Pope County 8 Lakes
Total Maximum Daily Load

March 2017

wq-iw7-35e

Primary Authors and Contributors

Minnesota Pollution Control Agency

Tim James

Pope County Soil and Water Conservation District

Luan Johnsrud

Emmons & Olivier Resources, Inc.

Jennifer Olson

Andrea Plevan

Meghan Funke, PhD

Pat Conrad

Jason Naber

<table>
<tr><th>EPA/MPCA Required Elements</th><th colspan="2">Summary</th><th>TMDL Page #</th></tr>
<tr><td>Location</td><td colspan="2">Chippewa River Watershed in the Minnesota River Basin, Pope County and Douglas County, Minnesota (HUC 07020005).</td><td>22</td></tr>
<tr><td>303(d) Listing Information</td><td colspan="2">For all lakes:
· Impaired Beneficial Use(s) - Aquatic recreation
· Indicator: Nutrient/Eutrophication Biological Indicators
· CALM Category: 5C
<table>
<tr><th>Lake Name</th><th>Lake ID</th><th>Year Listed</th><th>Target Start/Completion</th></tr>
<tr><td>Ann</td><td>61-0122-00</td><td>2006</td><td>2014/2018</td></tr>
<tr><td>Emily</td><td>61-0180-00</td><td>2002</td><td>2012/2015</td></tr>
<tr><td>Gilchrist</td><td>61-0072-00</td><td>2002</td><td>2012/2015</td></tr>
<tr><td>Leven</td><td>61-0066-00</td><td>2002</td><td>2012/2015</td></tr>
<tr><td>Malmedal</td><td>61-0162-00</td><td>2002</td><td>2012/2015</td></tr>
<tr><td>Pelican</td><td>61-0111-00</td><td>2002</td><td>2012/2015</td></tr>
<tr><td>Reno</td><td>61-0078-00</td><td>2002</td><td>2012/2015</td></tr>
<tr><td>Strandness</td><td>61-0128-00</td><td>2006</td><td>2014/2018</td></tr>
</table></td><td>22</td></tr>
<tr><td>Applicable Water Quality Standards/ Numeric Targets</td><td colspan="2">Class 2B waters, Minnesota Eutrophication Standards,
Minn. R. 7050.0222, Subp. 4
<table>
<tr><th rowspan="2">Parameter</th><th colspan="2">North Central Hardwood Forest Ecoregion</th></tr>
<tr><th>General</th><th>Shallow Lakes</th></tr>
<tr><td>TP (µg/l)</td><td>TP < 40</td><td>TP < 60</td></tr>
<tr><td>Chlorophyll-<i>a</i> (µg/l)</td><td>Chl < 14</td><td>Chl < 20</td></tr>
<tr><td>Secchi depth (m)</td><td>SD > 1.4</td><td>SD > 1.0</td></tr>
<tr><td>Applicable Lakes</td><td>Gilchrist, Leven, Pelican, Reno</td><td>Ann, Malmedal, Strandness</td></tr>
<tr><th rowspan="2">Parameter</th><th colspan="2">Northern Glaciated Plains Ecoregion</th></tr>
<tr><th>General</th><th>Shallow Lakes</th></tr>
<tr><td>TP (µg/l)</td><td>TP < 65</td><td>TP < 90</td></tr>
<tr><td>Chlorophyll-<i>a</i> (µg/l)</td><td>Chl < 22</td><td>Chl < 30</td></tr>
<tr><td>Secchi depth (m)</td><td>SD > 0.9</td><td>SD > 0.7</td></tr>
<tr><td>Applicable Lakes</td><td>--</td><td>Emily</td></tr>
</table></td><td>29</td></tr>
<tr><td rowspan="6">Loading Capacity (expressed as daily load)</td><th>Lake</th><th>Loading Capacity (lbs TP/day)</th><td></td></tr>
<tr><td>Ann</td><td>3.2</td><td>60</td></tr>
<tr><td>Emily</td><td>33</td><td>75</td></tr>
<tr><td>Gilchrist</td><td>12</td><td>92</td></tr>
<tr><td>Leven</td><td>4.3</td><td>108</td></tr>
<tr><td>Malmedal</td><td>1.14</td><td>122</td></tr>
</table>

EPA/MPCA Required Elements	Summary			TMDL Page #
	Pelican	4.6		138
	Reno	3.6		154
	Strandness	2.3		169
	Critical condition: in summer when TP concentrations peak and clarity is typically at its worst			174
Wasteload Allocation	**Source**	**Permit #**	**TMDL Lakes**	
	Lowry WWTF	MNG580123	Malmedal, Strandness, Pelican, Emily	75, 122, 138, 169
	Starbuck WWTF	MN0021415	Emily	75
	Blair Farms Inc.	MN0066273	Ann, Reno	60, 154
	Construction and industrial stormwater	Various	all	60, 75, 92, 108, 122, 138, 154, 169
	Reserve Capacity (and related discussion)	NA	--	47
Load Allocation	The load allocation (LA) is based on the following sources of phosphorus that do not require NPDES Permit coverage, as applicable to each lake: · Stormwater runoff · Loading from upstream waters · Runoff from feedlots not requiring NPDES Permit coverage · Atmospheric deposition · Subsurface sewage treatment systems (SSTS) · Groundwater · Internal loading			
	Lake	**LA (lbs TP/day)**		
	Ann	2.9		60
	Emily	26.3		75
	Gilchrist	10.7		92
	Leven	3.8		108
	Malmedal	0.81		122
	Pelican	3.73		138
	Reno	3.2		154
	Strandness	1.7		169
Margin of Safety	**Explicit MOS:** 10% of TMDL			46

EPA/MPCA Required Elements	**Summary**	**TMDL Page #**
Seasonal Variation	**Seasonal variation:** Critical conditions in these lakes occur in the summer, when TP concentrations peak and clarity is at its worst. The water quality standards are based on growing season averages. The load reductions are designed so that the lakes will meet the water quality standards over the course of the growing season (June through Sept).	172
Reasonable Assurance	***Summarize Reasonable Assurance*** NPDES Permit compliance Active local partners and agencies (Pope County, Pope SWCD, CRWP, Pope County COLA)	176
Monitoring	***Monitoring Plan included?*** yes	175
Implementation	***1. Implementation Strategy included?*** yes ***2. Cost estimate included?*** yes	60, 76, 92, 108, 122, 138, 154, 169
Public Participation	· Public kick-off meeting and open house, May 12, 2009 · Local Advisory Group (LAG) formed and met October 6, 2009, February 23, 2010 and September 14, 2010 · Technical Advisory Committee (TAC) formed and met April 10, 2012 and May 8, 2012 · Public Comment period: July 23, 2012, to August 22, 2012. · Extension of the public notice period: September 17 through October 17, 2012 · 11 comment letters received with more than 37 comments	177

Table of Contents

List of Tables

List of Figures

Abbreviations

AF	Anoxic factor
BD-P	Bicarbonate dithionite extractable phosphorus
BEHI	Bank Erosion Hazard Index
BMP	Best management practice
BOD	Biochemical oxygen demand
CAFO	Concentrated Animal Feeding Operation
COLA	Pope County Coalition of Lakes Association
CRWP	Chippewa River Watershed Project
DNR	Department of Natural Resources
DO	Dissolved oxygen
EMC	Event mean concentration
EPA	Environmental Protection Agency
GIS	Geographic Information System
GSM	Growing season mean
JD	Judicial ditch
LA	Load allocation
LAG	Local advisory group
LAP	Lake assessment program
LEIA	Lake Emily Improvement Association
MOS	Margin of safety
MNLEAP	Minnesota Lake Eutrophication Analysis Procedure
MPCA	Minnesota Pollution Control Agency
MS4	Municipal separate storm sewer system
NBS	Near bank shear stress
NCHF	North Central Hardwood Forest
NGP	North Glaciated Plains
NLCD	National Land Cover Database
NPDES	National Pollutant Discharge Elimination System
QWTA	Quaternary Water Table Aquifer

RR	Release rate
SDS	State Disposal System
SSTS	Subsurface sewage treatment system
SWCD	Soil and Water Conservation District
SWPPP	Stormwater Prevention Pollution Plan
TAC	Technical Advisory Committee
TMDL	Total maximum daily load
TP	Total phosphorus
TSI	Trophic State Index
TSS	Total suspended solids
USGS	U.S. Geological Survey
WARSS	Watershed Assessment for River Stability and Sediment Supply
WLA	Wasteload allocation
WQBEL	Water quality based effluent limits
WWTF	Wastewater treatment facility

EXECUTIVE SUMMARY

Eight lakes in Pope County that are on the U.S. Environmental Protection Agency (EPA) 303(d) list of impaired waters due to excess nutrients (total phosphorus) are the subject of this study. The lakes include Ann, Emily, Gilchrist, Leven, Malmedal, Pelican, Reno, and Strandness. The lakes are located in the Chippewa River Watershed and are tributary to the Minnesota River. The project study area is dominated by agricultural land uses.

All of the listed lakes are classified as Class 2B, 3C, 4A, 4B, 5, and 6 waters. The most protective of these classes is Class 2 waters, which are protected for aquatic life and recreation. The state eutrophication standards for these lakes are in the following table.

Parameter	**NCHF Ecoregion**		**Northern Glaciated Plains Ecoregion**	
	Eutrophication Standard, General	**Eutrophication Standard, Shallow Lakes**	**Eutrophication Standard, General**	**Eutrophication Standard, Shallow Lakes**
TP (µg/l)	TP < 40	TP < 60	TP < 65	TP < 90
Chlorophyll-*a* (µg/l)	Chl < 14	Chl < 20	Chl < 22	Chl < 30
Secchi depth (m)	SD > 1.4	SD > 1.0	SD > 0.9	SD > 0.7
Applicable lakes	Gilchrist, Leven, Pelican, Reno	Ann, Malmedal, Strandness	--	Emily

Phosphorus is identified as the primary pollutant leading to eutrophication in these lakes. Potential phosphorus sources include:

- Point sources requiring National Pollutant Discharge Elimination System (NPDES) Permit coverage
- Stormwater runoff
- Loading from upstream waters
- Runoff from feedlots not requiring NPDES Permit coverage
- Atmospheric deposition
- Subsurface sewage treatment systems (SSTS)
- Groundwater
- Internal loading
- In-stream erosion

Phosphorus loads from stormwater runoff were estimated using the Simple Method, which uses stormwater runoff volume and total phosphorus (TP) event mean concentrations (EMC). Phosphorus loads for the remaining sources were determined through a variety of mechanisms including methodologies set forth in the Detailed Assessment of Phosphorus Sources to Minnesota Watersheds (MPCA 2004a).

The loading capacity for each lake was calculated using BATHTUB, an empirical model of reservoir eutrophication developed by the U.S. Army Corps of Engineers. The models were calibrated to existing water quality data, and then were used to determine the phosphorus loading capacity of each lake. An explicit margin of safety (MOS) of 10% of the total maximum daily load (TMDL) was used for all lakes.

Individual wasteload allocations (WLAs) were set for the Lowry and Starbuck Wastewater Treatment Facilities (WWTFs) and for the Blair Farms Inc. NPDES Permit. Categorical WLAs were set for construction stormwater and industrial stormwater. One load allocation (LA) was set for each lake. The LA includes all phosphorus sources not requiring NPDES Permit coverage.

The following table presents the required reduction in phosphorus loads for each lake to meet the state eutrophication standards.

Lake Name	**TP Load Reduction to Meet State Standards (from existing)**
Ann	90 %
Emily	35 %
Gilchrist	48 %
Leven	35 %
Malmedal	72 %
Pelican	35 %
Reno	36 %
Strandness	54 %

A series of stakeholder meetings were held. Cities, counties, agencies, lake associations, and watershed residents were invited to provide input into the project approach. Public meetings were held to provide information to the public about the project and to solicit input regarding background information and implementation recommendations.

An implementation strategy is presented for each lake that includes activities to address point sources, watershed loading, and internal loading of phosphorus, where applicable.

The monitoring plan includes recommendations for standard in-lake monitoring, as well as additional recommendations for biological monitoring where time and budget allow. Watershed and best management practice (BMP) monitoring is also recommended.

1 BACKGROUND

1.1 303(d) Listings

Eight lakes within Pope County are on the EPA's 303(d) list of impaired waters due to excess nutrients and biological indicators including Ann, Emily, Gilchrist, Leven, Malmedal, Pelican, Reno, and Strandness (Table 1). The following applies to all of the impaired lakes in this project:

Impaired Use:	Aquatic recreation
Pollutant or Stressor:	Nutrient/eutrophication biological indicators
Hydrologic Unit Code:	07020005

Table 1. Impaired Waters Listing

Lake Name	Lake ID	Year Listed	Target Start/Completion	CALM Category*
Ann	61-0122-00	2006	2014/2018	5C
Emily	61-0180-00	2002	2012/2015	5C
Gilchrist	61-0072-00	2002	2012/2015	5C
Leven	61-0066-00	2002	2012/2015	5C
Malmedal	61-0162-00	2002	2012/2015	5C
Pelican	61-0111-00	2002	2012/2015	5C
Reno	61-0078-00	2002	2012/2015	5C
Strandness	61-0128-00	2006	2014/2018	5C

*5C: Impaired by one pollutant and no TMDL study plan is approved by EPA

1.2 Study Area Description

The eight lakes included in this study are located within Pope County in west central Minnesota (Figure 1) with a portion of Reno Lake located in Douglas County. All eight lakes are within the Chippewa River Watershed and are tributary to the Minnesota River. The study area totaling 347 square miles (221,762 acres) includes the watersheds of all eight lakes within Pope and Douglas Counties and the areas of the lakes themselves.

1.2.1 Watersheds

All eight lakes in this study are part of the Chippewa River Watershed (Figure 2). The Chippewa River Watershed drains approximately 2,080 square miles (roughly 1.3 million acres) of portions of eight counties in west central Minnesota. The Chippewa River flows south and outlets to the Minnesota River at Montevideo. There are three perennial streams within the study area including the Little Chippewa River, East Branch of the Chippewa River, and Trappers Run Creek, all of which eventually flow to the Chippewa River.

The Lake Leven Watershed includes the drainage area to West Ellen Lake and Judicial Ditch 4. Leven outlets to Lake Villard and eventually to the East Branch of the Chippewa River. Gilchrist Lake is located along the East Branch of the Chippewa River, downstream of the Villard Area Chain of Lakes including Leven, Villard, and Amelia.

Reno Lake and Ann Lake both drain to downstream lakes that do not typically outlet. Ann Lake has been known to historically receive inflow from adjacent John Lake, but this occurrence is not well documented. Reno Lake has been known to periodically outlet to Maple Lake through Turtle and Long Lakes, and eventually into the Douglas County Ditch System.

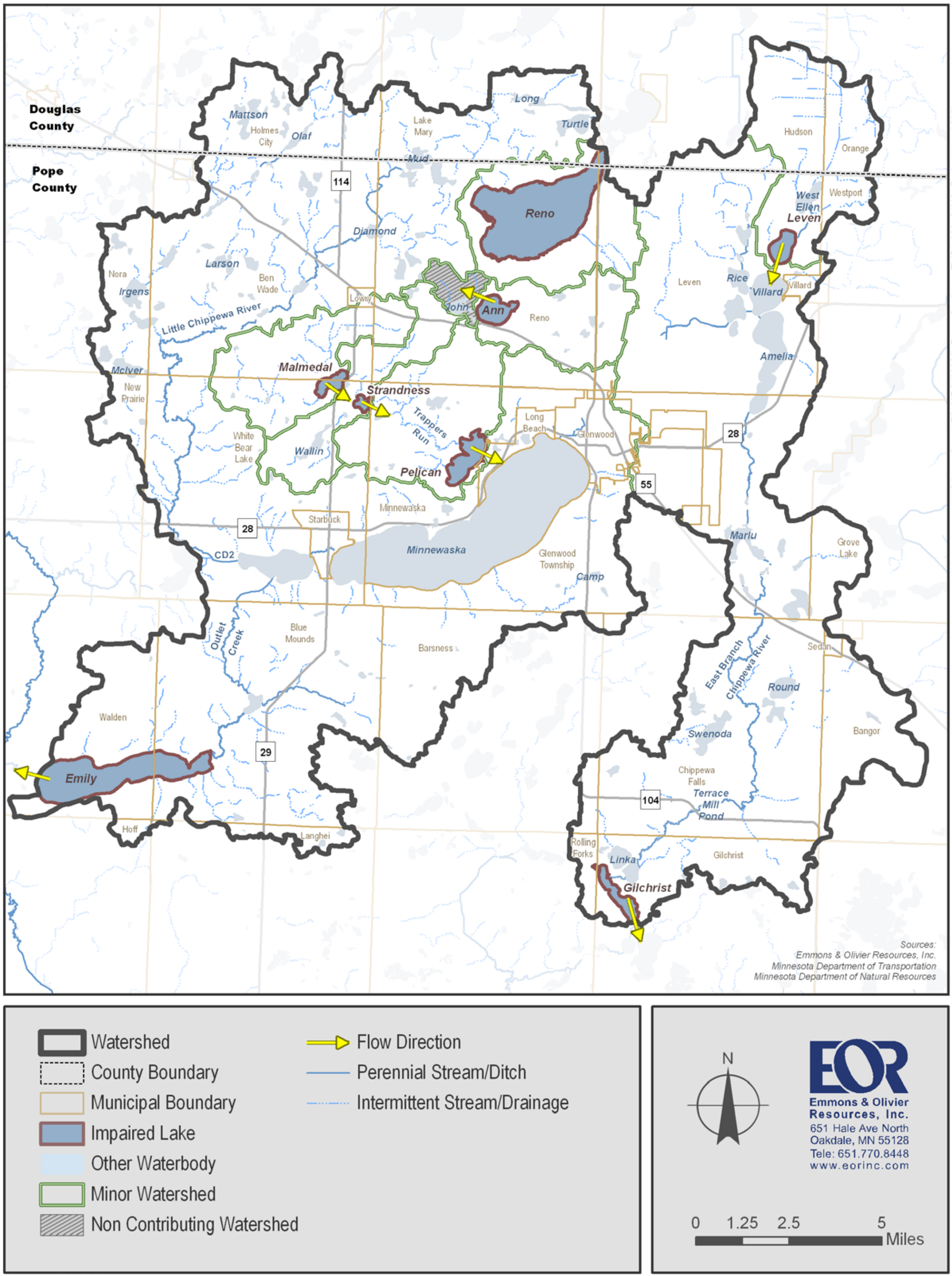
Malmedal and Strandness Lakes outlet through Trappers Run Creek to Pelican Lake, which in turn outlets to Lake Minnewaska and eventually to Lake Emily. Lake Emily outlets to the Chippewa River through Outlet Creek. The branch of the Chippewa River from Outlet Creek to the East Branch Chippewa has impairments related to biota (fish), fecal coliform, mercury, and turbidity. The Little Chippewa River was diverted historically through County Ditch 2 (CD 2) and now is tributary to Lake Emily. The Little Chippewa River is listed as having impaired biota (fish).

The Wadena and Des Moines Lobes of the Wisconsin Glaciation are responsible for the majority of landforms and topography in the study area. The western portion of the study area is characterized by rolling hills resulting from many glacial ice advances and recessions. The soils and geology are typically fine grained till deposits, while the eastern portion of the study area is a fairly level sand plain that was a result of glacial meltwater. This area is very sandy and typically has a water table that is very close to the surface.

The primary land uses within the study area are agricultural (Figure 3). The land is used heavily for cropland and pasture/hay as well as for livestock agriculture. The largest urban area is the city of Glenwood on the shores of Lake Minnewaska. Other developed areas include the cities of Starbuck, Long Beach, Villard, Sedan, and Lowry.

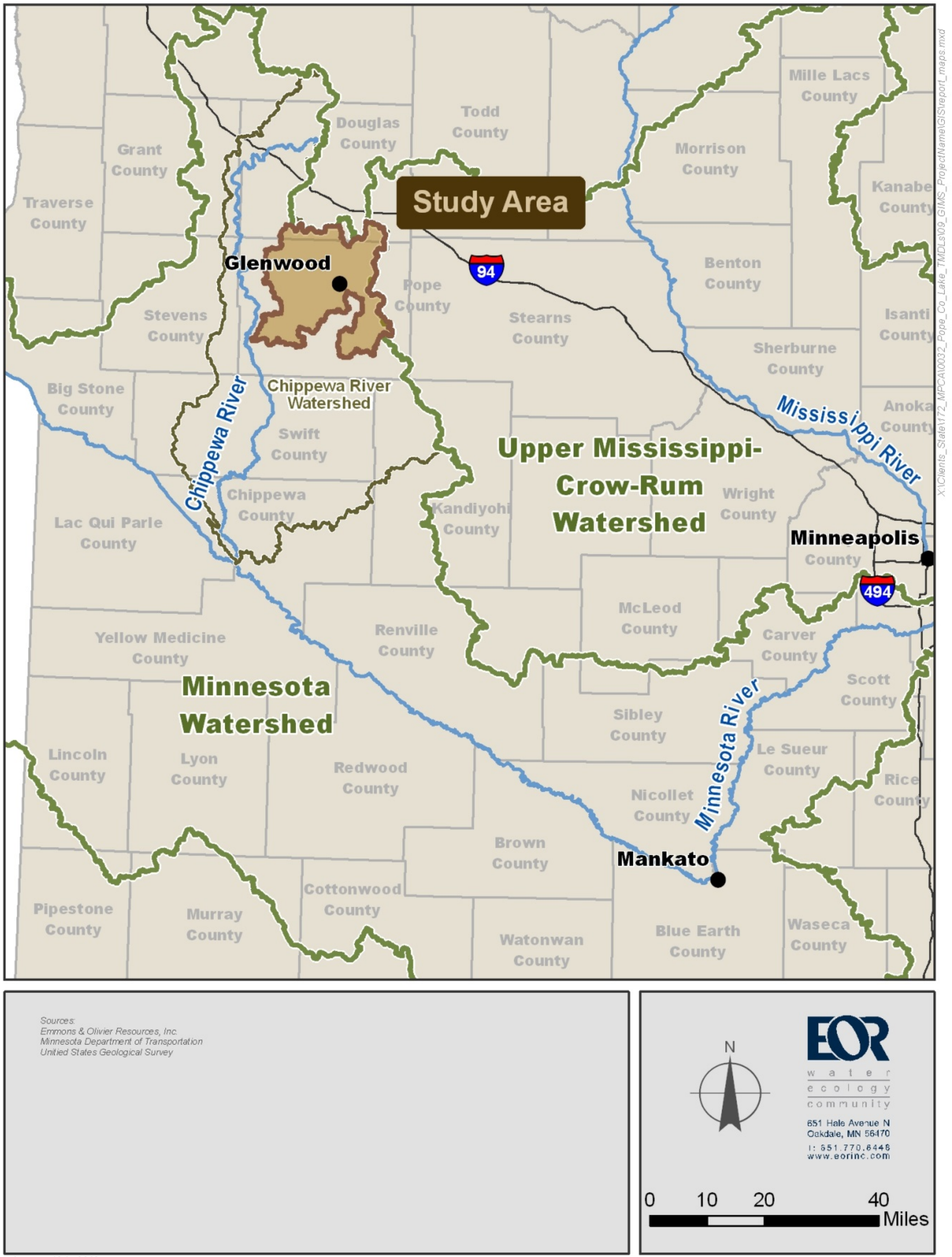
More detailed information on land use in the watersheds of each of the impaired lakes is included in the individual lake chapters (sections 4 through 11).

Figure 1. Study Area and TMDL Watersheds



January 19th, 2010

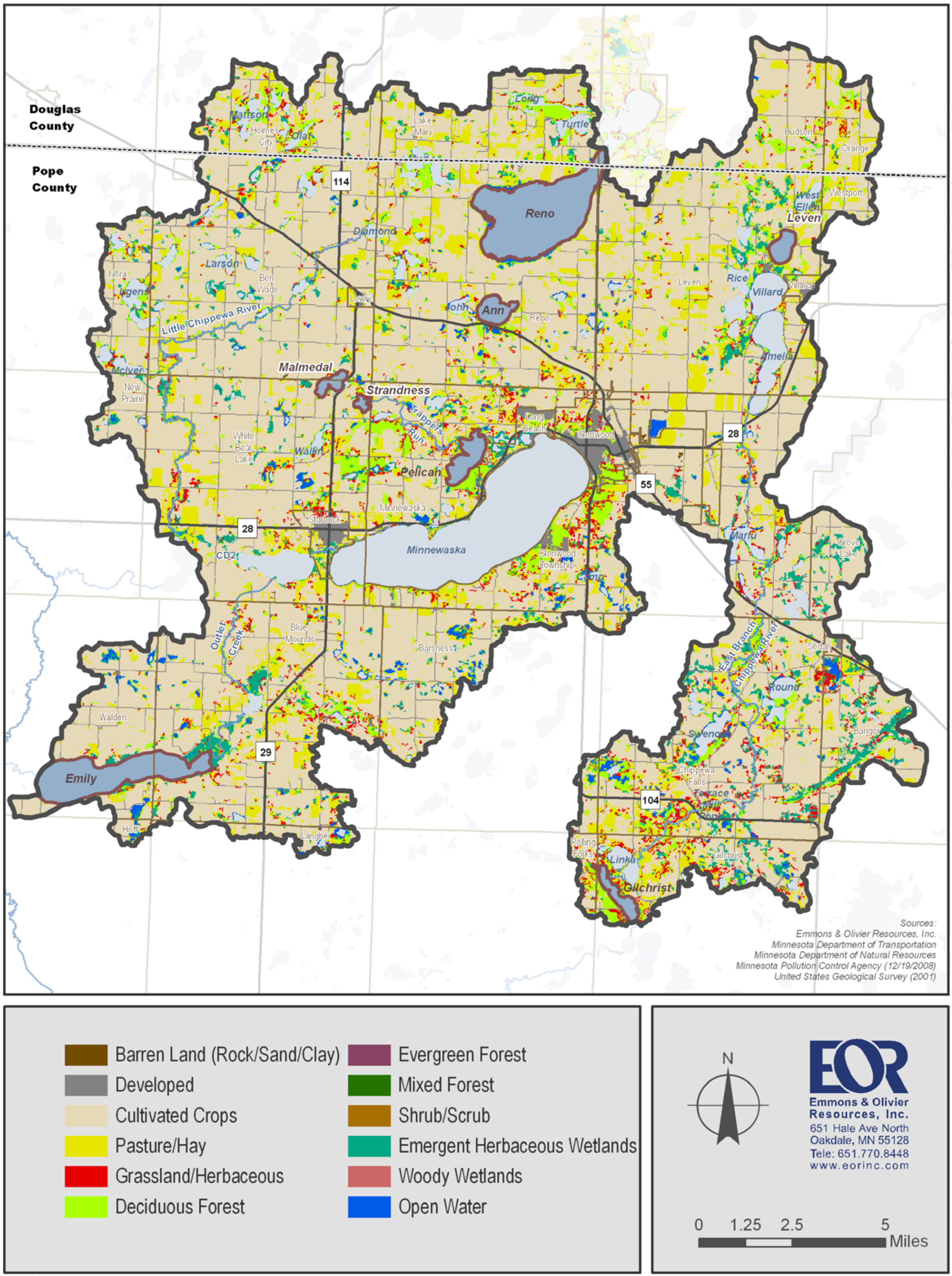
Figure 2. Chippewa River Watershed



Sources:
Emmons & Olivier Resources, Inc.
Minnesota Department of Transportation
United States Geological Survey

January 19th, 2010

Figure 3. Land Use



Sources:
Emmons & Olivier Resources, Inc.
Minnesota Department of Transportation
Minnesota Department of Natural Resources
Minnesota Pollution Control Agency (12/19/2008)
United States Geological Survey (2001)

April 30th, 2009

1.2.2 Population and Growth

Pope County is located in western Minnesota and covers a total area of approximately 717 square miles. According to the Minnesota State Demographic Center, Pope County had a population of 11,360 in 2005, with a projected increase in population of 12.3% by the year 2035.

Approximately 2,800 acres of the northern tip of Reno Lake lies within Douglas County as well as a portion of the overall drainage area to Lake Leven, Gilchrist Lake, and Lake Emily. The population of Douglas County, according to the Minnesota State Demographic Center, was 35,500 in 2005. Douglas County has a projected increase in population of 32.3% by the year 2035.

1.2.3 Existing Projects and Studies, Watershed-wide

The Pope County Coalition of Lakes Associations (COLA) was formed in cooperation with Pope County and a number of lake associations. The COLA participates in water quality monitoring and water stewardship education around the county. Since 1994, COLA has collected water quality data on all eight of the lakes in this study. Information on the COLA can be found at http://minnesotawaters.org/popecountycoalitionoflakes/.

The Chippewa River Watershed Project (CRWP) began in 1998 with a Clean Water Partnership Phase I Diagnostic Study Grant from the Minnesota Pollution Control Agency (MPCA). The CRWP is an organization governed by a Board of Directors. In 2001, the CRWP was awarded a Phase II Implementation Grant for efforts to implement water quality restoration strategies that were identified in Phase I. A major focus of the CRWP is improving water quality and reducing flooding in the Chippewa River and its tributaries, while supporting the recreational, industrial, and agricultural goals of the communities within the watershed. Through the help of volunteers, the CRWP continues to collect water quality and quantity data and benthic macroinvertebrate data throughout the watershed. Information on the CRWP can be found at http://www.chippewariver.com/.

In 2004, the *Chippewa River Un-ionized Ammonia TMDL* was completed and identified the Montevideo WWTF as the main source of the impairment. Upgrades to the plant have been made to limit the discharge of ammonia. Monitoring of the river stretch is continued to ensure that ammonia water quality standards are met. In 2006, this stretch of the river was removed from the impaired waters list. This TMDL can be found at https://www.pca.state.mn.us/water/tmdl/chippewa-river-unionized-ammonia-tmdl-project.

In 2006, the *Chippewa River Fecal Coliform TMDL* was completed on 10 stream reaches of the Chippewa River Watershed. The TMDL identified the point and non-point sources contributing to the impairment. The implementation plan was completed by the CRWP in February 2016. This TMDL can be found at https://www.pca.state.mn.us/water/tmdl/chippewa-river-%E2%80%94-fecal-coliform-tmdl-project.

In 2004, the *Lower Minnesota River Dissolved Oxygen TMDL* was completed, which identified high biochemical oxygen demand (BOD) as the cause of low dissolved oxygen (DO) in the impaired reach. Phosphorus is targeted in the TMDL because nutrients cause excessive algal growth, which in turn produces high BOD as a result of algal decomposition. A phosphorus WLA was set for the Starbuck WWTF requiring upgrades to the facility that would include phosphorus removal. In addition, phosphorus reduction strategies include stormwater pollution prevention, upgrades to failing septic systems, and implementing BMPs in the agricultural sector to increase groundwater recharge. This TMDL can be found at https://www.pca.state.mn.us/water/tmdl/lower-minnesota-river-low-dissolved-oxygen-tmdl-project. The Chippewa River Turbidity TMDL https://www.pca.state.mn.us/water/tmdl/chippewa-river-%E2%80%94-turbidity-tmdl-project was completed in October 2014.

Other relevant TMDL studies currently in progress are the following:

- Minnesota River Turbidity TMDL https://www.pca.state.mn.us/water/tmdl/minnesota-river-turbidity-tmdl-project
- Chippewa River Watershed Assessment and TMDL Study: The Chippewa River Watershed was monitored in 2009 with a comprehensive set of monitoring locations and parameters as part of the MPCA's watershed approach to condition monitoring and assessment. These data will be used to form the basis for the Watershed Assessment and TMDL Study.

2 WATER QUALITY STANDARDS

2.1 Designated Uses

The eight listed lakes are all classified as Class 2B, 3C, 4A, 4B, 5, and 6 waters. The most protective of these classes is Class 2 waters, which are protected for aquatic life and recreation. Minn. R. 7050.0140 Water Use Classification for Waters of the State reads:

> Subp. 3. Class 2 waters, aquatic life and recreation. Aquatic life and recreation includes all waters of the state that support or may support fish, other aquatic life, bathing, boating, or other recreational purposes and for which quality control is or may be necessary to protect aquatic or terrestrial life or their habitats or the public health, safety, or welfare.

2.2 Pollutant of Concern

TP is often the limiting factor controlling primary production in freshwater lakes. It is the nutrient of focus for this TMDL, and is referred to as the causal factor. As phosphorus concentrations increase, primary production also increases, as measured by higher chlorophyll-*a* concentrations. Higher concentrations of chlorophyll-*a* lead to lower water transparency. Both chlorophyll-*a* and Secchi transparency are referred to as response factors, since they indicate the ecological response of a lake to excessive phosphorus input.

