutrient, DO, Bacteria	$15,000	per year		10	$150,000
T:\0002\117\[TMDL Implementation_Report.xls]November 2009					**TOTAL:**	**$7,565,000**

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Appendix A

Historical Lake Water Quality Data

APPENDIX A
Historical Mean Flow and Phosphorus Loading

Clearwater River Watershed District

2007 Annual Report

Station Main Stem:	Year	Average Stream Flow (cu m/sec)	Average Stream Flow (cfs)	Flow-Weighted Average Total Phosphorus Concentration (mg/l)	Total Phosphorus Load (kg)	Total Phosphorus Load (lb)
CR 28.2	1981 (1)	--	--	1.400	--	--
	1981					
(Actual River	1982 (1)	0.93	32.8	0.740	19,700	43,500
Mile 27.2)	1983	2.62	92.6	0.920	76,000	168,000
	1984	1.49	52.6	0.760	35,700	78,800
	1985	2.32	81.9	0.900	65,500	144,000
	1986	3.20	113	0.780	55,200	122,000
	1987	0.11	3.90	0.130	460	1,020
	1988	0.09	3.12	0.660	1,850	4,080
	1989	0.02	0.72	0.190	120	260
	1990	0.51	18.0	0.440	7,040	15,500
	1991	1.11	39.1	0.290	10,200	22,500
	1992	0.26	9.30	0.200	1,660	3,650
	1993	1.28	45.2	0.290	11,600	25,600
	1994	1.17	41.2	0.280	10,100	22,300
	1995	1.15	40.4	0.288	10,400	22,900
	1996	0.33	11.7	0.274	2,860	6,300
	1997	0.27	9.36	0.260	2,170	4,790
	1998	0.41	14.4	0.250	3,190	7,020
	1999	0.08	2.78	0.160	400	870
	2000	0.02	0.72	0.380	240	530
	2001 (4),(5)	0.27	9.46	0.510	4,309	9,500
	2002	0.47	16.50	0.291	4,290	9,460
	2003	0.28	9.92	0.190	1,710	3,770
	2004	0.48	17.04	0.166	1,248	2,751
	2005 (6)	1.11	39.28	0.306	1,862	4,105
	2006	0.31	11.10	0.130	1,328	2,928
	2007	0.14	5.02	0.228	767	1,692

NOTES:

Flow values are time-weighted averages unless otherwise noted.
Total phosphorus values are flow- and time-weighted averages unless otherwise noted.

(1) Values in 1981 and 1982 are arithmetic means
(2) Station WR 0.2 was designated Station WC 0.2 in 1981-1983
(3) Phosphorus values in 2000 are flow-weighted and adjusted per log-log regression on flow so as to correspond to annual mean flows.
(4) 2001 Flow and total phosphorus values are arithmetic averages.
(5) 2001 total phosphorus loads estimated from arithmetic averages of flow and total phosphorus values.
(6) Values in 2005 and 2006 were calculated using supplemental flow data from CSAH 40 near Clearwa

T:\0002\117\Reports\Appendices\Appendix A\[Part 1.xls]Table 2

Appendix A
Summary of Historical Lake Water Quality Data
Summer (June-September) Epilimnetic Means
Clearwater River Watershed District

2007 Annual Report

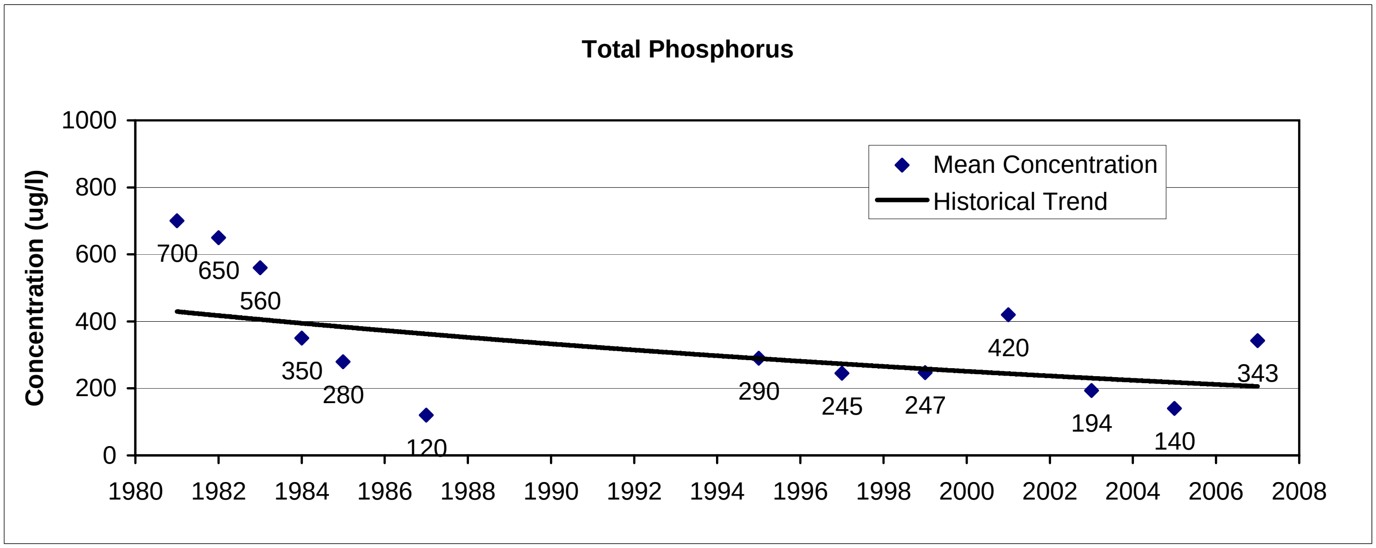
		Number of Samples	Total Phosphorous (ug/l)		Chlorophyll-a (ug/l)		Secchi Disk Transparency (m)	
			Mean (3)	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
BETSY								
1981		7	700	190	8	5.6	2.4	1.1
1982		7	650	90	59	50	1.3	0.7
1983		7	560	270	5	4	1.1	1.3
1984		7	350	160	7	5	0.8	0.2
1985		7	280	230	30	26	1.1	0.6
1987		2	120	0	74	35	0.9	0.41
1995		4 (2)	290	183	18	13	1.0	0.34
1997		4	245	108	100 (5)	98	0.8	0.05
1999		3(8)	247	110	170	85	0.8	0.2
2001		2	420	368	4	1	0.5	0.0
2003		4	194	78	45	52.0	1.3	
2005		4	140	58	20	11.4	1.1	
2007		4	343	174	70	95.0	0.7	
Mean			349	155	45	32	1.1	0.5
CLEAR								
1994		4	80	24	17	8	1.2	0.3
1998		4	220	141	110	141	1.0	0.1
1999		4	188	43	85	47	0.5	0.0
2000		4	228	30	134	42.6	0.3	0.1
2003		4	200	52	72	23	0.7	
2005		4	307	107	60	82	1.1	
2006		4	143	19	60	20	0.9	
Mean			195	59	77	52	0.8	0.1
LOUISA								
1981		7	440	110	39	29	1.4	0.4
1982		7	420	140	68	26	1.5	0.5
1983		7	410	170	4	4	1.4	1.4
1984		7	220	80	8	6	1.0	0.1
1985		7	160	100	26	17	1.1	0.3
1986		6	190	50	96	86	1.1	0.1
1987		7	100	10	70	44	0.8	0.2
1988		5	140	60	101	39	0.6	0.3
1989		6	110	40	69	78	0.8	0.5
1990		5	200	80	55	35	1.3	0.5
1991		3	160	70	31	18	1.5	0.3
1992		8	140	140	46	22	1.1	0.3
1993		4 (1)	170	40	35	13	1.2	0.2
1995		4 (2)	100	36	75	27	0.8	0.2
1997		4	68	7	59 (5)	8	0.9	0.2
1999		4	73	29	38	20	1.0	0.1
2001		2	33	30	5	4	0.9	
2003		3	100	13	68	28	1.1	
2006	Site 1	7	54	21	41	24	1.0	
2006	Site 2	7	57	20	43	25	1.0	
2007		4	79	44	79	52	1.1	
Mean			173	65	49	28	1.1	0.3

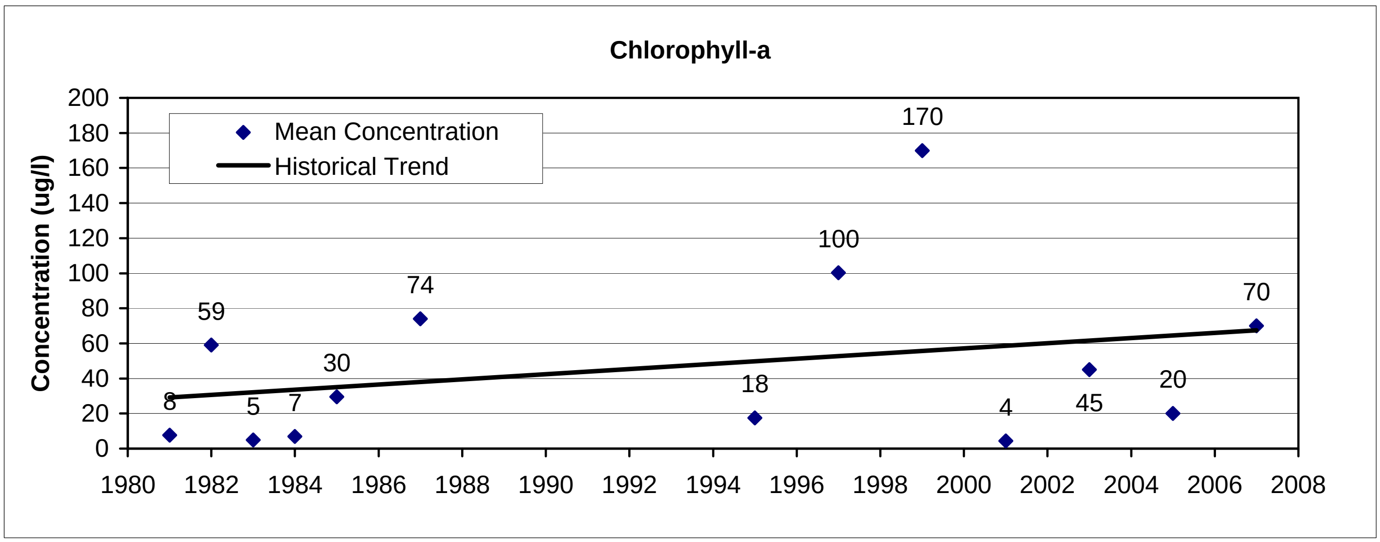
Appendix A
Summary of Historical Lake Water Quality Data
Summer (June-September) Epilimnetic Means
Clearwater River Watershed District

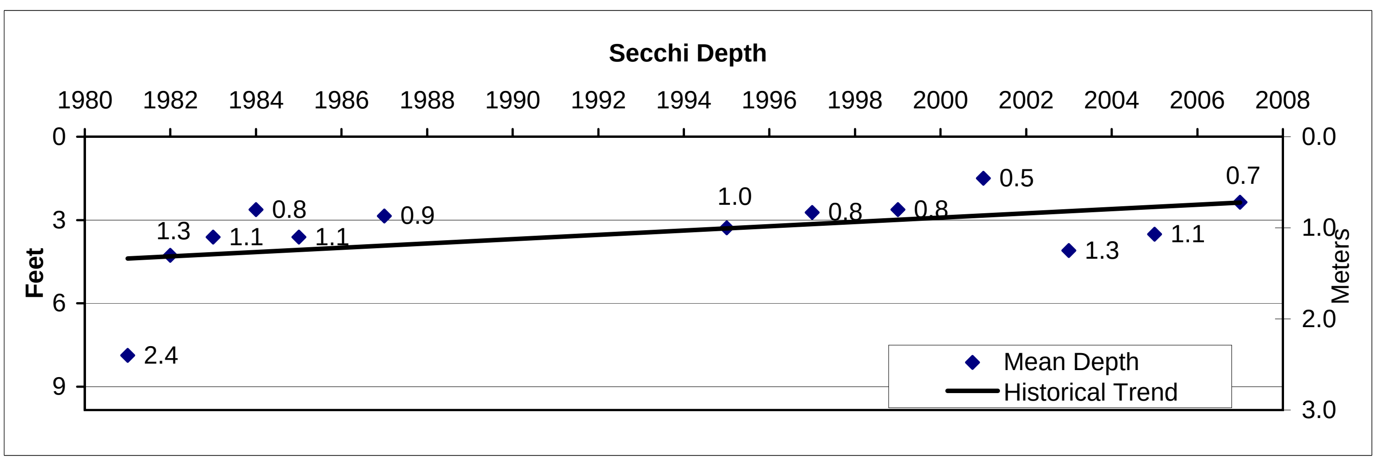
2007 Annual Report

	Number of Samples	Total Phosphorous (ug/l)		Chlorophyll-a (ug/l)		Secchi Disk Transparency (m)	
		Mean (3)	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
MARIE							
1981	7	270	130	31	19	1.3	0.5
1982	7	360	120	63	57	1.3	0.6
1983	7	340	160	4	4	0.9	0.3
1984	7	190	60	7	5	0.9	0.3
1985	7	230	210	34	14	1.0	0.2
1986	6	160	30	92	91	1.1	0.1
1987	7	120	30	95	30	0.6	0.1
1988	5	220	80	153	91	0.4	0.1
1989	6	120	40	58	54	0.6	0.4
1990	5	150	60	101	33	0.8	0.2
1994	4	90	99	71	19	0.6	0.1
1996	4	100	39	37	5	0.8	0.1
1998	4	76	15	56	12	1.1	0.1
2000	4	74	18	13	7.7	2.3	1.0
2002		70		37		1.2	
2003	3	87	50	81	67	1.3	
2004	4	84	45	34	16	1.1	0.0
2006	4	78	30.16	75	65	1.6	
Mean		157	72	58	35	1.1	0.3
SCOTT							
1981	7	660	340	26	27	1.9	0.9
1982	6	540	220	57	39	1.4	0.7
1983	7	450	170	3	3	1.2	1.4
1984	7	270	100	6	5	0.7	0.1
1985	7	260	280	35	29	1.1	0.5
1994	4	160	117	94	71	0.7	0.1
1996	4	280	174	223	68	0.5	0.1
1998	4 (5)	230	176	141	77	0.8	0.1
1999	3	223	163	76	30	0.6	0.1
2002		210		103		0.7	
2003	4	158	52	66	33	0.8	
2004	4	103	20	51	4	0.8	0.0
2006	3	120	392	61	17	0.8	
Mean		282	184	72	34	0.9	0.4
UNION							
1995	4	43	15	15	1	1.4	0.3
1998	4 (5)	50	27	16	9	1.7	0.4
1999	3	31	15	12	10	1.8	0.9
2002		88		39		1.0	
2005	7	58	13	22	17.0	1.9	0.7
2007	4	43	21	7	3.0	2.3	
Mean		54	18	21	9	1.6	1

Notes:
(1) The fourth sample was collected on October 6, 1993.
(2) The fourth sample was collected on October 2 or 3, 1995
(3) Starting in 1993, Total phosphorus means are rounded to two significant figures. Prior to 1993, the mean values were rounded to the nearest 10 ug/l.
(4) Values reported as "Less than" the detection limit were estimated as half of the detection limit.
(5) Three samples were analyzed for chlorophyll-a.
(6) Three samples were analyzed for total phosphorus.
(7) Three secchi disk readings were recorded.
(8) One secchi disk reading was recorded.
T:\0002\117\Reports\Appendices\Appendix A\[Part 2.xls]Data