2.3 Water Quality Standards

Water quality standards are established to protect the designated uses of the state's waters. Amendments to Minn. R. ch. 7050, approved in May 2008, include eutrophication standards for lakes (Table 2). Eutrophication standards were developed for lakes in general, and for shallow lakes in particular. Standards are less stringent for shallow lakes, due to higher rates of internal loading in shallow lakes and different ecological characteristics. In developing the lake nutrient standards for Minnesota lakes (Minn. R. ch. 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (Heiskary and Wilson 2005). Clear relationships were established between the causal factor TP and the response variables chlorophyll-*a* and Secchi transparency. Based on these relationships it is expected that by meeting the phosphorus standard in a lake, the chlorophyll-*a* and Secchi standards will likewise be met.

Standards are applied based on the ecoregion in which the lake is located (Figure 4). All of the lakes, with the exception of Lake Emily, are within the North Central Hardwood Forest (NCHF) ecoregion. Lake Emily is located within the Northern Glaciated Plains (NGP) ecoregion.

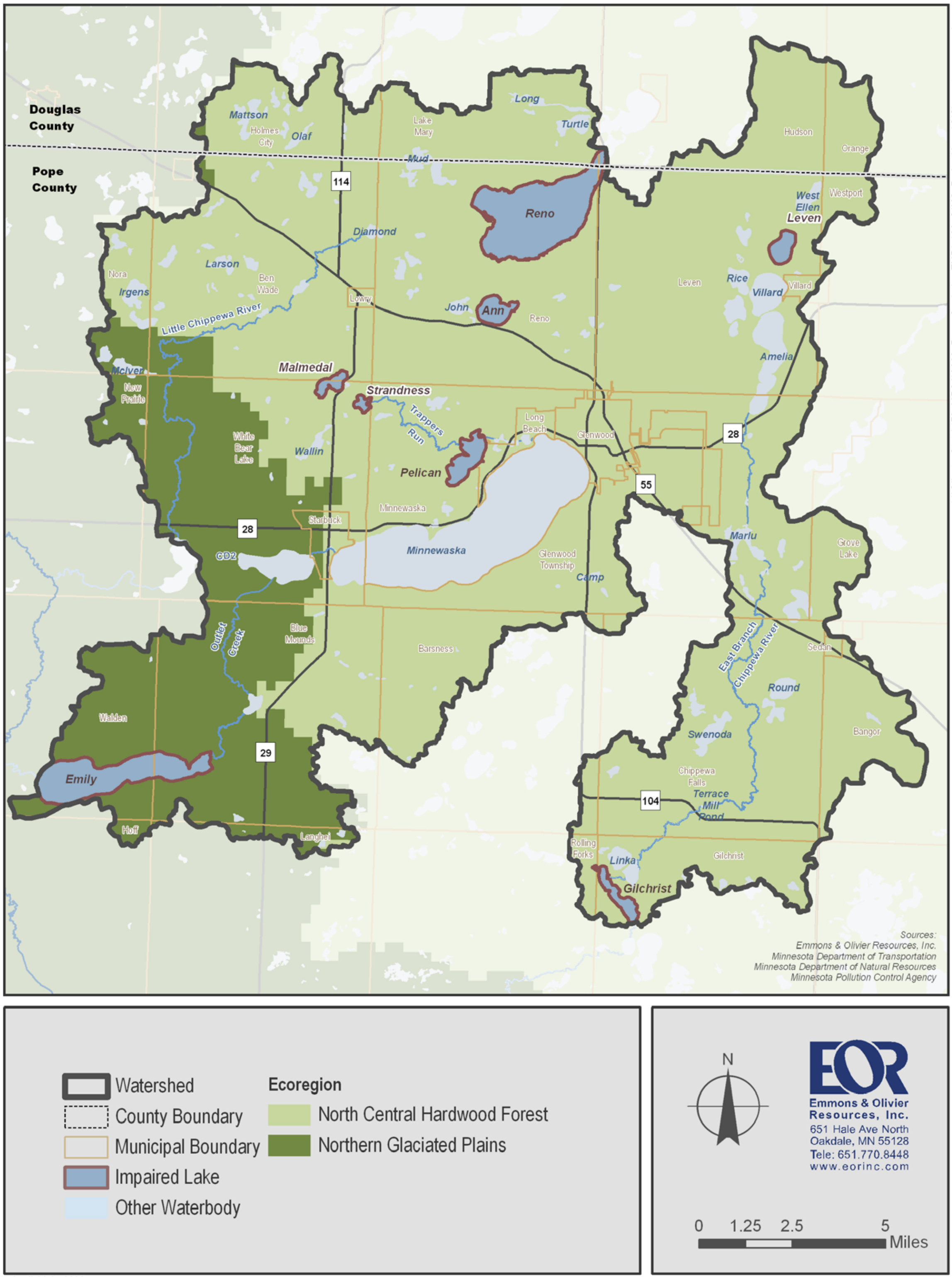
Table 2. Minnesota Eutrophication Standards

Parameter	NCHF Ecoregion		NGP Ecoregion	
	Eutrophication Standard, General	Eutrophication Standard, Shallow Lakes	Eutrophication Standard, General	Eutrophication Standard, Shallow Lakes
TP (µg/l)	TP < 40	TP < 60	TP < 65	TP < 90
Chlorophyll-*a* (µg/l)	Chl < 14	Chl < 20	Chl < 22	Chl < 30
Secchi depth (m)	SD > 1.4	SD > 1.0	SD > 0.9	SD > 0.7

According to the MPCA definition of shallow lakes, a lake is considered shallow if its maximum depth is less than 15 feet, or if the littoral zone (area where depth is less than 15 feet) covers at least 80% of the lake's surface area. Ann, Emily, Malmedal, and Strandness Lakes are shallow according to this definition. Pelican Lake's littoral zone is 80% of the lake's surface area, and the remaining three lakes are not shallow. Pelican Lake was assessed by the MPCA as a deep water lake; therefore, that standard will apply.

To be listed as impaired, the monitoring data must show that the standards for both TP (the causal factor) and either chlorophyll-*a* or Secchi depth (the response factors) were violated. If a lake is impaired with respect to only one of these criteria, it may be placed on a review list; a weight of evidence approach is then used to determine if it will be listed as impaired. For more details regarding the listing process, see the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment* (MPCA 2009).

Figure 4. Ecoregions



April 30th, 2009

3 METHODS

3.1 Phosphorus Source Assessment

A phosphorus source assessment was conducted for each of the eight lakes included in this study. Sources of phosphorus can be either external or internal. Examples of external sources include watershed runoff, point sources such as WWTFs, and atmospheric deposition. Internal sources of phosphorus can be released from sediments or can be a result of biological processes in the lake. Internal sources of phosphorus can be a result of phosphorus within the lake sediments that is either released due to anoxic conditions or due to suspension caused by wind mixing or benthic fish. The presence of curly-leaf pondweed can also contribute to internal sources of phosphorus.

This section provides a description of the potential sources of phosphorus to each of the lakes in the TMDL study area. In 2004, the MPCA conducted a study on the phosphorus sources contributing to the 10 major basins within Minnesota. The final report, *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds*, prepared by Barr Engineering (MPCA 2004a), identified both point and non-point sources and quantified the loading for each of the basins. For this report, an inventory was done on all of the potential individual phosphorus sources within the TMDL area, and TP loads were quantified based primarily on the methods and guidance within the 2004 MPCA report. Ultimately, a phosphorus budget was developed for each of the TMDL lakes in this study.

3.1.1 Sources of Phosphorus Requiring NPDES Permit Coverage

The sources of phosphorus within the study area that require NPDES Permit coverage are point sources, or those originating from a single, identifiable source in the watershed. Point sources are regulated through the NPDES and State Disposal System (SDS) Permits. Point sources include the following:

- Municipal and industrial wastewater treatment systems
- Regulated stormwater
- Feedlots requiring NPDES Permit coverage

Municipal and Industrial Wastewater Treatment Systems

For any discharge of municipal or industrial wastewater to surface water, ground surface, or subsurface, an NPDES/SDS Permit is required and administered by the MPCA. Table 3 is a list of the permitted facilities within the study area. Only the Lowry WWTF and the Starbuck WWTF have a discharge that contributes phosphorus to surface waters. The remaining permitted sites do not have a surface discharge.

Annual loads for each of the WWTFs were calculated based on monitored data collected at each site. The Lowry WWTF consists of a two-cell stabilization pond system and discharges periodically to a tributary to Malmedal Lake. The current NPDES Permit sets a mass loading limit on TP of 1 mg/L and 1.5 kg/day. The Starbuck WWTF does not have a current permit limit on TP but has been assigned a WLA of 1.6 lbs/day as part of the Minnesota River Dissolved Oxygen TMDL (MPCA 2004b) based on a 1 mg/L effluent concentration. Table 4 summarizes the data used to determine the TP load from each WWTF.

Table 3. Municipal and Industrial Wastewater Permitted Facilities

Permitted Facility Name	Permit #	TP Discharge
Glenwood Wastewater Treatment Plant	MN0052710	No discharge
Lowry Wastewater Treatment Plant	MNG580123	Permit limit
Starbuck Wastewater Treatment Plant	MN0021415	No permit limit
SunOpta Aseptic Inc – Northern	MNG960003	No discharge
Villard Wastewater Treatment Plant	MN0068144	No discharge

Table 4. NPDES Permitted Waste Water Point Sources with TP Discharge

Permit Holder (permit number)	Lakes Receiving Discharge	TP Loading Limits	Years Used to Calculate TP Load	Average Annual TP Load
Lowry Wastewater Treatment Plant (MNG580123)	Malmedal, Strandness, Pelican, Emily	1 kg/day TP	1999 to 2008	17.2 kg/year 37.9 lbs/year
Starbuck Wastewater Treatment Plant (MN0021415)	Emily	None[1]	2001 to 2008	403.6 kg/year 889.8 lbs/year

[1] No current NPDES Permitted loading limit

Regulated Stormwater

Stormwater runoff is generated in the watershed during precipitation events. Certain types of stormwater runoff are regulated under the NPDES/SDS Program including regulated Municipal Separate Storm Sewer Systems (MS4s), construction stormwater, and industrial stormwater.

MS4

MS4s are defined by the MPCA as conveyance systems owned or operated by an entity such as a state, city, town, county, district, or other public body having jurisdiction over disposal of stormwater or other wastes. A conveyance system includes ditches, roads, storm sewers, stormwater ponds, etc. Certain MS4 discharges are regulated by NPDES/SDS permits administered by the MPCA.

There are no current or projected MS4s within the study area of this TMDL.

Construction

Construction sites can contribute substantial amounts of sediment and phosphorus to stormwater runoff. The NPDES/SDS Construction Stormwater Permit administered by the MPCA requires that all construction activity disturbing areas equal to or greater than one acre of land obtain a permit and create a Stormwater Prevention Pollution Plan (SWPPP) that outlines how runoff pollution from the construction site will be minimized during and after construction. Construction stormwater permits cover construction sites throughout the duration of the construction activities, and the level of on-going construction activity varies. In 2008, there were 43 active construction permits within the study area.

Industrial

The NPDES/SDS Industrial Stormwater General Permit applies to facilities with Standard Industrial Classification Codes in 10 categories of industrial activity with significant materials and activities exposed to stormwater. Significant materials include any material handled, used, processed, or generated that when exposed to stormwater may leak, leach, or decompose and carried offsite. The permit identifies a phosphorus benchmark monitoring value for facilities within certain sectors that are known to be phosphorus sources.

Table 5 lists all of the industrial stormwater permitted facilities within the TMDL study area. None of these facilities have a phosphorus benchmark; therefore it is assumed that these facilities are not generating substantial phosphorus as a point source.

Table 5. Industrial Stormwater Permitted Facilities

Permitted Facility Name	Permit #
American Target - SW	95288890
Canadian Pacific Railway - Glenwood-SW	A00002699
Clyde Machines Inc - SW	58321290
Crosstown Auto & Truck - SW	A00001196
Dealers Livestock Equipment Center - SW	112873336
Farwell, City of - SW	A00010680
Gerdes Bus Service Inc - SW	76515063
Glenwood, City of- Municipal Airport - SW	A00000823
Glenwood Demolition Landfill Inc - SW	A00002661
Glenwood Ready Mix - SW	50734789
Lowry Manufacturing Co Inc - SW	71360937
McLaughlin & Schultz - Alexandria - SW	A00000928
MHC Fabrication Division - Glenwood - SW	A00007981
MHC Machining Division - Glenwood - SW	A00007980
R/C Machining Co Inc - SW	20492831
Starbuck Cement Products - SW	620807727
Starbuck City Shop	A00011033
Starbuck Fire Department	A00011034
Starbuck Municipal Airport - SW	A00000335
Starbuck Police Department	A00011040
Starbuck Transfer Station - SW	A00002234
WASP Inc - Conveyor Division - SW	97893960
WASP Inc - GSE Division - SW	A00002614
WASP Inc - Parts Warehouse - SW	A00002615
Sedan, City of	A00012466
Lowry, City of	A00012490
Waska Pond Development - SW	A00015260
Glenwood, City of, and City Garage - SW	A00016124

Feedlots Requiring NPDES Permit Coverage

Animal waste containing phosphorus can be transported in stormwater to surface waters. The primary goal of the state feedlot program is to ensure that surface waters are not contaminated by the runoff from feedlots, manure storage or stockpiles, and cropland with improperly applied manure. Feedlots that either (a) have a capacity of 1,000 animal units (AUs) or more, or (b) meet or exceed the EPA Concentrated Animal Feeding Operation threshold, are required to apply for coverage under an NPDES/SDS Permit for livestock production from the MPCA. The permit requires that the feedlots have zero discharge to surface water and therefore should not be a contributing phosphorus source. From 2003 to 2016, there was one feedlot requiring NPDES Permit coverage within the TMDL study area: Blair Farms Inc. This facility had been issued an individual NPDES Permit with a prescribed compliance schedule. The Farm consisted of two open lots: the east lot, located in the Reno Lake Watershed, and the west lot, located within the Ann Lake Watershed. The east lot had been non-compliant in the past, and it was required to be in full compliance with the zero discharge standard by September 1, 2010. Prior to the 2010 deadline Blair Farms ceased keeping animals in the east lot. In order to house animals on the east lot in the future, the owners would have to do so as a new feedlot and they would have to prove that their new feedlot is in compliance with feedlot rules and runoff standards. The west lot had been non-compliant with the NPDES Permit in the past, but it is currently in full compliance. In 2015, the west lot was sold to Reichmann Land & Cattle LLP. The west lot was in compliance with zero discharge standards and a general NPDES permit (Permit #MN0068489) was issued in March 2015. Reichmann Land & Cattle LLP then submitted a permit application and EAW to expand the west lot to 1900 animal units, with that process being completed a general NPDES permit was issued in November 2015 for the 1900 animal units. The facility has submitted a manure management plan for manure from the west lot.

3.1.2 Sources of Phosphorus Not Requiring NPDES Permit Coverage

Sources of phosphorus not permitted through the NPDES program include both point and nonpoint sources. Nonpoint sources are those that come from a diffuse source. For this study, the following non-permitted sources of phosphorus were evaluated:

- Stormwater runoff
- Loading from upstream waters
- Runoff from feedlots not requiring NPDES Permit coverage
- Atmospheric deposition
- SSTS (SSTS)
- Groundwater
- Internal loading
- In-stream erosion

Stormwater Runoff

The Simple Method (Schueler 1987), in combination with a lake loading analysis (see *Loading from Upstream Waters*), was used to calculate stormwater runoff and associated TP loads from the contributing watershed. The Simple Method uses a combination of precipitation and anticipated runoff from the land cover by subwatershed to approximate the volume of water delivered to the waterbody in question. A gridded surface was developed in a Geographic Information System (GIS) based on the Minnesota Hydrology Guide (SCS 1992) to determine the annual precipitation, evaporation, and runoff by watershed. Land cover data were gathered from the National Land Cover Database (NLCD) (USGS 2001). Each land use was assigned an EMC, which serves to estimate the loading rate of phosphorus from runoff. The EMCs were generated based on previous studies and an extensive literature search. A calibration site was identified where the Little Chippewa River crosses Highway 28, where flow and phosphorus data were available. Flows were approximated using regression equations for 2007, based on the U.S. Geological Survey (USGS) gauging station (05304500) located on the Chippewa River near Milan, Minnesota. Initial EMCs were applied based on land cover to verify that the EMCs as well as the impervious percentages used were appropriate for Pope County. The estimated TP load derived from the monitoring data was 7,106 lbs, while the calculated load using the Simple Method was 7,716 lbs.

The EMCs range from 0.01 mg/L for wetlands and open water surfaces to 0.46 mg/L for residential land uses. Table 6 provides EMC values by land use. EMCs for different land uses inherently include management practices that occur in the land use. For example, the EMC for cultivated crops includes runoff from fertilizers and manure applied within the area defined by the land use. Runoff from feedlots is not accounted for in the watershed runoff numbers.

Table 6. TP Event Mean Concentration (EMC) Values by Land Use

NLCD Land Use Description (USGS, 2001)	TP EMC [mg/L]
Barren Land (Rock/Sand/Clay)	0.04
Cultivated Crops	0.32
Deciduous Forest	0.04
Developed, High Intensity	0.30
Developed, Low Intensity	0.46
Developed, Medium Intensity	0.46
Developed, Open Space	0.40
Emergent Herbaceous Wetlands	0.01
Evergreen Forest	0.04
Grassland/Herbaceous	0.04
Mixed Forest	0.04
Open Water	0.01
Pasture/Hay	0.04
Shrub/Scrub	0.04
Woody Wetlands	0.04

TP reductions due to existing stream buffers were also taken into account by reducing the loading from stormwater runoff. Reaches of perennial and intermittent streams were examined within each subwatershed and a removal rate of 70% was applied to adjacent lands where buffers were present. The CRWP also provided data to verify the percentage of perennial streams that are buffered. For the Leven and Gilchrist Watersheds, on average 99% of perennial streams are buffered. For the remaining watersheds, on average 87% of the perennial streams are buffered. For the entire watershed, on average 78% of the intermittent streams are identified as buffered.

Loading from Upstream Waters

Lakes and streams upstream of impaired waters were evaluated in each watershed to determine if there were sufficient data to determine a TP load from that resource. Lakes Minnewaska, Amelia, Linka, Malmedal, and Strandness contained sufficient water quality data. The TP loads from these lakes and their watersheds were determined from in-lake phosphorus concentration data and average annual runoff values. The average annual runoff values were derived using the same gridded surface discussed under *Stormwater Runoff*. The watershed area being modeled using the Simple Method, described above, was then modified to eliminate the upstream lake and that lake's watershed area.

Runoff from Feedlots Not Requiring NPDES Permit Coverage

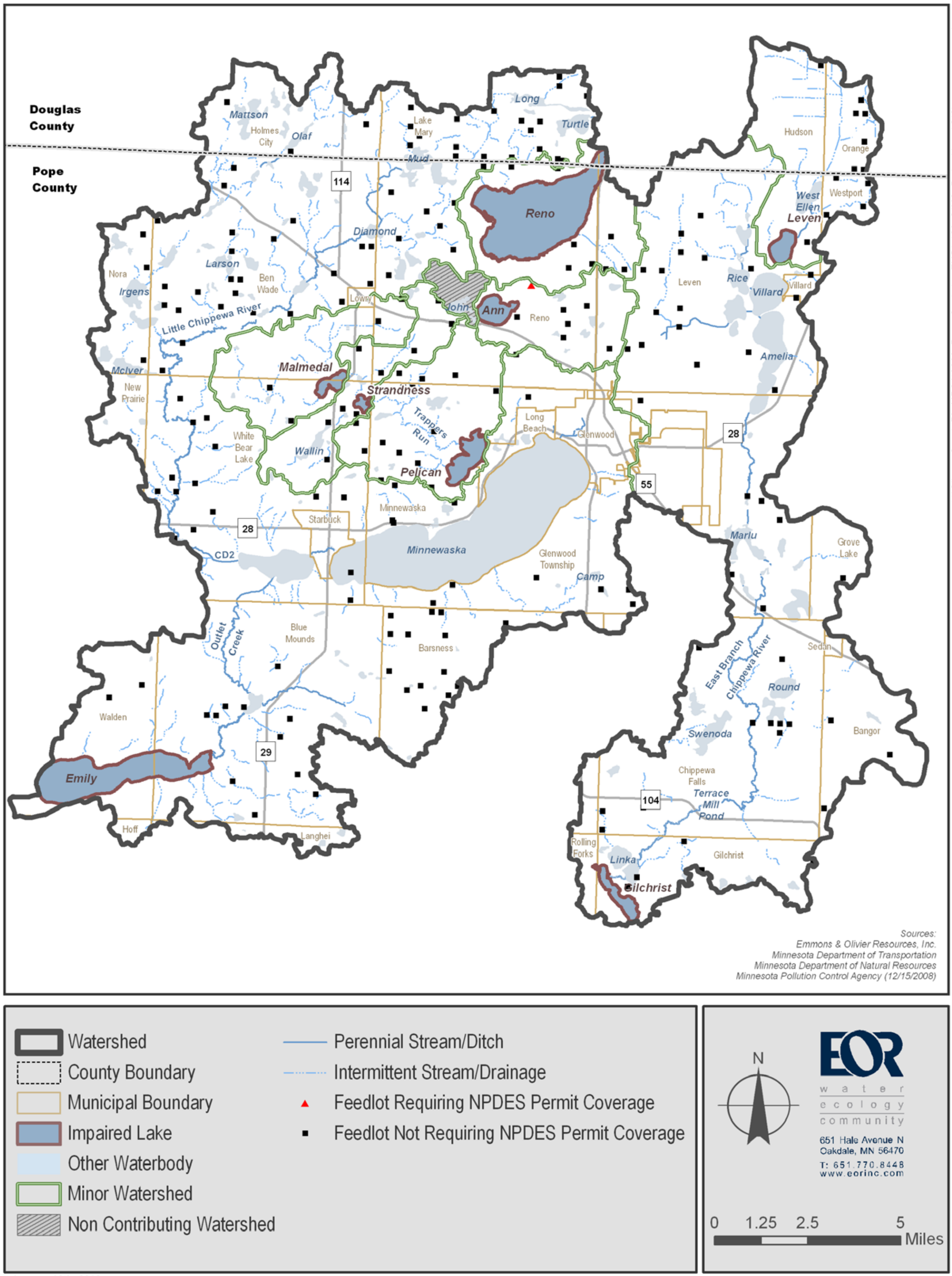
Runoff during precipitation and snow melt can carry phosphorus from uncovered feedlots to nearby surface waters. For the purpose of this report, non-permitted feedlots are defined as being all registered feedlots without an NPDES/SDS Permit that house under 1,000 AUs. Figure 5 identifies all of the feedlots included in this analysis. While these feedlots do not fall under NPDES regulation, other regulations still apply. Minn. R. 7053.0255, subp. 3, requires the removal of phosphorus to 1 mg/L when the discharge of a point source is directly to or affects a lake, shallow lake, or reservoir. Additionally, the MPCA and delegated counties (such as Pope County) often issue construction short-form and interim permits to smaller feedlots.

The protocol outlined in Appendix D of the Detailed Assessment of Phosphorus Sources to Minnesota Watersheds (MPCA 2004a) for calculating the TP loading to surface waters from open lot feedlots not requiring NPDES Permit coverage was evaluated and refined for this study area. Using feedlot data provided by the MPCA, the total number of AUs of beef and dairy cattle, swine, horse, sheep, and poultry were estimated for all non-permitted feedlots with open lots in each of the lake's watersheds. The number of AUs was multiplied by the annual manure phosphorus generated by each type of livestock to calculate the TP generated by livestock in all open lot feedlots that do not require NPDES Permit coverage (MWPS 2004).

Atmospheric Deposition

Atmospheric deposition represents the phosphorus that is bound to particulates in the atmosphere and is deposited directly onto surface waters as the particulates settle out of the atmosphere. Average phosphorus atmospheric deposition loading rates were calculated for the Minnesota River Basin (MPCA 2004a). The report determined that wet phosphorus atmospheric deposition equaled 0.165 lb/ac-yr and dry phosphorus atmospheric deposition equaled 0.068 lb/ac-yr for a TP loading rate of 0.233 lb/ac-yr. These rates were applied to each lake's surface area to determine the total lbs/yr of phosphorus deposition to each of the TMDL lakes.

Figure 5. Feedlots



January 19th, 2010

Subsurface Sewage Treatment Systems

Phosphorus loads attributed to SSTS adjacent to each of the lakes were calculated using data provided by Pope County Land and Resource Management and the MPCA's Detailed Assessment of Phosphorus Sources to Minnesota Watersheds (MPCA 2004a). Total loading is based upon the number of houses on the lake, whether the house is used as a permanent or seasonal residence, if the SSTS system is conforming or failing, the number of people using the system, and an average value for phosphorus production per person per year.

Pope County provided the number of houses on each lake, the assumed permanent versus seasonal residence percentages, and the percentage of conforming versus failing systems. Conforming versus failing systems were estimated primarily based upon real estate turnover on each lake. The assumption, based on an investigation that Pope County performed at Lake Leven, Villard, and Amelia, is that when a house is sold its septic system is investigated and most likely updated when needed.

The Pope County capita per residence value is derived from the 2000 Census. Values for phosphorus production per capita per year and the percentage of phosphorus passing through the SSTS for both conforming and non-conforming systems are derived from the MPCA's Detailed Assessment of Phosphorus Sources to Minnesota Watersheds (MPCA 2004a).

Groundwater

Phosphorus loading attributed to groundwater to the eight lakes included in this study is assumed to be negligible. This determination was reached after a thorough review of Parts A and B of the *Geologic Atlas of Pope County, Minnesota* (Harris 2003 and Berg 2006), review of Quaternary Water Table Aquifer (QWTA) TP concentrations collected as part of the MPCA Ground Water Monitoring and Assessment Program (GWMAP) program and for the *Geologic Atlas of Pope County, Minnesota,* and estimates of groundwater flux to each of the lakes using Darcy's Law. TP concentrations used in estimating loading attributed to groundwater ranged from 0.019 mg/L to 0.078 mg/L. Although groundwater underlying feedlots typically has greater TP concentrations, a study by the MPCA found that phosphorus concentrations are attenuated to generally below levels of concern within 200 feet down-gradient of the feedlot's manure basin (MPCA 2001b). Groundwater was determined to be a negligible source of TP. A groundwater source was only included for Reno Lake.

Internal Loading

Internal loading in lakes refers to the phosphorus load that originates in the bottom sediments and is released back into the water column. The phosphorus in the sediments was originally deposited in the lake sediments through the settling of particulates (attached to sediment that entered the lake from watershed runoff, or as phosphorus incorporated into biomass) out of the water column. Internal loading can occur through various mechanisms:

- Anoxic (lack of oxygen) conditions in the overlying waters: Water at the sediment-water interface may remain anoxic for a portion of the growing season, and low oxygen concentrations result in phosphorus release from the sediments. If a lake's hypolimnion (bottom area) remains anoxic for a portion of the growing season, the phosphorus released due to anoxia will be mixed throughout the water column when the lake loses its stratification at the time of fall mixing.

Alternatively, in shallow lakes, the periods of anoxia can last for short periods of time; wind mixing can then destabilize the temporary stratification, thus releasing the phosphorus into the water column.

- Physical disturbance by bottom-feeding fish such as carp and bullhead. This is exacerbated in shallow lakes since bottom-feeding fish inhabit a greater portion of the lake bottom than in deeper lakes.
- Physical disturbance due to wind mixing and motor boats. This is more common in shallow lakes than in deeper lakes. In shallower depths, wind energy can vertically mix the lake at numerous instances throughout the growing season.
- Phosphorus release from decaying curly-leaf pondweed (Potamogeton crispus). This is more common in shallow lakes since shallow lakes are more likely to have nuisance levels of curly-leaf pondweed.

Internal loading was estimated due to the release of phosphorus from sediments as a result of anoxic conditions. Additional internal loading due to bottom-feeding fish, wind mixing in shallow areas, and the release of phosphorus from curlyleaf pondweed was not added to the estimate.

The internal phosphorus loading to the lake was estimated based on the expected release rate (RR) of phosphorus from the lakebed sediment, the lake anoxic factor (AF), and the lake area. Lake sediment samples were taken and tested for concentration of TP and bicarbonate dithionite extractable phosphorus (BD-P), which analyzes iron-bound phosphorus. Phosphorus RRs were calculated using two different equations relating the sediment concentrations to RR. Given the potential error and uncertainty in the estimates, multiple equations were used in order to increase confidence and arrive at a reasonable range of internal loading values.

Both equations are statistical regression equations, developed using measured RR and sediment concentration data from different sets of lakes (Nürnberg 1988; Nürnberg 1996). The approach assumes that if a regression equation adequately characterizes the relationship between RR and sediment phosphorus concentration data in the study set of lakes, then it is reasonable to apply the same equation to other lakes for which the sediment phosphorus concentration is known.

In general, this is appropriate if the lakes under consideration are similar in nature to the lakes in the studies from which the equations were developed, and if the sediment phosphorus concentrations are within the range of the observed values. In this particular study, the measured phosphorus concentrations were generally lower than the concentrations in the study sets used to derive the equations. However, they are applicable to some extent, and given that they are the best feasible methods currently available, these equations were used to arrive at the estimated range for internal phosphorus loading.

The loading results for the two different methods are shown in Table 7. For purposes of reporting, method "A" was selected as the low end of the internal loading range, and method "B" was selected as the high end. It is reasonable to use method "A" as the low end because our lake observations are at the low end of the study dataset, and at low enough values the equation leads to RRs below zero, which is an under-prediction. It is reasonable to use method "B" as the high end because, at this range of values, the worldwide study tends to over-predict, based on the fact that there are a number of outliers in that dataset near the low end of TP concentrations with RRs well below the regression line.

Table 7. Range of Results from Internal Load Modeling

Lake	Modeled TP Internal Load		Average TP Internal Load
	Method A[1] (lbs/yr)	Method B[2] (lbs/yr)	(lbs/yr)
Ann - FULL RECORD	193	1,764	979
Ann - LAST 3 YEARS	182	1,663	923
Emily	1,603	5,335	3,469
Gilchrist	47	1,050	549
Leven	26	822	424
Malmedal	124	816	470
Pelican	264	1,453	859
Reno	1,209	12,883	7,046
Strandness	49	304	176

[1] Regression equation based on the sediment BD-P concentration and the North American lakes dataset

[2] Regression equation based on the sediment TP concentration and literature data from lake studies done in various locations around the world

In-stream Erosion

In-stream erosion is a potential source of phosphorus to water bodies, particularly within the Minnesota River Basin. Analysis was conducted to determine sediment and phosphorus loads from streambank erosion contributing to eutrophication of Lakes Emily and Gilchrist.

Using the Bank Assessment for Non-point Source Consequences of Sediment (BANCS) model, Bank Erosion Hazard Index (BEHI) and estimated Near Bank Shear Stress (NBS) were measured using methods described in the Watershed Assessment for River Stability and Sediment Supply (WARSSS) (Rosgen 2006). The BEHI and NBS scores are used to predict annual rates of streambank erosion. Bank loading rates were estimated for the East Branch of the Chippewa River, Little Chippewa River and Outlet Creek, tributaries to Lake Emily and Gilchrist. Small ditches and minor tributaries were not included in the analysis. To account for deposition, the Brune equation for reservoir deposition was used. Much of the sediment eroded from the streambanks may also be deposited on floodplains or pointbars, but there is no simple way to measure that, so it was not taken into account in these calculations. Consequently the total amount of streambank erosion calculated will be greater than the amounts actually reaching the lakes (Emily and Gilchrist). The conversion of sediment load to phosphorus load was based on work by Fang et al. (2002). A rate of 1.59 lbs TP/ton of soil was used to determine the total load of TP.

For Lake Emily, only Outlet Creek was evaluated for deposition due to the availability of monitoring data along the Little Chippewa that was used to evaluate modeled watershed loading values. The monitoring data suggested that the modeled watershed loading for Lake Emily accounted for in-stream loadings. In-stream loading to Gilchrist is attenuated by numerous wetlands and ponds along the stream channel. Upstream of Lake Gilchrist there are three fairly effective sediment traps, Lake Marlu, Marlu Mill Pond, and Terrace Mill Pond, capturing an estimated 60% of the sediment as estimated with the Brune equation. This estimate assumes that the ponds have capacity to allow deposition.