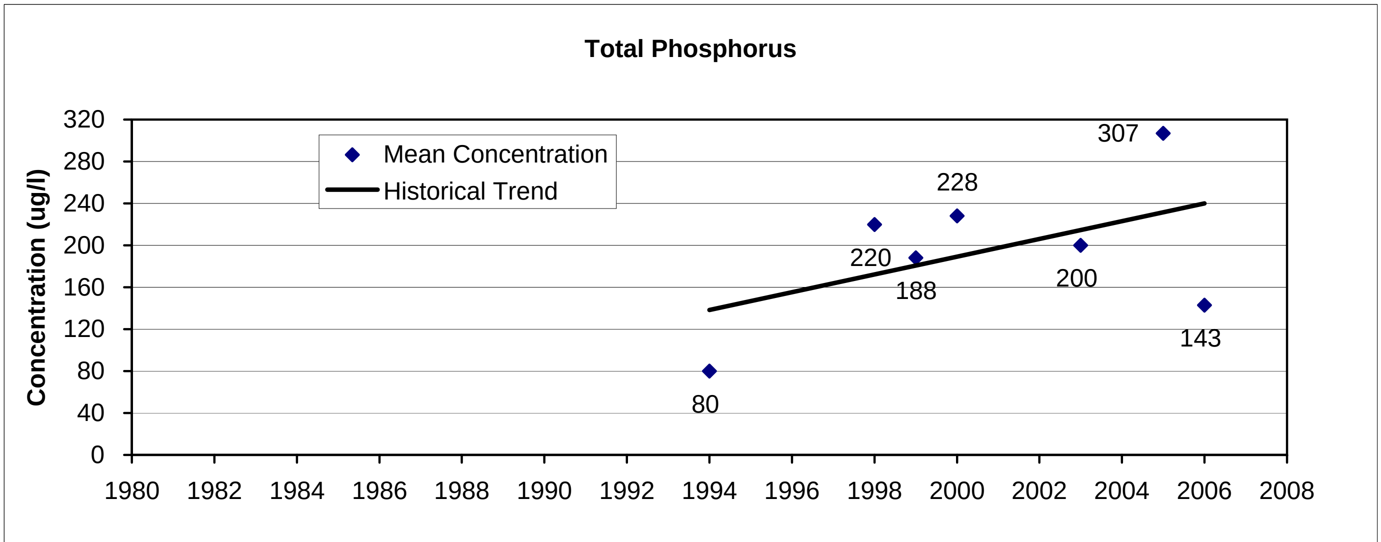


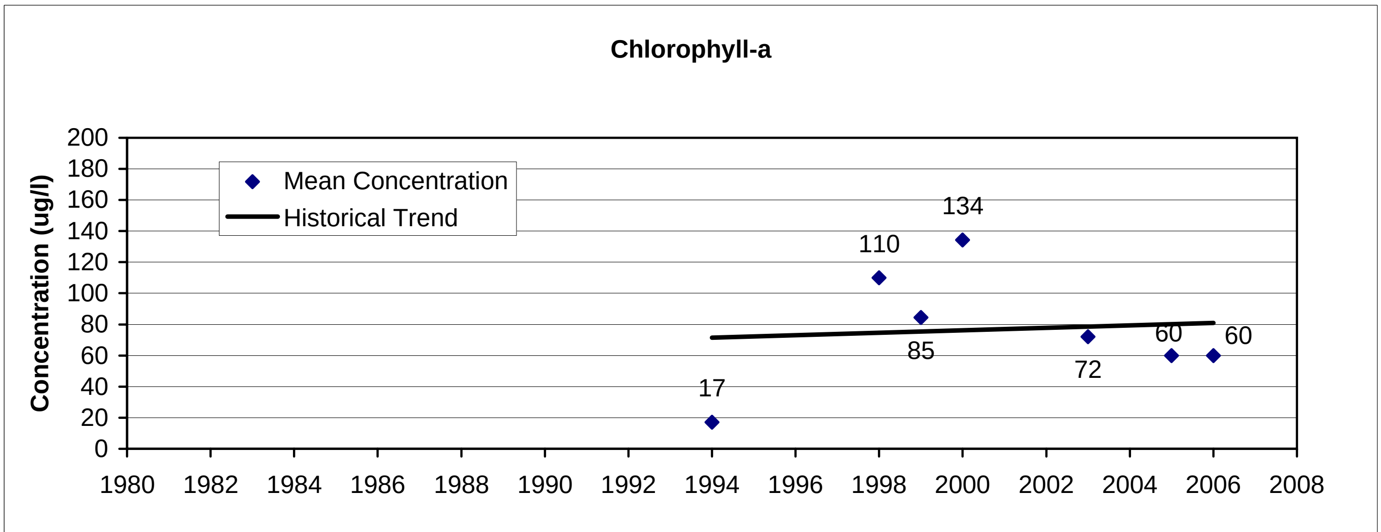


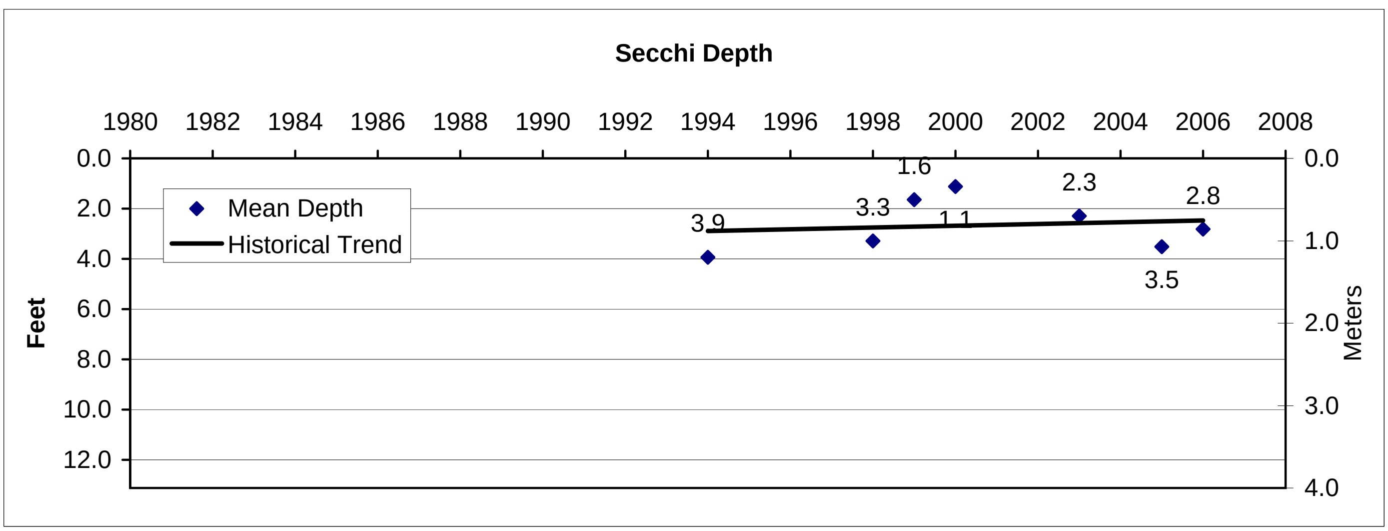


Clearwater River Watershed District	Wenck Associates, Inc. Environmental Engineers 1800 Pioneer Creek Center Maple Plain, MN 55359	Jan 2008
Lake Betsy Historical Data		Appendix C

T:\0002\117\Reports\Appendices\Appendix A\Part 2Lake Betsy

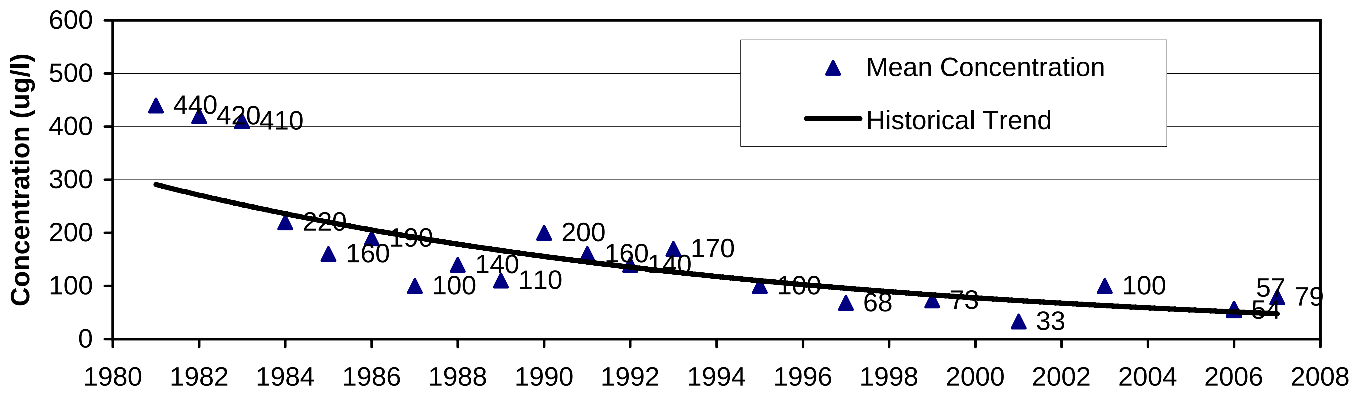




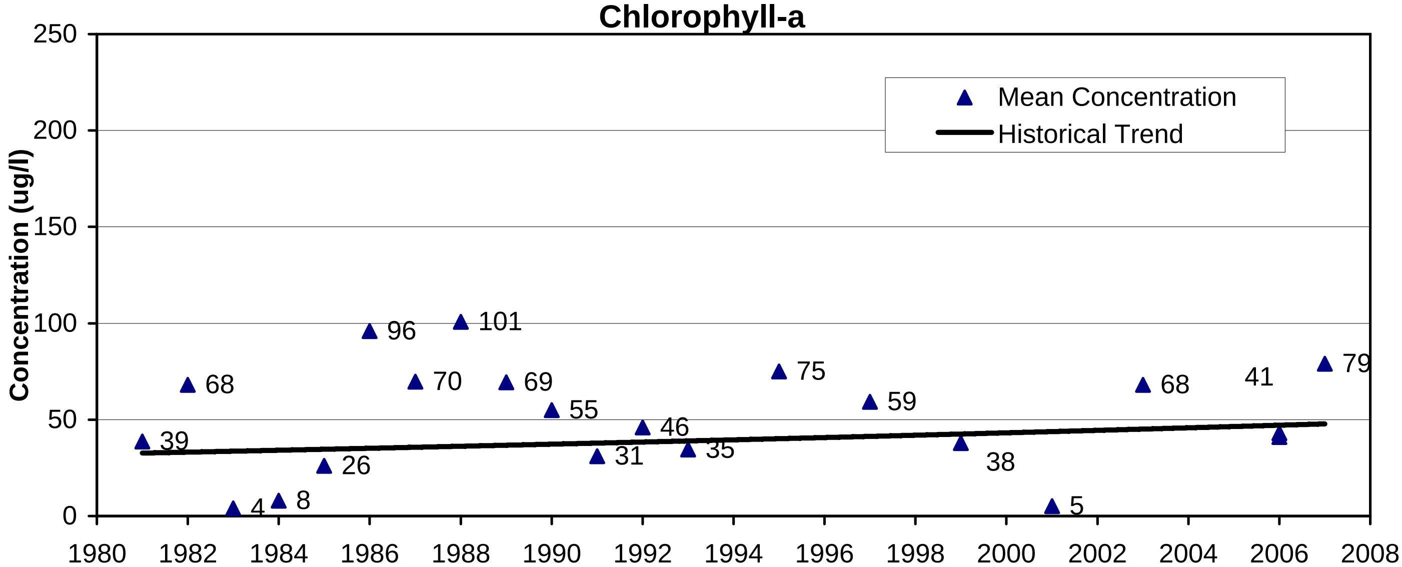


Clearwater River Watershed District	Wenck Associates, Inc. Environmental Engineers 1800 Pioneer Creek Center Maple Plain, MN 55359	Jan 2008
Clear Lake Historical Data		Appendix C

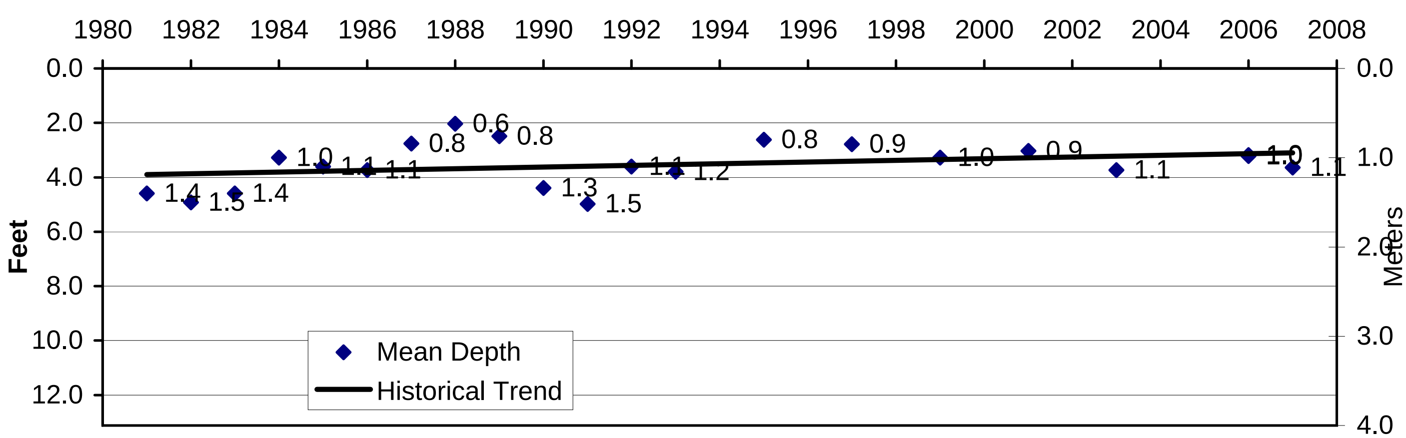
Total Phosphorus



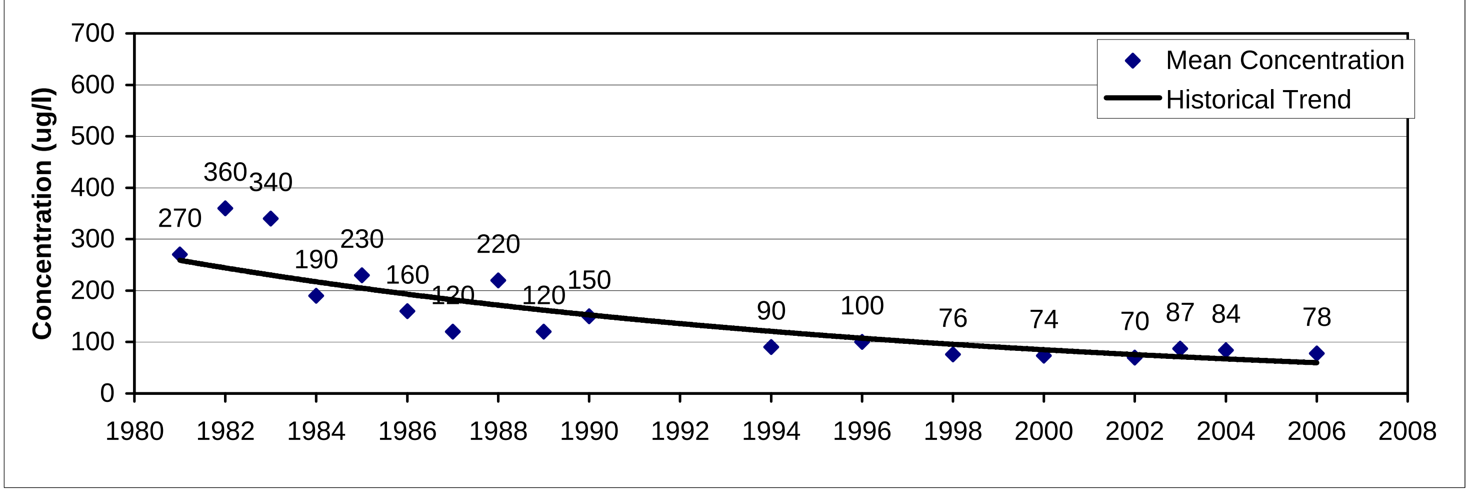
Chlorophyll-a



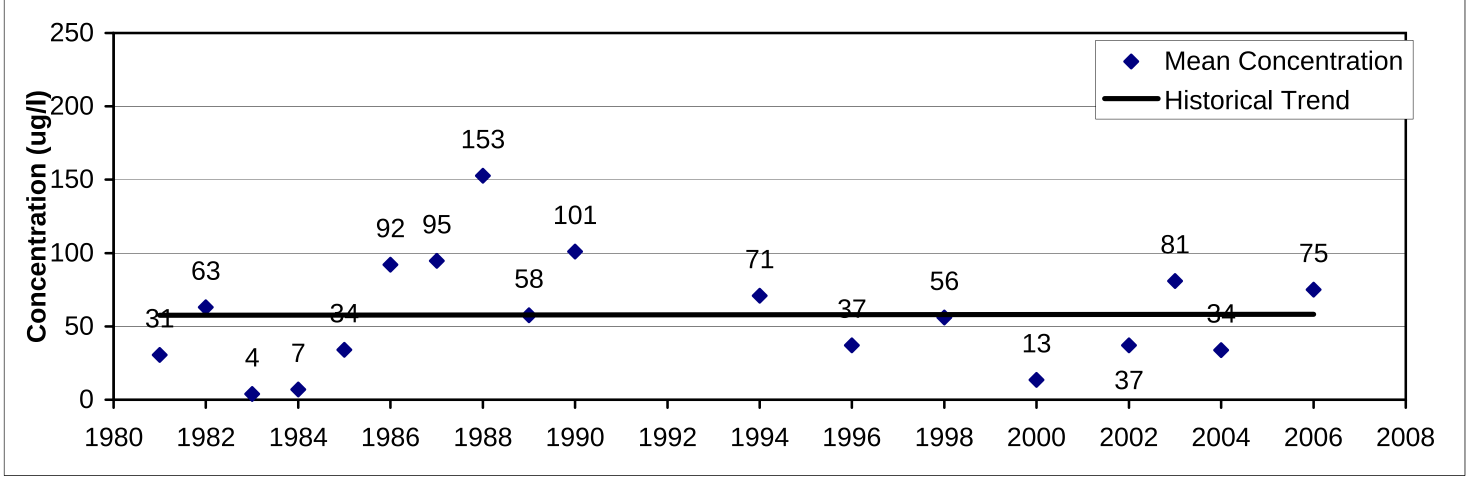
Secchi Depth



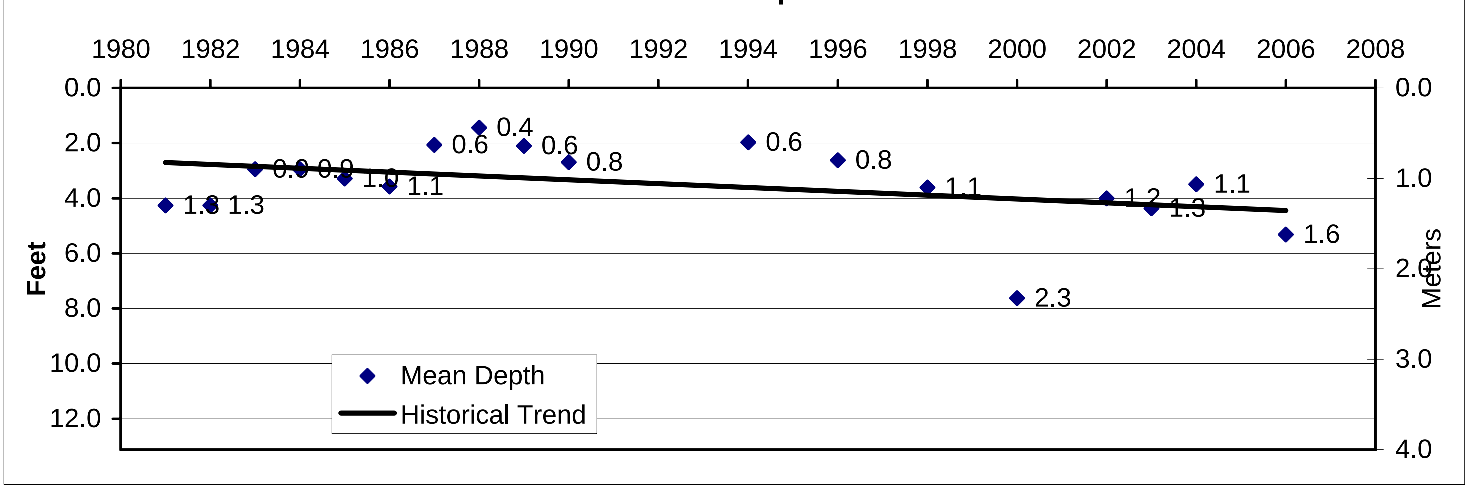
Clearwater River Watershed District	Wenck	Jan 2008
Lake Louisa Historical Data	Wenck Associates, Inc. Environmental Engineers 1800 Pioneer Creek Center Maple Plain, MN 55359	Appendix C



Total Phosphorus



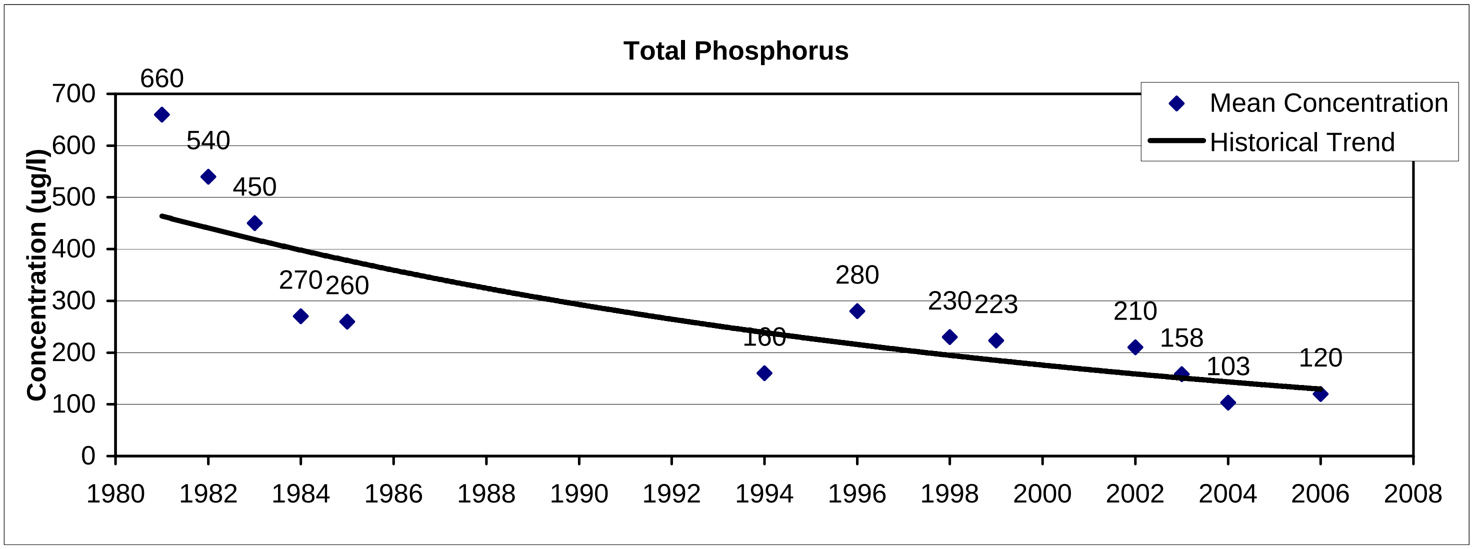
Chlorophyll-a

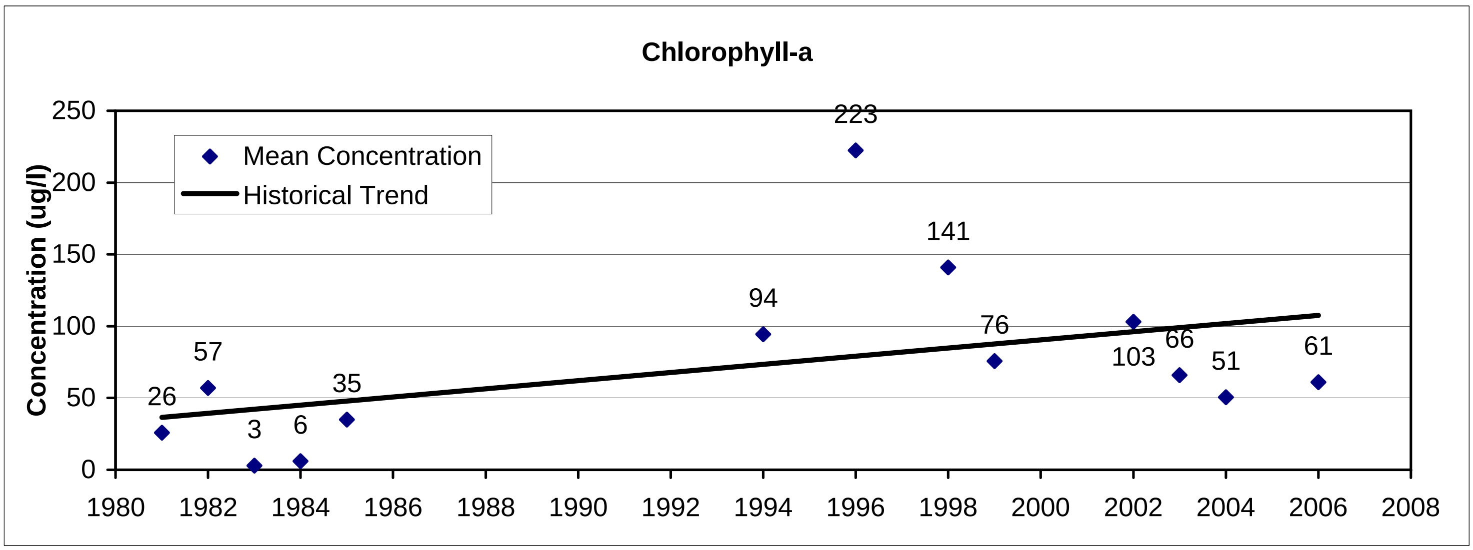


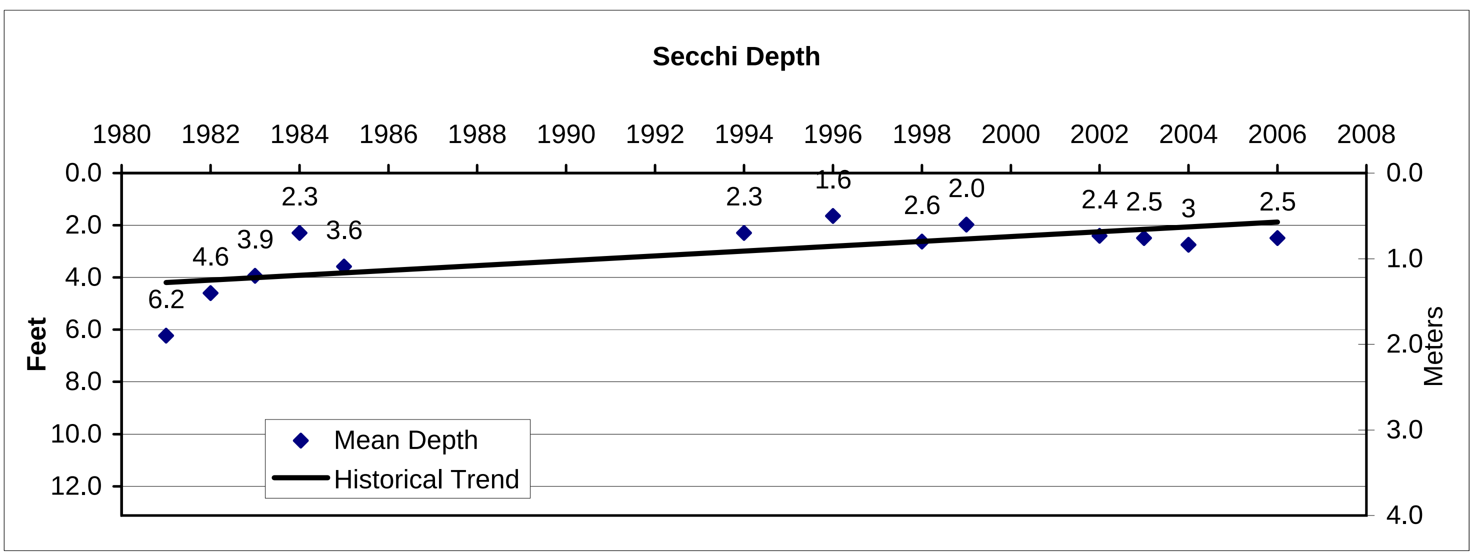
Secchi Depth

Clearwater River Watershed District	Wenck Associates, Inc. Environmental Engineers — 1800 Pioneer Creek Center, Maple Plain, MN 55359	Jan 2008
Lake Marie Historical Data		Appendix C

T:\0002\117\Reports\Appendices\Appendix A\Part 2Lake Marie

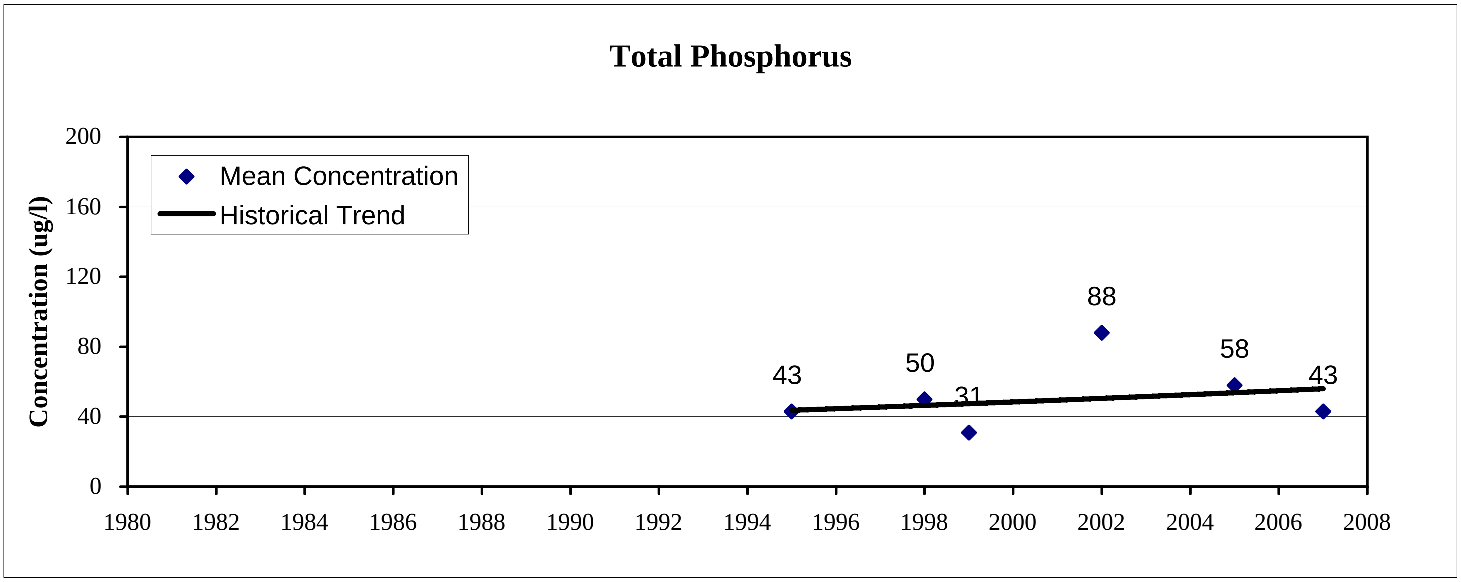


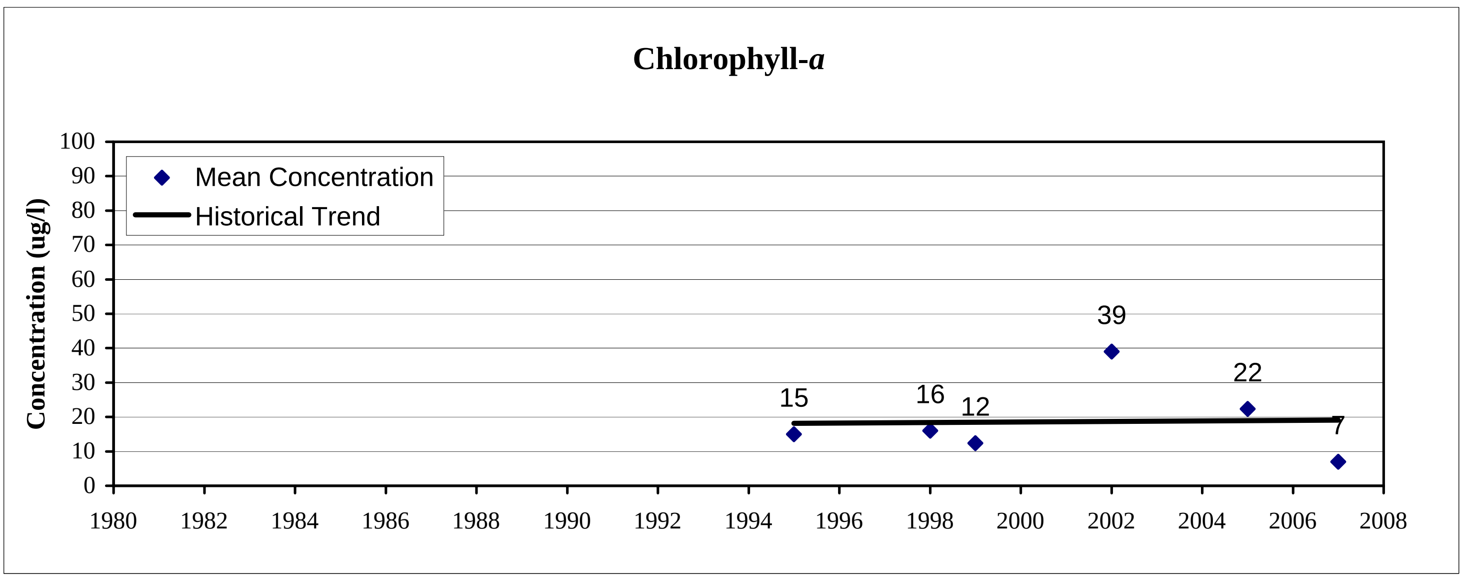


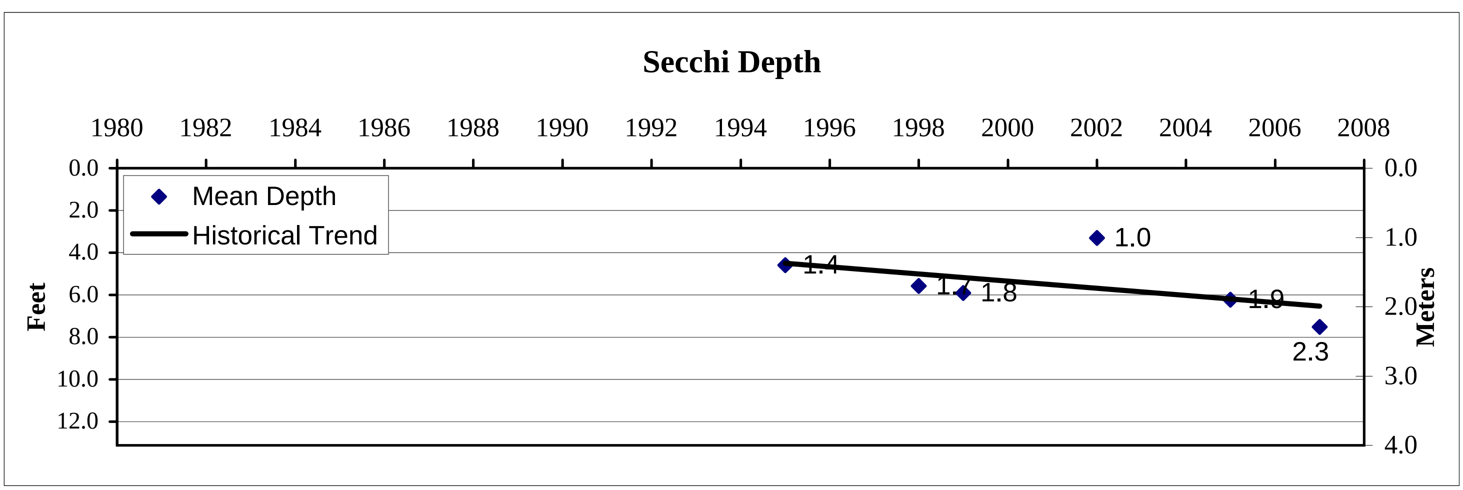


Clearwater River Watershed District	Wenck Wenck Associates, Inc. Environmental Engineers 1800 Pioneer Creek Center Maple Plain, MN 55359	Jan 2008
Scott Lake Historical Data		Appendix C