Most of the streams evaluated in Pope County were narrow, highly sinuous channels characterized by the E type in the Rosgen System. Review of aerial photos combined with field investigations shows there has been a loss of sinuosity in most streams, increasing the erosivity of stream flow and the sediment transport capacity of streams, ultimately leading to more sediment and phosphorus being delivered to downstream lakes. The loss of sinuosity is thought to be a result of direct channelization, increased stream flow, and cattle grazing. Based on this analysis, phosphorus loads due to in-stream erosion to Emily and Gilchrist were estimated at less than 10% of the total load. Due to the known uncertainties and underestimates in deposition, in-stream TP loadings were determined to be negligible and are not accounted for specifically in the phosphorus source assessment for each lake.

Shoreline Erosion

The extent of shoreline erosion was evaluated through input from stakeholders at Technical Advisory Committee (TAC) and public meetings. Shoreline erosion is an issue in Lake Emily and likely contributes phosphorus to the lake. It was not an issue in the other lakes, and is not accounted for specifically in the phosphorus source assessment for each lake.

3.2 Lake Assessments

Lake assessments are included for each lake, including a summary of available water quality data, lake morphology, fisheries, macrophytes, and lake stratification when applicable. To quantify the existing water quality conditions, data from the last 10 years (1998 through 2007) were used. This corresponds to the time period (the most recent 10 years) that the MPCA uses to assess lakes for nutrient impairments (MPCA 2009). The growing season means (GSMs) for TP, chlorophyll-*a*, and Secchi depth were calculated using data from June through September.

3.3 TMDL Derivation

This section presents the overall approach to estimating the components of the TMDL. The pollutant sources were first identified and estimated in the phosphorus source assessment (Section 3.1). The loading capacity (TMDL) of each lake was then estimated (Section 3.3.1) using an in-lake phosphorus response model and was divided among WLAs and LAs.

- Loading capacity (TMDL): the total amount of pollutant that the water body can assimilate and still maintain water quality standards.
- Wasteload allocations (WLAs): the pollutant load that is allocated to point sources, including WWTFs, regulated construction stormwater, and regulated industrial stormwater, all covered under NPDES Permits. A source can receive a WLA for a current or future permitted pollutant source.
- Load allocations (LA): the pollutant load that is allocated to sources not requiring NPDES Permit coverage, including non-regulated stormwater runoff, atmospheric deposition, and internal loading.

3.3.1 Loading Capacity: Lake Response Model

The modeling software BATHTUB (Version 6.1) was selected to link phosphorus loads with in-lake water quality. A publicly available model, BATHTUB was developed by William W. Walker for the U.S. Army Corps of Engineers (Walker 1999). It has been used successfully in many lake studies in Minnesota and throughout the United States. BATHTUB is a steady-state annual or seasonal model that predicts a lake's summer (June through September) mean surface water quality. BATHTUBs time-scales are appropriate because watershed phosphorus loads are determined on an annual or seasonal basis, and the summer season is critical for lake use and ecological health. BATHTUB has built-in statistical calculations that account for data variability and provide a means for estimating confidence in model predictions. The heart of BATHTUB is a mass-balance phosphorus model that accounts for water and phosphorus inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and (if appropriate) groundwater; and outputs through the lake outlet, groundwater (if appropriate), water loss via evaporation, and phosphorus sedimentation and retention in the lake sediments.

Long-term averages were used as input data to the models, due to the lack of detailed annual loading and water balance data for each of the lakes. The outputs from the phosphorus source assessment (Section 3.1) were used as inputs to the BATHTUB lake models. The models were calibrated to existing water quality data, and then were used to determine the phosphorus loading capacity of each lake. The loading capacity of each lake is the TMDL; the TMDL is then split into WLAs, LAs, and a MOS.

The TMDL (or loading capacity) was first determined in terms of annual loads. In-lake water quality models predict annual averages of water quality parameters based on annual loads. Symptoms of nutrient enrichment normally are the most severe during the summer months; the state eutrophication standards were established with this seasonal variability in mind. The annual loads were converted to daily loads by dividing the annual loads by 365.

System Representation in Model

In typical applications of BATHTUB, lake and reservoir systems are represented by a set of segments and tributaries. Segments are the basins (lakes, reservoirs, etc.) or portions of basins for which water quality parameters are being estimated, and tributaries are the defined inputs of flow and pollutant loading to a particular segment. For this study, the direct drainage area for each lake (i.e., segment) counted as one tributary for that lake. Tributaries were also defined where streams conveyed flow to the lake from upstream lakes or drainage areas. In the case of Reno Lake, a tributary was also included to represent groundwater inflow, given its importance to the overall water balance of that lake.

Under normal use, internal loading is not represented explicitly in BATHTUB. However, there is an option (generally not recommended) to include an additional load, identified as an internal load in the program, if circumstances warrant. In one case (Ann Lake), this option was used, because the evidence strongly suggested that an additional load, beyond that which was delivered from the watershed, was contributing to a high phosphorus concentration in the lake (additional explanation provided below). For modeling purposes, this additional load was included on the "internal load" input screen, but whether it actually comes from an internal source or an external source is not known at this point.

Model Input

See *Appendix A: Modeling Support Data* for a summary table of model inputs.

Precipitation and Evaporation

See discussion titled "Stormwater Runoff" under Section 3.1.2 for estimates of annual precipitation and evaporation rates, which were based on data from the Minnesota Hydrology Guide.

Atmospheric Deposition

Average phosphorus atmospheric deposition loading rates were estimated to be 0.233 lb/ac-yr for the Minnesota River Basin (MPCA 2004a), applied over each lake's surface area. See Section 3.1.2 (Atmospheric Deposition under Phosphorus Source Assessment) for more details.

Segment Data: Lake Morphometry and Observed Water Quality

Lake morphometry data were gathered from multiple sources, including the MPCA Minnesota Inventory of Impaired Lakes database (July 2008), COLA reports, and data collected for this study. Sources for the individual values are provided in the individual lake TMDL chapters. Observed water quality averages are from the lake assessments (Section 3.2) and are 10-year (1998 to 2007) growing season (June through September) means of TP, chlorophyll-*a*, and Secchi depth.

Tributary Data: Flow Rate and Phosphorus Concentration

All of the watershed sources from the phosphorus source assessment (Section 3.1) were compiled into the tributary inputs. Watershed phosphorus sources include stormwater runoff, loading from upstream waters, runoff from feedlots, atmospheric deposition, SSTS, groundwater when applicable, and permitted WWTFs.

Chlorophyll-Secchi Coefficient

Among the key empirical model parameters is the ratio of the inverse of Secchi depth (the inverse being proportional to the light extinction coefficient) to the chlorophyll-*a* concentration. The coefficient was calculated independently for each lake using lake-specific chlorophyll-*a* and Secchi depth monitoring data.

Selection of Equations

BATHTUB allows choice among several different mass balance phosphorus models. For deep lakes in Minnesota, the option of the Canfield-Bachmann lake formulation (Canfield and Bachmann 1981) has proven to be appropriate in most cases. For each lake in this study, all phosphorus models were tested to determine which equation delivered a result closest to the observed concentration. In most cases, the Canfield Bachmann lake formulation provided the best fit to the data, and in order to perform a uniform analysis it was selected as the standard equation for the study. For other parameters, the default model selections (chlorophyll-*a* model based on phosphorus, light, and flushing; transparency model based on chlorophyll-*a* and turbidity) were used.

Model Calibration

In the calibration process, it is first necessary to check that the lake behaves like the lakes in the dataset used to develop the regression equation, and that calibration coefficients will not have to be adjusted to an unrealistic degree. Before calibration coefficients were adjusted to calibrate the model, it was verified that the predictions made by the uncalibrated model were sufficiently close to the observed concentrations to warrant using the normal calibration process.

In the case of the Canfield Bachmann lakes equation, the 95% confidence interval corresponds to 31% to 288% of the calculated TP value. This would suggest that calibration coefficients in the range of 0.31 to 2.88 could be considered reasonable. Even if this is further restricted to a range of 0.5 to 2 (as suggested for other phosphorus retention equations in BATHTUB), the Canfield Bachmann lakes equation delivers results sufficiently close to observed values for all but one lake. The exception is Ann Lake, with an observed phosphorus concentration well above that predicted by the model.

For all lake models except the Ann Lake model, calibration coefficients were then modified so that the predicted values of phosphorus, chlorophyll-*a*, and Secchi depth matched the observed values. Matches were made to the nearest whole number for phosphorus and chlorophyll-*a* concentrations, and to the nearest tenth for Secchi depths. Details on the specific model calibration for Ann Lake are included in the Ann Lake TMDL chapter.

Estimated Phosphorus Load Reduction Requirements

With calibrated existing conditions models completed for all the lakes, reductions in phosphorus loading could be simulated in order to estimate the effects on lake water quality. Specifically, the goal of the analysis was to identify the reduction in phosphorus loading required in order to meet water quality standards for TP and either chlorophyll-*a* or Secchi depth. Using the calibrated existing conditions model as a starting point, the phosphorus concentrations associated with all tributaries in a given lake model were reduced until the model indicated that the requisite two out of three water quality standards were being met.

With this process, a series of models were developed that included a level of phosphorus loading consistent with lake water quality standards. Actual load values are calculated within the BATHTUB software, so loads from the goal (standards) models could be compared to the loads from the existing conditions models to determine the amount of load reduction required.

Internal vs. External Load

BATHTUB does not, under normal use, account explicitly for internal load. However, because it does employ empirical equations derived from actual lakes and reservoirs, a certain average level of internal loading is implicit in the results. Through the process described above, the total amount of phosphorus load reduction required to meet two out of three water quality standards can be estimated. Even though each lake’s internal loading was not defined explicitly in the BATHTUB models, if that loading can be calculated separately for existing conditions and reduced through lake management activities, the resultant internal load reduction can count toward the overall phosphorus reduction in the system. For that reason, and generally in order to better characterize lake behavior, internal loads were estimated using models independent of the BATHTUB model (see the "Internal Loading" discussion under Section 3.1.2).

3.3.2 TMDL Allocations

Margin of Safety

An explicit MOS is included in the Ann, Emily, Gilchrist, Leven, Pelican, Reno, and Strandness TMDL equations to account for both the inability to precisely describe current water quality conditions and the unknowns in the relationship between the allocations and the in-lake water quality.

An explicit MOS of 10% was used for all lakes. This MOS accounts for the uncertainty in predicting the loads to the lakes, and the uncertainty in predicting how the lake responds to changes in phosphorus loading. The 10% MOS is appropriate since the lakes have relatively good records of monitoring data (eight years minimum); therefore the in-lake water quality conditions are relatively well-known and there is no need to set an MOS higher than 10%.

Wasteload Allocations

Feedlots Requiring NPDES Permit Coverage

The open lots of the NPDES-permitted feedlot (Blair Farms Inc., Permit #MN0066273) are located in the Ann Lake and Reno Lake watersheds. This individual WLA is set at 0 lbs/yr per the requirements of the NPDES Permit.

Permitted Wastewater Treatment Facilities

The Lowry WWTF WLA was set based on the existing 1 mg/L TP effluent limit and the desired ability to discharge for 42 days/year, corresponding to an annual flow volume of 16 million gallons per year. Discharges occur in the spring and fall, and within discharge windows specified in the permit.

The Starbuck WWTF WLA was set based on the Lower Minnesota River Dissolved Oxygen TMDLs WLA assumptions (1 mg/L TP limit at 70% of the design flow) applied over the Minnesota River Basin General Phosphorus permit's critical time period (May through September), and a 1 mg/L TP limit at the design flow of 350,000 gallons per day (per Minn. R. ch. 7053.0255) from October through April. An additional 41 lbs/yr of TP was added to this WLA to provide additional capacity in the future.

Regulated Construction Stormwater

The construction stormwater WLAs were calculated based on the estimated area of Pope County under permitted construction activity over the past five years (2005 through 2009). Project areas of permits were summed up within the county and presented as an annual average percent of total county area that has been issued a construction stormwater permit, which was 0.02%

This percentage was multiplied by the total TMDL (loading capacity) minus the MOS to determine the construction stormwater WLA. Construction stormwater activities are considered in compliance with provisions of the TMDL if they obtain a Construction General Permit under the NPDES program and properly select, install, and maintain all BMPs required under the permit, including any applicable additional BMPs required in Appendix A of the Construction General Permit for discharges to impaired waters, or meet local construction stormwater requirements if they are more restrictive than requirements of the state General Permit.

Regulated Industrial Stormwater

There are no current regulated industrial stormwater sources within any of the lakes' watersheds. A small portion of the TMDL was set aside for future regulated industrial stormwater sources; the industrial stormwater WLA was calculated as 0.5% of the total WLA. Industrial stormwater activities are considered in compliance with provisions of the TMDL if they are covered under the Multi-Sector Industrial Stormwater General Permit or General Sand and Gravel General Permit (MNG49) under the NPDES program and properly select, install, and maintain all BMPs required under the permit.

Load Allocations

One LA was set for each lake. The LA includes all sources of phosphorus that do not require NPDES Permit coverage, including watershed runoff, internal loading, atmospheric deposition, and any other identified loads as described in Section 3.1.

Reserve Capacity

Reserve capacity, an allocation for future growth, was not explicitly estimated. The communities served by the Starbuck and Lowry WWTFs are not expected to grow substantially in the foreseeable future.

4 ANN LAKE TMDL

4.1 Lake Assessment

4.1.1 Physical Characteristics

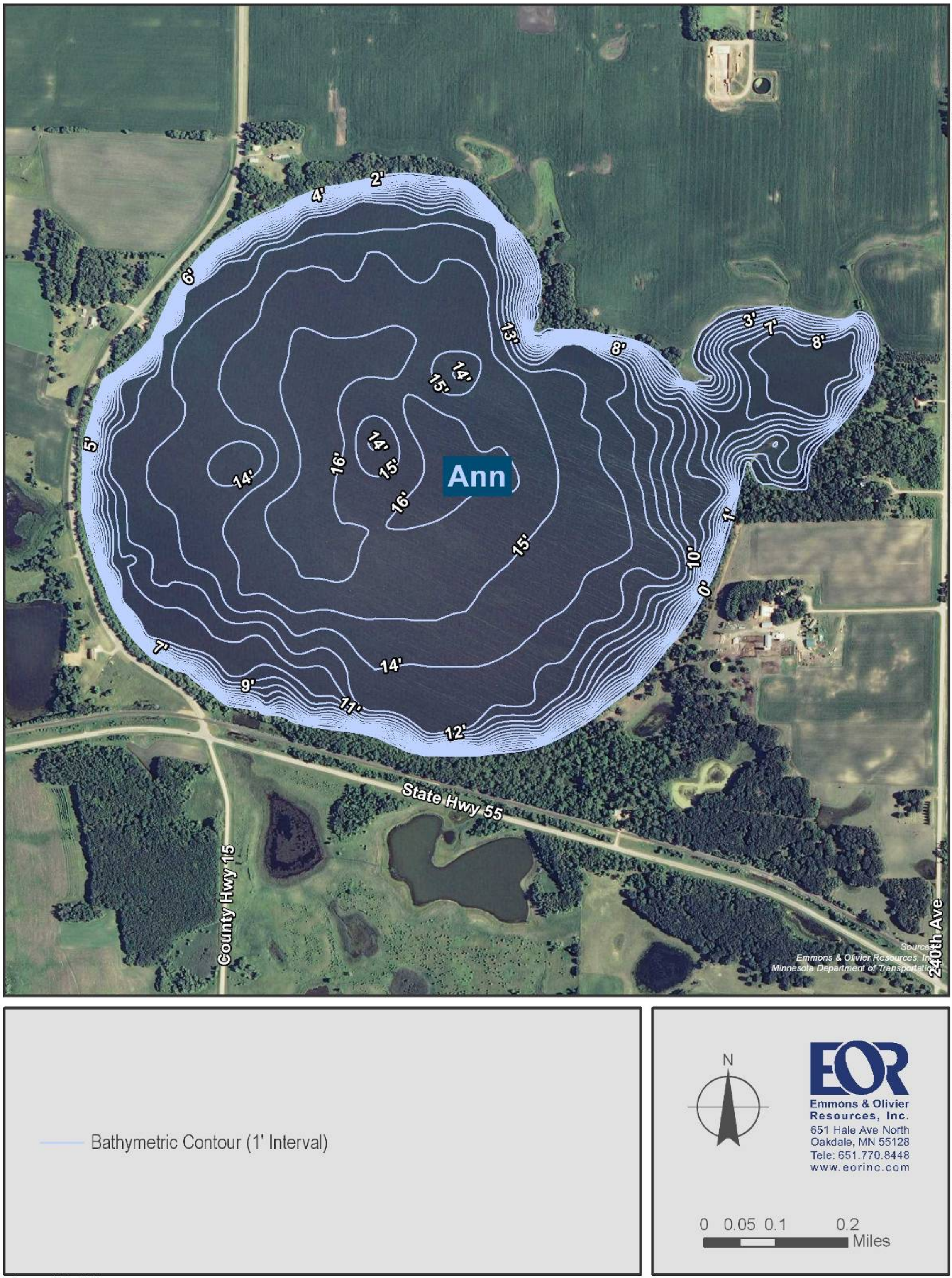
Ann Lake is located northwest of the city of Glenwood in north central Pope County. The lake is 365 acres in size with a watershed area draining to the lake of 4,882 acres (Table 8 and Figure 6). Ann Lake was assessed by the MPCA as a shallow lake based on Department of Natural Resources (DNR) bathymetry; however, during 2009, bathymetry was surveyed and it was determined that the lake was only 70% littoral. At the time the 2009 bathymetry measurements were made, the lake elevation was slightly higher than the ordinary high water level. The bathymetry of the lake suggests that a 1-foot change in lake elevation could result in the lake being 91% littoral. A review of depth profiles indicates that the lake does not stratify during the growing season and aquatic vegetation has been described as covering the entire lake in the past. This TMDL is therefore considering Ann Lake to be a shallow lake.

Ann Lake outlets to John Lake to the west. John Lake is typically below its runout elevation. Periodically, a backwater effect occurs when John Lake drains into Ann Lake for a short period of time (DNR 2009).

Table 8. Ann Lake Characteristics

Characteristic	Value	Source
Lake total surface area (ac)	365	MPCA Minnesota Inventory of Impaired Lakes database (July 2008)
Percent lake littoral surface area	70% to 91%	Calculated based on bathymetry
Lake volume (ac-ft)	4,525	Calculated (mean depth x surface area)
Mean depth (ft)	12	Bathymetry
Maximum depth (ft)	17	Bathymetry
Drainage area (acres)	4,882	DNR Waters Lakesheds (2004)
Watershed area : lake area	13	Calculated

Figure 6. Ann Lake Bathymetry, 2009



January 19th, 2010

Land Use

Land use throughout the watershed is primarily agriculture. Eighty percent of the land is categorized as cultivated crop land and pasture/hay land. Table 9 shows the total acres and percent of the watershed for each type of land use. There are six homes on the shores of the lake.

Table 9. Ann Lake Watershed Land Use

Land Use	Total Acres	% of Watershed
Barren Land (Rock/Sand/Clay)	0	0%
Cultivated Crops	3,254	67%
Deciduous Forest	281	6%
Developed, High Intensity	0	0%
Developed, Low Intensity	66	1%
Developed, Medium Intensity	2	0%
Developed, Open Space	240	5%
Emergent Herbaceous Wetlands	53	1%
Evergreen Forest	7	0%
Grassland/Herbaceous	90	2%
Mixed Forest	3	0%
Open Water	253	5%
Pasture/Hay	631	13%
Shrub/Scrub	0	0%
Woody Wetlands	2	0%
Total	4,882	100%

Source: NLCD 2001, USGS.

4.1.2 Biological Characteristics

Fisheries

Ann Lake has one public access on the northwest side of the lake. The lake is classified as a natural environment lake by the DNR shoreland management lake classifications. Black bullhead abundance is extremely high (2005 DNR fish survey). In general, bullheads are benthivorous fish; they forage in the lake sediments, which physically disturb the sediments and causes high rates of phosphorus release from the sediments to the water column. Sunfish are present but abundance is extremely low. Sunfish are considered planktivores, so the low predation on the zooplankton could partially explain the lower chlorophyll-*a* concentrations in relation to TP. Very few adult game fish were present, primarily northern pike, largemouth bass, and walleye. As these species are the top predators in the fishery, this causes a reduction in predation on the benthivores and planktivores. The DNR stocks Ann Lake with walleye, and in 2004, introduced 40 pairs of adult largemouth bass to increase the numbers of predatory, popular game fish.

Macrophytes

An aquatic vegetation survey was completed by the DNR in July of 2000. This survey showed the dominant vegetation within the lake to be coontail, northern water milfoil, sago pondweed, and flatstem pondweed. Curlyleaf pondweed was recorded as rare. Observations of the macrophyte community were recorded during a 2005 DNR fish survey, in which extremely high submergent vegetation abundance was noted. Curlyleaf pondweed was observed to dominate the aquatic vegetation, likely contributing to the internal loading through phosphorus release from decaying curlyleaf pondweed in the spring.

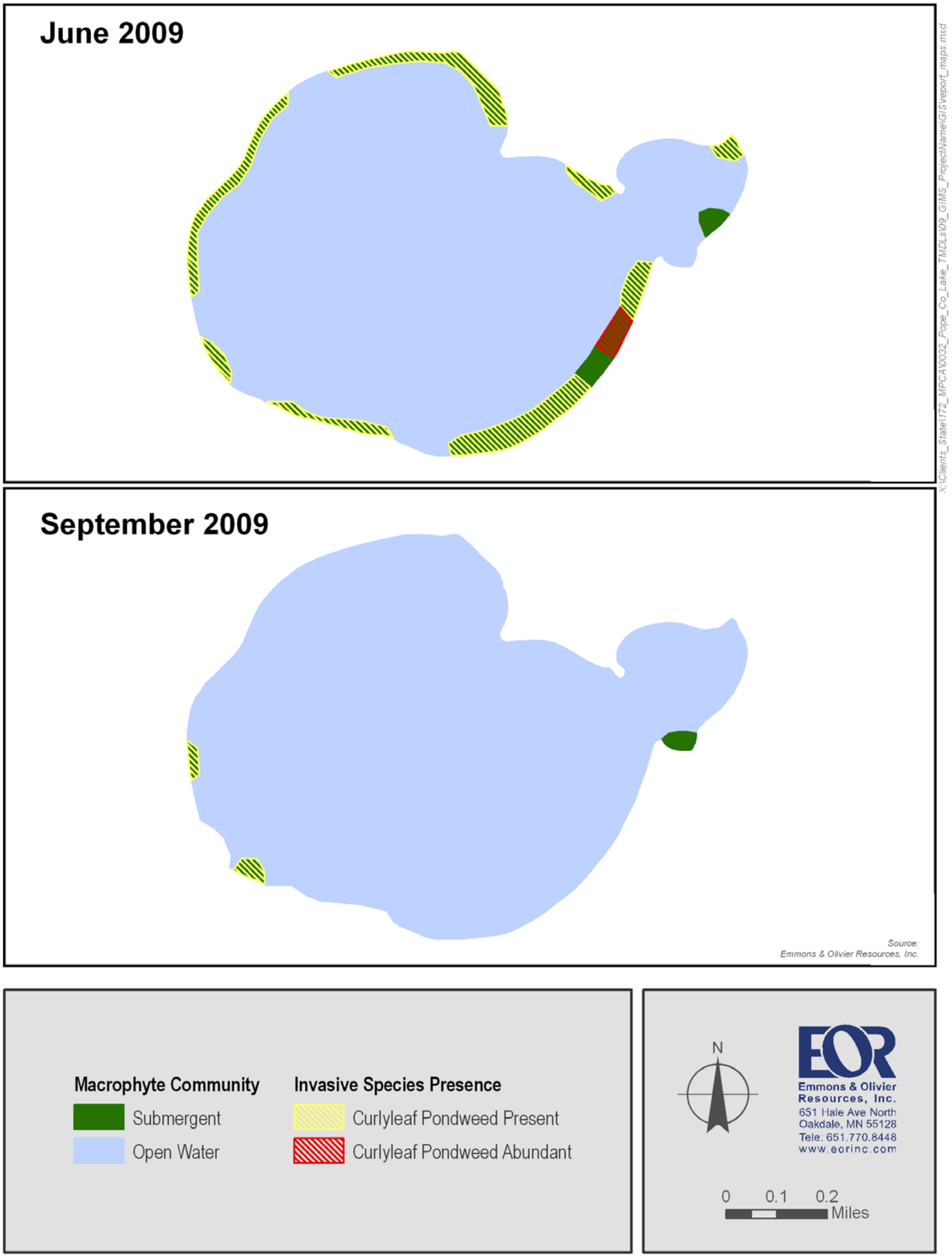
Although curlyleaf pondweed was not present in high abundance in the 2000 vegetation survey, it does not mean that curlyleaf pondweed was not present that year; the survey was completed in July, which is after typical curlyleaf pondweed senescence.

A macrophyte survey was completed again in 2009, during the summer and fall (Figure 7 and Table 10). During 2009, there was a notable lack of macrophytes in the lake. A ring of curlyleaf pondweed was present along the perimeter of the lake during the summer. Very few macrophytes were present in the fall. A ring of dense blue-green algae was found around the perimeter of the lake extending out at least 30 feet from the shore and somewhat in the center.

Table 10. Plant Species Observed During 2009 Ann Lake Macrophyte Surveys

Scientific Name	Common Name	Summer	Fall
Potamogeton crispus	Curlyleaf pondweed	X	X
Potamogeton pectinatus	Sago pondweed		X
Potamogeton filiformis	Slender pondweed	X	
	Blue green algae	X	X

Figure 7. Ann Lake Macrophytes, 2009



4.1.3 Existing Studies and Monitoring

Status and Trend Monitoring Summary for Selected Pope and Douglas County, Minnesota Lakes

In 2001, the MPCA produced the “Status and Trend Monitoring Summary for Selected Pope and Douglas County, Minnesota Lakes.” Ann Lake was included in the summary report and characterized as a hypereutrophic lake. Water quality samples were collected from Ann Lake monthly from June through September of 2000. The lake water quality summer mean for TP was 264 µg/L, the highest TP of all seven lakes in the study. The summer mean for chlorophyll-*a* was 38 µg/L and the Secchi depth summer mean was 2.0 meters. As part of the study, a Minnesota Lake Eutrophication Analysis Procedure (MNLEAP) model was used to model Ann Lake’s TP, chlorophyll-*a*, and Secchi values. The MNLEAP predicted values were significantly lower than the observed values. The study suggested that the difference in predicted and observed water quality was due to watershed nutrient loading. The study also showed that blue-green algae dominated the algal community within the lake (MPCA 2001a). The report can be found at https://www.pca.state.mn.us/sites/default/files/lar-61-0122.pdf.

Trapper’s Run Creek Watershed Project

In 1994, a water resources study of Trapper’s Run Creek was completed by the DNR to analyze the physical, biological, and chemical characteristics of the creek and identify point and non-point sources of pollution. Lake Minnewaska and Pelican Lake are two of the most aesthetically and economically valuable water resources within Pope County and are directly impacted by the poor water quality draining from Trapper’s Run Creek. The study identified high nutrient concentrations, low biodiversity, and low DO levels within the creek (Pope County 1994). Ann Lake was included in the Trapper’s Run Creek Watershed Project due to an intermittent stream that flows periodically from Ann and John Lakes down to the Peopple’s Wetland and Trapper’s Run Creek (Pope County 1996).

In 1995, the study continued by looking at the runoff to the creek, collecting additional flow data along the stream, evaluating the status of contributing lakes including Ann Lake, and starting inventories of the tile systems within the watershed, feedlots, and septic systems. At that time, Ann Lake was found to be hypereutrophic with a mean TP concentration of 146 µg/L.

The project report published by Pope County Environmental Services in 1996 provided a comprehensive look at all of the inventoried data on the creek and identified goals and objectives to prevent further degradation of the water quality and protect Pelican and Minnewaska. The report identified additional monitoring that could be done, programs to implement, and BMPs that could be used throughout the watershed. The problems within the watershed were diagnosed in 1996, and the largest contributors included feedlot runoff, extensive tiling, non-code septic systems, and fertilizer runoff. The data collected within the subwatersheds of the creek that fall within the Ann Lake Watershed were analyzed and it was concluded that feedlots were the main causes of pollution to the creek in that area (Pope County 1996). The water quality collected at monitoring sites showed the highest fecal coliform values in the entire Trapper’s Run Creek Watershed.

From 2000 to 2004, with grant assistance from the MPCA, the Trapper's Run Creek Watershed Project implemented programs to identify and upgrade non-compliant feedlots, set up a manure management planning program, conduct additional water quality monitoring and data assessment on the watershed, and start an incentive-based program for septic system upgrades.

4.1.4 Impairment Assessment

Monitoring data are available from as far back as 1992, although there were only one or two samples taken per year and conclusions should not be drawn from sampling at this low frequency. Sampling frequency increased in 1999, and samples have been collected every year since then. The last 10 years of data were used to calculate the water quality data means (Table 11).

Ann Lake is a hypereutrophic lake, with trophic state index (TSI) values for chlorophyll-*a* and TP in the hyper-eutrophic range and Secchi depth in the eutrophic range (Table 11). TP annual mean concentrations have improved since 2001 when the annual mean spiked to 479 µg/L (Figure 8); the annual means after 2001 range from 200 µg/L to 350 µg/L. There was no spring (June) sample in 2001, which artificially raised the mean TP concentration for that year. The high TP relative to the chlorophyll-*a* and the Secchi depths suggests that the lake has so much phosphorus in it that the algae are not limited by phosphorus, but by some other limiting factor. This does not mean that TP doesn't impact the water quality of the lake, but rather it means that phosphorus will have to be reduced by a substantial amount before improvements in the chlorophyll-*a* are realized.

The TP standard for shallow lakes in the NCHF ecoregion is 60µg/L. TP concentration growing season means in the years 1999 to 2007 exceeded the standard every year with means ranging from 202 µg/L to 479 µg/L (Figure 8). Chlorophyll-*a* concentration growing season means ranged from to 14 µg/L to 142 µg/L in the years 1999 to 2007 (Figure 9), only meeting the NCHF ecoregion shallow lakes standard of 20 µg/L in 2001 and 2004. The Secchi depth growing season means ranged from 0.9 m to 2.9 m in 1992 to 2007 (Figure 10), meeting the NCHF ecoregion shallow lakes standard of 1.0 m in all years except 2003 and 2007.

TP consistently increases throughout the growing season (Figure 11); however, the seasonal patterns of chlorophyll-*a* and transparency are not as defined. There is also not a clear relationship between TP and chlorophyll-*a* (Figure 12), indicating that phytoplankton biomass is likely not currently limited by phosphorus. Phytoplankton growth is likely either limited by nitrogen, since TP concentrations are so high, or the biomass is being grazed by zooplankton, keeping the algal concentration relatively low.