T:\0002\117\Reports\Appendices\Appendix A\Part 2Scott


Total Phosphorus
Concentration (ug/l)
200
160
120
80
40
0
Mean Concentration
Historical Trend
43
50
31
88
58
43
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008


Chlorophyll-*a*
Concentration (ug/l)
100
90
80
70
60
50
40
30
20
10
0
Mean Concentration
Historical Trend
15
16
12
39
22
7
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008


Secchi Depth
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Feet
0.0
2.0
4.0
6.0
8.0
10.0
12.0
Meters
0.0
1.0
2.0
3.0
4.0
Mean Depth
Historical Trend
1.4
1.7
1.8
1.0
1.9
2.3

Appendix B

Lake Model Results

Average Existing Nutrient Loading for Clear Lake

	Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas							
		Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Calibration Factor	Load
	Name	[acre]	[in/yr]	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1	Watershed	6,801.31	4.7	2,664	600.0	1.00	4,347
2						1.0	
3						1.0	
4						1.0	
5						1.0	
	Summation	*6,801*	*5*	*2,664*	*600.0*		*4,346.9*
Failing Septic Systems							
	Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1	Watershed	6,801	7	25%	4.2	0.0	7.4
2							
3							
4							
5							
	Summation	*6,801*	*7*	*25%*		*0.0*	*7.4*
Inflow from Upstream Lakes							
				Discharge	Estimated P Concentration	Calibration Factor	Load
	Name			[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1					-	1.0	
2					-	1.0	
3					-	1.0	
	Summation			*0*	*-*		*0*
Atmosphere							
	Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
	[acre]	[in/yr]	[in/yr]	[ac-ft/yr]	[lb/ac-yr]	[--]	[lb/yr]
	515	27.2	27.2	0.00	0.24	1.0	123.6
				Dry-year total P deposition =	0.230		
				Average-year total P deposition =	0.240		
				Wet-year total P deposition =	0.268		
				(Barr Engineering 2007)			
Groundwater							
	Lake Area	Groundwater Flux	Net Inflow	Net Inflow	Phosphorus Concentration	Calibration Factor	Load
	[acre]	[m/yr]	cfs	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
	515		2.1	1,548	56	1.0	236
Internal							
	Lake Area	Anoxic Factor			Release Rate	Calibration Factor	Load
	[acre]	[days]			[mg/m^2-day]	[--]	[lb/yr]
	515	28.0			65.00	1.0	8,364
			Net Discharge [ac-ft/yr] =	**4,212**		**Net Load [lb/yr] =**	**13,078**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Existing Nutrient Loading for Clear Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = P_i / \left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	13,078 [lb/yr]
		Q (lake outflow) =	4,212 [ac-ft/yr]
		V (modeled lake volume) =	4,504 [ac-ft]
		T = V/Q =	1.07 [yr]
		P_i = W/Q =	1142 [ug/l]
Model Predicted In-Lake [TP]			**219 [ug/l]**
Observed In-Lake [TP]			**- [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\text{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**61.2 [ug/l]**
	$[\text{Chl}a] = \frac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \text{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \frac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	219 [ug/l]
		N (Total Nitrogen) =	1815 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	130.9 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\frac{N - 150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	117.1 [ug/l]
		G (Kinematic factor) =	0.14 [--]
		F_s (Flushing Rate) =	0.93 [year^{-1}]
	$G = Z_{mix}(0.14 + 0.0039 F_s)$	Z_{mix} (Mixing Depth) =	3.28 [ft]
	$F_s = \frac{Q}{V}$; $a = \frac{1}{SD} - 0.015 \times [\text{Chl}a]$	a (Non algal turbidity) =	0.10 [m^{-1}]
		S (Secchi Depth) =	1.43 [ft]
		Maximum lake depth =	17.00 [ft]
Model Predicted In-Lake [Chl-a]			**87.8 [ug/l]**
Observed In-Lake [Chl-a]			**- [ug/l]**
SECCHI DEPTH			
	$SD = \frac{CS}{(\text{a} + 0.015 \times [\text{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.10 [m^{-1}]
Model Predicted In-Lake SD			**0.44 [m]**
Observed In-Lake SD			**- [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**10,575 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**2,503 [lb/yr]**

Average Existing Nutrient Loading for Clear Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**13,078**	219	78	2.59	10575	**2503**	81.8	73.4	63.4	**72.9**
5%	**12,424**	212	77	2.61	10000	**2424**	81.4	73.3	63.3	**72.6**
10%	**11,770**	205	77	2.63	9428	**2342**	80.9	73.2	63.2	**72.4**
15%	**11,116**	197	76	2.66	8857	**2259**	80.4	73.1	63.0	**72.1**
20%	**10,462**	190	75	2.69	8289	**2173**	79.8	73.0	62.9	**71.9**
25%	**9,809**	182	74	2.72	7723	**2086**	79.2	72.8	62.7	**71.6**
30%	**9,155**	174	73	2.76	7159	**1996**	78.6	72.7	62.5	**71.2**
35%	**8,501**	166	72	2.81	6598	**1903**	77.9	72.5	62.2	**70.9**
40%	**7,847**	158	70	2.86	6040	**1807**	77.1	72.3	62.0	**70.5**
45%	**7,193**	149	68	2.93	5485	**1708**	76.3	72.1	61.6	**70.0**
50%	**6,539**	140	66	3.00	4934	**1605**	75.4	71.8	61.3	**69.5**
55%	**5,885**	131	64	3.10	4388	**1497**	74.4	71.4	60.8	**68.9**
60%	**5,231**	121	62	3.22	3846	**1385**	73.3	71.0	60.3	**68.2**
65%	**4,577**	111	58	3.38	3310	**1267**	72.0	70.5	59.6	**67.4**
70%	**3,923**	100	55	3.59	2781	**1143**	70.5	69.8	58.7	**66.4**
75%	**3,270**	88	50	3.89	2260	**1010**	68.7	69.0	57.6	**65.1**
80%	**2,616**	76	44	4.33	1750	**866**	66.5	67.8	56.0	**63.4**
85%	**1,962**	62	37	5.06	1254	**708**	63.6	66.0	53.8	**61.1**
90%	**1,308**	46	28	6.45	779	**529**	59.4	63.1	50.3	**57.6**
95%	**654**	28	15	10.10	338	**316**	52.0	57.4	43.8	**51.0**

Average Existing Nutrient Loading for Lake Betsy

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	**Calibration Factor [--]**	Load [lb/yr]
1 Watershed	36,988	4.7	14486.8	250.0	**1.0**	9,850
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*36,988*	*5*	*14,487*	*250.0*		*9,849.9*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Watershed	36,988	20	25%	4.2	0.0	21.0
2						
3						
4						
5						
Summation	*36,988*	*20*	*25%*		*0.0*	*21.0*

Inflow from Upstream Lakes

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	**Calibration Factor [--]**	Load [lb/yr]
1 CR 28.2	10984	4.7	4,302.1	418	**1.0**	4,887
2				-	1.0	
3				-	1.0	
Summation			*4,302*	*417.7*		*4,887*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
148	27.2	27.2	0.00	0.24	1.0	35.5
			Dry-year total P deposition =	0.230		
			Average-year total P deposition =	0.240		
			Wet-year total P deposition =	0.268		
			(Barr Engineering 2007)			

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow cfs	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
148	0.0	1.5	1,115	56	1.0	170

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
148	67.0			80.00	1.0	7,080
		Net Discharge [ac-ft/yr] =	**19,904**		**Net Load [lb/yr] =**	**22,043**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

T:\0002\117\Lake Response Modeling\Goal\AVG LRModel (Clear-Betsy-Union-Scott-Louisa-Marie)Review
Worksheet Name:Betsy
10/21/2009

Average Existing Nutrient Loading for Lake Betsy

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	22,043 [lb/yr]
		Q (lake outflow) =	19,904 [ac-ft/yr]
		V (modeled lake volume) =	1,791 [ac-ft]
		T = V/Q =	0.09 [yr]
		P_i = W/Q =	407 [ug/l]
Model Predicted In-Lake [TP]			**241.2 [ug/l]**
Observed In-Lake [TP]			**343.0 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**67.5 [ug/l]**
	$[\mathrm{Chl}a] = \frac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \mathrm{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \frac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	241 [ug/l]
		N (Total Nitrogen) =	1712 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	127.0 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\frac{N - 150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	114.5 [ug/l]
		G (Kinematic factor) =	0.37 [--]
		F_s (Flushing Rate) =	11.11 [year^{-1}]
	$G = Z_{mix}(0.14 + 0.0039 F_s)$	Z_{mix} (Mixing Depth) =	6.56 [ft]
	$F_s = \frac{Q}{V}$; $a = \frac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$	a (Non algal turbidity) =	0.23 [m^{-1}]
		S (Secchi Depth) =	2.07 [ft]
		Maximum lake depth =	29.00 [ft]
Model Predicted In-Lake [Chl-a]			**54.1 [ug/l]**
Observed In-Lake [Chl-a]			**70.0 [ug/l]**
SECCHI DEPTH			
	$SD = \frac{CS}{(\mathrm{a} + 0.015 \times [\mathrm{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.23 [m^{-1}]
Model Predicted In-Lake SD			**0.63 [m]**
Observed In-Lake SD			**0.70 [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**8,993 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**13,056 [lb/yr]**

T:\0002\117\Lake Response Modeling\Goal\AVG LRModel (Clear-Betsy-Union-Scott-Louisa-Marie)Review
Worksheet Name:Betsy
10/21/2009

Average Existing Nutrient Loading for Lake Betsy

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**22,044**	241	46	3.57	8991	**13054**	83.3	68.1	58.8	**70.0**
5%	**20,942**	231	45	3.58	8423	**12520**	82.6	68.0	58.7	**69.8**
10%	**19,840**	221	45	3.60	7862	**11979**	82.0	68.0	58.7	**69.5**
15%	**18,738**	211	45	3.62	7308	**11430**	81.3	67.9	58.6	**69.3**
20%	**17,636**	201	44	3.65	6762	**10874**	80.6	67.8	58.5	**69.0**
25%	**16,533**	190	44	3.67	6224	**10309**	79.8	67.7	58.4	**68.6**
30%	**15,431**	180	43	3.71	5695	**9736**	79.0	67.6	58.2	**68.3**
35%	**14,329**	169	43	3.75	5176	**9153**	78.1	67.4	58.1	**67.9**
40%	**13,227**	158	42	3.80	4666	**8561**	77.2	67.3	57.9	**67.4**
45%	**12,124**	147	41	3.85	4168	**7957**	76.1	67.1	57.7	**67.0**
50%	**11,022**	136	40	3.93	3681	**7341**	75.0	66.8	57.4	**66.4**
55%	**9,920**	124	39	4.02	3207	**6713**	73.7	66.5	57.1	**65.7**
60%	**8,818**	112	37	4.13	2748	**6070**	72.2	66.1	56.7	**65.0**
65%	**7,716**	100	35	4.29	2304	**5411**	70.6	65.6	56.1	**64.1**
70%	**6,613**	87	33	4.50	1879	**4735**	68.6	64.9	55.4	**63.0**
75%	**5,511**	75	30	4.80	1474	**4037**	66.3	64.0	54.5	**61.6**
80%	**4,409**	61	26	5.24	1093	**3316**	63.5	62.6	53.2	**59.8**
85%	**3,307**	47	21	5.95	741	**2566**	59.8	60.5	51.4	**57.3**
90%	**2,204**	33	15	7.18	427	**1778**	54.5	57.1	48.7	**53.4**
95%	**1,102**	17	7	9.57	164	**938**	45.3	50.0	44.6	**46.6**

Average Existing Nutrient Loading for Union Lake

Water Budgets | **Phosphorus Loading**

Inflow from Drainage Areas

	Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1	Watershed	4,741	4.7	1856.9	100.0	1.0	505
2						1.0	
3						1.0	
4						1.0	
5						1.0	
	Summation	*4,741*	*5*	*1,857*	*100.0*		*505.0*

Failing Septic Systems

	Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1	Watershed	4,741	20	25%	4.2	0.0	21.0
2							
3							
4							
5							
	Summation	*4,741*	*20*	*25%*		*0.0*	*21.0*

Inflow from Upstream Lakes

	Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1			-	1.0	
2			-	1.0	
3			-	1.0	
	Summation	*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
92	27.2	27.2	0.00	0.24	1.0	22.2

Dry-year total P deposition =	0.230
Average-year total P deposition =	0.240
Wet-year total P deposition =	0.268
(Barr Engineering 2007)	

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow cfs	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
92	3.2	1.3	968	56	1.0	147

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
92	30.0	3.00	1.0	74

Net Discharge [ac-ft/yr] =	**2,825**	**Net Load [lb/yr] =**	**770**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Average Existing Nutrient Loading for Union Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	770 [lb/yr]
		Q (lake outflow) =	2,825 [ac-ft/yr]
		V (modeled lake volume) =	1,700 [ac-ft]
		T = V/Q =	0.60 [yr]
		P_i = W/Q =	100 [ug/l]
Model Predicted In-Lake [TP]			**49.7 [ug/l]**
Observed In-Lake [TP]			**43.0 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**13.9 [ug/l]**
	$[\mathrm{Chl}a] = \dfrac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \mathrm{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	50 [ug/l]
		N (Total Nitrogen) =	1627 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\dfrac{N - 150}{12}\right)^{-2}\right]^{-0.5}$	B_x (Nutrient-Potential Chl-a conc.) =	37.9 [ug/l]
		X_{pn} (Composite nutrient conc.)=	46.1 [ug/l]
	$G = Z_{mix}(0.14 + 0.0039 F_s)$	G (Kinematic factor) =	0.29 [--]
	$F_s = \dfrac{Q}{V}$	F_s (Flushing Rate) =	1.66 [year^{-1}]
	$a = \dfrac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$	Z_{mix} (Mixing Depth) =	6.56 [ft]
		a (Non algal turbidity) =	0.31 [m^{-1}]
		S (Secchi Depth) =	3.31 [ft]
		Maximum lake depth =	35.00 [ft]
Model Predicted In-Lake [Chl-a]			**27.2 [ug/l]**
Observed In-Lake [Chl-a]			**7.0 [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{(\mathrm{a} + 0.015 \times [\mathrm{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.31 [m^{-1}]
Model Predicted In-Lake SD			**1.01 [m]**
Observed In-Lake SD			**2.30 [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**388 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**382 [lb/yr]**

Average Existing Nutrient Loading for Union Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUC-TION [%]	NET LOAD [lb]	[TP] [ug/L]	[Chla] [ug/L]	SD [ft]	P SEDIMEN-TATION [lb]	TP OUT-FLOW [lb]	TSI [TP] [--]	TSI [Chla] [--]	TSI SD [--]	TSI Avg. [--]
0%	**770**	50	25	4.75	388	**382**	60.5	62.3	54.7	**59.2**
5%	**731**	48	24	4.85	364	**367**	59.9	62.0	54.4	**58.7**
10%	**693**	46	24	4.95	341	**352**	59.3	61.6	54.1	**58.3**
15%	**654**	44	23	5.06	317	**337**	58.7	61.2	53.8	**57.9**
20%	**616**	42	22	5.18	294	**321**	58.0	60.7	53.4	**57.4**
25%	**577**	40	21	5.31	272	**306**	57.3	60.2	53.1	**56.9**
30%	**539**	38	19	5.46	249	**289**	56.5	59.7	52.7	**56.3**
35%	**500**	36	18	5.61	227	**273**	55.6	59.1	52.3	**55.7**
40%	**462**	33	17	5.79	206	**256**	54.7	58.5	51.8	**55.0**
45%	**423**	31	16	5.98	184	**239**	53.7	57.7	51.3	**54.3**
50%	**385**	29	15	6.20	164	**221**	52.6	56.9	50.8	**53.5**
55%	**346**	26	13	6.44	143	**203**	51.4	56.0	50.3	**52.6**
60%	**308**	24	12	6.71	123	**185**	50.0	54.9	49.7	**51.5**
65%	**269**	22	10	7.02	104	**166**	48.4	53.7	49.0	**50.4**
70%	**231**	19	9	7.37	85	**146**	46.6	52.2	48.3	**49.0**
75%	**192**	16	8	7.76	67	**125**	44.4	50.4	47.6	**47.4**
80%	**154**	13	6	8.22	50	**104**	41.7	48.1	46.8	**45.5**
85%	**115**	11	4	8.74	34	**81**	38.1	45.0	45.9	**43.0**
90%	**77**	7	3	9.33	20	**57**	33.0	40.6	44.9	**39.5**
95%	**38**	4	1	9.99	8	**31**	24.1	32.7	44.0	**33.6**

Average Existing Nutrient Loading for Scott Lake

	Water Budgets			Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Watershed	2,473	4.7	968.6	80.0	1.0	211
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*2,473*	*5*	*969*	*80.0*		*210.8*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Watershed	2,473	0	25%	4.2	0.0	0.0
2						
3						
4						
5						
Summation	*2,473*	*0*	*25%*		*0.0*	*0.0*
Inflow from Upstream Lakes						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Lake Betsy	43789	4.7	17,150.7	343.0	1.0	15,999
2 Union Lake	4741	4.7	1,856.9	43.0	1.0	217
3				-	1.0	
Summation			*19,008*	*193.0*		*16,216*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
83	27.2	27.2	0.00	0.24	1.0	20.0
			Dry-year total P deposition =	0.230		
			Average-year total P deposition =	0.240		
			Wet-year total P deposition =	0.268		
			(Barr Engineering 2007)			
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow cfs	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
83	4.3	1.6	1,161	56	1.0	177
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
83	4.0			20.00	1.0	59
			Net Discharge [ac-ft/yr] = 21,137		**Net Load [lb/yr] =**	**16,683**

NOTES | Existing Load Out 11233

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

T:\0002\117\Lake Response Modeling\Goal\AVG LRModel (Clear-Betsy-Union-Scott-Louisa-Marie)Review
Worksheet Name:Scott
10/21/2009

Average Existing Nutrient Loading for Scott Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	16,683 [lb/yr]
		Q (lake outflow) =	21,137 [ac-ft/yr]
		V (modeled lake volume) =	833 [ac-ft]
		T = V/Q =	0.04 [yr]
		P_i = W/Q =	266 [ug/l]
Model Predicted In-Lake [TP]			**195.4 [ug/l]**
Observed In-Lake [TP]			**292.7 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\text{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**54.7 [ug/l]**
	$[\text{Chl}a] = \dfrac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \text{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	195 [ug/l]
		N (Total Nitrogen) =	1887 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	129.6 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\dfrac{N-150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	116.3 [ug/l]
		G (Kinematic factor) =	0.48 [--]
		F_s (Flushing Rate) =	25.39 [year^{-1}]
	$G = Z_{mix}(0.14 + 0.0039 F_s)$	Z_{mix} (Mixing Depth) =	6.56 [ft]
	$F_s = \dfrac{Q}{V}$; $a = \dfrac{1}{SD} - 0.015 \times [\text{Chl}a]$	a (Non algal turbidity) =	0.03 [m^{-1}]
		S (Secchi Depth) =	2.56 [ft]
		Maximum lake depth =	23.00 [ft]
Model Predicted In-Lake [Chl-a]			**50.1 [ug/l]**
Observed In-Lake [Chl-a]			**- [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{(\text{a} + 0.015 \times [\text{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.03 [m^{-1}]
Model Predicted In-Lake SD			**0.78 [m]**
Observed In-Lake SD			**- [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**4,068 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**11,232 [lb/yr]**

Average Existing Nutrient Loading for Scott Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUC-TION [%]	NET LOAD [lb]	[TP] [ug/L]	[Chla] [ug/L]	SD [ft]	P SEDIMEN-TATION [lb]	TP OUT-FLOW [lb]	TSI [TP] [--]	TSI [Chla] [--]	TSI SD [--]	TSI Avg. [--]
0%	**13,905**	180	40	5.21	3580	**10325**	79.0	66.8	53.3	**66.4**
5%	**13,210**	172	39	5.26	3342	**9868**	78.4	66.7	53.2	**66.1**
10%	**12,515**	164	39	5.32	3108	**9407**	77.7	66.6	53.0	**65.7**
15%	**11,819**	156	39	5.38	2878	**8942**	76.9	66.4	52.9	**65.4**
20%	**11,124**	147	38	5.46	2652	**8472**	76.2	66.3	52.7	**65.0**
25%	**10,429**	139	37	5.55	2431	**7998**	75.3	66.1	52.4	**64.6**
30%	**9,734**	131	37	5.65	2214	**7520**	74.4	65.9	52.2	**64.2**
35%	**9,038**	122	36	5.77	2002	**7036**	73.5	65.7	51.9	**63.7**
40%	**8,343**	114	35	5.92	1796	**6547**	72.4	65.4	51.5	**63.1**
45%	**7,648**	105	34	6.11	1596	**6052**	71.3	65.1	51.0	**62.5**
50%	**6,953**	97	32	6.34	1401	**5551**	70.1	64.7	50.5	**61.8**
55%	**6,257**	88	31	6.62	1213	**5044**	68.7	64.3	49.9	**60.9**
60%	**5,562**	79	29	7.00	1032	**4530**	67.1	63.7	49.1	**60.0**
65%	**4,867**	70	27	7.51	859	**4008**	65.4	63.0	48.1	**58.8**
70%	**4,172**	60	25	8.21	694	**3477**	63.3	62.0	46.8	**57.4**
75%	**3,476**	51	22	9.23	540	**2937**	60.9	60.8	45.1	**55.6**
80%	**2,781**	41	18	10.82	396	**2385**	57.9	59.0	42.8	**53.2**
85%	**2,086**	32	14	13.58	265	**1821**	54.0	56.5	39.5	**50.0**
90%	**1,391**	22	9	19.18	150	**1241**	48.4	52.5	34.6	**45.2**
95%	**695**	11	4	23.00	56	**639**	38.9	44.8	31.9	**38.5**

Average Existing Nutrient Loading for Lake Louisa

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Watershed	1,852	4.7	725	150.0	1.0	296
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*1,852*	*5*	*725*	*150.0*		***295.9***

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure Rate (%	Load / System	[lb/ac]	[lb/yr]
1 Watershed	1,852	56	25%	4.2	0.0	58.8
2						
3						
4						
5						
Summation	*1,852*	*56*	*25%*		*0.0*	*58.8*

Inflow from Upstream Boundary Condition

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 CR19.3	52029	4.7	20,378.0	104.0	1.0	5,764
2				-	1.0	
3				-	1.0	
Summation			*20,378*	*104.0*		*5,764*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
193	27.2	27.2	0.00	0.24	1.0	46.4
			Dry-year total P deposition =	0.230		
			Average-year total P deposition =	0.240		
			Wet-year total P deposition =	0.268		
			(Barr Engineering 2007)			

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow cfs	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
193	8.8	7.7	5,575	56	1.0	849

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m²-day]	Calibration Factor [--]	Load [lb/yr]
193	61.0			6.00	1.0	631
			Net Discharge [ac-ft/yr] = 26,678			**Net Load [lb/yr] = 7,646**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

T:\0002\117\Lake Response Modeling\Goal\AVG LRModel (Clear-Betsy-Union-Scott-Louisa-Marie)Review
Worksheet Name:Louisa
10/21/2009

Average Existing Nutrient Loading for Lake Louisa

Modeled Parameter	Equation	Parameters	Value [Units]

TOTAL IN-LAKE PHOSPHORUS CONCENTRATION

$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$

as f(W,Q,V) from Canfield & Bachmann (1981)

C_P =	1.00	[--]
C_{CB} =	0.162	[--]
b =	0.458	[--]
W (total P load = inflow + atm.) =	7,646	[lb/yr]
Q (lake outflow) =	26,678	[ac-ft/yr]
V (modeled lake volume) =	2,232	[ac-ft]
T = V/Q =	0.08	[yr]
P_i = W/Q =	105	[ug/l]

Model Predicted In-Lake [TP] **77.7 [ug/l]**

Observed In-Lake [TP] **79.0 [ug/l]**

CHLOROPHYLL-A CONCENTRATION

$$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$$

as f(TP), Walker 1999, Model 4

CB (Calibration factor) = 1.00 [--]

Model Predicted In-Lake [Chl-a] **21.8 [ug/l]**

$$[\mathrm{Chl}a] = \frac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \mathrm{a})]}$$

$$B_x = \frac{X_{pn}^{1.33}}{4.31}$$

$$X_{pn} = \left[P^{-2} + \left(\frac{N - 150}{12}\right)^{-2}\right]^{-0.5}$$

$$G = Z_{mix}(0.14 + 0.0039 F_s)$$

$$F_s = \frac{Q}{V} \qquad a = \frac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$$

as f(TP, N, Flushing), Walker 1999, Model 1

CB (Calibration factor) =	1.00	
P (Total Phosphorus) =	78	[ug/l]
N (Total Nitrogen) =	1737	[ug/l]
B_x (Nutrient-Potential Chl-a conc.) =	62.2	[ug/l]
X_{pn} (Composite nutrient conc.)=	67.0	[ug/l]
G (Kinematic factor) =	0.37	[--]
F_s (Flushing Rate) =	11.95	[year^{-1}]
Z_{mix} (Mixing Depth) =	6.56	[ft]
a (Non algal turbidity) =	0.17	[m^{-1}]
S (Secchi Depth) =	2.99	[ft]
Maximum lake depth =	44.00	[ft]

Model Predicted In-Lake [Chl-a] **37.0 [ug/l]**

Observed In-Lake [Chl-a] **79.0 [ug/l]**

SECCHI DEPTH

$$SD = \frac{CS}{(\mathrm{a} + 0.015 \times [\mathrm{Chl}a])}$$

as f(Chla), Walker (1999)

CS (Calibration factor) =	1.00	[--]
a (Non algal turbidity) =	0.17	[m^{-1}]

Model Predicted In-Lake SD **0.91 [m]**

Observed In-Lake SD **1.10 [m]**

PHOSPHORUS SEDIMENTATION RATE

$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$

P_{sed} (phosphorus sedimentation) = **2,009 [lb/yr]**

PHOSPHORUS OUTFLOW LOAD

W-P_{sed} = **5,636 [lb/yr]**

Average Existing Nutrient Loading for Lake Louisa

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUC-TION [%]	NET LOAD [lb]	[TP] [ug/L]	[Chla] [ug/L]	SD [ft]	P SEDIMEN-TATION [lb]	TP OUT-FLOW [lb]	TSI [TP] [--]	TSI [Chla] [--]	TSI SD [--]	TSI Avg. [--]
0%	**7,644**	78	33	4.93	2009	**5636**	66.9	64.8	54.1	**62.0**
5%	**7,262**	74	32	5.04	1875	**5387**	66.3	64.5	53.8	**61.5**
10%	**6,880**	71	31	5.16	1744	**5136**	65.6	64.2	53.5	**61.1**
15%	**6,498**	67	30	5.29	1615	**4882**	64.8	63.9	53.1	**60.6**
20%	**6,115**	64	29	5.44	1489	**4627**	64.1	63.5	52.7	**60.1**
25%	**5,733**	60	27	5.60	1365	**4369**	63.2	63.1	52.3	**59.5**
30%	**5,351**	57	26	5.79	1243	**4108**	62.4	62.6	51.8	**58.9**
35%	**4,969**	53	25	6.01	1125	**3844**	61.4	62.1	51.3	**58.3**
40%	**4,587**	49	23	6.26	1009	**3578**	60.4	61.5	50.7	**57.5**
45%	**4,204**	46	22	6.56	897	**3308**	59.2	60.8	50.0	**56.7**
50%	**3,822**	42	20	6.90	787	**3035**	58.0	60.0	49.3	**55.8**
55%	**3,440**	38	18	7.30	682	**2758**	56.6	59.1	48.5	**54.7**
60%	**3,058**	34	16	7.79	580	**2477**	55.1	58.1	47.5	**53.6**
65%	**2,676**	30	15	8.37	483	**2192**	53.3	56.8	46.5	**52.2**
70%	**2,293**	26	12	9.09	391	**1903**	51.3	55.3	45.3	**50.6**
75%	**1,911**	22	10	9.98	304	**1607**	48.8	53.5	44.0	**48.8**
80%	**1,529**	18	8	11.10	223	**1306**	45.8	51.1	42.4	**46.5**
85%	**1,147**	14	6	12.54	149	**998**	41.9	47.9	40.7	**43.5**
90%	**764**	9	4	14.37	84	**680**	36.4	43.2	38.7	**39.5**
95%	**382**	5	2	16.64	32	**351**	26.9	34.8	36.6	**32.8**

Average Existing Nutrient Loading for Lake Marie

	Water Budgets			Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Watershed	5,956	4.7	2,333	150.0	1.0	952
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*5,956*	*5*	*2,333*	*150.0*		*951.6*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Watershed	5,956	70	25%	4.2	0.0	73.5
2						
3						
4						
5						
Summation	*5,956*	*70*	*25%*		*0.0*	*73.5*

Inflow from Upstream Lakes

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Lake Louisa	53881	4.7	26,680.2	79.0	1.0	5,636
2				-	1.0	
3				-	1.0	
Summation			*26,680*	*79.0*		*5,636*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
140	27.2	27.2	0.00	0.24	1.0	33.7
			Dry-year total P deposition =	0.230		
			Average-year total P deposition =	0.240		
			Wet-year total P deposition =	0.268		
			(Barr Engineering 2007)			

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow cfs	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
140	12.1	7.7	5,575	56	1.0	849

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m²-day]	Calibration Factor [--]	Load [lb/yr]
140	15.0			18.00	1.0	338

		Net Discharge [ac-ft/yr] =	**34,588**		**Net Load [lb/yr] =**	**7,882**

NOTES

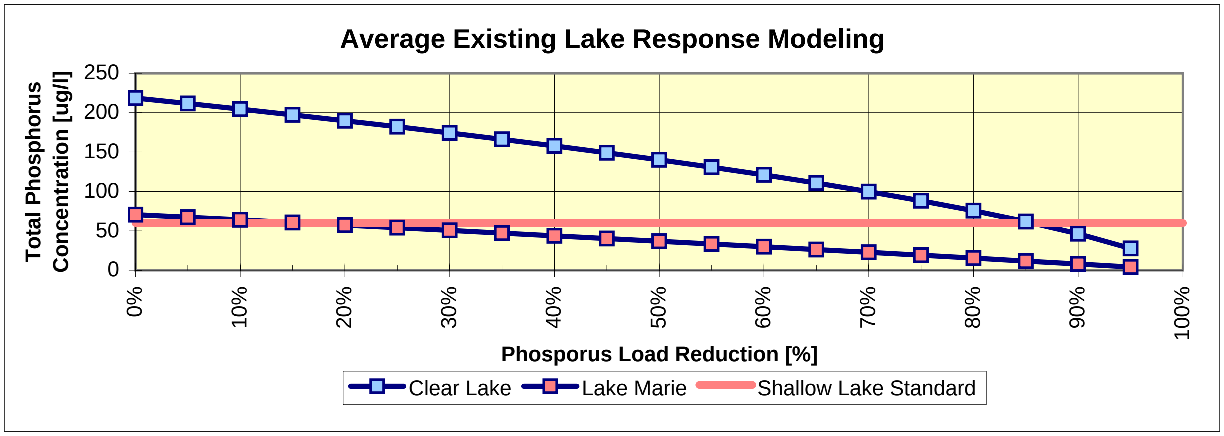
[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

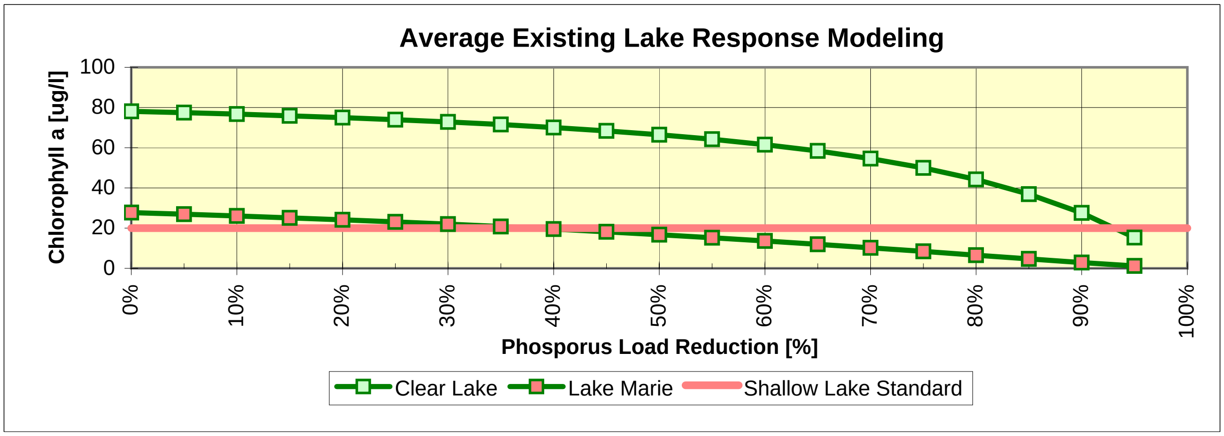
Average Existing Nutrient Loading for **Lake Marie**