Table 11. Surface Water Quality Means, Ann Lake, 1998 to 2007

Parameter	Growing Season Mean (June – September)	Trophic Status Index	NCHF Shallow Lakes Standard
TP	306 µg/L	87	< 60 µg/L
Chlorophyll-*a*	60 µg/L	71	< 20 µg/L
Secchi depth	1.8 m	50	> 1.0 m

Figure 8. TP Monitoring Data, Ann Lake

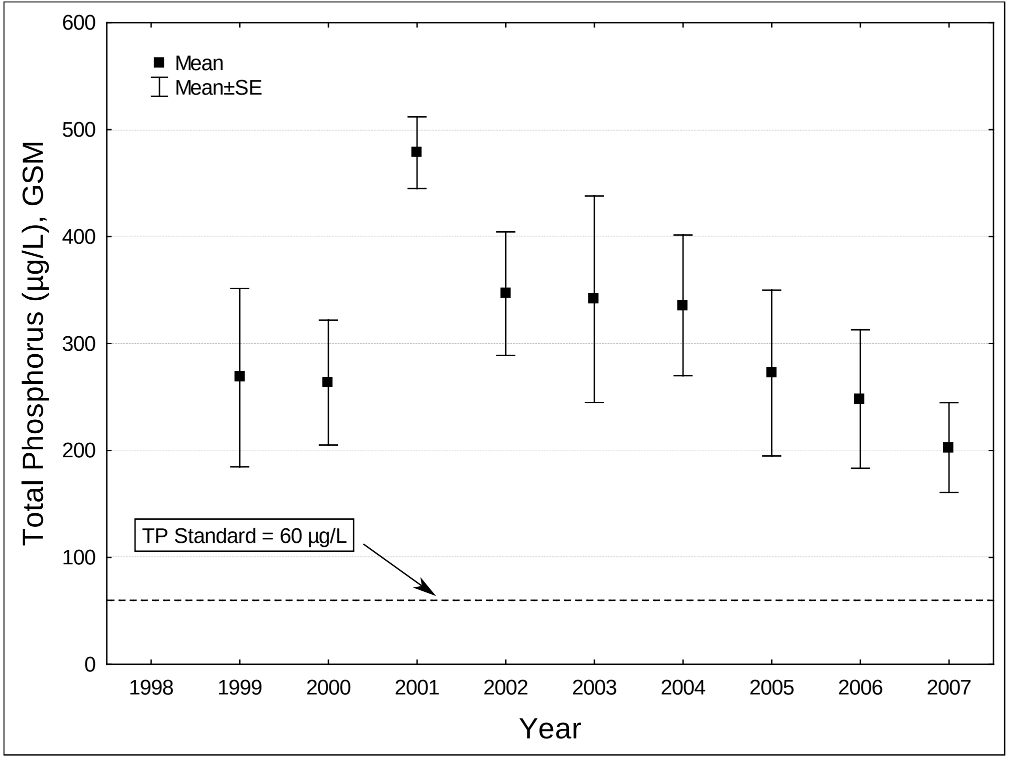


Figure 9. Mean Chlorophyll-*a* Monitoring Data, Ann Lake

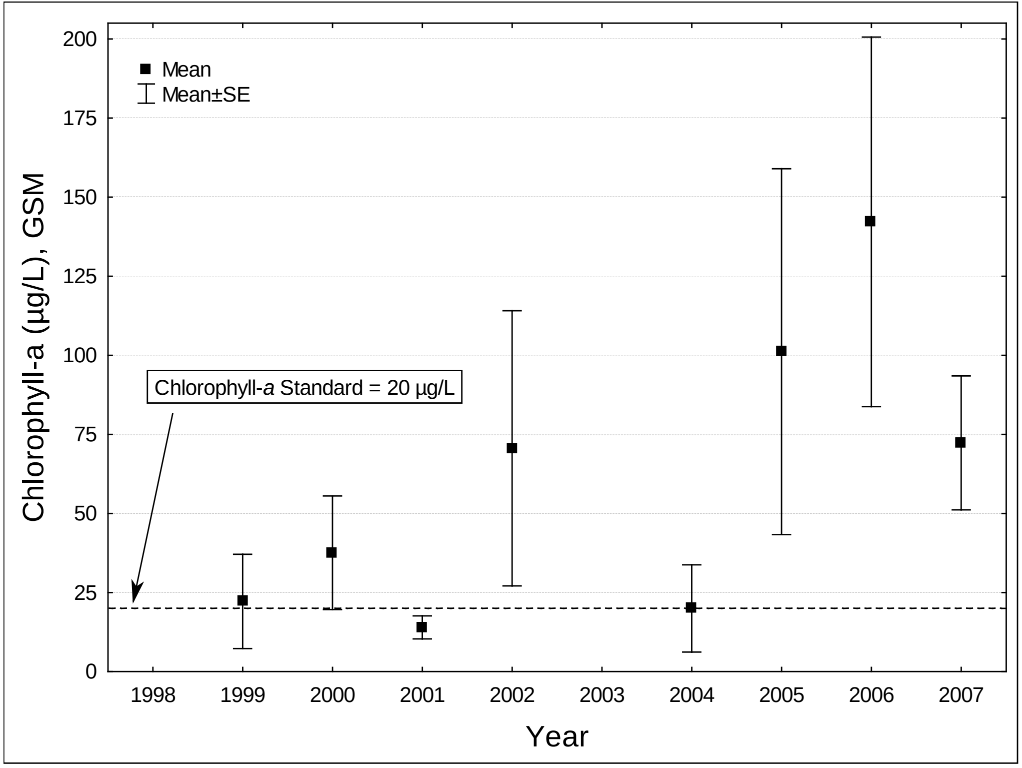


Figure 10. Secchi Depth Monitoring Data, Ann Lake

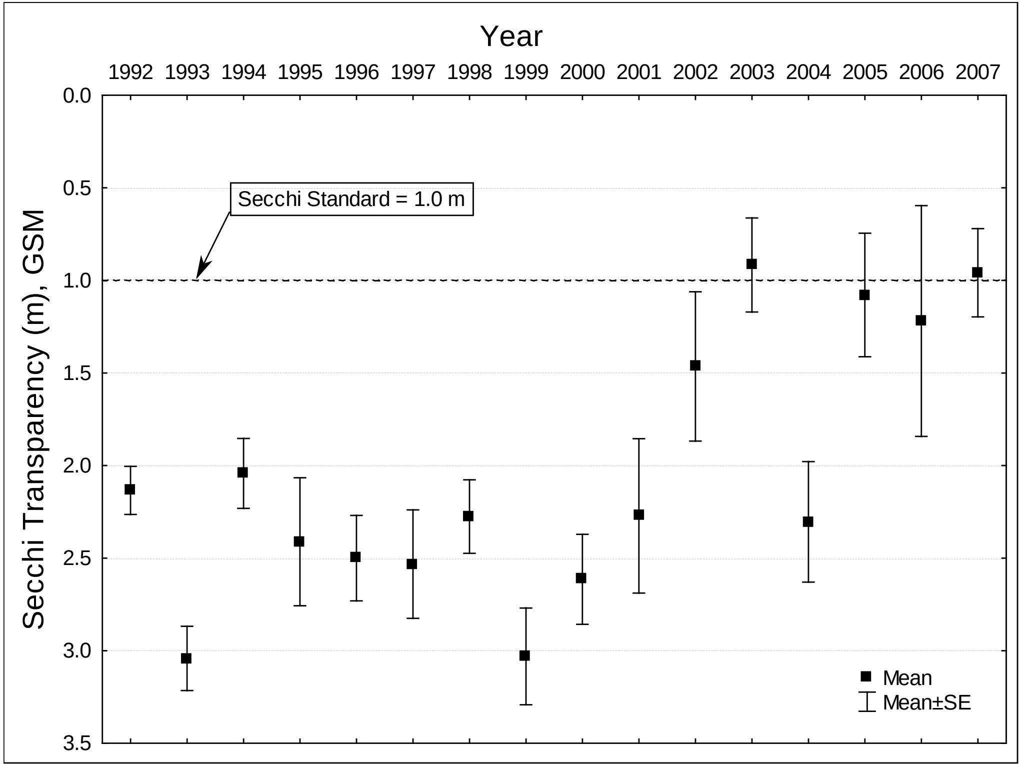


Figure 11. Ann Lake Seasonal TP Patterns, 1998 to 2007

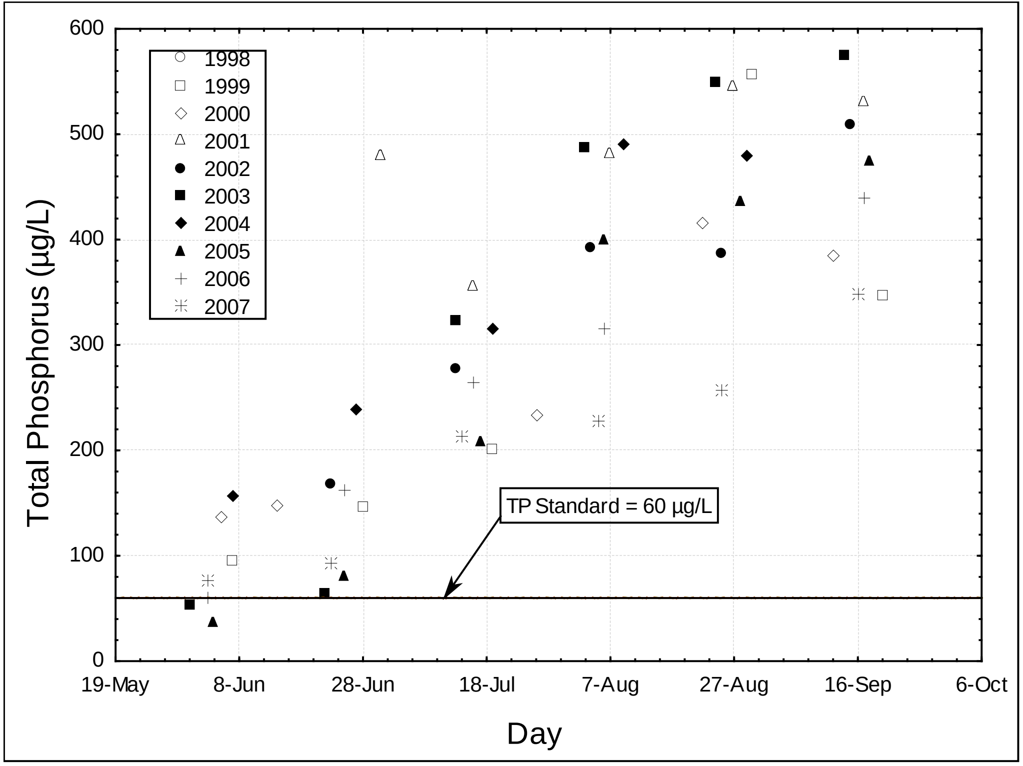
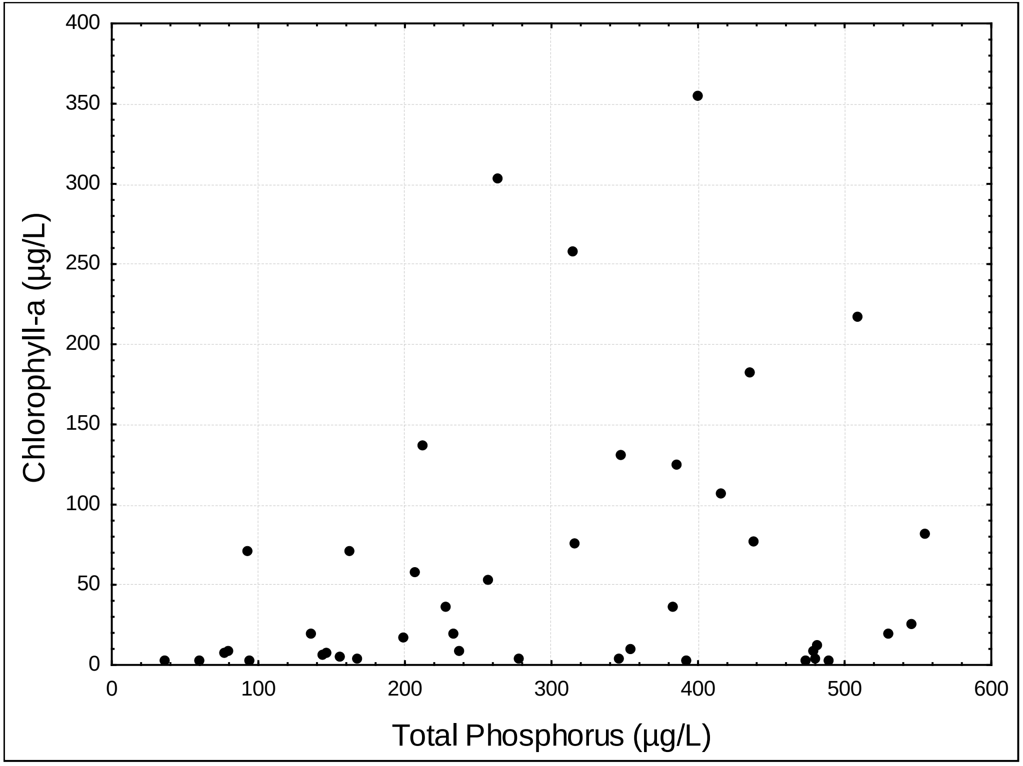


Figure 12. Relationship of Chlorophyll-*a* to TP in Ann Lake, 1998 to 2007



4.2 Phosphorus Source Assessment

It is estimated that Ann Lake receives between 12,295 and 13,776 lbs of phosphorus annually from external and internal sources combined. Much of the external phosphorus to Ann Lake is coming from the watershed and feedlots (Figure 13, Table 12). Using the methods developed for this study to estimate watershed loads, it was determined that 1,350 lbs of phosphorus are from known external sources, and 182 to 1,663 lbs are from internal loading. The exact sources of the remaining 10,763 lbs are not known; this load is likely attributable to watershed sources such as nutrient management practices on agricultural fields, drain tiles, and non-compliant feedlots (see discussion in Section 3.1.1 regarding feedlots requiring NPDES Permit coverage), in addition to internal loading sources. The MPCA staff has determined that the majority of this additional phosphorus load comes from land application of manure within the watershed; it will be referred to as such in this report.

Figure 13. Ann Lake External Phosphorus Inventory

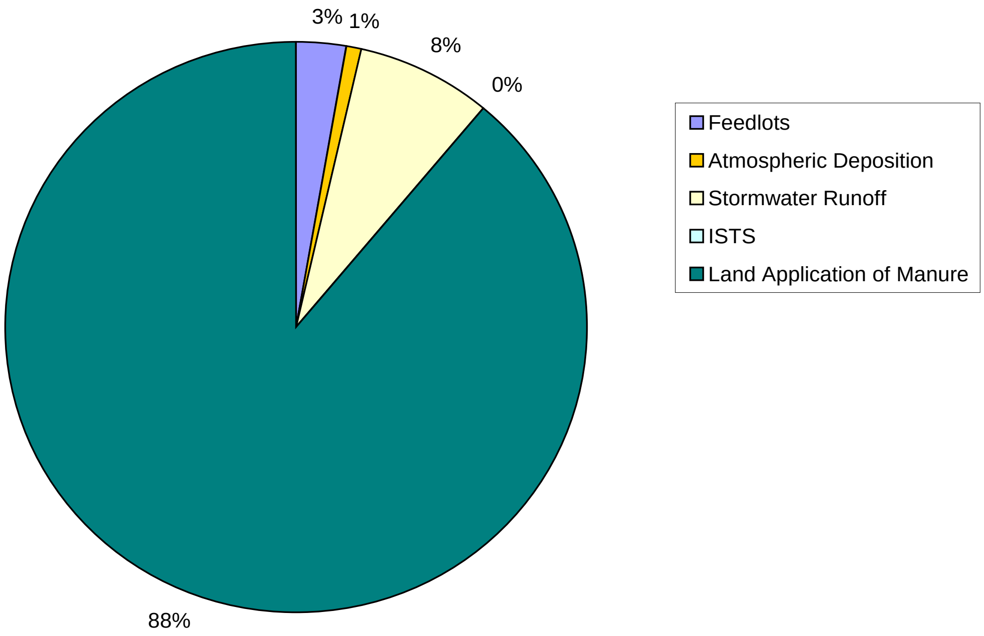


Table 12. Ann Lake External Phosphorus Source Summary

Phosphorus Source	Annual TP Load [lbs/yr]
Stormwater Runoff	921
Feedlots	336.4
Atmospheric Deposition	85
SSTS	8.3
Land Application of Manure	10,763
Total	12,113.6

4.2.1 Sources of Phosphorus Requiring NPDES Permit Coverage

Feedlots

From 2003 to 2008 there was one NPDES Permitted feedlot within the TMDL study area: Blair Farms Inc. (Permit #MN0066273) located within the Ann Lake and Reno Lake Watersheds. A new permit was issued in 2009. Due to the fact that these open lots were not permitted through the NPDES program prior to 2003, and based on information that suggests the feedlots did contribute phosphorus to the lake prior to permit issuance in 2003, this feedlot is accounted for as a feedlot not requiring NPDES Permit coverage. Going forward, it will be assumed that under the existing NPDES Permit, discharge from this feedlot will not reach Ann Lake.

4.2.2 Sources of Phosphorus Not Requiring NPDES Permit Coverage

Stormwater Runoff

The entire Ann Lake drainage area (4,882 acres) was modeled using the Simple Method. A total of 949 lbs of phosphorus per year are generated by stormwater runoff. Currently, approximately 28 lbs of phosphorus per year are being removed from runoff due to buffers throughout the watershed.

Loading from Upstream Waters

There are no upstream waters to Ann Lake with sufficient data to evaluate.

Runoff from Feedlots Not Requiring NPDES Permit Coverage

Within the Ann Lake Watershed, there are six feedlots under 1,000 AUs in size, all of which are open lot feedlots. In addition, included in the calculations is one feedlot requiring NPDES Permit coverage, as explained above in *Sources of Phosphorus Requiring NPDES Permit Coverage*. These feedlots house a total of 2,706.9 AUs mostly consisting of beef and dairy cattle (Table 13). The estimated TP load coming from these feedlots within the watershed under average flow conditions is approximately 336.3 lbs/yr.

Table 13. Phosphorus Contributed to Ann Lake from Open Lot Feedlots

Animal	Animal Units	Phosphorus contributing to surface waters during average flow year (lbs/yr)
Beef	1,405.7	174.6
Dairy	1,265.3	157.6
Sheep	30.0	3.9
Horse	6.0	0.2
Total	2,706.9	336.3

Atmospheric Deposition

The TP load from atmospheric deposition is 85 lbs/yr (Table 14).

Table 14. Ann Lake Atmospheric Deposition

Source	Phosphorus Deposition (lbs/yr)
Wet Deposition	60
Dry Deposition	25
Total	85

Subsurface Sewage Treatment Systems

There are six homes on Ann Lake that use an SSTS. Of these systems, it is estimated that 40% are failing and that all of the homes are permanent residences. The total estimated TP load from SSTS to Ann Lake is 8.3 lbs/yr.

4.3 TMDL Loading Capacity and Allocations

For Ann Lake, where the observed phosphorus concentration was above the range of values considered acceptably close to the modeled value, the calibration process for the lake response model (BATHTUB) was different than for the other lakes. First, in order to account for recent trends in the lake's water quality, only the last three years (2005 to 2007) of data were used to calculate mean phosphorus, chlorophyll-*a*, and Secchi depth (see Figure 8 through Figure 10). It was determined that the high observed phosphorus concentration was most likely the result of an additional load, and not simply due to the typical variability in lake response to external loading. This additional phosphorus load, attributed to the land application of manure (see Section 4.2), was included on the "internal load" input screen. This load was adjusted until the modeled phosphorus concentration matched the observed mean concentration. Finally, the calibration coefficients for the chlorophyll-*a* concentration and Secchi depth values were adjusted so that model also matched the observations for these parameters.

To arrive at the goal phosphorus concentration in the lake model, the additional load (land application of manure) described above was first removed from the simulation, prior to reducing the tributary phosphorus concentration.

The phosphorus loading capacity of Ann Lake is 1,184 lbs/yr, to be split among allocations according to Table 15. The NPDES-permitted sources in the Ann Lake Watershed receive individual WLAs (Table 16).

Table 15. Ann Lake Allocation Summary

Allocation	TP (lbs/yr)	TP (lbs/day)
TMDL	1,184	3.2
MOS	118.4	0.32
WLA	5.5	0.015
LA	1,060	2.9

Table 16. Ann Lake WLAs

Source	Permit #	TP WLA	
		lbs/yr	lbs/day
Construction stormwater	Various	0.20	0.00055
Industrial stormwater	No current regulated sources	5.3	0.0146
Blair Farms Inc.	MN0066273	0	0

4.4 Implementation Strategy

4.4.1 Approach to Lake Restoration

Lake restoration activities can be grouped into two main categories: those practices aimed at reducing external nutrient loads, and those practices aimed at reducing internal loads. The focus of restoration activities depends on the lake's nutrient balance and opportunities for restoration. A reduction of 10,929 lbs of TP annually is needed to achieve the Ann Lake TMDL and meet water quality standards.

Ann Lake has a fairly small watershed. As described in Section 4.2, a substantial source of phosphorus has been identified that is likely from a combination of internal loading, poor nutrient management on agricultural fields, feedlots, and drain tile in the watershed. The MPCA staff has determined that the majority of this load is from land application of manure. Each of these potential sources will need to be further evaluated to determine the most appropriate suite of activities and practices aimed at improving the water quality of Ann Lake.

Due to the potential for extensive watershed loads to the lake, in-lake management activities should not be conducted until there are significant reductions in watershed loading to the lake. This discussion separates the management strategies into practices addressing watershed load and internal load. The total cost for implementation is estimated to be $200,000 to $450,000. Implementation costs do not take into account existing programs and are assumed to be spent over the next 20 to 30 years.

4.4.2 Watershed Load Reduction Activities

Reduction of TP reaching the lake from the watershed will be the primary implementation activity for Ann Lake. Further quantification of the sources of TP to the lake will be critical to developing appropriate strategies to improve the lake water quality. Drain tile was identified as a significant phosphorus source and a diagnostic study of the watershed should be undertaken to determine how to reduce phosphorus from drain tiles. This study could include mapping and monitoring of drain tile outlets to the lake, mapping of drain tile inlets within the watershed, survey of watershed farmers to determine nutrient management practices, and soil testing. Monitoring for water quality parameters should be conducted at tile and ditch outlets to the lake to determine nutrient loadings from each source. Monitoring of the tiles should begin during or close to spring melt to determine the impact of snowmelt on in-lake nutrient loadings and continue through the growing season. The results of this work will focus watershed implementation activities on fields and activities that are the greatest contributors of TP to the lake and prioritize drain tiles for BMP implementation.

Overall watershed loadings will be reduced through a variety of mechanisms including expansion of existing programs to encourage and promote agricultural BMPs such as conservation tillage, alternative tile inlets, and buffers. Enhanced feedlot BMPs and nutrient management plans will need to be developed and implemented. Wetland restoration can also be used to provide water quality treatment in the watershed.

4.4.3 Internal Load Reduction Activities

Internal loading of TP will need to be addressed, but not until watershed loads are identified and mitigated. In-lake TP concentrations should be lowered considerably before in-lake restoration efforts should be pursued. In-lake activities could include management of the abundant curlyleaf pondweed, chemical treatment to precipitate phosphorus out of the water column, and fisheries management.

5 LAKE EMILY TMDL

5.1 Lake Assessment

5.1.1 Physical Characteristics

Lake Emily is located approximately 10 miles southwest of the city of Starbuck in southwest Pope County, Minnesota. The lake is 2,262 acres in size with an east-west orientation, with an inlet coming from Outlet Creek on the east end of the lake and an outlet on the west end referred to as Lake Emily Outlet Creek (Table 17). In the early 1900s, County Ditch #2 was created and connected the Little Chippewa River with Outlet Creek. This increased the size of Lake Emily Watershed from approximately 150 square miles to over 200 square miles (DNR Waters 2008). Lake Emily Watershed can be divided into three parts: the watershed of Lake Minnewaska via Outlet Creek (approximately 49,838 acres), the watershed of the Little Chippewa River via County Ditch #2 (approximately 46,660 acres), and Lake Emily's direct drainage area (approximately 36,328 acres).

The lake is unique as it lies within the transition zone between two ecoregions of the state. The lake itself lies within the North Glaciated Plains (NGP) Ecoregion of Minnesota, while a portion of its watershed is within the NCHF Ecoregion.

Lake Emily is 100% littoral (less than 15 feet deep) and is classified as a shallow lake (Figure 14). DO depth profiles were taken in Lake Emily. With its shallow depth, Lake Emily does not remain stratified throughout the growing season.

Table 17. Lake Emily Characteristics

Characteristic	Value	Source
Lake total surface area (ac)	2,262	MPCA Minnesota Inventory of Impaired Lakes database (July 2008)
Percent lake littoral surface area	100%	Bathymetry
Lake volume (ac-ft)	10,855	Calculated (mean depth x surface area)
Mean depth (ft)	5	Bathymetry
Maximum depth (ft)	6	Bathymetry
Drainage area (acres)	132,826	DNR Waters Lakesheds (2004), DNR (2008), Pope County (1996)
Watershed area : lake area	59	Calculated

Figure 14. Lake Emily Bathymetry, 2009

January 19th, 2010

Land Use

Land use throughout the watershed is primarily agriculture, and there are six homes along the shores of the lake. Approximately 73% of the land is used for cultivated crops and pasture/hay. Table 18 summarizes the total acres and the percent of the watershed of the different land uses.

Table 18. Lake Emily Watershed Land Use

Land Use	Total Acres	% of Watershed
Barren Land (Rock/Sand/Clay)	25	0%
Cultivated Crops	81,104	61%
Deciduous Forest	6,513	5%
Developed, High Intensity	111	0%
Developed, Low Intensity	1,240	1%
Developed, Medium Intensity	162	0%
Developed, Open Space	5,789	4%
Emergent Herbaceous Wetlands	4,990	4%
Evergreen Forest	166	0%
Grassland/Herbaceous	3,506	3%
Mixed Forest	64	0%
Open Water	13,477	10%
Pasture/Hay	15,562	12%
Shrub/Scrub	5	0%
Woody Wetlands	103	0%
Total	132,826	100%

Source: NLCD 2001, USGS.

5.1.2 Biological Characteristics

Fisheries

Lake Emily has one public access located on the southwestern side of the lake. The lake is classified as a natural environment lake by the DNR's shoreland management lake classifications. Presently, the DNR manages Lake Emily as a sport fishery and stocks the lake with walleye. Carp, buffalo, freshwater drum, black bullhead, and white sucker are relatively abundant (2005 DNR fish survey). According to local fishermen familiar with the lake, northern pike, black crappies, channel catfish, smallmouth bass are also present. In general these species contribute to degradation of conditions in Lake Emily; they forage in the lake sediments and feed on the submergent vegetation, disturbing the sediments and causing high rates of phosphorus release from the sediments to the water column. Game fish were present with numerous age classes represented, evidence that Lake Emily has only experienced limited to infrequent partial fish kills. Shallow lakes typically experience winterkills on a somewhat regular basis. The DNR survey states that the atypical frequency of winterkills is likely due to the ground water exchange, springs, and flow from the Little Chippewa River and Lake Minnewaska.

Macrophytes

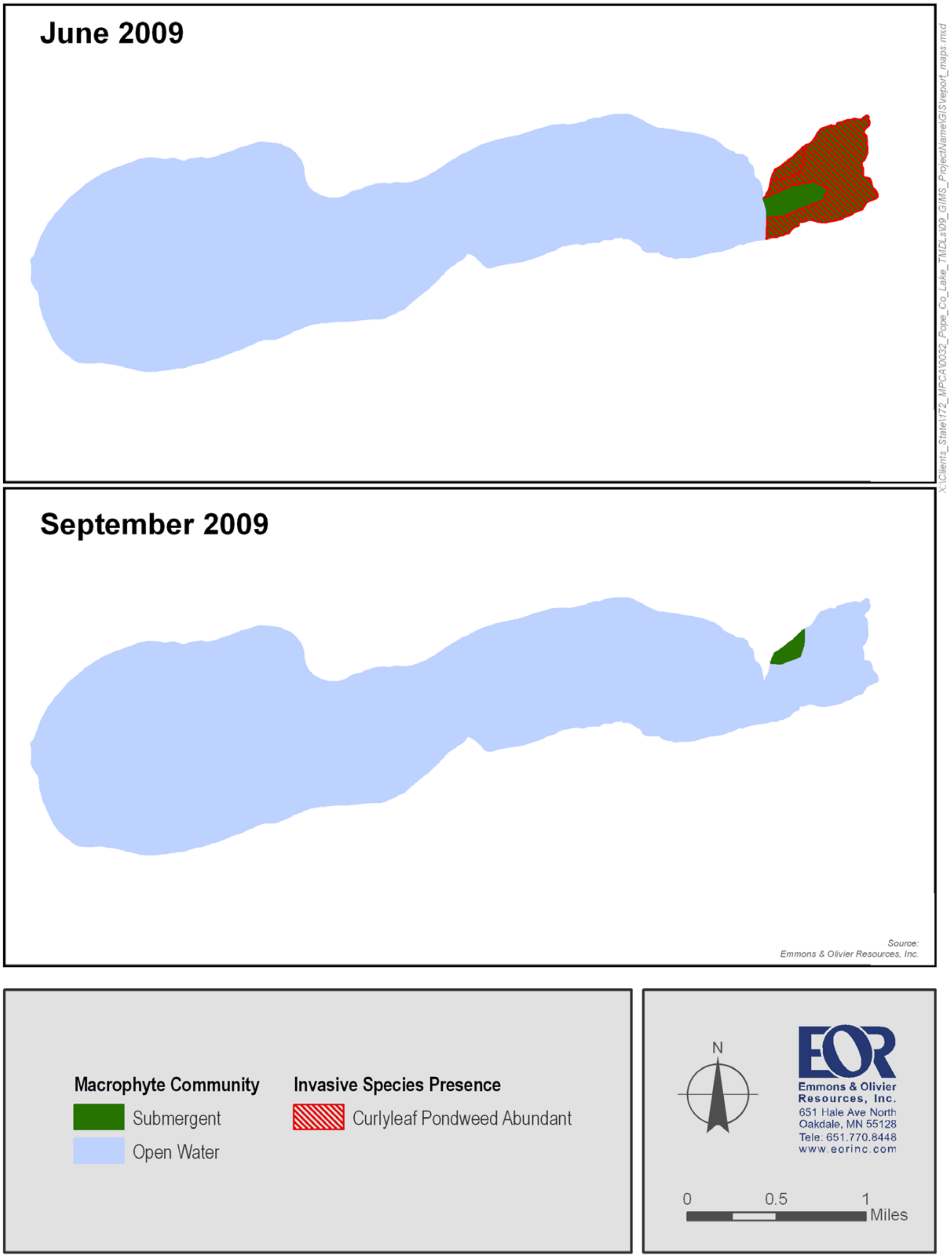
Little is known about the aquatic vegetation in the lake (Lake Emily Management Plan: LEIA 2008). A macrophyte survey was completed in June of 2000 by the DNR that reported no significant macrophytes. The 1995 Lake Assessment Program (LAP) for Lake Emily reported that submergent macrophytes are rare due to the turbid conditions in the lake.

A macrophyte survey was conducted in the spring and fall of 2009 as part of this TMDL study (Figure 15 and Table 19). The survey validated previous findings that very few macrophytes exist in the lake. Curlyleaf pondweed was abundant in the eastern portion of the lake during the spring.

Table 19. Plant Species Observed During 2009 Lake Emily Macrophyte Surveys

Scientific Name	Common Name	Spring	Fall
Potamogeton crispus	Curlyleaf pondweed	X	
Potamogeton pectinatus	Sago pondweed	X	
Potamogeton species	Pondweed species		X

Figure 15. Lake Emily Macrophytes, 2009



5.1.3 Existing Studies and Monitoring

Lake Emily Improvement Association

In the 1990s, the Lake Emily Improvement Association (LEIA) was formed by a group of local land owners, fishermen, hunters, and other interested community members to focus on restoring the water quality of the lake. LEIA has been working with the MPCA since 1994 on collecting water quality data on the lake and is currently drafting a lake management plan for Lake Emily with the help of the CWRP. This plan identifies issues, goals, and strategies that will improve the water quality of the lake.

Lake Emily: Lake Assessment Program

In 1995, a LAP was completed for Lake Emily by the MPCA. The physical, biological, and chemical characteristics of the lake were evaluated with the intent to identify existing problems facing the lake. Water quality data collected for the LAP suggest that Lake Emily is a hypereutrophic lake with heavy external loading of phosphorus from the Little Chippewa River. One of the recommendations of the LAP was to consider restoring the original drainage of the Little Chippewa River and prevent it from flowing through County Ditch #2 and into Lake Emily (MPCA 1995).

Lake Emily Water Budget

In 2008, a water budget was completed to look at the option of removing the Little Chippewa River as a contributing source to Lake Emily. The study concluded that by rerouting the Little Chippewa River, lake levels in Lake Emily would be lower; however, there may be options to divert a portion of the Little Chippewa flow to Lake Emily to equally benefit the Little Chippewa River and Lake Emily (DNR 2008).

Little Chippewa River Monitoring

The Little Chippewa River has been monitored at three locations by the CRWP since 2007. Monitoring occurs at Highway 28 (Little Chippewa), Highway 14 (Outlet Creek) and 370th Ave (Lake Emily Outlet). Parameters collected include flow, DO, *E. coli*., nitrogen, phosphorus, ortho-phosphorus, total suspended solids (TSS), temperature, transparency, and turbidity. Results are available on the MPCA website.

5.1.4 Impairment Assessment

Monitoring data are available from as far back as 1993. In 1995, the MPCA monitored Lake Emily as part of a LAP study, and Lake Emily has had frequent sampling since 1994. The last 10 years of data were used to calculate the water quality data means (Table 20).

Lake Emily is a hypereutrophic lake, with TSI values for TP and Secchi in the hypereutrophic range and chlorophyll-*a* in the eutrophic range (Table 20). Based on data over the last 10 years, the standards are not being met for any of these parameters.