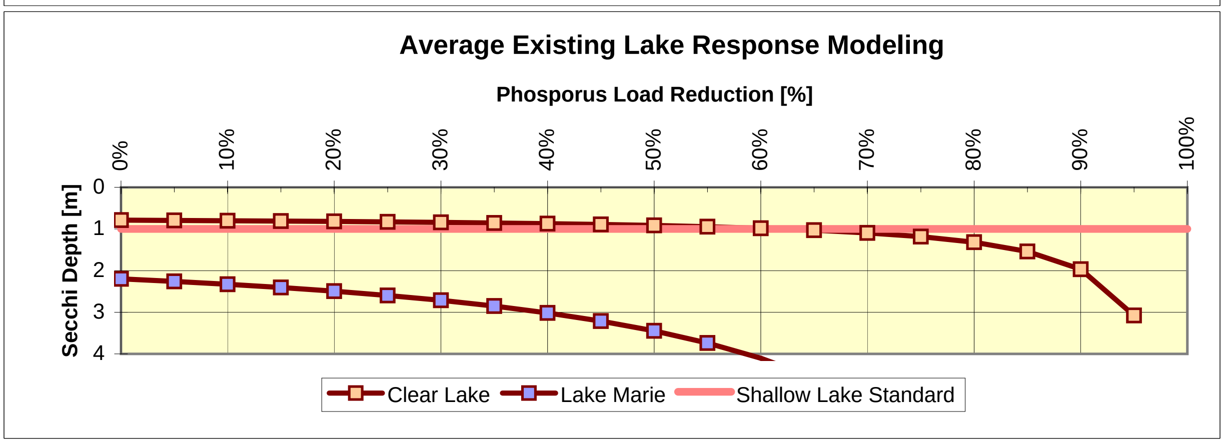
Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	7,882 [lb/yr]
		Q (lake outflow) =	34,588 [ac-ft/yr]
		V (modeled lake volume) =	1,085 [ac-ft]
		T = V/Q =	0.03 [yr]
		P_i = W/Q =	84 [ug/l]
Model Predicted In-Lake [TP]			**70.5 [ug/l]**
Observed In-Lake [TP]			**- [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\text{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**19.7 [ug/l]**
	$[\text{Chl}a] = \dfrac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \text{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	70 [ug/l]
		N (Total Nitrogen) =	1998 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	58.7 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\dfrac{N - 150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	64.1 [ug/l]
		G (Kinematic factor) =	0.53 [--]
		F_s (Flushing Rate) =	31.87 [year^{-1}]
	$G = Z_{mix}(0.14 + 0.0039 F_s)$	Z_{mix} (Mixing Depth) =	6.56 [ft]
	$F_s = \dfrac{Q}{V}$; $a = \dfrac{1}{SD} - 0.015 \times [\text{Chl}a]$	a (Non algal turbidity) =	0.04 [m^{-1}]
		S (Secchi Depth) =	3.87 [ft]
		Maximum lake depth =	36.00 [ft]
Model Predicted In-Lake [Chl-a]			**32.4 [ug/l]**
Observed In-Lake [Chl-a]			**- [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{(\text{a} + 0.015 \times [\text{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.04 [m^{-1}]
Model Predicted In-Lake SD			**1.18 [m]**
Observed In-Lake SD			**- [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**1,251 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**6,631 [lb/yr]**

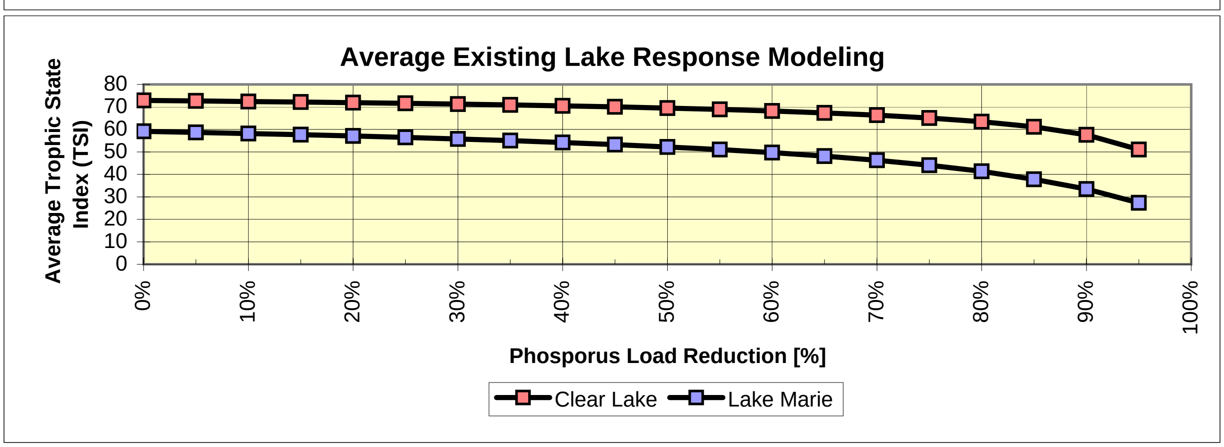
Average Existing Nutrient Loading for Lake Marie

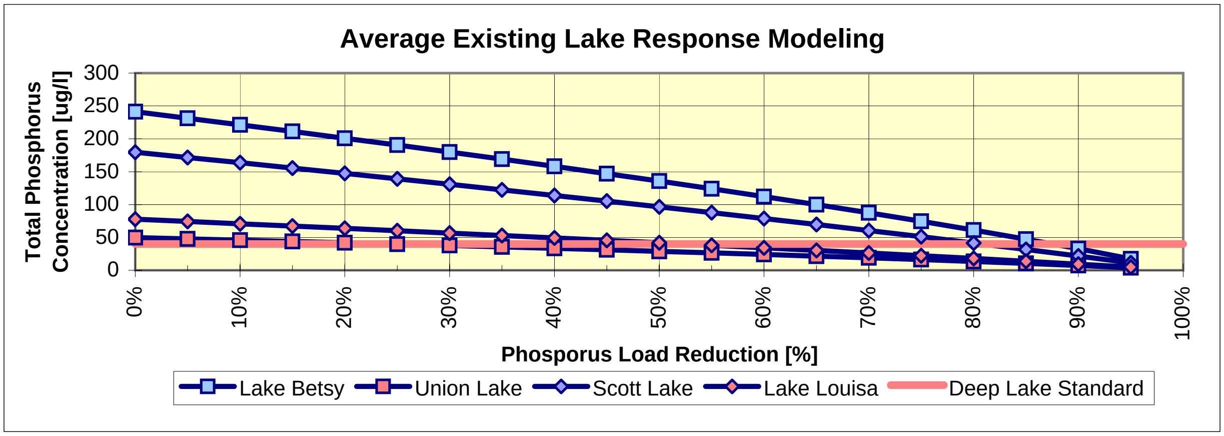
LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**7,881**	70	28	7.21	1251	**6631**	65.5	63.2	48.7	**59.1**
5%	**7,487**	67	27	7.41	1165	**6323**	64.8	62.9	48.3	**58.7**
10%	**7,093**	64	26	7.63	1081	**6013**	64.1	62.6	47.8	**58.2**
15%	**6,699**	61	25	7.89	998	**5701**	63.3	62.2	47.4	**57.6**
20%	**6,305**	57	24	8.18	917	**5388**	62.5	61.8	46.8	**57.1**
25%	**5,911**	54	23	8.52	839	**5072**	61.7	61.4	46.3	**56.4**
30%	**5,517**	51	22	8.91	762	**4755**	60.7	60.9	45.6	**55.7**
35%	**5,123**	47	21	9.36	687	**4436**	59.7	60.4	44.9	**55.0**
40%	**4,729**	44	19	9.89	614	**4115**	58.6	59.7	44.1	**54.2**
45%	**4,335**	40	18	10.53	544	**3791**	57.5	59.0	43.2	**53.2**
50%	**3,941**	37	17	11.31	476	**3465**	56.2	58.2	42.2	**52.2**
55%	**3,547**	33	15	12.26	410	**3136**	54.7	57.3	41.0	**51.0**
60%	**3,153**	30	14	13.46	348	**2805**	53.1	56.2	39.7	**49.7**
65%	**2,758**	26	12	15.01	288	**2470**	51.3	55.0	38.1	**48.1**
70%	**2,364**	23	10	17.04	232	**2133**	49.2	53.4	36.3	**46.3**
75%	**1,970**	19	8	19.84	179	**1791**	46.6	51.5	34.1	**44.1**
80%	**1,576**	15	7	23.84	130	**1446**	43.6	49.1	31.4	**41.3**
85%	**1,182**	12	5	29.93	87	**1096**	39.6	45.8	28.1	**37.8**
90%	**788**	8	3	36.00	49	**740**	33.9	41.0	25.5	**33.4**
95%	**394**	4	1	36.00	18	**376**	24.1	32.4	25.5	**27.4**

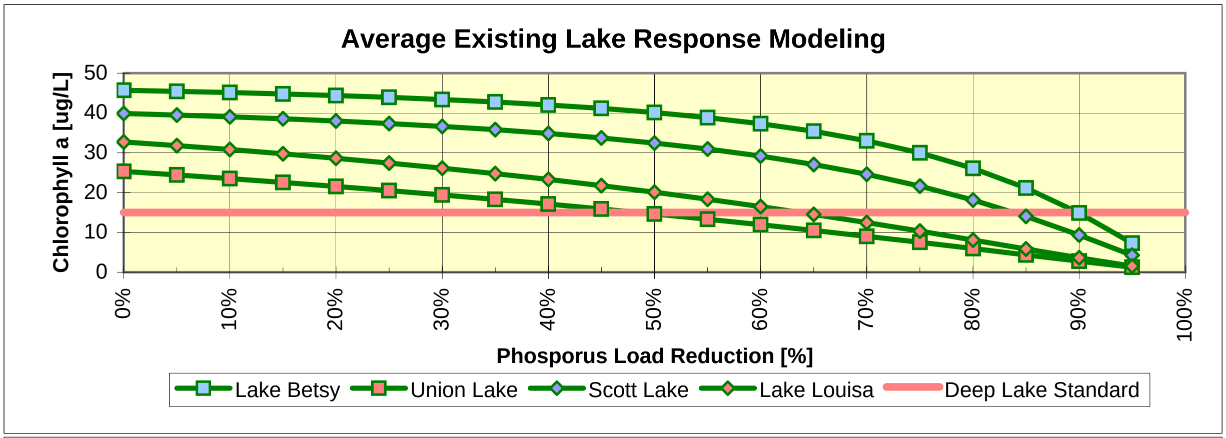

Average Existing Lake Response Modeling
Total Phosphorus Concentration [ug/l]
Phosporus Load Reduction [%]
Clear Lake
Lake Marie
Shallow Lake Standard

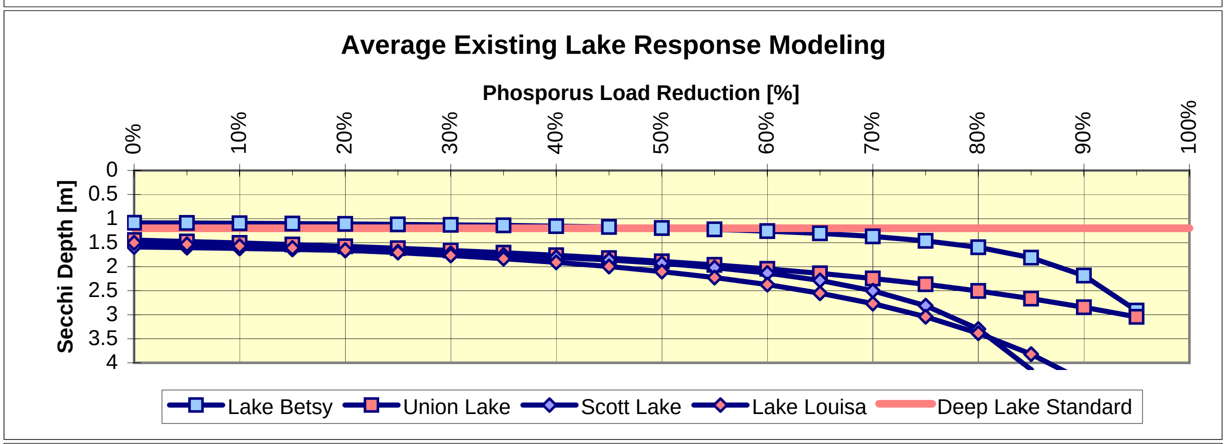

Average Existing Lake Response Modeling
Chlorophyll a [ug/l]
Phosporus Load Reduction [%]
Clear Lake
Lake Marie
Shallow Lake Standard

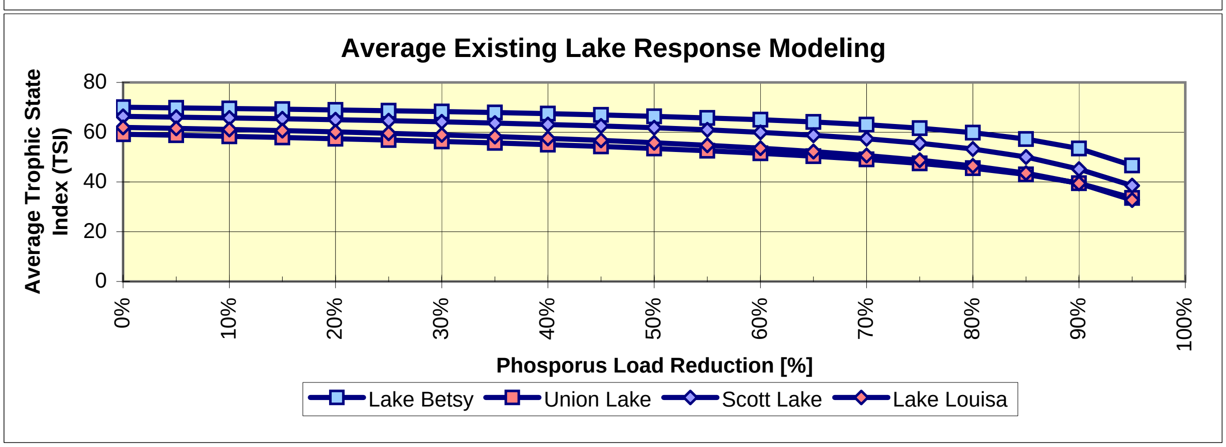

Average Existing Lake Response Modeling
Phosporus Load Reduction [%]
Secchi Depth [m]
Clear Lake
Lake Marie
Shallow Lake Standard


Average Existing Lake Response Modeling
Average Trophic State Index (TSI)
Phosporus Load Reduction [%]
Clear Lake
Lake Marie


Average Existing Lake Response Modeling
Total Phosphorus Concentration [ug/l]
300
250
200
150
100
50
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Lake Betsy
Union Lake
Scott Lake
Lake Louisa
Deep Lake Standard


Average Existing Lake Response Modeling
Chlorophyll a [ug/L]
50
40
30
20
10
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Lake Betsy
Union Lake
Scott Lake
Lake Louisa
Deep Lake Standard


Average Existing Lake Response Modeling
Phosporus Load Reduction [%]
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Secchi Depth [m]
0
0.5
1
1.5
2
2.5
3
3.5
4
Lake Betsy
Union Lake
Scott Lake
Lake Louisa
Deep Lake Standard


Average Existing Lake Response Modeling
Average Trophic State Index (TSI)
80
60
40
20
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Lake Betsy
Union Lake
Scott Lake
Lake Louisa

Nutrient Loading Goal for Clear Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Load Reduction Factor	Load
Name	[acre]	[in/yr]	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1 Watershed	6,801.31	4.7	2,664	600.0	**0.20**	869
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*6,801*	*5*	*2,664*	*600.0*		*869.4*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Allowable Failure Rate	Load / System	[lb/ac]	[lb/yr]
1 Watershed	6,801	7	**0%**	4.2	0.0	0.0
2						
3						
4						
5						
Summation	*6,801*	*7*	*0%*		*0.0*	*0.0*
Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1				-	1.0	
2				-	1.0	
3				-	1.0	
Summation			*0*	-		*0*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
515	27.2	27.2	0.00	0.24	1.0	123.6
			Dry-year total P deposition =	0.230		
			Average-year total P deposition =	0.240		
			Wet-year total P deposition =	0.268		
			(Barr Engineering 2007)			
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow cfs	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
515		2.1	1,548	56	1.0	236
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Load Reduction Factor [--]	Load [lb/yr]
515	28.0			65.00	**0.05**	21
		Net Discharge [ac-ft/yr] =	**4,212**		**Net Load [lb/yr] =**	**1,250**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Nutrient Loading Goal for Clear Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	1,250 [lb/yr]
		Q (lake outflow) =	4,212 [ac-ft/yr]
		V (modeled lake volume) =	4,504 [ac-ft]
		T = V/Q =	1.07 [yr]
		P_i = W/Q =	144 [ug/l]
Model Predicted In-Lake [TP]			**54.6 [ug/l]**
Observed In-Lake [TP]			**- [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**15.3 [ug/l]**
	$[\mathrm{Chl}a] = \dfrac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \mathrm{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	55 [ug/l]
		N (Total Nitrogen) =	1815 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	43.1 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\dfrac{N - 150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	50.8 [ug/l]
		G (Kinematic factor) =	0.14 [--]
		F_s (Flushing Rate) =	0.93 [year^{-1}]
	$G = Z_{mix}(0.14 + 0.0039 F_s)$	Z_{mix} (Mixing Depth) =	3.28 [ft]
	$F_s = \dfrac{Q}{V}$; $a = \dfrac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$	a (Non algal turbidity) =	0.10 [m^{-1}]
		S (Secchi Depth) =	3.23 [ft]
		Maximum lake depth =	17.00 [ft]
Model Predicted In-Lake [Chl-a]			**36.8 [ug/l]**
Observed In-Lake [Chl-a]			**- [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{(\mathrm{a} + 0.015 \times [\mathrm{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.10 [m^{-1}]
Model Predicted In-Lake SD			**0.99 [m]**
Observed In-Lake SD			**- [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**1,022 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**625 [lb/yr]**

Nutrient Loading Goal for Lake Betsy

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	**Load Reduction Factor [--]**	Load [lb/yr]
1 Watershed	36,988	4.7	14486.8	250.0	**0.16**	1,576
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*36,988*	*5*	*14,487*	*250.0*		*1,576.0*

Failing Septic Systems

Name	Area [ac]	# of Systems	Allowable Failure Rate	Load / System	[lb/ac]	[lb/yr]
1 Watershed	36,988	20	**0%**	4.2	0.0	0.0
2						
3						
4						
5						
Summation	*36,988*	*20*	*0%*		*0.0*	*0.0*

Inflow from Upstream Lakes

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	**Load Reduction Factor [--]**	Load [lb/yr]
1 CR 28.2	10984	4.7	4,302.1	418	**0.15**	733
2				-	1.0	
3				-	1.0	
Summation			*4,302*	*417.7*		*733*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
148	27.2	27.2	0.00	0.24	1.0	35.5
			Dry-year total P deposition =	0.230		
			Average-year total P deposition =	0.240		
			Wet-year total P deposition =	0.268		
			(Barr Engineering 2007)			

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow cfs	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
148	0.0	1.5	1,115	56	1.0	170

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	**Load Reduction Factor [--]**	Load [lb/yr]
148	67.0			80.00	**0.05**	354
		Net Discharge [ac-ft/yr] =	**19,904**		**Net Load [lb/yr] =**	**2,868**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Nutrient Loading Goal for Lake Betsy

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	2,868 [lb/yr]
		Q (lake outflow) =	19,904 [ac-ft/yr]
		V (modeled lake volume) =	1,791 [ac-ft]
		T = V/Q =	0.10 [yr]
		P_i = W/Q =	51 [ug/l]
Model Predicted In-Lake [TP]			**40.0 [ug/l]**
Observed In-Lake [TP]			**[ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**11.2 [ug/l]**
	$[\mathrm{Chl}a] = \dfrac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \mathrm{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	40 [ug/l]
		N (Total Nitrogen) =	1712 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	29.5 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\dfrac{N - 150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	38.2 [ug/l]
		G (Kinematic factor) =	0.36 [--]
		F_s (Flushing Rate) =	10.44 [year^{-1}]
	$G = Z_{mix}(0.14 + 0.0039 F_s)$	Z_{mix} (Mixing Depth) =	6.56 [ft]
	$F_s = \dfrac{Q}{V}$; $a = \dfrac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$	a (Non algal turbidity) =	0.23 [m^{-1}]
		S (Secchi Depth) =	4.26 [ft]
		Maximum lake depth =	29.00 [ft]
Model Predicted In-Lake [Chl-a]			**21.5 [ug/l]**
Observed In-Lake [Chl-a]			**70.0 [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{(\mathrm{a} + 0.015 \times [\mathrm{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.23 [m^{-1}]
Model Predicted In-Lake SD			**1.30 [m]**
Observed In-Lake SD			**0.70 [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**559 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**2,032 [lb/yr]**

Nutrient Loading Goal for Union Lake

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	**Load Reduction Factor [--]**	Load [lb/yr]
1 Watershed	4,741	4.7	1856.9	100.0	**0.65**	328
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*4,741*	*5*	*1,857*	*100.0*		*328.3*

Failing Septic Systems

Name	Area [ac]	# of Systems	Allowable Failure Rate	Load / System	[lb/ac]	[lb/yr]
1 Watershed	4,741	20	**0%**	4.2	0.0	0.0
2						
3						
4						
5						
Summation	*4,741*	*20*	*0%*		*0.0*	*0.0*

Inflow from Upstream Lakes

Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1		-	1.0	
2		-	1.0	
3		-	1.0	
Summation	*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
92	27.2	27.2	0.00	0.24	1.0	22.2
			Dry-year total P deposition =	0.230		
			Average-year total P deposition =	0.240		
			Wet-year total P deposition =	0.268		
			(Barr Engineering 2007)			

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow cfs	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
92	3.2	1.3	968	56	1.0	147

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Load Reduction Factor [--]	Load [lb/yr]
92	30.0			3.00	1.0	74
		Net Discharge [ac-ft/yr] =	**2,825**		**Net Load [lb/yr] =**	**572**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Nutrient Loading Goal for Union Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	572 [lb/yr]
		Q (lake outflow) =	2,825 [ac-ft/yr]
		V (modeled lake volume) =	1,700 [ac-ft]
		T = V/Q =	0.60 [yr]
		P_i = W/Q =	74 [ug/l]
Model Predicted In-Lake [TP]			**39.5 [ug/l]**
Observed In-Lake [TP]			**43.0 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$$[\text{Chl}a] = CB \times 0.28 \times [TP]$$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**11.1 [ug/l]**
	$$[\text{Chl}a] = \frac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times a)]}$$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$$B_x = \frac{X_{pn}^{1.33}}{4.31}$$	P (Total Phosphorus) =	39 [ug/l]
		N (Total Nitrogen) =	1627 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	28.9 [ug/l]
	$$X_{pn} = \left[P^{-2} + \left(\frac{N - 150}{12}\right)^{-2}\right]^{-0.5}$$	X_{pn} (Composite nutrient conc.)=	37.6 [ug/l]
		G (Kinematic factor) =	0.29 [--]
		F_s (Flushing Rate) =	1.66 [year^{-1}]
	$$G = Z_{mix}(0.14 + 0.0039F_s)$$	Z_{mix} (Mixing Depth) =	6.56 [ft]
	$$F_s = \frac{Q}{V}$$ $$a = \frac{1}{SD} - 0.015 \times [\text{Chl}a]$$	a (Non algal turbidity) =	0.31 [m^{-1}]
		S (Secchi Depth) =	3.83 [ft]
		Maximum lake depth =	35.00 [ft]
Model Predicted In-Lake [Chl-a]			**21.9 [ug/l]**
Observed In-Lake [Chl-a]			**7.0 [ug/l]**
SECCHI DEPTH			
	$$SD = \frac{CS}{(a + 0.015 \times [\text{Chl}a])}$$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.31 [m^{-1}]
Model Predicted In-Lake SD			**1.17 [m]**
Observed In-Lake SD			**2.30 [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$		
		P_{sed} (phosphorus sedimentation) =	**269** [lb/yr]
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**303 [lb/yr]**

Nutrient Loading Goal for Scott Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Watershed	2,473	4.7	968.6	80.0	1.0	211
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*2,473*	*5*	*969*	*80.0*		*210.8*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Allowable Failure Rate	Load / System	[lb/ac]	[lb/yr]
1 Watershed	2,473	0	**0%**	4.2	0.0	0.0
2						
3						
4						
5						
Summation	*2,473*	*0*	*0%*		*0.0*	*0.0*
Inflow from Upstream Lakes						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Goal P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Lake Betsy	43789	4.7	17,150.7	**40.0**	1.0	1,866
2 Union Lake	4741	4.7	1,856.9	**40.0**	1.0	202
3				-	1.0	
Summation			*19,008*	*40.0*		*2,068*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
83	27.2	27.2	0.00	0.24	1.0	20.0
		Dry-year total P deposition =		0.230		
		Average-year total P deposition =		0.240		
		Wet-year total P deposition =		0.268		
		(Barr Engineering 2007)				
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow cfs	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
83	4.3	1.6	1,161	56	1.0	177
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
83	4.0			20.00	1.0	59
		Net Discharge [ac-ft/yr] =	**21,137**		**Net Load [lb/yr] =**	**2,535**

NOTES Goal Load Out: 2180 74% reduction over existing

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

T:\0002\117\Lake Response Modeling\Goal\Goal LRModel (Clear-Betsy-Union-Scott-Louisa-Marie)Review
Worksheet Name:Scott
10/21/2009

Nutrient Loading Goal for Scott Lake

Modeled Parameter	Equation	Parameters	Value [Units]

TOTAL IN-LAKE PHOSPHORUS CONCENTRATION

$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$

as f(W,Q,V) from Canfield & Bachmann (1981)		
C_P =	1.00	[--]
C_{CB} =	0.162	[--]
b =	0.458	[--]
W (total P load = inflow + atm.) =	2,535	[lb/yr]
Q (lake outflow) =	21,137	[ac-ft/yr]
V (modeled lake volume) =	833	[ac-ft]
T = V/Q =	0.04	[yr]
P_i = W/Q =	44	[ug/l]
Model Predicted In-Lake [TP]	**37.9**	**[ug/l]**
Observed In-Lake [TP]	**292.7**	**[ug/l]**

CHLOROPHYLL-A CONCENTRATION

$$[\text{Chl}a] = CB \times 0.28 \times [TP]$$

as f(TP), Walker 1999, Model 4		
CB (Calibration factor) =	1.00	[--]
Model Predicted In-Lake [Chl-a]	**10.6**	**[ug/l]**

$$[\text{Chl}a] = \frac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \text{a})]}$$

$$B_x = \frac{X_{pn}^{1.33}}{4.31}$$

$$X_{pn} = \left[P^{-2} + \left(\frac{N - 150}{12}\right)^{-2}\right]^{-0.5}$$

$$G = Z_{mix}(0.14 + 0.0039 F_s)$$

$$F_s = \frac{Q}{V}$$

$$a = \frac{1}{SD} - 0.015 \times [\text{Chl}a]$$

as f(TP, N, Flushing), Walker 1999, Model 1		
CB (Calibration factor) =	1.00	
P (Total Phosphorus) =	38	[ug/l]
N (Total Nitrogen) =	1887	[ug/l]
B_x (Nutrient-Potential Chl-a conc.) =	27.9	[ug/l]
X_{pn} (Composite nutrient conc.)=	36.7	[ug/l]
G (Kinematic factor) =	0.50	[--]
F_s (Flushing Rate) =	28.41	[year^{-1}]
Z_{mix} (Mixing Depth) =	6.56	[ft]
a (Non algal turbidity) =	0.03	[m^{-1}]
S (Secchi Depth) =	6.07	[ft]
Maximum lake depth =	23.00	[ft]
Model Predicted In-Lake [Chl-a]	**20.4**	**[ug/l]**
Observed In-Lake [Chl-a]	**-**	**[ug/l]**

SECCHI DEPTH

$$SD = \frac{CS}{(\text{a} + 0.015 \times [\text{Chl}a])}$$

as f(Chla), Walker (1999)		
CS (Calibration factor) =	1.00	[--]
a (Non algal turbidity) =	0.03	[m^{-1}]
Model Predicted In-Lake SD	**1.85**	**[m]**
Observed In-Lake SD	**-**	**[m]**

PHOSPHORUS SEDIMENTATION RATE

$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$

P_{sed} (phosphorus sedimentation) = 363 [lb/yr]

PHOSPHORUS OUTFLOW LOAD

W-P_{sed} = **2,439 [lb/yr]**

Nutrient Loading Goal for Lake Louisa

	Water Budgets			Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Load Reduction Factor [--]	Load [lb/yr]
1 Watershed	1,852	4.7	725	150.0	**0.90**	266
2					0.9	
3					0.9	
4					0.9	
5					0.9	
Summation	*1,852*	*5*	*725*	*150.0*		***266.3***

Failing Septic Systems

Name	Area [ac]	# of Systems	Allowable Failure Rate	Load / System	[lb/ac]	[lb/yr]
1 Watershed	1,852	56	**0%**	4.2	0.0	0.0
2						
3						
4						
5						
Summation	*1,852*	*56*	*0%*		*0.0*	*0.0*

Inflow from Upstream Boundary Condition

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Load Reduction Factor [--]	Load [lb/yr]
1 CR19.3	52029	4.7	20,378.0	104.0	**0.26**	1,499
2				-	1.0	
3				-	1.0	
Summation			*20,378*	*104.0*		*1,499*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
193	27.2	27.2	0.00	0.24	1.0	46.4
			Dry-year total P deposition =	0.230		
			Average-year total P deposition =	0.240		
			Wet-year total P deposition =	0.268		
			(Barr Engineering 2007)			

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow cfs	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
193	8.8	7.7	5,575	56	1.0	849

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Load Reduction Factor [--]	Load [lb/yr]
193	61.0			6.00	**1.0**	631
		Net Discharge [ac-ft/yr] =	**26,678**		**Net Load [lb/yr] =**	**3,292**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

T:\0002\117\Lake Response Modeling\Goal\Goal LRModel (Clear-Betsy-Union-Scott-Louisa-Marie)Review
Worksheet Name:Louisa
10/21/2009

Nutrient Loading Goal for Lake Louisa

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	3,292 [lb/yr]
		Q (lake outflow) =	26,678 [ac-ft/yr]
		V (modeled lake volume) =	2,232 [ac-ft]
		T = V/Q =	0.08 [yr]
		P_i = W/Q =	45 [ug/l]
Model Predicted In-Lake [TP]			**36.5 [ug/l]**
Observed In-Lake [TP]			**[ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\text{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**10.2 [ug/l]**
	$[\text{Chl}a] = \dfrac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \text{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	37 [ug/l]
		N (Total Nitrogen) =	1737 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	26.5 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\dfrac{N - 150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	35.2 [ug/l]
		G (Kinematic factor) =	0.37 [--]
		F_s (Flushing Rate) =	11.95 [year^{-1}]
	$G = Z_{mix}(0.14 + 0.0039 F_s)$	Z_{mix} (Mixing Depth) =	6.56 [ft]
	$F_s = \dfrac{Q}{V}$; $a = \dfrac{1}{SD} - 0.015 \times [\text{Chl}a]$	a (Non algal turbidity) =	0.17 [m^{-1}]
		S (Secchi Depth) =	4.88 [ft]
		Maximum lake depth =	44.00 [ft]
Model Predicted In-Lake [Chl-a]			**19.9 [ug/l]**
Observed In-Lake [Chl-a]			**79.0 [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{(\text{a} + 0.015 \times [\text{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.17 [m^{-1}]
Model Predicted In-Lake SD			**1.49 [m]**
Observed In-Lake SD			**1.10 [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**642 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**2,650 [lb/yr]**

Nutrient Loading Goal for Lake Marie

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Watershed	5,956	5.3	2,637	150.0	**0.5**	538
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*5,956*	*5*	*2,637*	*150.0*		*538.0*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Allowable Failure Rate	Load / System	[lb/ac]	[lb/yr]
1 Watershed	5,956	70	**0%**	4.2	0.0	0.0
2						
3						
4						
5						
Summation	*5,956*	*70*	*0%*		*0.0*	*0.0*
Inflow from Upstream Lakes						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Goal P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Lake Louisa	53881	5.9	26,680.2	**40.0**	1.0	2,902
2				-	1.0	
3				-	1.0	
Summation			*26,680*	*40.0*		*2,902*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
140	27.2	27.2	0.00	0.24	1.0	33.7
			Dry-year total P deposition =	0.230		
			Average-year total P deposition =	0.240		
			Wet-year total P deposition =	0.268		
			(Barr Engineering 2007)			
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow cfs	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
140	12.1	7.7	5,575	56	1.0	849
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	**Load Reduction Factor [--]**	Load [lb/yr]
140	15.0			18.00	**0.7**	236
			Net Discharge [ac-ft/yr] = **34,893**		**Net Load [lb/yr] =**	**4,560**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

Nutrient Loading Goal for Lake Marie

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	4,560 [lb/yr]
		Q (lake outflow) =	34,893 [ac-ft/yr]
		V (modeled lake volume) =	1,085 [ac-ft]
		T = V/Q =	0.03 [yr]
		P_i = W/Q =	45 [ug/l]
Model Predicted In-Lake [TP]			**40 [ug/l]**
Observed In-Lake [TP]			**- [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$$[\text{Chl}a] = CB \times 0.28 \times [TP]$$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**11.1 [ug/l]**
	$$[\text{Chl}a] = \frac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times a)]}$$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$$B_x = \frac{X_{pn}^{1.33}}{4.31}$$	P (Total Phosphorus) =	40 [ug/l]
		N (Total Nitrogen) =	1998 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	29.8 [ug/l]
	$$X_{pn} = \left[P^{-2} + \left(\frac{N - 150}{12}\right)^{-2}\right]^{-0.5}$$	X_{pn} (Composite nutrient conc.)=	38.5 [ug/l]
		G (Kinematic factor) =	0.53 [--]
		F_s (Flushing Rate) =	32.15 [year^{-1}]
	$$G = Z_{mix}(0.14 + 0.0039 F_s)$$	Z_{mix} (Mixing Depth) =	6.56 [ft]
	$$F_s = \frac{Q}{V}$$ $$a = \frac{1}{SD} - 0.015 \times [\text{Chl}a]$$	a (Non algal turbidity) =	0.04 [m^{-1}]
		S (Secchi Depth) =	5.84 [ft]
		Maximum lake depth =	36.00 [ft]
Model Predicted In-Lake [Chl-a]			**20.9 [ug/l]**
Observed In-Lake [Chl-a]			**- [ug/l]**
SECCHI DEPTH			
	$$SD = \frac{CS}{(a + 0.015 \times [\text{Chl}a])}$$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.04 [m^{-1}]
Model Predicted In-Lake SD			**1.78 [m]**
Observed In-Lake SD			**- [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$		
		P_{sed} (phosphorus sedimentation) =	**535 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**3,772 [lb/yr]**

Appendix C

Public Participation Materials

Clearwater River Watershed District

March 2008

Box 481, Annandale, MN 55302 (320) 202-0554 www.crwd.org

Clear Lake Benefits From CRWD Actions

Clear Lake, a 555-acre lake in Meeker County at the headwaters of the Clearwater River Watershed District (CRWD), has been the focus of water quality improvements for nearly 40 years.

In the 1960s, the Minnesota DNR removed rough fish from the lake and restocked it with game fish.

The CRWD also provided grant application funds for Forest Prairie Township to acquire the money to install a sanitary sewer system around Clear Lake. The project was initiated by several Clear Lake property owners who approached the Township Board to request action. The system collects wastewater from 125 homes and pipes it to the City of Watkins, where it is treated in a facility north of the City.

The District has also completed many other water quality projects focused on Clear Lake, including the Nistler/Geislinger sedimentation basin, the Clear Lake north wetland retention basin, the Ostmark Church erosion control project, and the County Ditch 20 erosion control project at the outlet of Clear Lake.