Lake Emily is in the NGP ecoregion, with most of its watershed in the NCHF ecoregion. Since the lake itself is located in the NGP ecoregion and since it is more characteristic of an NGP lake than a NCHF lake, the NGP standards apply to the lake. The TP standard for shallow lakes in the NGP ecoregion is 90 µg/L. TP growing season means ranged from 73 µg/L to 165 µg/L in the years 1994 to 2007, and exceeded the standard during every year except for 2000 and 2003 (Figure 16). Chlorophyll-*a* growing season means ranged from to 21 µg/L to 74 µg/L in the years 1995 to 2007 (Figure 17), meeting the standard of 30 µg/L during five growing seasons. The Secchi depth growing season means ranged from 0.28 m to 0.84 m in 1994 to 2007 (Figure 18), meeting the standard of 0.7 m only during one growing season.

TP and chlorophyll-*a* worsen slightly over the growing season (Figure 19 and Figure 20). The pattern is less clear for transparency, although fewer individual transparency readings meet the standard later on in the season (Figure 21). There is a positive relationship between TP and chlorophyll-*a*, a negative relationship between TP and Secchi depth, and a negative relationship is apparent between chlorophyll-*a* and Secchi depth (Figure 22 through Figure 24)

Table 20. Surface Water Quality Means, Lake Emily, 1998 to 2007

Parameter	Growing Season Mean (June – September)	Trophic Status Index	NGP Shallow Lakes Standard
TP	108 µg/L	72	< 90 µg/L
Chlorophyll-*a*	42 µg/L	67	< 30 µg/L
Secchi depth	0.5 m	71	> 0.7 m

Figure 16. TP Monitoring Data, Lake Emily

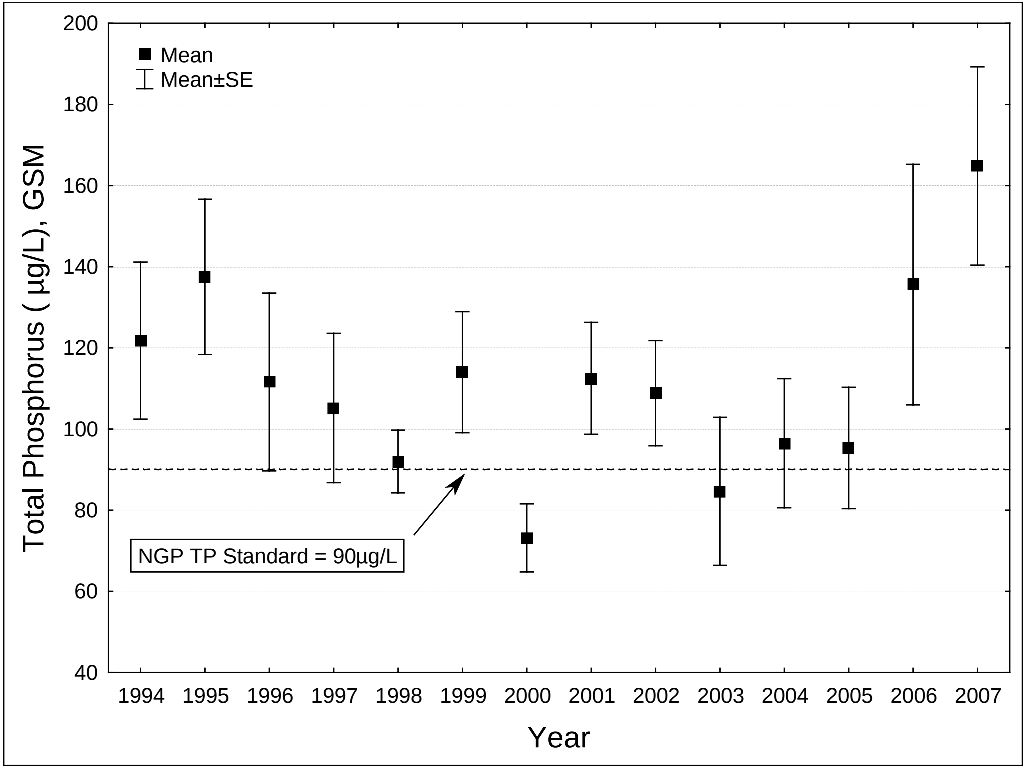


Figure 17. Mean Chlorophyll-*a* Monitoring Data, Lake Emily

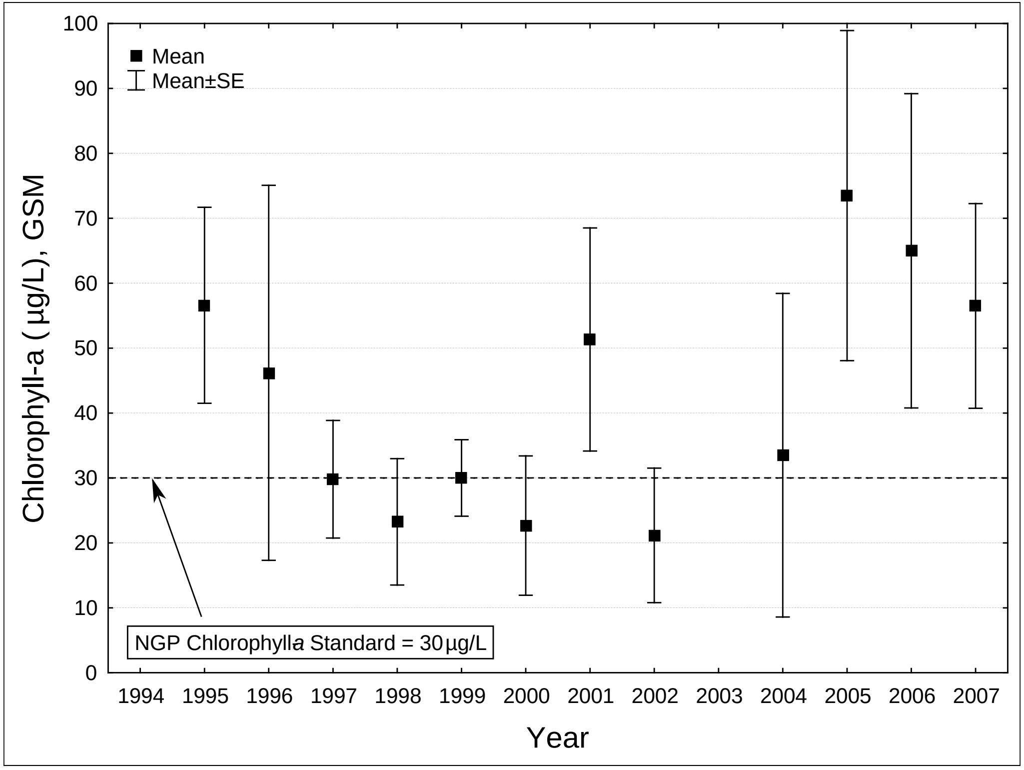


Figure 18. Secchi Depth Monitoring Data, Lake Emily

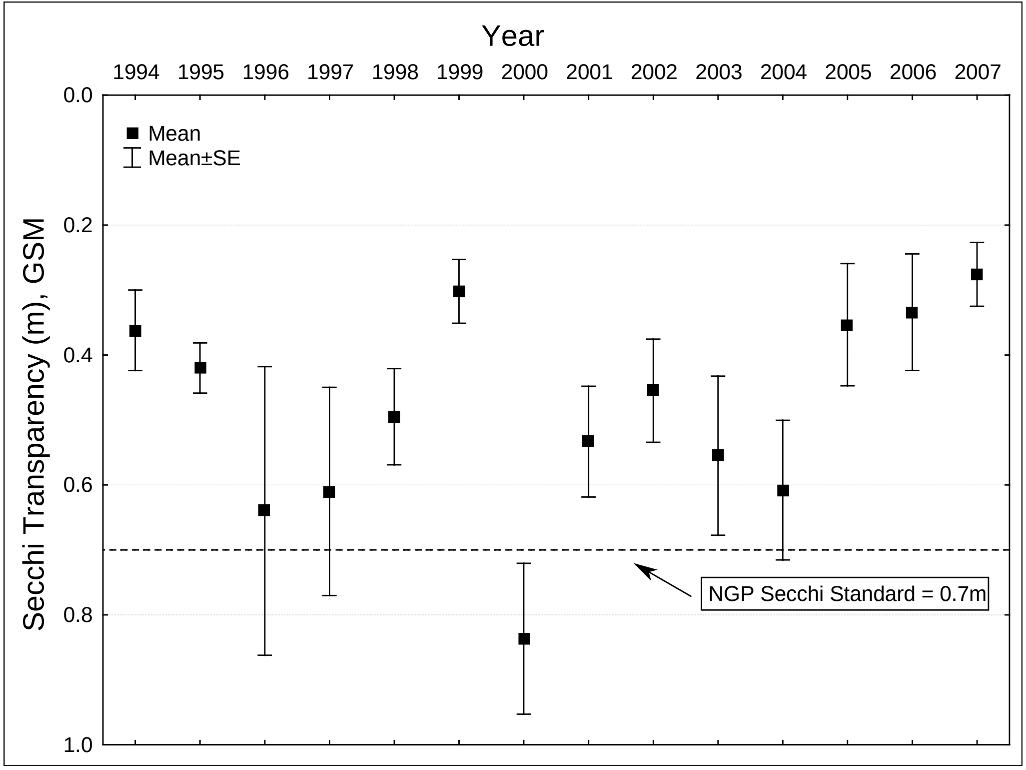


Figure 19. Lake Emily Seasonal TP Patterns, 1998 to 2007

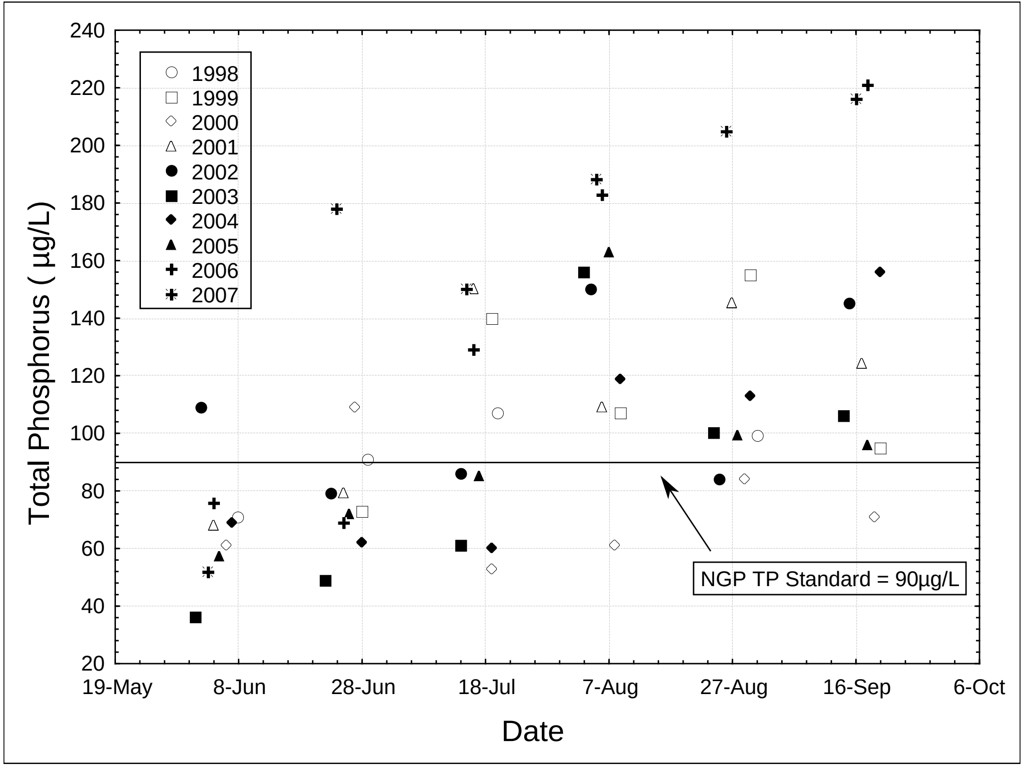


Figure 20. Lake Emily Seasonal Chlorophyll-*a* Patterns, 1998 to 2007

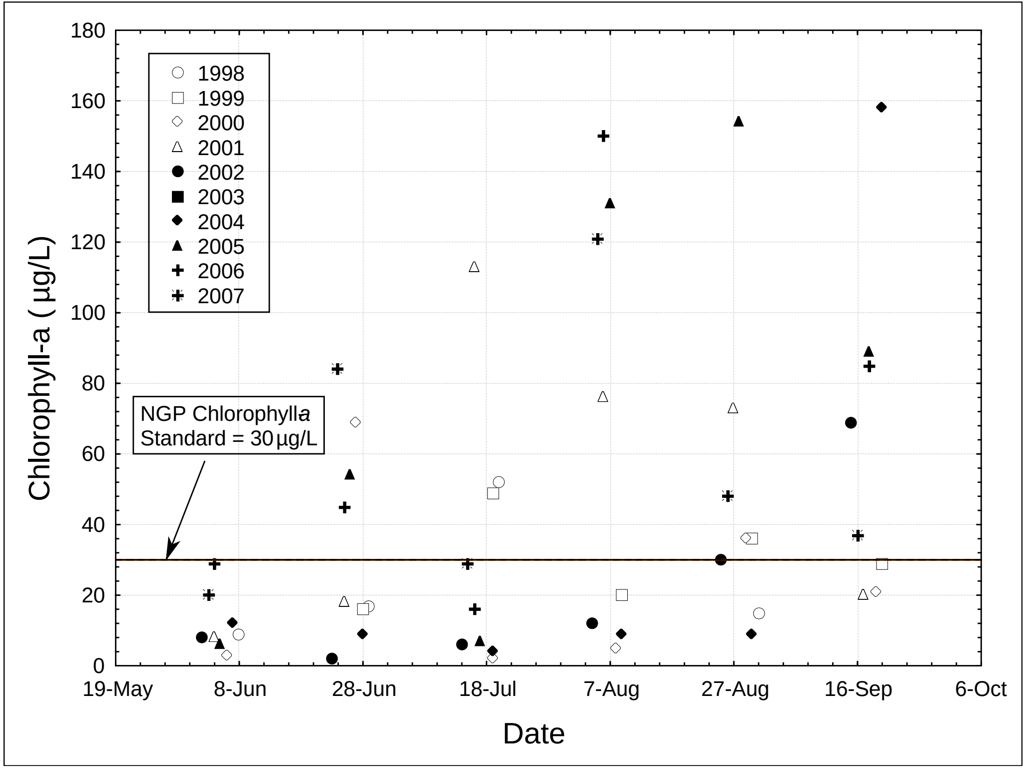


Figure 21. Lake Emily Seasonal Transparency Patterns, 1998 to 2007

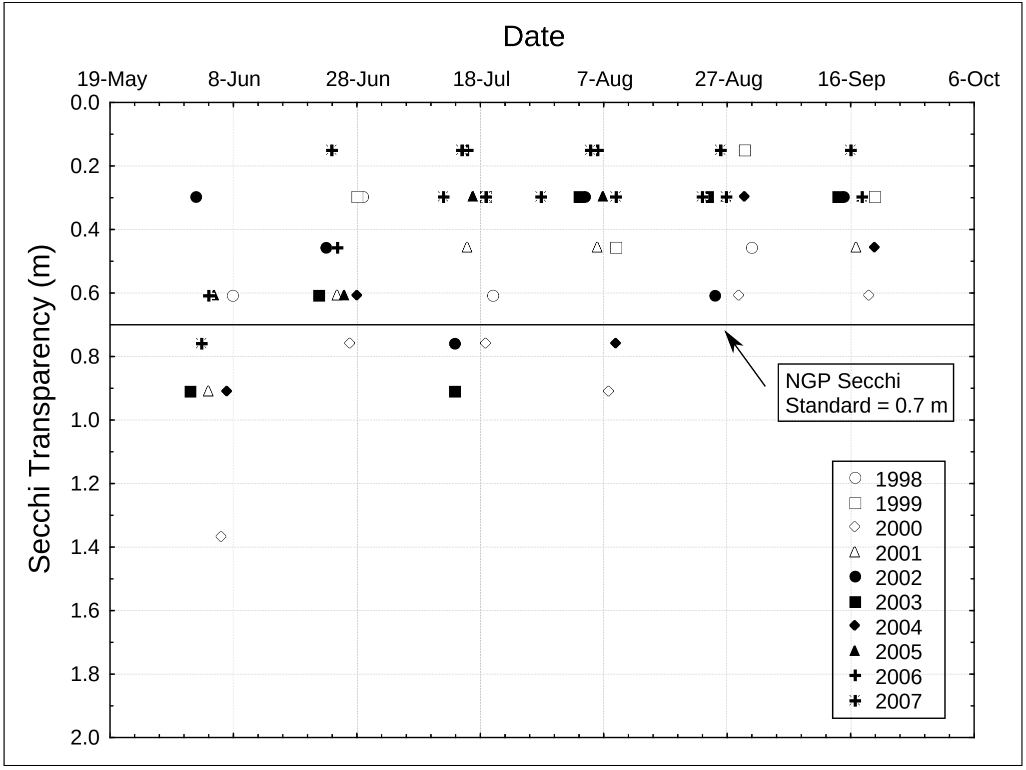


Figure 22. Relationship of Chlorophyll-*a* to TP in Lake Emily, 1998 to 2007

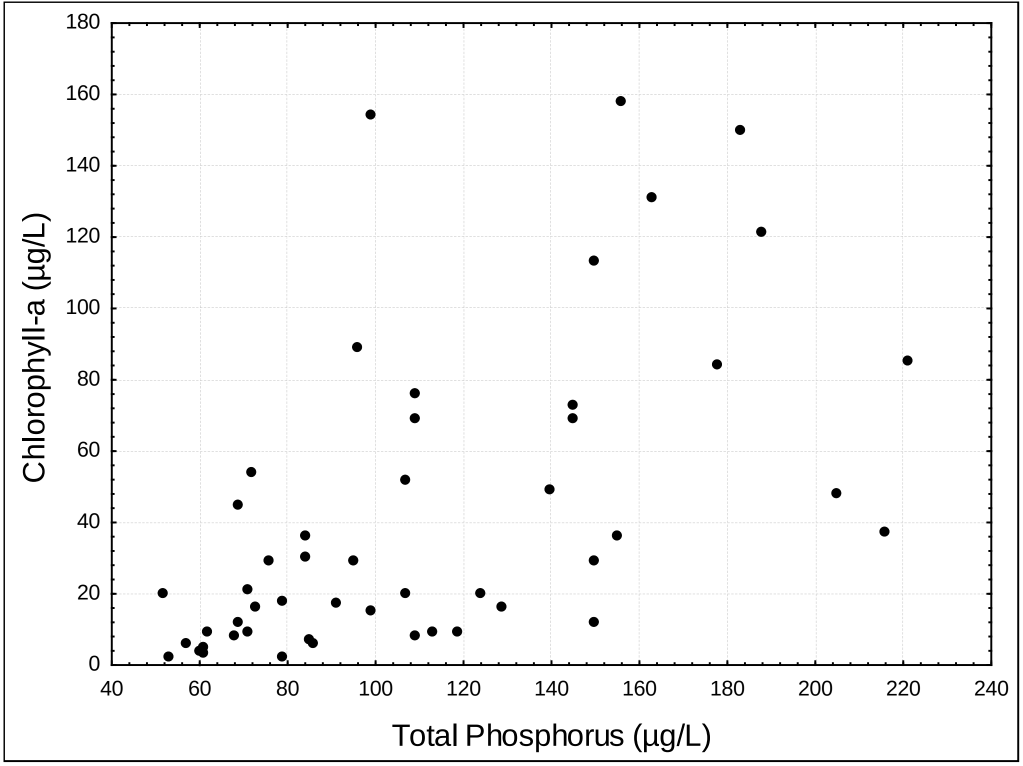


Figure 23. Relationship of Secchi Depth to TP in Lake Emily, 1998 to 2007

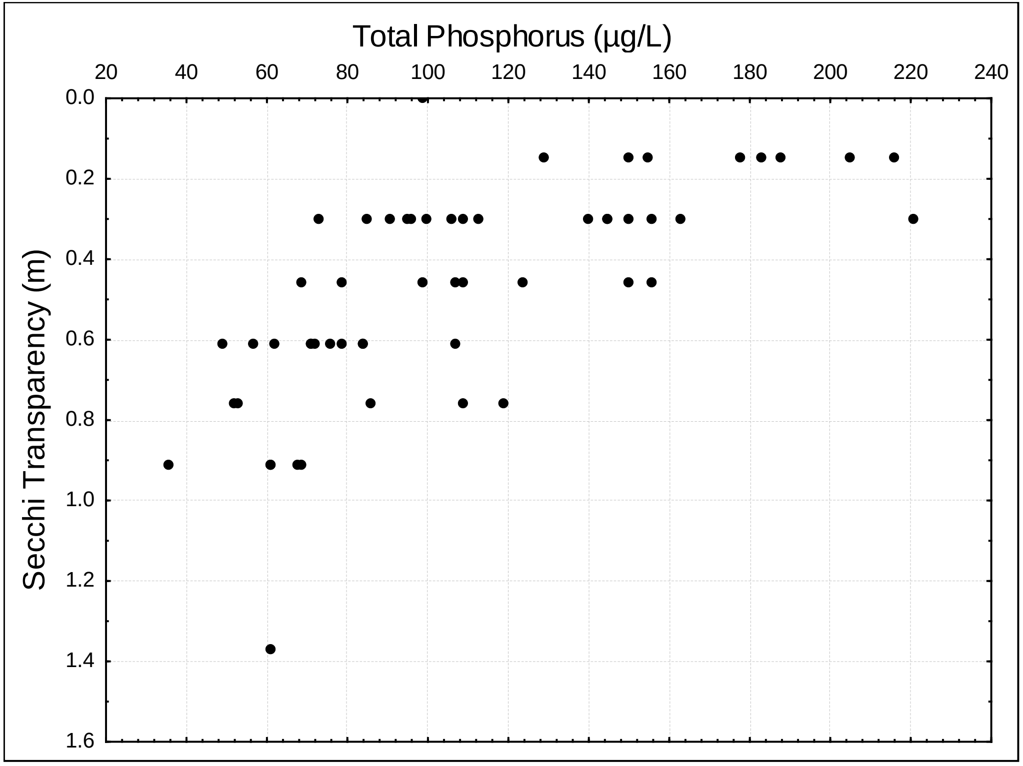
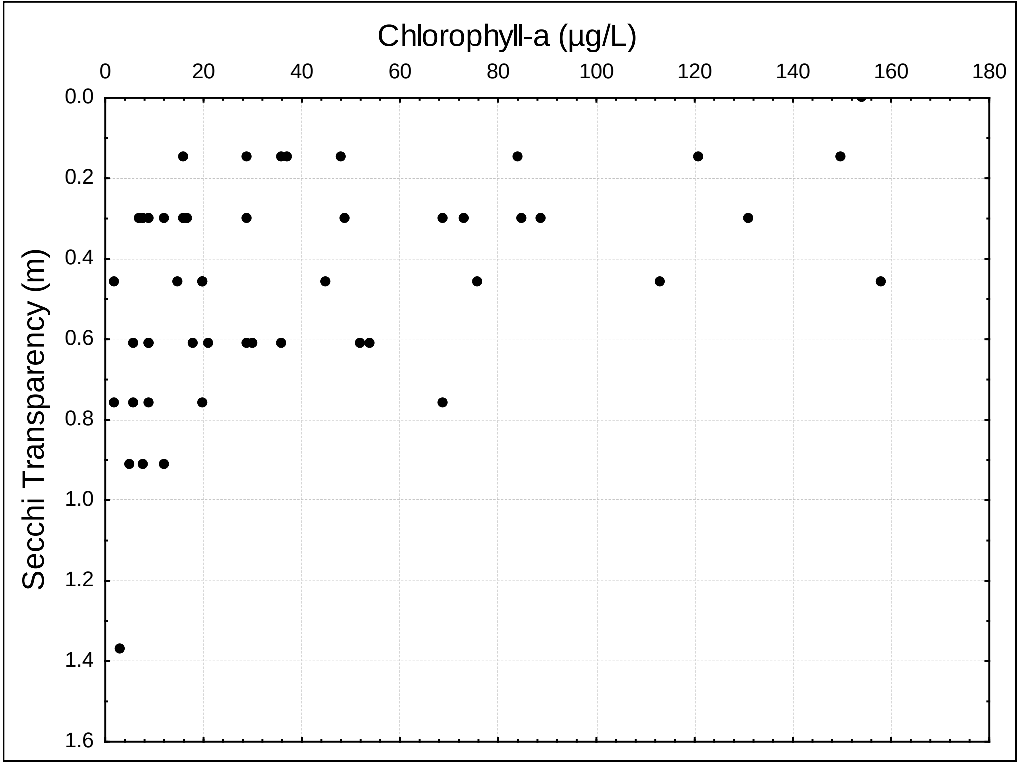


Figure 24. Relationship of Secchi Depth to Chlorophyll-*a* in Lake Emily, 1998 to 2007



5.2 Phosphorus Source Assessment

The Lake Emily Watershed (132,826 acres) includes the direct drainage area to the lake (36,328 acres), the drainage area to Lake Minnewaska and the lake itself (49,838 acres), and the drainage area to the Little Chippewa River upstream of Highway 28 (46,660 acres). It is estimated that Lake Emily receives 18,270 lbs of phosphorus annually from external sources within the entire watershed. The majority of the external phosphorus to Lake Emily is coming from the direct drainage area, the loading from the Little Chippewa River, and the loading from Lake Minnewaska (Figure 25, Table 21). Internal loading accounts for an additional 1,603 to 5,335 lbs/year of loading to the lake.

Figure 25. Lake Emily Phosphorus Inventory

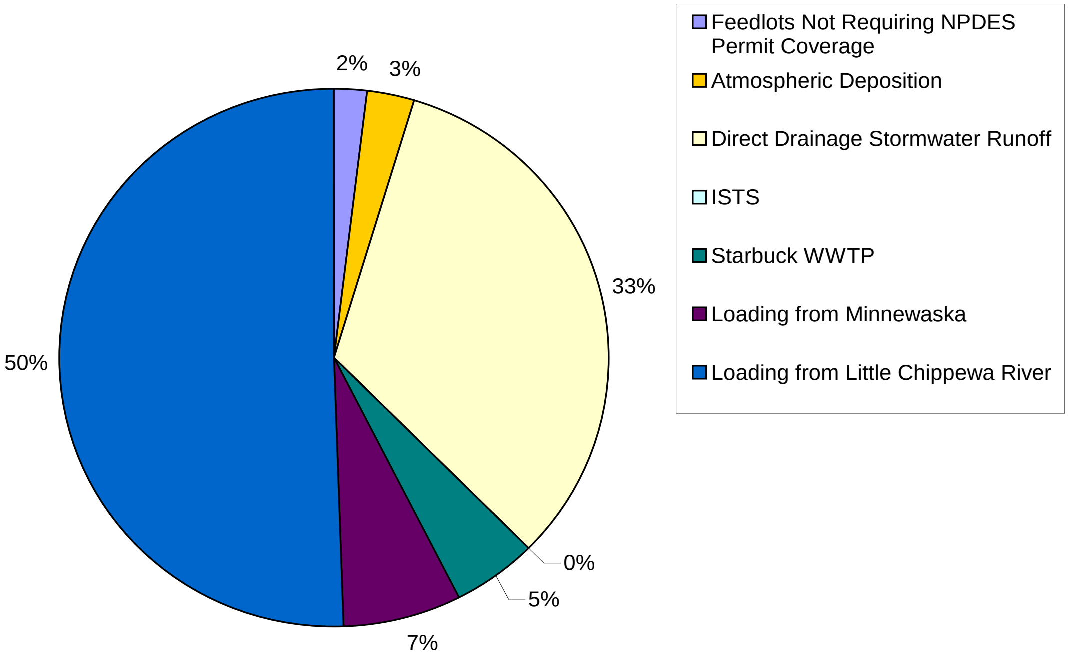


Table 21. Lake Emily Phosphorus Source Summary

Phosphorus Source	Annual TP Load [lbs/yr]
Direct Drainage Stormwater Runoff	5,981
Feedlots Not Requiring NPDES Permit Coverage	350.9
Atmospheric Deposition	527
SSTS	7
Starbuck WWTF	890
Loading from Lake Minnewaska	1,263
Loading from Little Chippewa River	9,251
Total	**18,269.9**

5.2.1 Sources of Phosphorus Requiring NPDES Permit Coverage

Municipal and Industrial Wastewater Treatment Systems

Both the Lowry and Starbuck WWTFs are located in the Lake Emily Watershed. The Lowry WWTF annual load is accounted for in the loading from Lake Minnewaska. The Starbuck WWTF contributes 889.9 lbs/year TP annually to Lake Emily (Table 21).

5.2.2 Sources of Phosphorus Not Requiring NPDES Permit Coverage

Stormwater Runoff

The Lake Emily Watershed is broken down into three areas including the area tributary to Lake Minnewaska, the area tributary to the Little Chippewa River upstream of Highway 28, and the direct drainage area that includes the remaining areas. The Simple Method was used to quantify the watershed TP loading coming from the direct drainage area. A total of 6,208 lbs/yr of TP are delivered to Lake Emily from the direct drainage area. The Simple Method was also used to calculate the TP load for the area tributary to the Little Chippewa River upstream of Highway 28. A total of 9,250 lbs/year TP are generated by stormwater runoff in that area, which in this case also includes feedlot runoff. Approximately 227 lbs of phosphorus per year are removed from runoff due to buffers throughout the watershed.

Loading from Upstream Waters

In-lake data collected in Lake Minnewaska were used to determine an average annual TP load (between 1998 and 2007) of 1,263 lbs/yr contributing to Lake Emily from the Lake Minnewaska Watershed. The TP load coming from runoff from feedlots not requiring NPDES Permit coverage within the Little Chippewa River Watershed was added to the Simple Method model resulting in an estimated 9,251 lbs/yr of TP loading to Lake Emily from the Little Chippewa River.

Runoff from Feedlots Not Requiring NPDES Permit Coverage

Within the Lake Emily Watershed there are 26 registered feedlots under 1,000 AUs in size, of which 23 are open lot feedlots. The open lot feedlots house a total of 2,554.2 AUs mostly consisting of beef and dairy cattle. The estimated TP load coming from registered feedlots within the Lake Emily Watershed under average flow conditions is approximately 350.9 lbs/yr (Table 22).

Table 22. Phosphorus Contributed to Lake Emily from Open Lot Feedlots Not Requiring NPDES Permit Coverage

Animal	Animal Units	Phosphorus contributing to surface waters during average flow year (lbs/yr)
Beef	947.3	133.0
Dairy	1,280.9	180.4
Swine	254	34.3
Horse	72	3.2
Total	**2,554.2**	**350.9**

Atmospheric Deposition

The TP atmospheric deposition to Lake Emily is 527 lbs/yr (Table 23).

Table 23. Lake Emily Wet and Dry Atmospheric Deposition

Source	Phosphorus Deposition (lbs/yr)
Wet Deposition	374
Dry Deposition	153
Total	**527**

Subsurface Sewage Treatment Systems

There are six homes on Lake Emily that use an SSTS. Of these systems, it is estimated that all are permanent residences and 25% are failing. The total estimated TP load from SSTS to Lake Emily is 7.0 lbs/yr.

Shoreline erosion

Shoreline erosion is an issue in Lake Emily and likely contributes phosphorus to the lake. The contribution from shoreline erosion was not quantified and is not accounted for specifically in the phosphorus source assessment. However, it will be addressed in implementation for Lake Emily.

5.3 TMDL Loading Capacity and Allocations

The phosphorus loading capacity of Lake Emily is 11,872 lbs/yr, to be split among allocations according to Table 24.

Table 24. Lake Emily Allocation Summary

Allocation	lbs/yr	lbs/day
TMDL	11,872	33
MOS	1,187	3.3
WLA	1,101	3.0
LA	9,584	26.3

The permitted sources in the Lake Emily Watershed receive individual WLAs (Table 25). Watershed scale pollutant load modeling was conducted and analyzed on an annual basis to establish this TMDL at a level necessary to attain and maintain applicable water quality standards. Daily WLAs were derived from this analysis. See Section 5.4 for alternative, non-daily, pollutant load expressions recommended for the development of water quality based effluent limits (WQBEL) based on EPA, 2006.

Table 25. Lake Emily WLAs

Source	Permit #	WLA	
		lbs/yr	lbs/day
Construction stormwater	Various	2.0	0.0055
Industrial stormwater	No current regulated sources	53	0.15
Starbuck WWTF	MN0021415	912	2.5
Lowry WWTF	MNG580123	134	0.37

5.4 Implementation Strategy

5.4.1 Approach to Lake Restoration

Lake restoration activities can be grouped into two main categories: those practices aimed at reducing external nutrient loads, and those practices aimed at reducing internal loads. The focus of restoration activities depends on the lake's nutrient balance and opportunities for restoration. A reduction of 6,415 lbs of TP annually is needed to achieve the Lake Emily TMDL and meet water quality standards.

Lake Emily is influenced by a very large watershed, a result of the diversion of the Little Chippewa River in the early 1900s. Improvements to Lake Emily will need to first address the water quality and watershed loading from the watershed. Only when watershed loadings are significantly reduced can in-lake management activities begin to have a long-term effect on water quality. In-lake work conducted prior to controlling the watershed loadings to Lake Emily will likely be very short-term solutions.

This discussion separates the management strategies into practices addressing point sources, watershed load, and internal load. The total cost for implementation is estimated to be $800,000 to $2,500,000. Implementation costs do not take into account existing programs and are assumed to be spent over the next 20 to 30 years.

5.4.2 Point Source Reduction Activities

The WLA for the Starbuck WWTF reflects current regulatory requirements plus a load allocated for future growth of the facility. The WWTF was meeting their Minnesota River General Phosphorus permit limit through trading with the city of Mankato's WWTF. Under the June 15, 2011 NPDES permit the facility was not able to meet its WLA through trading with Mankato since the Mankato discharge is located outside of the Lake Emily Watershed. This necessitated an upgrade of the Starbuck WWTF to decrease the TP load to Lake Emily. The upgrade was completed by October 1, 2012.

Although the TMDLs individual WLAs are expressed in terms of both daily (lbs./day) and annual (lbs./yr), for implementation purposes, WQBELs developed for NPDES Permits do not necessarily have to be expressed in terms of a daily limit (EPA 2006). WQBELs should be consistent with the time increment assumptions upon which the TMDL was established. Additional considerations for the development of permit limits include the type of facility, the nature and frequency of the discharge, and compatibility with any other applicable effluent limits.

5.4.3 Watershed Load Reduction Activities

Overall watershed loadings will be reduced through a variety of mechanisms including expansion of existing programs to encourage and promote agricultural BMPs such as conservation tillage, alternative tile inlets, and buffers. Enhanced feedlot BMPs and nutrient management plans will need to be developed and implemented.

Small and large scale water quality BMPs including ponds, raingardens, permeable pavements, and other low impact techniques could be considered in areas where there is development and along roadways. Water quality ordinances could also be used to strengthen existing protection measures during development, specifically related to lakeshore development and development in and around the larger cities in the watershed.

Wetland and stream restoration has the ability to provide water quality and habitat improvements within the watershed. Priority wetland restoration sites will be identified within the TMDL implementation plan. The Starbuck Swamp offers a significant restoration opportunity.

An emphasis on protecting and improving the water quality in Lake Minnewaska will serve to protect Lake Emily from future degradation due to development and land use activities within the Minnewaska watershed. A watershed management plan should be developed and implemented for Lake Minnewaska to ensure no further degradation and protection of this high quality lake.

The Little Chippewa River should be further considered for a partial diversion back to the river's original channel, which will effectively cut off a large portion of the watershed draining to Lake Emily. Evaluation should consider the needs and desires of the residents coupled with the desired outcome for the lake's water quality. A project that would divert the majority of river storm flows while maintaining a steady baseflow contribution to Lake Emily could achieve the majority of goals for Lake Emily.

5.4.4 Internal Load Reduction Activities

Reductions in internal loading to Lake Emily will focus on the establishment of a healthy macrophyte community, removal of rough fish, and reduction of shoreline erosion. An ecosystem management plan should be developed to determine the appropriate balance of fisheries and macrophyte communities for Lake Emily. Fish barriers and commercial harvesting may be needed to manage abundant carp populations.

6 GILCHRIST LAKE TMDL

6.1 Lake Assessment

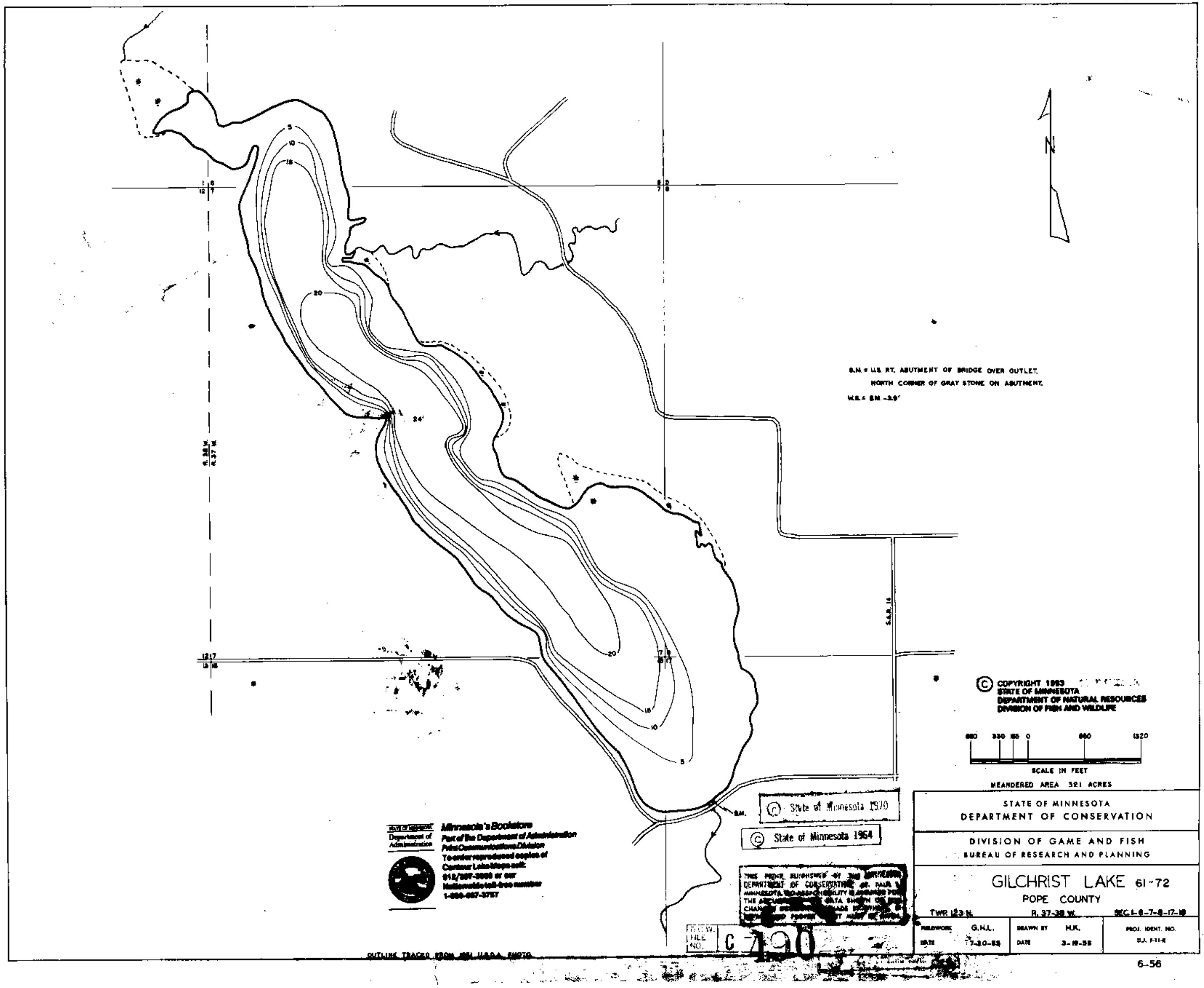
6.1.1 Physical Characteristics

Gilchrist Lake is 324 acres in size (Table 26 and Figure 26) and located along the East Branch of the Chippewa River near Gilchrist Township. The main inlet to Gilchrist Lake is the East Branch of the Chippewa River on the northwest side of the lake. Gilchrist outlets on the south end of the lake to the East Branch Chippewa River, which then flows south into Swift County and eventually discharges into the Chippewa River. There are several small springs and tributaries along the shores of Gilchrist contributing to the lake. The watershed to Gilchrist Lake is approximately 72,098 acres and includes the East Branch of the Chippewa River and the drainage area to the Villard Chain of Lakes.

Table 26. Gilchrist Lake Characteristics

Characteristic	Value	Source
Lake total surface area (ac)	324	MPCA Minnesota Inventory of Impaired Lakes database (July 2008)
Percent lake littoral surface area	61%	DNR Lake Finder
Lake volume (ac-ft)	3,240	Calculated (mean depth x surface area)
Mean depth (ft)	10	COLA (2005)
Maximum depth (ft)	24	DNR Lake Finder
Drainage area (acres)	72,098	DNR Waters Lakesheds (2004), Pope County (2004b)
Watershed area : lake area	223	Calculated

Figure 26. Gilchrist Lake Bathymetry



Land Use

Land throughout the watershed is primarily used for agriculture. Approximately 74% of the watershed is classified as cultivated crops or pasture and hay. The developed areas are mainly confined to the city of Villard at the north end of the watershed near the Villard Chain of Lakes. There are 53 homes on the shores of the lake. Table 27 shows the total number of acres and percent of each land use within the watershed.

Table 27. Gilchrist Lake Watershed Land Use

Land Use	Total Acres	% of Watershed
Barren Land (Rock/Sand/Clay)	14	0%
Cultivated Crops	4,420	61%
Deciduous Forest	3,624	5%
Developed, High Intensity	20	0%
Developed, Low Intensity	431	1%
Developed, Medium Intensity	25	0%
Developed, Open Space	2,560	4%
Emergent Herbaceous Wetlands	4,790	7%
Evergreen Forest	154	0%
Grassland/Herbaceous	2,799	4%
Mixed Forest	22	0%
Open Water	4,044	6%
Pasture/Hay	9,280	13%
Shrub/Scrub	28	0%
Woody Wetlands	67	0%
Total	72,098	100%

Source: NLCD 2001, USGS.

6.1.2 Biological Characteristics

Fisheries

Gilchrist Lake is classified as a recreational development lake by the DNR shoreland management lake classifications. It has one public access site located on the south end of the lake. The lake is used heavily for fishing, boating, and swimming. The 2006 DNR fish survey reports that the game fish populations found in Gilchrist Lake are normal relative to similar lakes. It also notes that growth rates are fast and the fish species are fairly long lived, with the exception of northern pike for which most of the fish sampled were less than five years of age. The fast growth rates and fairly long life span indicate that this lake is a productive lake. The DNR has stocked walleyes in 6 of the last 10 years.

The 2006 survey also reported the presence of rough fish like bullheads and carp in the lake, although the sampling results indicate that their populations are less than what would be considered normal for in lakes of this size.

Macrophytes

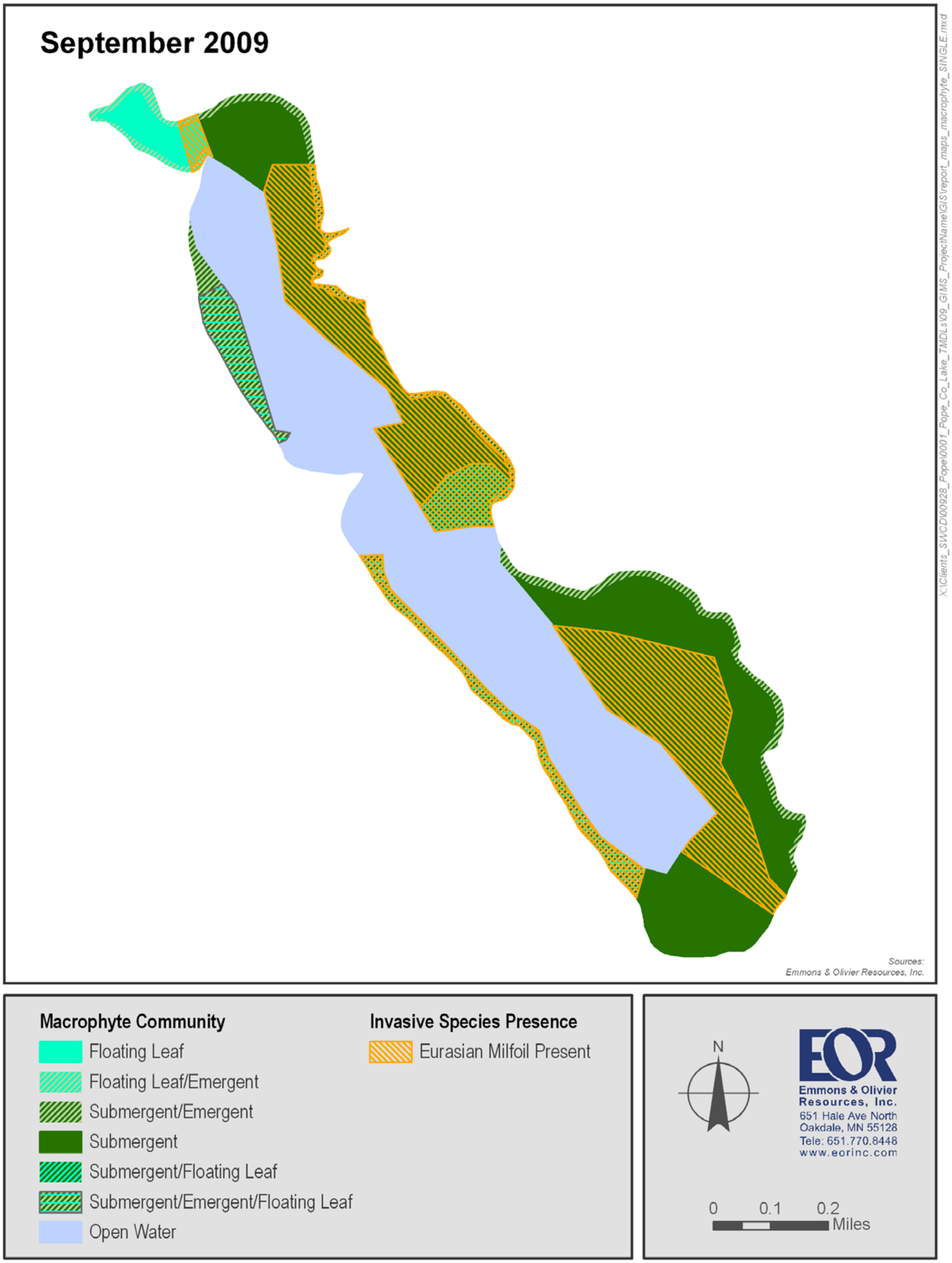
The macrophyte community in Gilchrist Lake is abundant and diverse, which is positive for maintaining good water quality in productive lakes (2006 DNR lake survey). In 1996, the invasive Eurasian watermilfoil was discovered in the lake and it has since expanded to nuisance levels. An aquatic vegetation survey was completed in July of 1996. This survey showed populations of coontail, Canada waterweed, yellow waterlily, sago pondweed, narrowleaf pondweed, flatstem pondweed, and common cattail.

In 2009, a macrophyte survey was conducted in the fall to document the extent of Eurasian watermilfoil and other macrophytes in the lake (Table 28 and Figure 27). The lake contained a very high diversity of submergent, floating leaf, and emergent vegetation including elodea, coontail, northern milfoil, and native pondweeds. Eurasian milfoil was present in approximately 30% of the lake during the survey.

Table 28. Plant Species Observed During 2009 Gilchrist Lake Macrophyte Survey

Scientific Name	Common Name	Fall
Ceratophyllum demersum	Coontail	X
Chara vulgaris	Muskgrass	X
Elodea canadensis	Elodea	X
Myriophyllum exalbescens	Northern water milfoil	X
Myriophyllum spicatum	Eurasian water milfoil	X
Najas flexilis	Bushy pondweed	X
Nymphaea odorata	White water-lily	X
Potamogeton amplifolius	Large-leaved pondweed	X
Potamogeton natans	Floating-leaved pondweed	X
Potamogeton pectinatus	Sago pondweed	X
Potamogeton zosteriformis	Flat-stemmed pondweed	X
Utricularia macrorhiza	Bladderwort	X
Potamogeton richardsonii	Claspingleaf pondweed	X
Potamogeton crispus	Curlyleaf pondweed	X

Figure 27. Gilchrist Lake Macrophytes, 2009



6.1.3 Existing Studies and Monitoring

Gilchrist Lake currently has a lake association involved in monitoring and improving the water quality of the lake. The association is an active member of the Pope County Coalition of Lakes Association which in turn is a member of Minnesota Waters http://minnesotawaters.org/popecountycoalitionoflakes/.

Gilchrist Lake: Lake Assessment Program

In 1992, a LAP was completed on Gilchrist Lake by the MPCA and the DNR. The study showed moderate levels of phosphorus and chlorophyll-*a* within the lake and identified that the state of the lake could be variable due to the large watershed and the changing flows of the East Branch of the Chippewa River. The report included recommendations such as continued data collection on the state of the lake, working with homeowners on septic system education, working with local units of government to regulate and enforce shoreland and land use ordinances, restoring and protecting wetlands, and a need to carefully examine the nutrient sources such as agricultural runoff, feedlot runoff, lawn fertilizers, and septic systems (MPCA 1993).

Status and Trend Monitoring Summary for Selected Pope and Douglas County, Minnesota Lakes

In 2001, the MPCA produced the report "Status and Trend Monitoring Summary for Selected Pope and Douglas County, Minnesota Lakes." Gilchrist Lake was included in the report and exhibited eutrophic to hypereutrophic conditions. Water quality samples were collected from Gilchrist Lake from June through September of 2000. The lake water quality summer mean for TP was 73 µg/L, which is significantly above the average TP concentrations for lakes within the NCHF Ecoregion. The summer mean for chlorophyll-*a* was 59 µg/L and the Secchi depth summer mean was 1.2 meters. The study showed that the phytoplankton community within the lake was dominated by blue-green algae throughout the summer. As part of the study, a MNLEAP model was used to predict the TP, chlorophyll-*a*, and Secchi values. The model showed that the predicted TP concentrations were higher than the observed. The study suggested that the difference between the predicted and observed concentrations could be due to the filtering capabilities of upstream lakes and wetlands (MPCA 2001a). The report can be found at https://www.pca.state.mn.us/sites/default/files/lar-61-0122.pdf.

East Branch of the Chippewa River Monitoring

The CWRP began monitoring water quality and flow at the inlet and outlet to Gilchrist Lake in 2009. In this first year of monitoring, there were higher phosphorus concentrations leaving the lake than entering on 12 of the 17 monitored days. This trend reversed during the period of May 13 through July 15, where five of the six measurements showed lower concentrations leaving the lake than entering from the East Branch of the Chippewa River. The average TP concentration at the outlet and inlet were 0.056 mg/l and 0.048 mg/l, respectively. The load at the outlet and inlet were 2,132 lbs and 3,871 lbs, respectively. This monitoring is planned to continue and will provide important information regarding the state of the lake and the relationship with the East Branch Chippewa River.

6.1.4 Impairment Assessment

Monitoring data are available from as far back as 1955, although there were only one or two samples taken per year and conclusions should not be drawn from sampling at this low frequency. Sampling frequency increased in 1994. The last 10 years of data were used to calculate the water quality data means (Table 29).

Gilchrist is a eutrophic lake, with TSI values ranging between 56 and 67 for the three standard monitoring parameters (Table 29). The TP standard for lakes in the NCHF ecoregion is 40 µg/L. TP concentration growing season means in the years 1992 to 2007 exceeded the standard every year with concentrations ranging from 51 µg/L to 85 µg/L (Figure 28). Chlorophyll-*a* concentration growing season means ranged from 15 µg/L to 62 µg/L in the years 1996 to 2007 (Figure 29), never meeting the NCHF Ecoregion lakes standard of 14 µg/L. The Secchi depth growing season means ranged from 0.9 m to 1.7 m in 1991 to 2007 (Figure 30), meeting the NCHF Ecoregion lakes standard of 1.4 m during 7 of the years monitored since 1992.

TP concentrations in Gilchrist Lake generally increase throughout the growing season (Figure 31). Transparency is satisfactory during May and June, after which it declines and typically remains below the standard for the remainder of the growing season (Figure 32). There is a positive relationship between TP and chlorophyll-*a*, a negative relationship between TP and Secchi depth, and a negative relationship is apparent between chlorophyll-*a* and Secchi depth (Figure 33 through Figure 35).

The DO depth profiles were taken at the deepest point in Gilchrist Lake. The DO depth profile from 2000 indicates that the deep portion of the lake stratifies weakly during the growing season (Figure 36). The bottom TP concentration on two dates is slightly higher than the surface TP, suggesting that the stratification does not lead to excessively high rates of phosphorus release from the sediments (Figure 37).

Table 29. Surface Water Quality Means, Gilchrist Lake, 1998 to 2007

Parameter	Growing Season Mean (June – September)	Trophic Status Index	NCHF Lakes Standard
TP	68 µg/L	65	< 40 µg/L
Chlorophyll-*a*	41 µg/L	67	< 14 µg/L
Secchi depth	1.3 m	56	> 1.4 m