The many projects completed or underway for Clear Lake address concerns about lake water quality. According to the most recent monitoring data collected for Clear Lake, there is reason for continued concern. Several measures of water quality do not meet standards established by the Minnesota Pollution Control Agency (MPCA). For example, average summer phosphorus concentration is more than double the MPCA standard for the lake, and the chlorophyll-a concentration (a measure of algal growth) is more than triple the MPCA limit.

The Nistler/Geislinger sedimentation basin is one of many projects implemented on Clear Lake to improve water quality.

As a result of these findings, Clear Lake is listed by the MPCA as an impaired water body. To address the problem, the Agency requires that a Total Maximum Daily Load, or TMDL, study be completed to reduce pollutant loads. (See related article on page 3.)

Clear Lake Property Owners Spearhead Curly Leaf Pondweed Control, Bullhead Removal

Aided by a DNR Pilot Project grant of $20,000, Clear Lake property owners treated the lake in May 2007 to control Curly Leaf Pondweed, an introduced plant that crowds out native vegetation and interferes with internal cycling of phosphorus, thereby worsening water quality. The group plans an additional treatment in spring 2008 to kill newly germinated plants. With less Curly Leaf, growth of native vegetation will increase and release of sediment phosphorus may decrease.

The group also supported the removal of 5,600 pounds of bullheads, which disturb native vegetation and increase water turbidity with their bottom-feeding activities. The group plans to remove an additional 20,000 pounds of bullheads from the lake in 2008. They estimate that a total of 80,000 bullheads will be harvested from the lake.

Clear Lake property owners treated the lake in May 2007 to control Curly Leaf Pondweed.

Inside:

Restoration Project Continues on Cedar Chain of Lakes

Swimming, fishing, and boating will be more pleasant experiences on Cedar Lake as a restoration project continues.

In response to concerns from lake shore residents about declining water quality in Cedar Lake, the Clearwater River Watershed District started the restoration project in the Cedar Chain of Lakes last spring.

The goal of the restoration project is to reduce the concentration of phosphorus in Cedar Lake and so reduce the growth of algae and improve water quality.

Because most of the phosphorus in Cedar Lake comes from the upper watershed, the project focuses on reducing upstream nutrient runoff and lowering the concentration of phosphorus in Henshaw, Albion, and Swartout lakes.

The District implemented several Best Management Practices to accomplish this, including fish barriers, buffers, and a treatment basin.

Carp and other rough fish will find their movement through the chain of lakes restricted by fish barriers constructed at three locations: the Highway 55 wetland outlet and the Swartout and Henshaw lake outlets. The barriers are intended to reduce the population of rough fish, whose bottom-feeding activities can uproot vegetation and release phosphorus from sediments.

In addition to restricting rough fish movement, the project also harvested rough fish from Swartout Lake. The first harvest of carp occurred in early February 2008 and removed slightly more than 42,000 pounds of fish. More harvests are planned.

To reduce the amount of phosphorus in water draining from the upper watershed, 146 acres of buffers were planted at tile intakes and will remain in place for one to three years. The buffers will help prevent phosphorus-containing sediments from entering the water stream and, ultimately, Cedar Lake.

Commercial fishermen netted slightly more than 42,000 pounds of rough fish from Swartout Lake in early February 2008.

A diversion berm was constructed in December 2007 to divert stream flow into Segner Pond, a sedimentation basin on the Cedar Lake inlet.

As the water from the upper watershed approaches Cedar Lake, it will enter a newly constructed treatment basin on the Cedar Lake inlet. The 2.9 acre basin, called Segner Pond, will use a limestone-containing filter along with sedimentation to remove both particulate and dissolved phosphorus from the water before it enters the lake.

A special monitoring program begun in 2007 will track the progress of the restoration project. Cedar, Swartout, Albion, and Henshaw lakes were sampled four times by the District in 2007. Eight tributary streams were also sampled in April, May and June. Volunteers assisted District staff by sampling Cedar Lake eight times during 2007. The water samples were analyzed for total phosphorus concentration, chlorophyll-a concentration (a measure of algal growth), and Secchi depth (a measure of turbidity) .

So far, the monitoring results show that average phosphorus concentrations and chlorophyll-a concentrations do not meet MPCA standards in Henshaw, Albion, and Swartout lakes. The average Secchi depth also does not meet the MPCA standard in Henshaw and Swartout lakes.

In Cedar Lake, the average phosphorus concentration decreased in 2007 compared to previous years, but this was likely the result of below-normal rainfall and runoff that year. However, the restoration project is expected to accomplish the same results in years with normal and even above-normal precipitation, with the goal of limiting the external phosphorus load to 1,000 pounds per year.

Segner Pond's limestone filter dike will remove additional phosphorus from water before it enters Cedar Lake.

CRWD Addresses Impaired Waters Through TMDL Study

Learn more about the Total Maximum Daily Load (TMDL) Process and How to Protect Water Quality

Impaired Waters and TMDLs

Impaired waters are those that do not meet state water quality standards for dissolved oxygen, nutrients, sediments, bacteria, metals, or other criteria required to support aquatic life or allow the designated use of a water body, such as swimming.

The Federal Clean Water Act requires the Minnesota Pollution Control Agency to identify impaired water bodies and develop total maximum daily loads, or TMDLs, for nutrients, sediments bacteria, and other parameters. The TMDL is the total amount of a pollutant a water body can assimilate while meeting the established water quality standards.

In the Clearwater River Watershed District, two stretches of the Clearwater River are impaired for having low oxygen or high levels of bacteria, and 11 lakes are impaired for having high levels of nutrients (see sidebar). Using a 2003 grant from the MPCA, the CRWD has embarked on a TMDL study of these impaired waters with the goal of improving water quality so these waters meet state standards.

Water samples are gathered and analyzed early in the TMDL process.

CRWD Impaired Waters

The MPCA listed the following water bodies in CRWD as impaired. TMDLs for those marked with an asterisk (*) are planned to begin in 2009 or as funding becomes available. TMDLs for all other water bodies are underway.

- Clearwater River between Clear Lake and Lake Betsy (bacteria and dissolved oxygen)
- Clearwater River between Grass Lake and the Mississippi River (dissolved oxygen)
- Lake Louisa (nutrients)
- Lake Betsy (nutrients)
- Clear Lake (nutrients)
- Lake Marie (nutrients)
- Scott Lake (nutrients)
- Union Lake (nutrients)
- Swartout Lake (nutrients)*
- Lake Albion (nutrients)*
- Henshaw Lake (nutrients)*
- Lake Augusta (nutrients)*
- Lake Caroline (nutrients)*

Typically, a TMDL is developed in four phases. In Phase 1, existing data is reviewed, data gaps are identified, and plans are developed to collect and analyze the additional data needed. In Phase 2, that data is collected and evaluated.

In the third phase, the TMDL is set. Loads are allocated to point and non-point sources and an implementation plan to meet load reductions is prepared.

Finally, in the fourth phase, plans are implemented to reduce loads to the limits identified in Phase 3.

TMDL Progress in CRWD

To date, TMDL Phases 1 and 2 have been completed for impaired waters in the CRWD. Phase 3, now underway, will use water quality models to quantify existing loads and calculate required reductions. Load reduction alternatives will be identified, an implementation plan will be developed, and a future monitoring plan will be prepared.

The findings of the TMDL study will be presented at public meetings. Check the CRWD website or local newspapers for public notices of the meetings.

Implementation of the recommendations will depend on approval of the Phase 3 study by the MPCA and the U.S. Environmental Protection Agency and acquisition of funding.

How to Protect Our Waters

Many opportunities exist for the public to participate in protecting water quality in the CRWD.

Participate in the TMDL Process. District residents are encouraged to learn about the TMDL process and attend the public meeting presenting the results of the third phase of the study. The meeting also will be an opportunity to learn about urban stormwater management, septic system upgrades, buffer installations, and other practices that could be implemented to reach TMDL goals.

Plant a shoreline buffer or a rain garden—and get paid! Those who live along a lake or river can take advantage of financial incentives to plant buffers or rain gardens to prevent sediment and nutrients from entering the water. For more information, contact the CRWD.

Plant farm buffers using additional CRWD incentives. Farmers who have rivers or lakes near their properties can qualify for additional incentives from the CRWD to join federal conservation programs or install various buffers. More information is available from the CRWD.

Contact the CRWD for more information about water quality and how to get involved in protecting this vital natural resource.

This dam on the Clearwater River just upstream from the Mississippi River marks the end of Clearwater River's reach. Two river stretches and 11 lakes in the CRWD have been listed as impaired by the MPCA.

Incentive Programs Help District Residents Improve Water Quality

Several incentive programs are available to residents interested in protecting water quality in District lakes, rivers, and streams. For more information about any of the following programs, please call the District office.

Shoreline Buffer Incentive

District residents with lakefront or riverfront property can receive a one-time incentive of $250 to plant a shoreline buffer. These buffers of beautiful native plants not only protect water quality by preventing sediment and nutrient runoff, they also attract a variety of birds, butterflies, and other wildlife. Technical assistance to plant a buffer is available from local Soil and Water Conservation District offices. Buffers must meet a minimum size to qualify for the incentive.

Rain gardens and lakeshore buffers capture sediment and nutrients.

Farm Buffer Incentives

Farmers who have a lake or river near their property can receive an additional incentive from the CRWD for joining the federal conservation program. The CRWD will offer a one-time payment of $200/acre to a farmer who enrolls or establishes a buffer in the Conservation Reserve Program.

Farmers who plant seeded, harvestable buffers along rivers, streams, or county ditches for a three-year period will receive a one-time payment from the CRWD of $350/acre.

Native plant buffers protect water quality, add beauty, and attract birds, butterflies, and wildlife.

These are just two of several incentives available to farmers. Please contact the District office to learn about more opportunities.

Rain Garden Incentives

The CRWD will pay a one-time incentive of $2.50 per square foot to plant and maintain a rain garden on lakeshore property. The payment is limited to an area no more than 10% of the impervious surface on the property. The rain garden plan must also be pre-approved by the CRWD to qualify.

For more information about rain gardens and their benefits to water quality, visit the web site for Rice Creek Watershed District's Blue Thumb educational program at http://bluethumb.org/why/.

Animal Feedlot Upgrade Incentive

Animal producers upgrading their feedlots to reduce phosphorus runoff may be eligible for financial assistance from the CRWD. The amount is based on the degree of phosphorus reduction required and the distance between the feedlot and surface water. Contact the District Administrator for more information.

Meet Your CRWD Board Members and District Staff

Board of Managers

Marvin Brunsell
Chairperson
Wright County
320-274-5018
marv@lkdllink.net

Dennis Loewen
Vice-Chairperson
Stearns County
320-398-6012
dlmansup@yahoo.com

Jerry Risberg
Public Relations and Information
Stearns County
320-274-3635
jandprisberg@hotmail.com

Robert Schiefelbein
Treasurer
Meeker County
320-398-8400
rgaaa@juno.com

Mark Kampa
Secretary
Wright County
320-274-5332
mkampa@lakedalelink.net

District Staff

District Administrator
Merle Anderson
320-202-0554
merleanderson@cloudnet.com

District Attorney
Gray Plant Mooty Mooty & Bennett
Stan Weinberger
St. Cloud, Minnesota
320-202-5334
Stanley.Weinberger@gpmlaw.com

District Engineer
Wenck Associates, Inc.
Norm Wenck, P.E.
763-479-4201
nwenck@wenck.com
Rebecca Kluckhohn, P.E.
763-479-4224
rkluckhohn@wenck.com

Mailing address

Box 481
Annandale, Minnesota 55302

admin@crwd.org

District Governance

A five-member Board of Managers governs the CRWD. The Managers serve staggered three-year terms. The Wright County Board of Commissioners appoints two Managers, the Stearns County Board appoints two, and the Meeker County Board appoints one. The largest portion of the District lies in Wright and Stearns Counties, with a smaller portion in Meeker. The powers and duties of Watershed Districts and their Boards of Managers are set forth in Minnesota Statute 103D.

CRWD Board Meetings

Regular meetings of the CRWD Board of Managers are held twice a month and are open to the public. The Board meets on the second Wednesday of the month at 7:00 p.m. at the Annandale Middle School. Workshops are held on the fourth Wednesday of the month at 6:30 p.m. at Stanley's restaurant in Kimball. Meeting notices and minutes are published in the Annandale, Kimball, and Watkins weekly papers and are posted on the CRWD website at www.crwd.org.

Did You Know?

- Parts of three counties make up the CRWD:northeastern Meeker County, southeastern Stearns County, and northern Wright County.
- The CRWD covers159 square miles and includes 7,336 acres of lake basins contained mostly in 19 meandered lakes.
- The headwaters of the Clearwater River are in Meeker County. From its headwaters the river flows east-northeast until it meets the Mississippi River at the City of Clearwater. The river is approximately 39 miles long.

Appendix D

CRWD's Annual Monitoring Program

DRAFT MEMORANDUM

TO: Clearwater River Watershed District Board of Managers

FROM: Norman C. Wenck
Engineer for the District

DATE: February 11, 2007

RE: Proposed 2007 Water Quality Monitoring Program

Introduction
The Clearwater River Watershed District conducts annual water quality monitoring at selected lakes and selected locations on streams. The District's proposed 2007 program is intended to provide data throughout the District. Three TMDL studies, currently underway, will focus on the impaired waters. Phase II of the TMDL study (data collection) will continue in 2007.

The 2007 proposed lake monitoring follows the long-term plan shown in Table 1. The proposed stream monitoring sites together with laboratory and field parameters are shown in Table 2.

Lake Monitoring
The District 2007 regular lake monitoring includes Clearwater Lake East, Lake Augusta, Lake Louisa, Lake Betsy, Pleasant Lake, School Section Lake and Otter Lake. The Clearwater River below Grass Lake will also be monitored under the TMDL Grant. The proposed stations and the parameters to be monitored are shown on Table 2. Citizens also monitor approximately 10 lakes for secchi depth. The Cedar Lake watershed and its upper watershed lakes will be monitored under a special program as part of the Cedar, Albion, Swartout, Henshaw Improvement Project No 06-1.

Stream Monitoring
The Clearwater River will be monitored at station CR28.2. Warner Creek will be monitored at WR 0.2. These stations will be monitored six times for water quality and flow. Parameters are total phosphorus and soluble reactive phosphorus.

Bass Lake
Several (5) run-in points to Bass Lake have been identified and will be sampled and analyzed during three storm events in 2007. No flow occurred for this proposed sampling during 2006.

Estimated Cost
This proposed basic program is estimated to cost $19,700.

Summary
The proposed monitoring program continues the program in place since 1981, coordinates with other programs, and reflects input from the Board and citizens. Please feel free to call me at 763-479-4201 or Rebecca Kluckhohn at 763-479-4224 with any questions or comments that you may have.

TABLE 1
PROPOSED LONG-TERM WATER QUALITY MONITORING PLAN FOR CRWD LAKES

LAKE STATIONS[1]	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Clearwater Lake:														
Clearwater East	X	X	X	X	X	X	X	X	DNR		X		X	
Clearwater West	X	X	X	X	X	X	X	X	DNR	X		X		X
Main Stem Lakes:														
Augusta	X		X		X		X		DNR		X		X	
Louisa	X		X		X		X		TMDL/ DNR	TMDL	X		X	
Caroline		X				X		X	DNR	X		X		X
Scott		X	X			X		X		X		X		X
Marie		X		X		X		X	DNR	X		X		X
Betsy	X		X		X		X		X		X		X	
Other Lakes:														
Cedar			X		X		X	X	X	X		X		X
Pleasant	X		X	X				X	MPCA		X			X
School Section	X		X	X				X			X			X
Nixon	X		X		X			X			X			X
Otter	X		X		X			X			X			X
Bass		X	X		X				MPCA/ DNR	X			X	
Clear		X	X	X			X		X			X		
Union		X	X			X			MPCA			X		
Henshaw		X	X			X			X		X			
Little Mud			X			X				X			X	
Wiegand			X			X			X				X	
Swartout			X				X		X	X			X	
Albion			X				X		X	X			X	
Grass			X				X		DNR			X		
Number of Lakes Monitored W/ CRWD Funding	9	9	20	6	9	9	10	10	7	10	9	8	9	9

Note: [1]Lake selection based on total lake size ranking scores (Lake Priority Ranking, 1990)

TABLE 2
Proposed 2007 CRWD Monitoring Plan Summary

Category	2007 Schedule	Station	Parameters
Lakes:	May 15 -16	The CRWD will monitor Clearwater (East), Augusta, Louisa, Betsy, Grass, Pleasant, School Section, and Otter	Field: Secchi depth, DO and temperature profiles
	June 19 - 20	Cedar, Albion, Swartout, and Hensaw Lakes will be monitored under Project No. 06-1	Lab: surface samples only for total phosphorus, soluble reactive phosphorus, chlorophyll-a
	Jul 24 - 25		
	Aug 28 - 29		Citizen Secchi: 10 sites not listed here
Streams:	April 10 May 1	WRO.2	Field: flows, DO and temperature Lab: total phosphorus, soluble reactive phosphorus, total suspended solids
	June 5 July 10 August 2 September 5	CR 28.2 The Clearwater River downstream of Grass Lake will be monitored through the TMDL Study	
	Bi-weekly	River Stage at CR10.5(TMDL)	
Precipitation:	Daily	Watkins and Corrinna	
Special:	3 events	Bass Lake Run in points	Tributaries Field: DO, temperature, conductivity, pH profiles; Lab: total phosphorus, soluble reactive phosphorus Lakes Field: DO, temperature, conductivity, pH profiles; Lab: 3 profile samples for total phosphorus, soluble reactive phosphorus, iron, chlorophyll-a