Figure 28. TP Monitoring Data, Gilchrist Lake

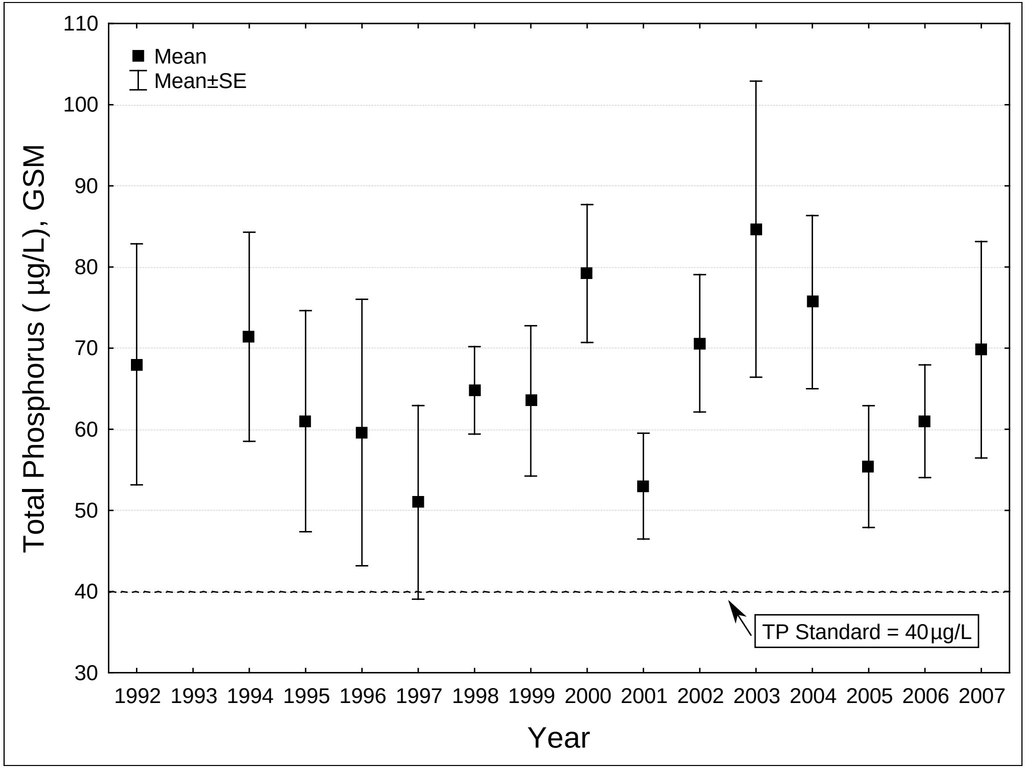


Figure 29. Mean Chlorophyll-*a* Monitoring Data, Gilchrist Lake

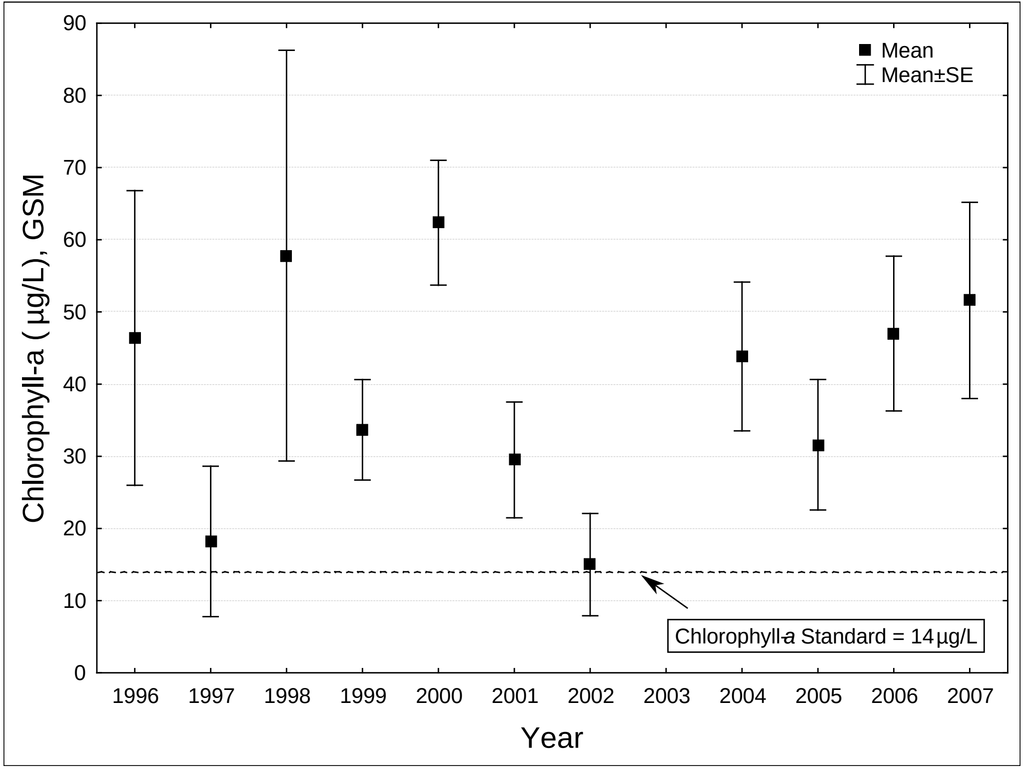


Figure 30. Secchi Depth Monitoring Data, Gilchrist Lake

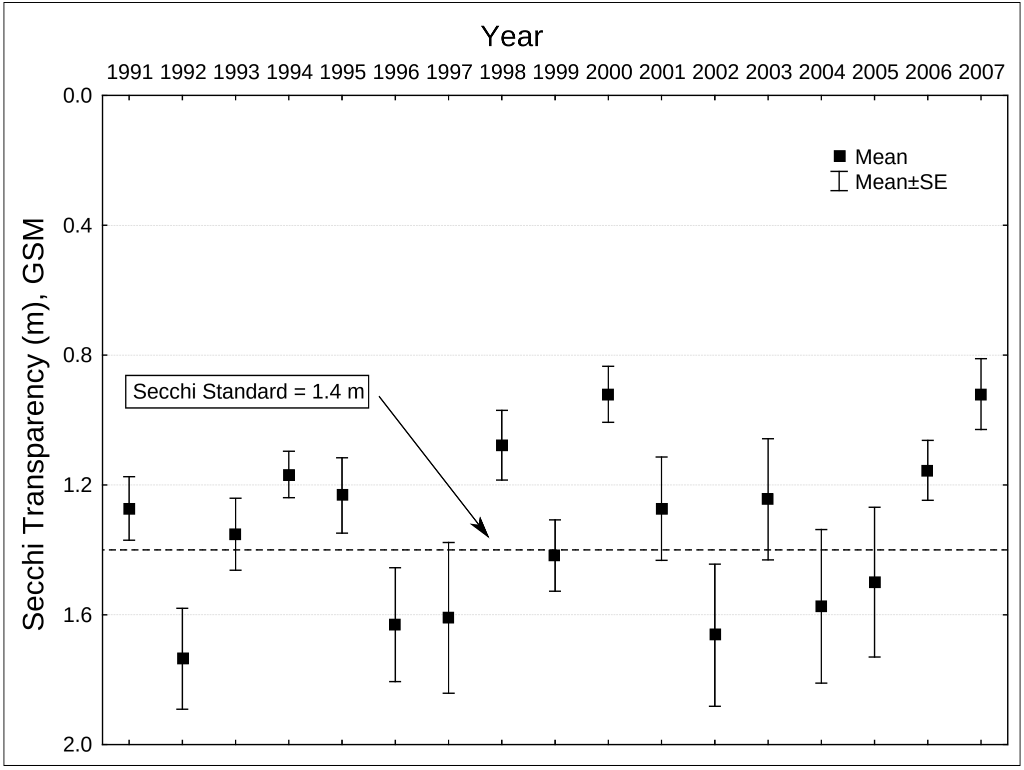


Figure 31. Gilchrist Lake Seasonal TP Patterns, 1998 to 2007

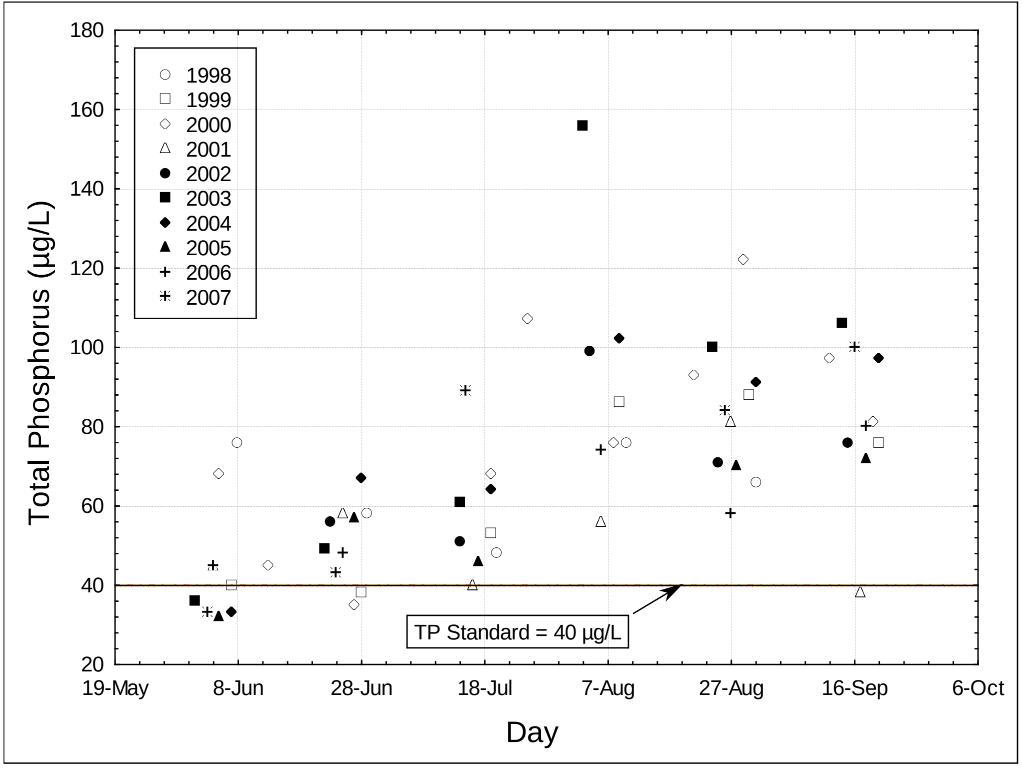


Figure 32. Gilchrist Lake Seasonal Transparency Patterns, 1998 to 2007

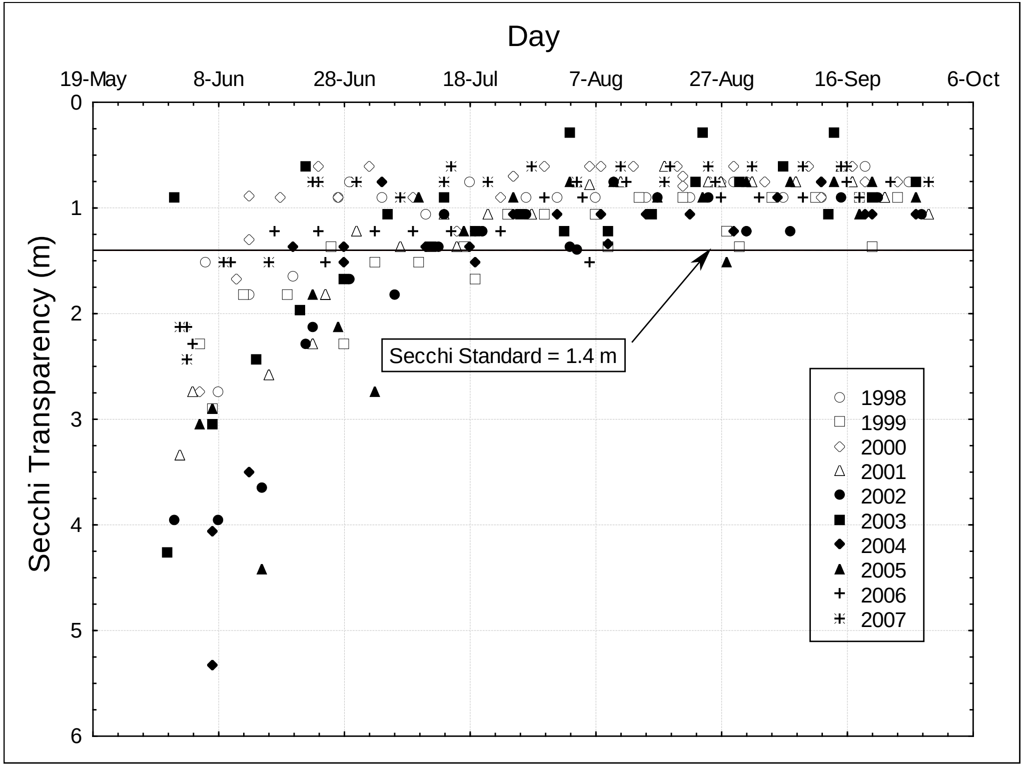


Figure 33. Relationship of Chlorophyll-*a* to TP in Gilchrist Lake, 1998 to 2007

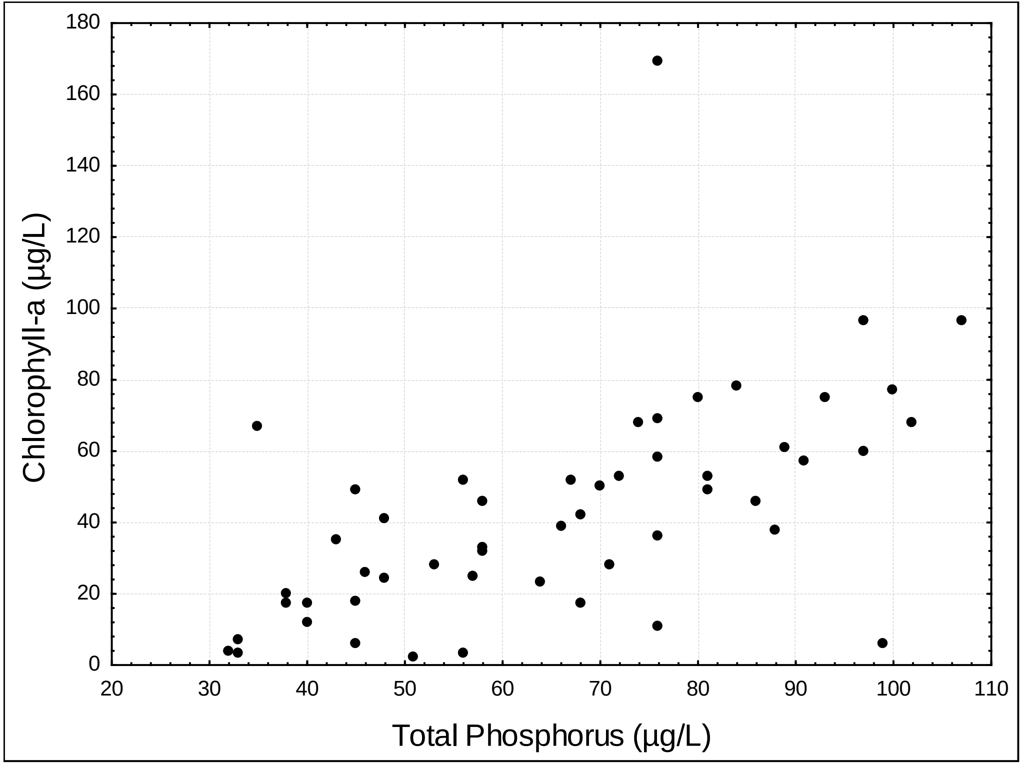


Figure 34. Relationship of Secchi Depth to TP in Gilchrist Lake, 1998 to 2007

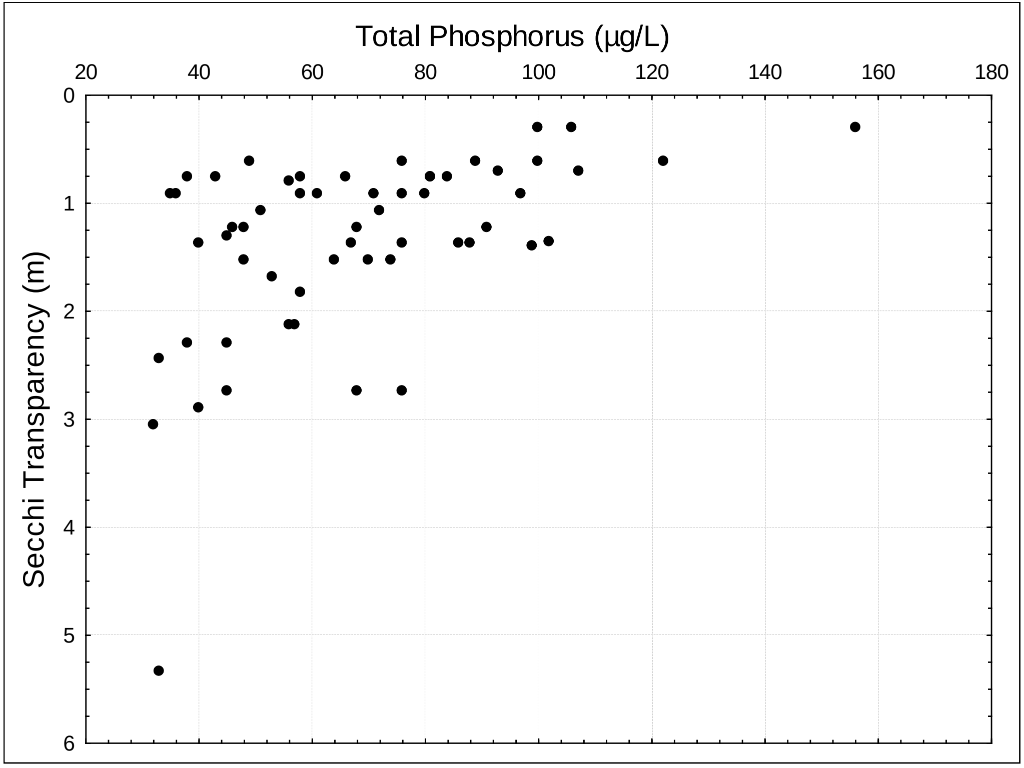


Figure 35. Relationship of Secchi Depth to Chlorophyll-*a* in Gilchrist Lake, 1998 to 2007

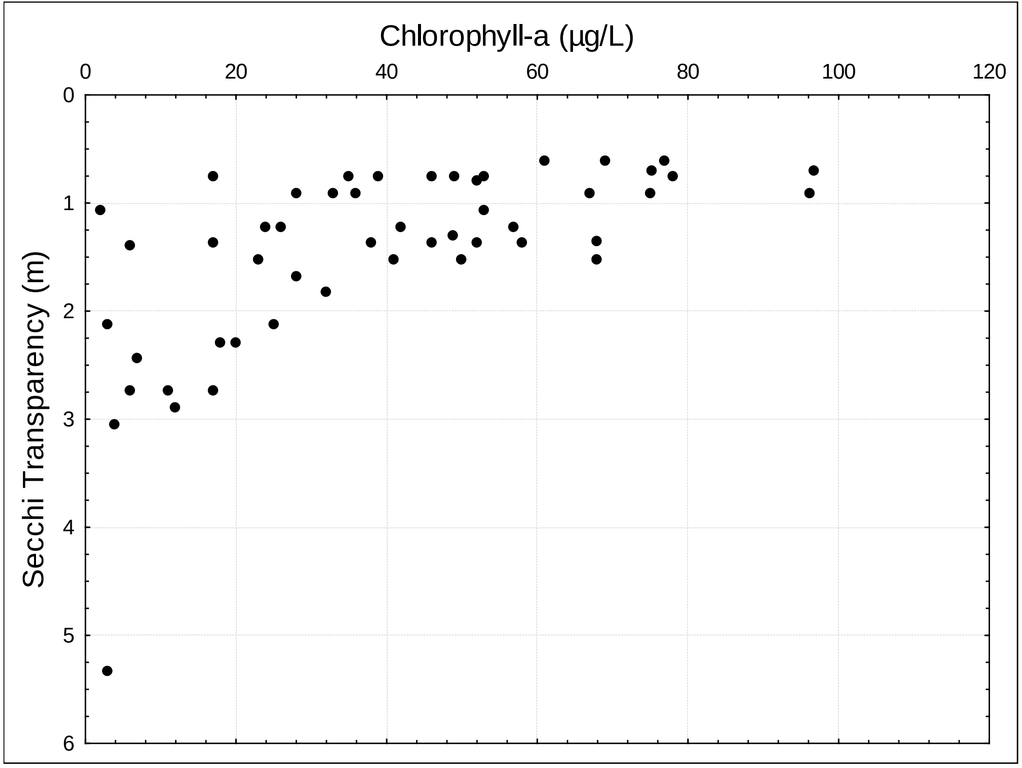


Figure 36. Gilchrist Lake DO, 2000

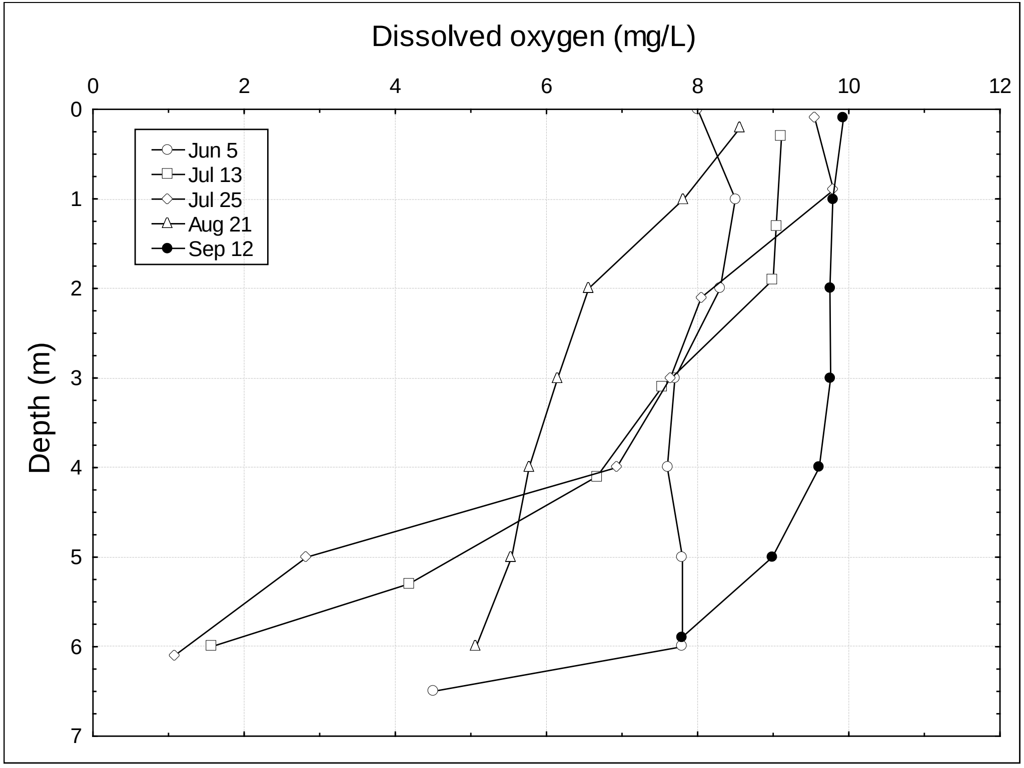
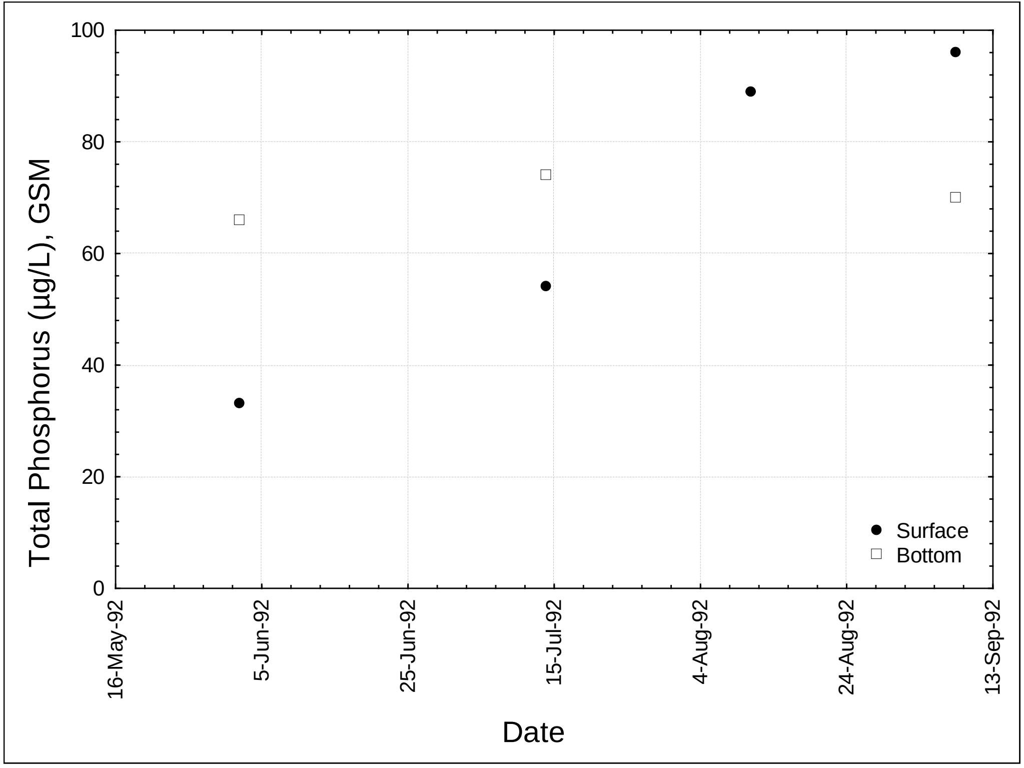


Figure 37. Gilchrist Lake Surface vs. Bottom TP, 1992



6.2 Phosphorus Source Assessment

The Gilchrist Lake Watershed (72,098 acres) includes the direct drainage to the lake (40,469 acres), drainage area to Amelia Lake (30,302 acres), and the drainage area of Linka Lake (1,327 acres). It is estimated that Gilchrist Lake receives 8,434 lbs of phosphorus annually from external sources within the entire watershed. The majority of the external phosphorus to Gilchrist Lake is coming from the direct drainage stormwater runoff, loading from Amelia, and feedlots not requiring NPDES Permit coverage (Figure 38, Table 30). Internal loading accounts for an additional 47 to 1,050 lbs/year of TP loading to the lake.

Figure 38. Gilchrist Lake Phosphorus Inventory

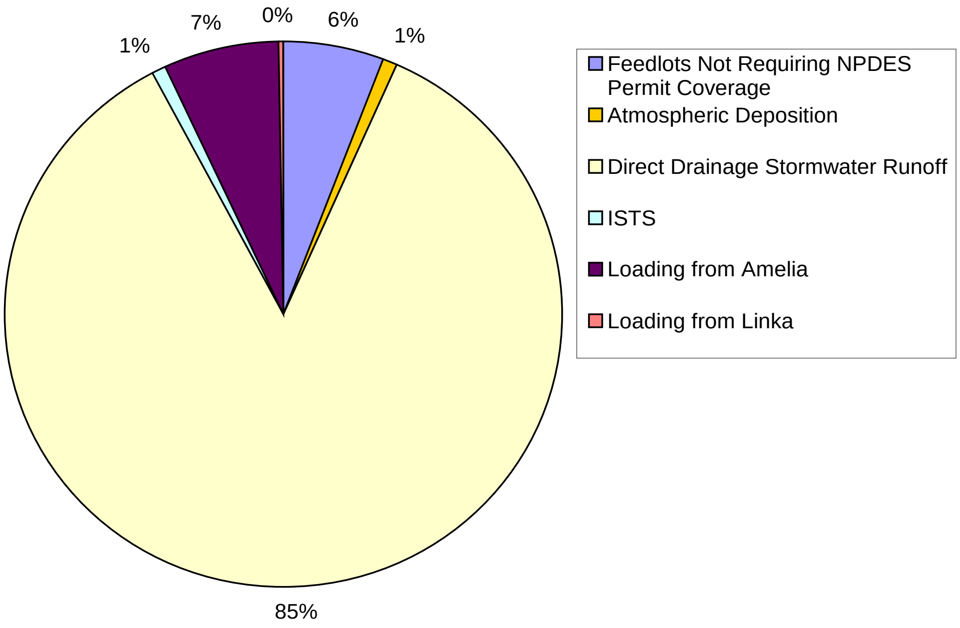


Table 30. Gilchrist Lake Phosphorus Source Summary

Phosphorus Source	Annual TP Load [lbs/yr]
Direct Drainage Stormwater Runoff	7,200
Feedlots Not Requiring NPDES Permit Coverage	494.3
Atmospheric Deposition	76
SSTS	68.1
Loading from Amelia Lake	565
Loading from Linka Lake	31
Total	8,434.4

6.2.1 Sources of Phosphorus Requiring NPDES Permit Coverage

There are no point sources in the Gilchrist Lake Watershed.

6.2.2 Sources of Phosphorus Not Requiring NPDES Permit Coverage

Stormwater Runoff

A Simple Method model was used to quantify a TP load of 7,366 lbs/yr coming from the direct drainage area to Gilchrist Lake as stormwater runoff. Approximately 166 lbs of phosphorus per year is removed from runoff due to buffers throughout the watershed. The 2009 monitoring data shows the load entering Gilchrist from the east branch of the Chippewa River as 2,132 lbs. This is substantially lower than the Simple Method estimate used in the watershed modeling and the watershed load should be reexamined once additional years of monitoring are completed.

Loading from Upstream Waters

In-lake data collected in Amelia Lake were used to determine an average annual TP load (between 1998 and 2007) of 565 lbs/yr contributing to Gilchrist Lake from the Amelia Lake Watershed. Similarly, in-lake data collected from Linka Lake determined an annual TP load of 31 lbs/yr contributing to Gilchrist Lake.

Feedlots Not Requiring NPDES Permit Coverage

Within the Gilchrist Lake Watershed there are 23 registered feedlots under 1,000 AUs in size, 21 of which are open lot feedlots. The open lot feedlots house a total of 3,646.75 AUs consisting mainly of beef and dairy cattle. The estimated TP load coming from feedlots within the Gilchrist Lake Watershed under average flow conditions is approximately 494.3 lbs/yr (Table 31).

Table 31. Phosphorus Contributing to Gilchrist Lake from Open Lot Feedlots Not Requiring NPDES Permit Coverage.

Animal	Animal Units	Phosphorus contributing to surface waters during average flow year (lbs/yr)
Beef	2,849.5	387.7
Dairy	570.6	77.8
Swine	215.5	28.2
Horse	10.0	0.4
Poultry	1.15	0.2
Total	**3,646.75**	**494.3**

Atmospheric Deposition

The TP atmospheric deposition to Gilchrist Lake is 76 lbs/yr (Table 32).

Table 32. Gilchrist Lake Wet and Dry Atmospheric Deposition

Source	Phosphorus Deposition (lbs/yr)
Wet Deposition	54
Dry Deposition	22
Total	**76**

Subsurface Sewage Treatment Systems

There are 53 houses on Gilchrist Lake that use SSTS. It is estimated that 40% are failing systems and that 90% are permanent residences. The total estimated TP load from SSTS to Gilchrist Lake is 68.1 lbs/yr.

6.3 TMDL Loading Capacity and Allocations

The phosphorus loading capacity of Gilchrist Lake is 4,363 lbs/yr, to be split among allocations according to Table 33. The permitted sources in the Gilchrist Lake Watershed receive individual WLAs (Table 34).

Table 33. Gilchrist Lake Allocation Summary

Allocation	lbs/yr	lbs/day
TMDL	4,363	12
MOS	436	1.2
WLA	20.4	0.056
LA	3,907	10.7

Table 34. Gilchrist Lake WLAs

Source	Permit #	WLA	
		lbs/yr	lbs/day
Construction stormwater	Various	0.75	0.002
Industrial stormwater	No current regulated sources	19.6	0.054

6.4 Implementation Strategy

6.4.1 Approach to Lake Restoration

Lake restoration activities can be grouped into two main categories: those practices aimed at reducing external nutrient loads, and those practices aimed at reducing internal loads. The focus of restoration activities depends on the lake's nutrient balance and opportunities for restoration. A reduction of 4,071 lbs of TP annually is needed to achieve the Gilchrist Lake TMDL and meet water quality standards.

This discussion separates the management strategies into practices addressing watershed load and internal load. The total cost for implementation is estimated to be $400,000 to $600,000. Implementation costs do not take into account existing programs and are assumed to be spent over the next 20 to 30 years.

6.4.2 Watershed Load Reduction Activities

Overall watershed loadings will be reduced through a variety of mechanisms including expansion of existing programs to encourage and promote agricultural BMPs such as conservation tillage, alternative tile inlets, and buffers. Enhanced feedlot BMPs and nutrient management plans will need to be developed and implemented.

Small and large scale water quality BMPs including ponds, raingardens, permeable pavements, and other low impact techniques could be considered in areas where there is development and along roadways. Water quality ordinances could also be used to strengthen existing protection measures during development, specifically related to lakeshore development and development in and around the larger towns in the watershed.

Wetland and stream restoration has the ability to provide water quality and habitat improvements within the watershed. Priority wetland restoration sites will be identified within the TMDL implementation plan.

An evaluation of existing mill ponds along the East Branch of the Chippewa River should be conducted to determine their role in water quality within the river and downstream receiving waters. The existing ponds and associated stream could either be restored or enhanced to provide additional water quality treatment.

Lake Amelia is a high priority water body within Pope County that outlets to the East Branch of the Chippewa River. Marlu Lake, Round Lake, Linka Lake, and Lake Swenoda also contribute phosphorus loading to Gilchrist Lake. Water quality protection and improvement is needed to ensure high quality resources into the future. Protection strategies should focus on Lakes Amelia, Round, Marlu, and Linka. Protection strategies could include enhanced stormwater runoff BMPs, expansion of existing agricultural BMP programs, and actively working to limit the phosphorus contribution from lake homes as a result of lawn and lot management and septic systems.

Improvement strategies should focus on Lake Swenoda. The average TP concentration during 2009 was 91 µg/L TP, which exceeds the water quality standard. Improvement strategies should begin as soon as possible to reduce the TP load from this lake. Watershed load reduction activities described above can be used to reduce TP loading to Lake Swenoda and improve in-lake water quality.

6.4.3 Internal Load Reduction Activities

Internal loading has not been identified as a significant source of TP to Gilchrist Lake. No in-lake activities are proposed.

7 LAKE LEVEN TMDL

7.1 Lake Assessment

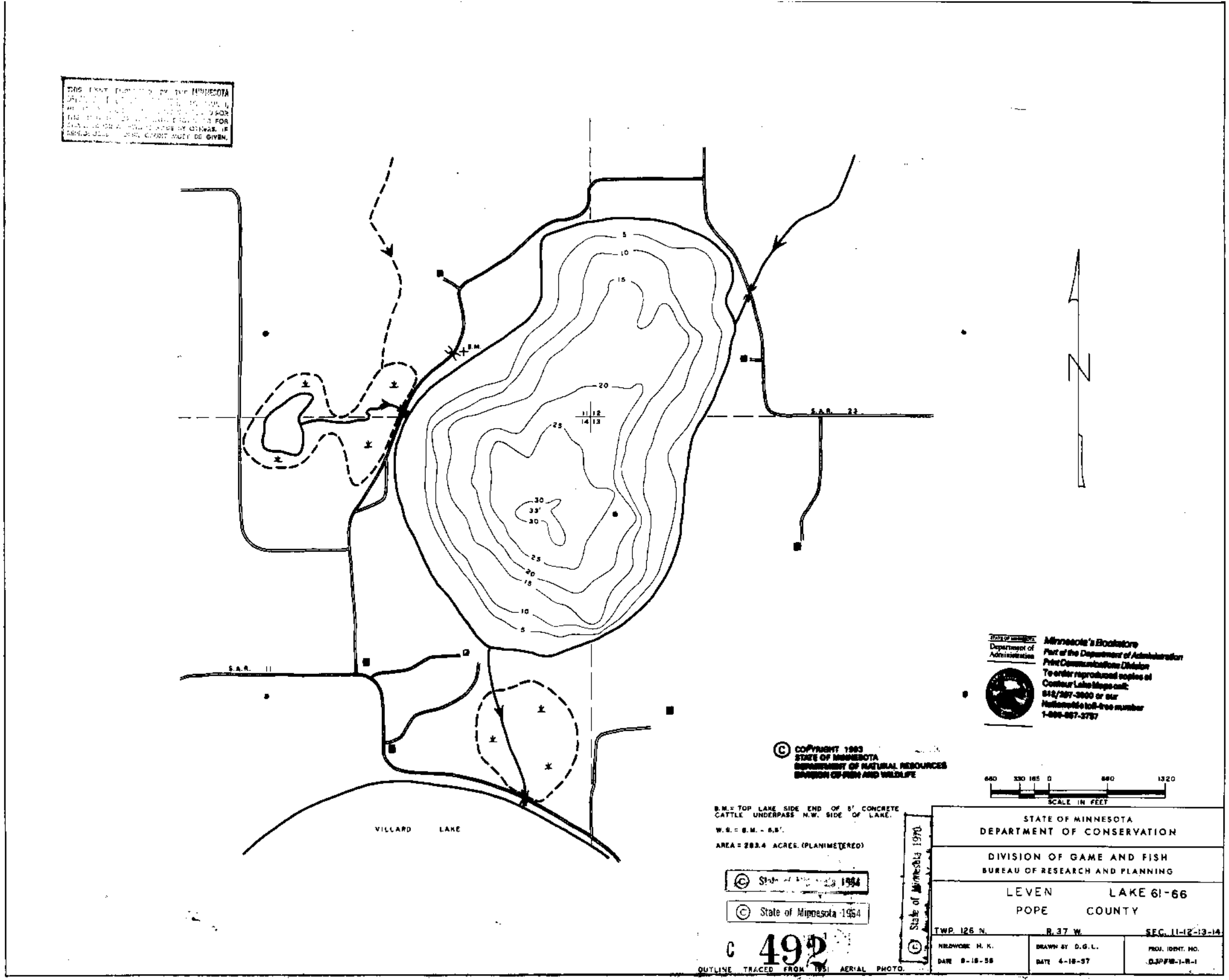
7.1.1 Physical Characteristics

Lake Leven, along with Villard Lake and Amelia Lake, make up the Villard Area chain of lakes near the city of Villard in northeastern Pope County. This set of lakes serves as the headwaters to the East Branch of the Chippewa River. Lake Leven is 281 acres in size (Table 35 and Figure 39) and is the northern-most lake of the chain. The watershed draining to Lake Leven includes drainage to Lake Ellen and Judicial Ditch 4 (JD4) within Douglas and Pope Counties.

Table 35. Lake Leven Characteristics

Characteristic	Value	Source
Lake total surface area (ac)	281	MPCA Minnesota Inventory of Impaired Lakes database (July 2008)
Percent lake littoral surface area	57%	DNR Lake Finder
Lake volume (ac-ft)	5,058	Calculated (mean depth x surface area)
Mean depth (ft)	18	COLA (2005)
Maximum depth (ft)	33	DNR Lake Finder
Drainage area (acres)	9,415	DNR Waters Lakesheds (2004), Pope County (2004b)
Watershed area : lake area	33	Calculated

Figure 39. Lake Leven Bathymetry



Land Use

The dominant land use within the Lake Leven Watershed is agriculture. Approximately 82% of the watershed is identified as cultivated crop or pasture/hay. Compared to the other lakes in this study, Leven has the greatest percent of deciduous forest within its watershed. There are 26 homes along the shores of Lake Leven. Table 36 shows the total number of acres and percent of each land use within the watershed.

Table 36. Lake Leven Watershed Land Use

Land Use	Total Acres	% of Watershed
Barren Land (Rock/Sand/Clay)	0	0%
Cultivated Crops	5,934	64%
Deciduous Forest	692	7%
Developed, High Intensity	0	0%
Developed, Low Intensity	4	0%
Developed, Medium Intensity	0	0%
Developed, Open Space	348	4%
Emergent Herbaceous Wetlands	420	4%
Evergreen Forest	26	0%
Grassland/Herbaceous	200	2%
Mixed Forest	0	0%
Open Water	19	0%
Pasture/Hay	1,768	19%
Shrub/Scrub	0	0%
Woody Wetlands	4	0%
Total	**9,415**	**100%**

Source: NLCD 2001, USGS.

7.1.2 Biological Characteristics

Fisheries

Lake Leven has a DNR managed public access on the east side of the lake off of County Road 27. The lake is classified as a natural environment lake by the DNR's shoreland management lake classifications. The lake has historically been a quality angling lake and used for various water recreation activities. From 1996 to 2001, Leven was stocked every third year with walleye fingerlings. Starting in 2002, as part of the DNR's accelerated walleye program, Leven has been stocked every even year to encourage a strong walleye population. It is reported that Lake Leven suffered a partial winterkill during the winter of 1996 to 1997 (2003 DNR fish survey), and that various game fish and carp were found on shore the following spring. A 2008 DNR fish survey reported a diverse game fish population including northern pike, walleye, largemouth bass, black crappie, and bluegills. It is noted in the survey that bluegill numbers have increased in recent years. Dense populations of planktivores such as these can lower zooplankton densities, lessening the grazing pressure on phytoplankton and thereby increasing the algal density. During the survey, one black bullhead and one common carp were caught showing a presence of these benthivorous fish in the lake. Both species forage in the lake sediments, which physically disturbs the sediments and causes high rates of phosphorus release from the sediments to the water column.

Macrophytes

Lake Leven has a history of an abundant and diverse aquatic plant community that provides habitat for fish spawning and maintains the lake's water clarity. In August of 2008, the DNR performed an aquatic plant survey that identified an abundance of northern milfoil and coontail. The survey also noted less abundant populations of cattail, hardstem bulrush, muskgrass, sago pondweed, and water celery.

A macrophyte survey in the July 2009 had similar findings but also identified the presence of curlyleaf pondweed within the lake (Table 37 and Figure 40). A wide zone of macrophyte vegetation was present and consisted of a high diversity of native submergent plants, dominated by coontail, muskgrass, native pondweeds, and some wild celery. One area was identified as having an abundant population of curlyleaf pondweed.

Table 37. Plant Species Observed During 2009 Lake Leven Macrophyte Survey

Scientific Name	Common Name	Summer
Ceratophyllum demersum	Coontail	X
Chara vulgaris	Muskgrass	X
Myriophyllum exalbescens	Northern water milfoil	X
Potamogeton crispus	Curlyleaf pondweed	X
Potamogeton illinoensis	Illinois pondweed	X
Potamogeton pectinatus	Sago pondweed	X
Vallisneria americana	Wild Celery	X

Figure 40. Lake Leven Macrophytes, 2009

7.1.3 Existing Studies and Monitoring

The Amelia/Villard/Leven Lake Association is an active member the Pope County Coalition of Lakes Association which in turn is a member of Minnesota Waters http://minnesotawaters.org/popecountycoalitionoflakes/, a non-profit organization engaging citizens in the protection and restoration of Minnesota lakes and organizing volunteer citizen monitoring programs around the state.

Status and Trend Monitoring Summary for Selected Pope and Douglas County, Minnesota Lakes

In 2001, the MPCA produced the report "Status and Trend Monitoring Summary for Selected Pope and Douglas County, Minnesota Lakes." Lake Leven was included in the report. Water quality samples were collected from Lake Leven monthly from June through September of 2000. The lake water quality summer-mean for TP was 45 µg/L, chlorophyll-*a* was 21 µg/L, and the Secchi summer-mean value was 1.8 meters. The study identified Lake Leven as being eutrophic to hypereutrophic based on its TSI values. The algae community was dominated by blue-green algae throughout the summer, leading to nuisance algae blooms. As part of the study, a MNLEAP model was used to predict the lake's TP, chlorophyll-*a* and Secchi values. The predicted values were not significantly different from the observed. The MNLEAP model showed that the lake retains approximately 63% of its phosphorus load, which benefits Lake Villard downstream (MPCA 2001a). The report can be found at https://www.pca.state.mn.us/sites/default/files/lar-61-0122.pdf

2004 Lake Leven Watershed Implementation Plan

In 2004, Pope County completed a watershed plan for Lake Leven and the JD4 Watershed in order to examine how the changes within the watershed and the development of JD4 have impacted the water quality of Lake Leven. Since the early 1900s when JD4 was developed, Lake Ellen to the north of Leven was drained, a sheet pile weir was constructed, and various road crossings and culverts were developed within the JD4 Watershed. All of these alterations have been beneficial to agriculture in the area; however the impacts to Lake Leven had not been measured. The scope of the implementation plan was to identify "hot spots" or areas that contribute a substantial amount of pollutants to Lake Leven. The five hot spots identified in the study included areas with shoreline erosion, bank instability, banks disturbed by livestock, and areas polluted with livestock manure. The study concluded that the JD4 Watershed and specifically the hot spot areas are contributing sediment and other pollutants to Lake Leven, degrading the water quality of the lake. The report provided specific approaches, recommendations, and cost improvements to clean up the hot spots, such as rip rap revetment, upstream wetland restoration, livestock control, and native plantings (Pope County 2004b).

7.1.4 Impairment Assessment

Monitoring data are available from as far back as 1992, although there were only one or two samples taken per year during the first few years and conclusions should not be drawn from sampling at this low frequency. Sampling frequency increased in 1994. The last 10 years of data were used to calculate the water quality data means (Table 38).

Lake Leven is a eutrophic lake, with similar TSI values for TP and chlorophyll-a and a relatively lower TSI for Secchi (Table 38). The TP standard for lakes in the NCHF ecoregion is 40 µg/L. TP concentration growing season means in the years 1994 to 2007 exceeded the standard every year, with annual means ranging from 43 µg/L to 105 µg/L (Figure 41) Chlorophyll-a concentration growing season means ranged from 12 µg/L to 40 µg/L in the years 1996 to 2007 (Figure 42) meeting the standard of 14 µg/L in only 1997. The Secchi depth growing season means ranged from 0.9 m to 2.2 m in 1992 to 2007, meeting the standard of 1.4 m in the majority of the last 16 years (Figure 43) There is not a strong seasonal TP pattern, but both chlorophyll-a and transparency worsen slightly throughout the growing season (Figure 44 and Figure 45). There is a positive relationship between TP and chlorophyll-a, a negative relationship between TP and Secchi depth, and a negative relationship is apparent between chlorophyll-a and Secchi depth (Figure 46 through 48).

Water quality sampling and DO depth profiles were taken at the deepest point in Lake Leven. The DO depth profile from 2000 indicates that the lake stratifies during the growing season, and the hypolimnion is anoxic during part of the growing season (Figure 49). TP data from this site show that the concentration in the hypolimnion is higher than the surface water samples taken when the lake is stratified (Figure 50), suggesting that internal loading is a source of phosphorus in Lake Leven.

Table 38. Surface Water Quality Means, Lake Leven, 1998 to 2007

Parameter	Growing Season Mean (June – September)	Trophic Status Index	NCHF Lakes Standard
TP	53 µg/L	61	< 40 µg/L
Chlorophyll-*a*	23 µg/L	61	< 14 µg/L
Secchi depth	1.5 m	54	> 1.4 m

Figure 41. TP Monitoring Data, Lake Leven

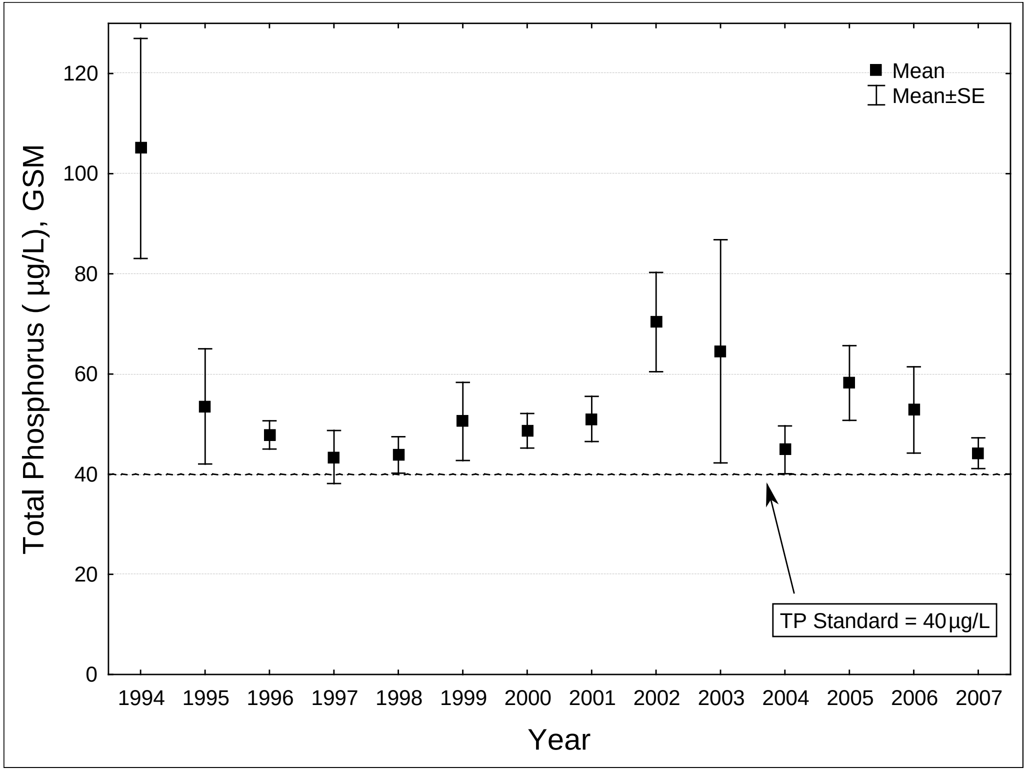


Figure 42. Mean Chlorophyll-*a* Monitoring Data, Lake Leven

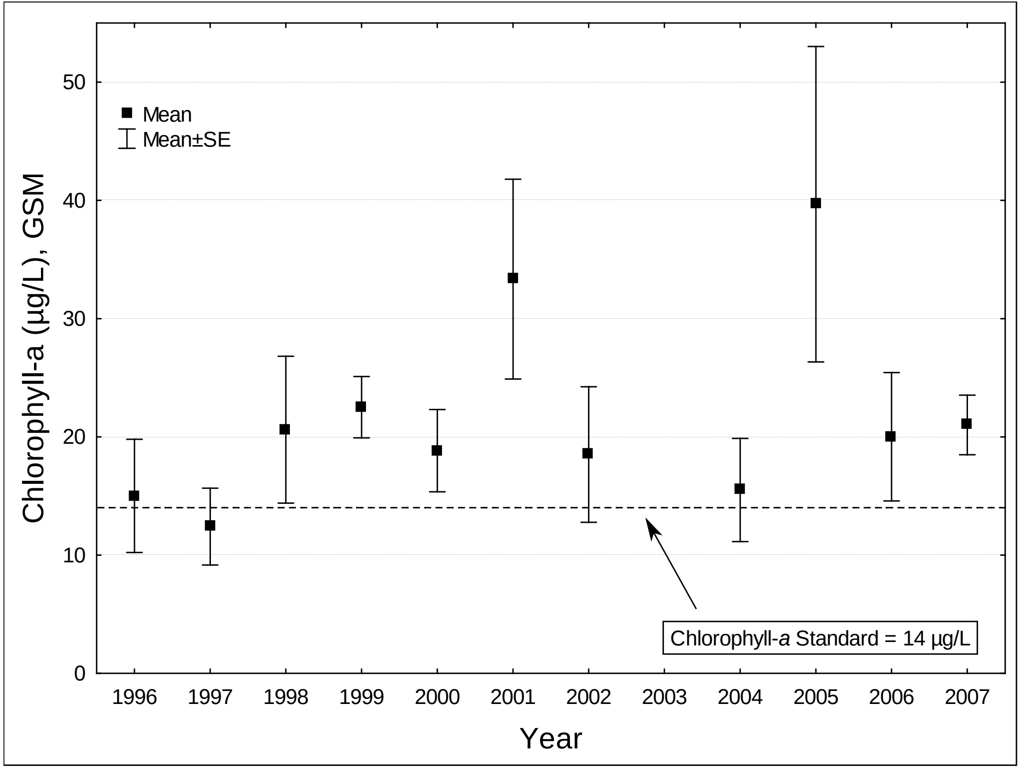


Figure 43. Secchi Depth Monitoring Data, Lake Leven

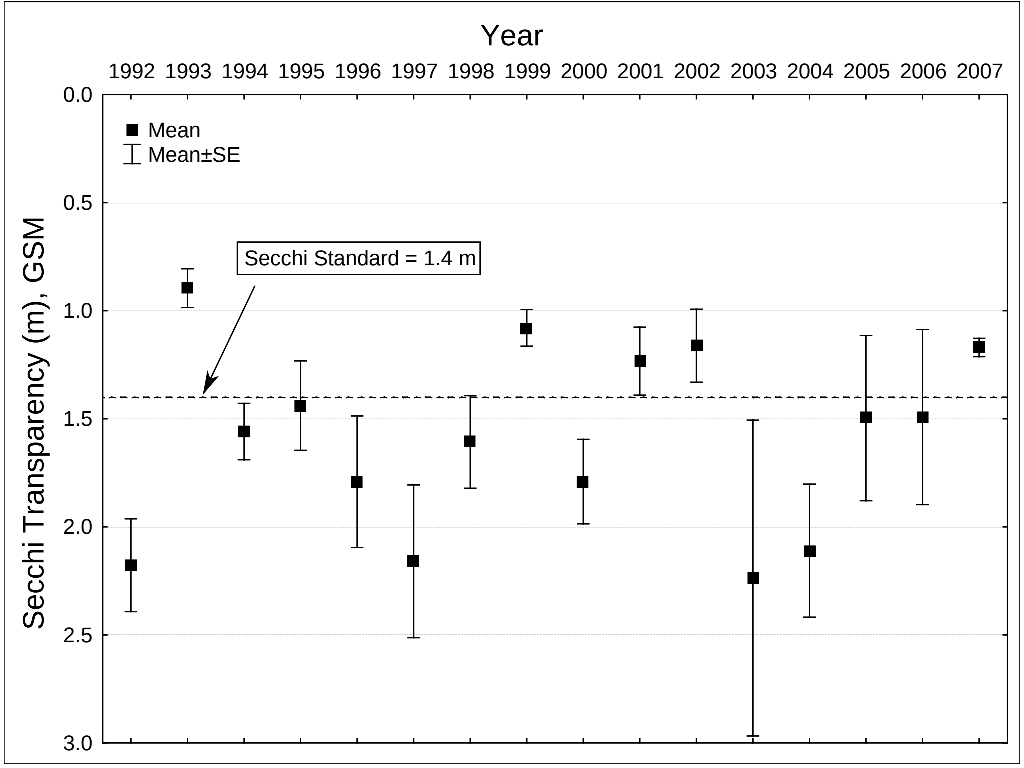


Figure 44. Lake Leven Seasonal Chlorophyll-*a* Patterns, 1998 to 2007

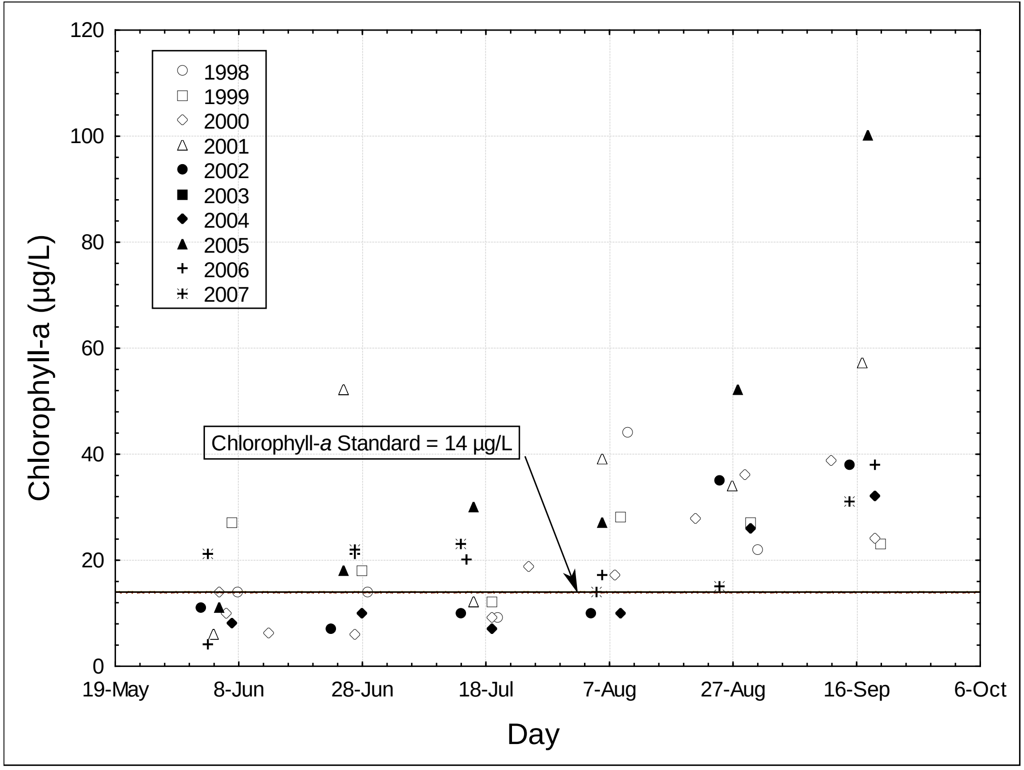


Figure 45. Lake Leven Seasonal Transparency Patterns, 1998 to 2007

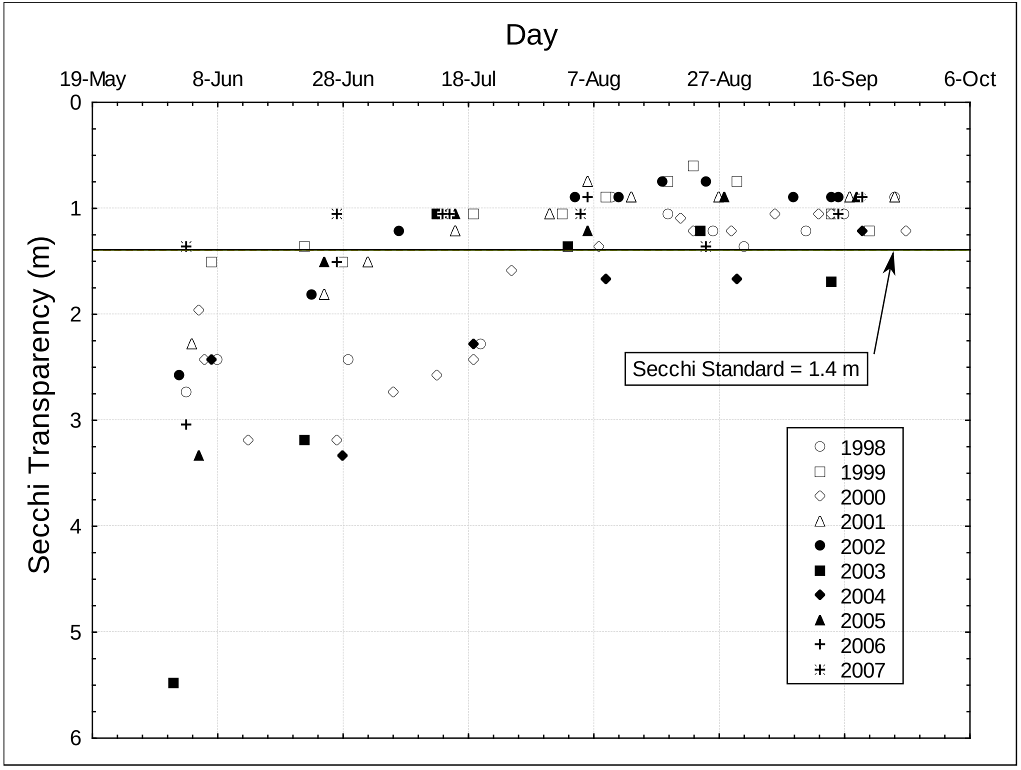


Figure 46. Relationship of Chlorophyll-*a* to TP in Lake Leven, 1998 to 2007

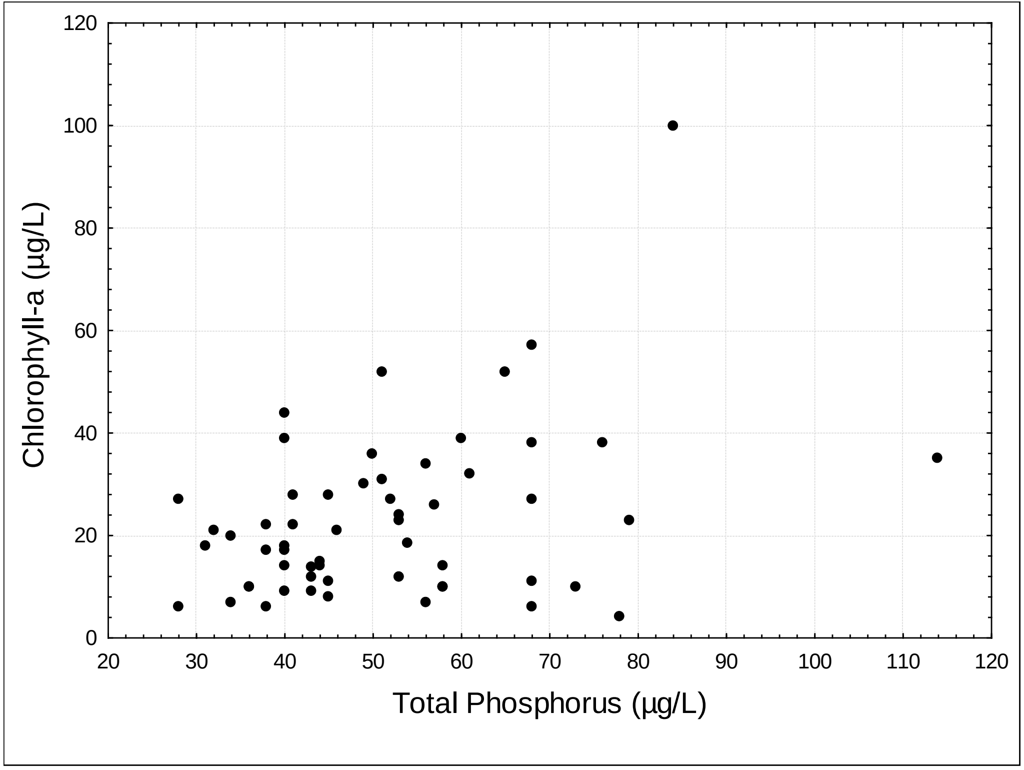


Figure 47. Relationship of Secchi Depth to TP in Lake Leven, 1998 to 2007

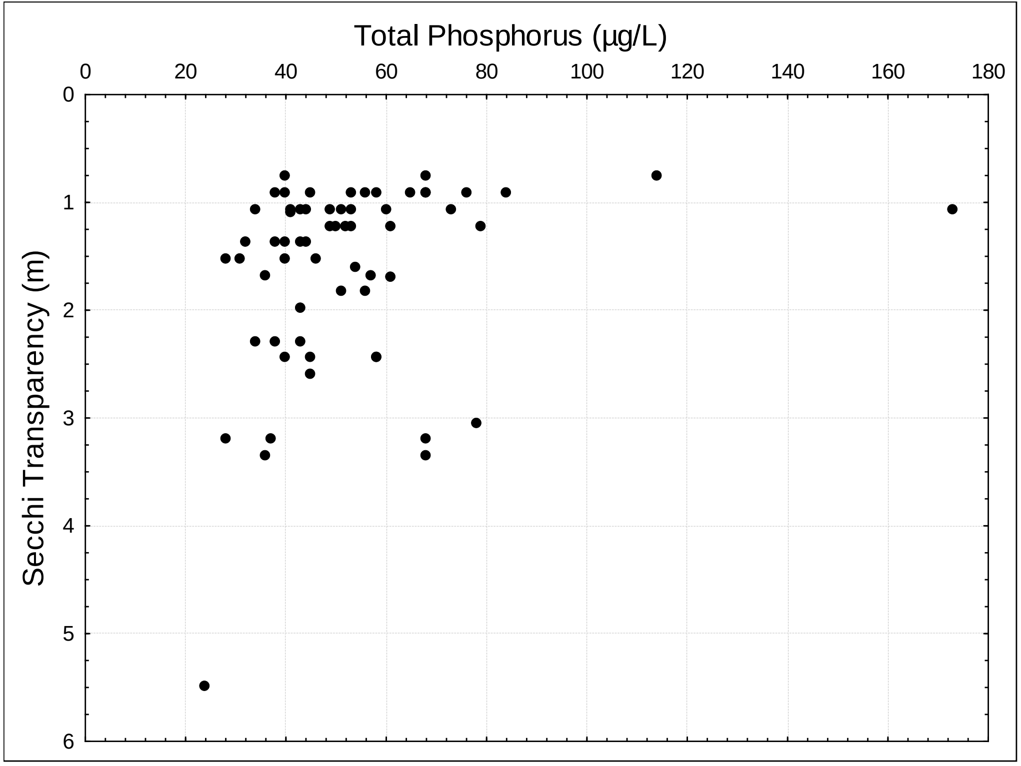


Figure 48. Relationship of Secchi Depth to Chlorophyll-*a* in Lake Leven, 1998 to 2007

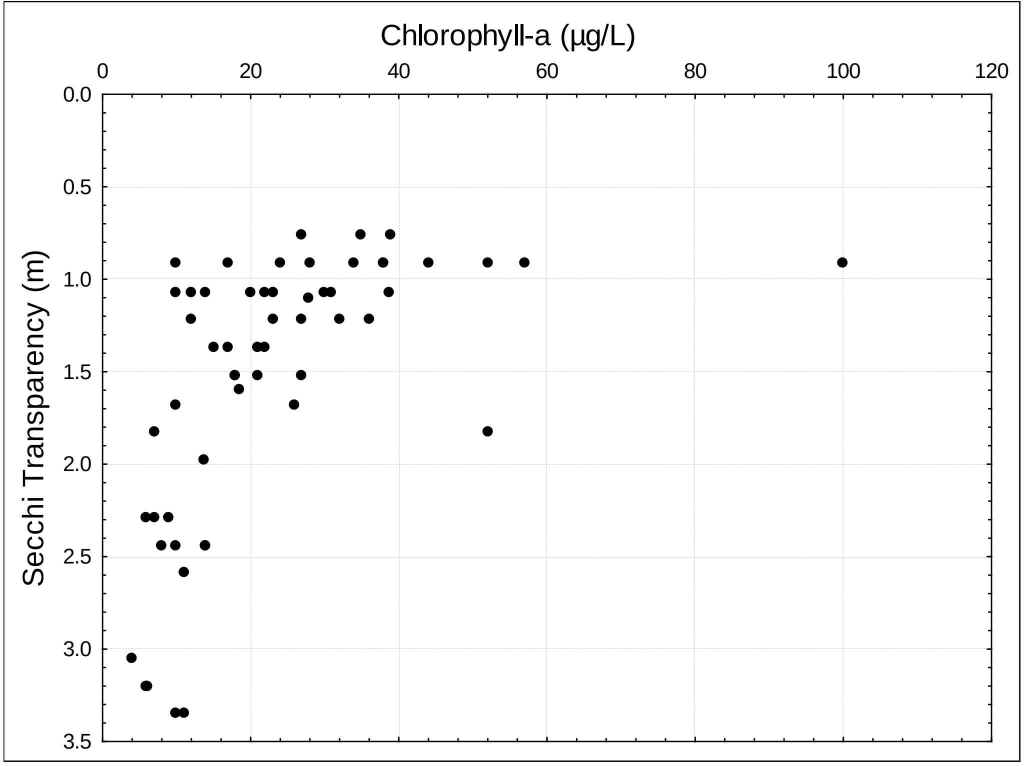


Figure 49. Lake Leven Temperature and DO, 2000

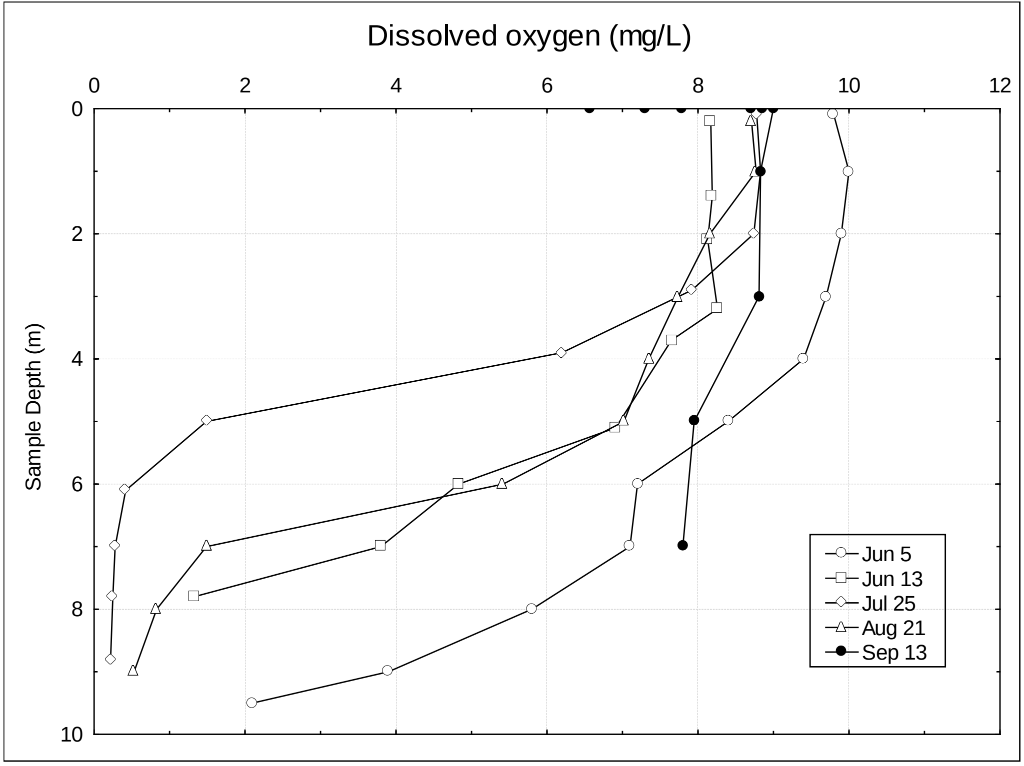
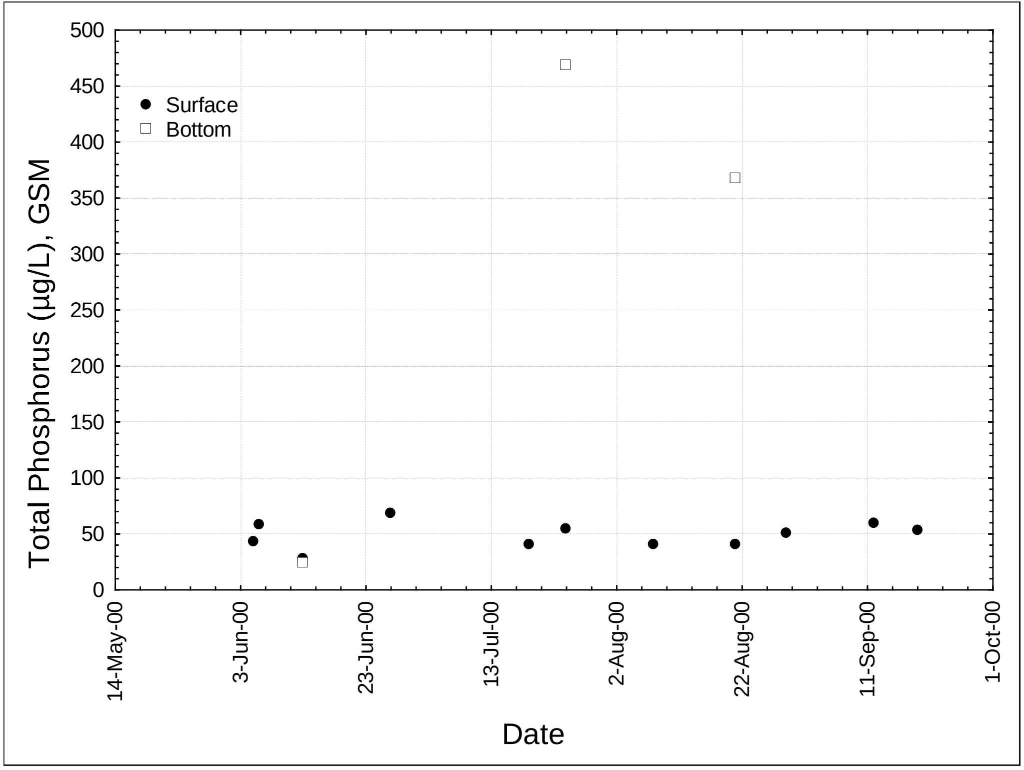


Figure 50. Lake Leven Surface vs. Bottom TP, 2000



7.2 Phosphorus Source Assessment

It is estimated that Lake Leven receives 2,396 lbs of phosphorus annually from external sources. The majority of the external phosphorus to Lake Leven is coming from stormwater runoff and feedlots not requiring NPDES Permit coverage (Figure 51, Table 39). Internal loading accounts for an additional 26 to 822 lbs/year of TP loading to the lake.

Figure 51. Lake Leven Phosphorus Inventory

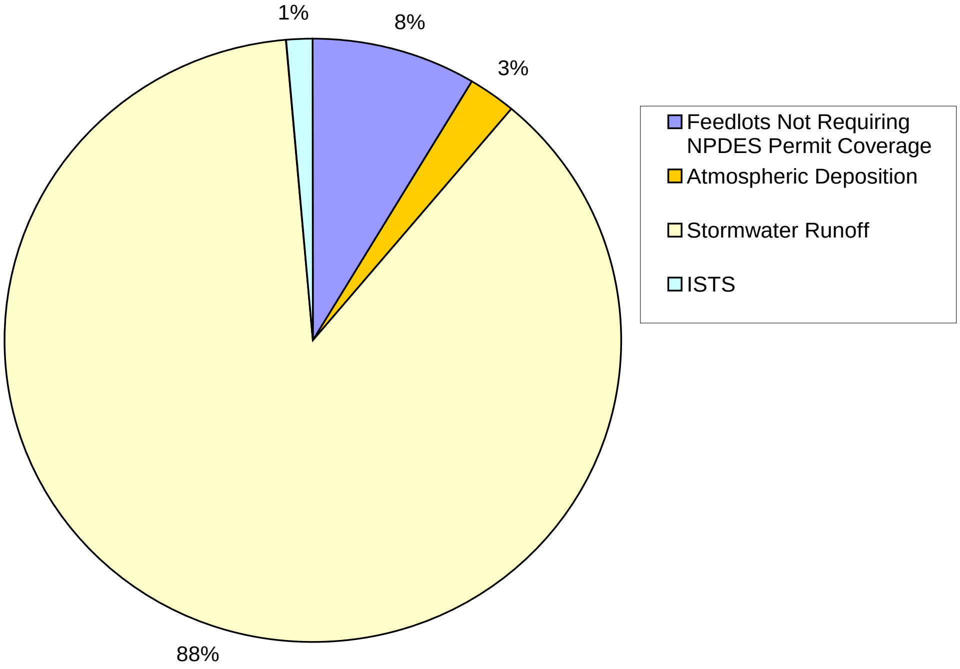


Table 39. Lake Leven Phosphorus Source Summary

Phosphorus Source	Annual TP Load [lbs/yr]
Stormwater Runoff	2,097
Feedlots Not Requiring NPDES Permit Coverage	203
Atmospheric Deposition	66
SSTS	30
Total	**2,396**

7.2.1 Sources of Phosphorus Requiring NPDES Permit Coverage

There are no point sources in the Lake Leven Watershed.

7.2.2 Sources of Phosphorus Not Requiring NPDES Permit Coverage

Stormwater Runoff

The entire drainage area to Lake Leven (9,415 acres) was modeled using the Simple Method. A total of 2,097 lbs of phosphorus per year are generated by stormwater runoff. Approximately 122 lbs of phosphorus is currently being removed from runoff due to buffers.

Loading from Upstream Waters

There are no upstream waters to Lake Leven with sufficient data to evaluate.

Runoff from Feedlots Not Requiring NPDES Permit Coverage

Within the Lake Leven Watershed there are 14 registered feedlots under 1,000 AUs in size, 12 of which are open lot feedlots. The open lot feedlots house a total of 1,420.3 AUs consisting of mainly beef and dairy cattle (Table 40). The estimated TP load coming from feedlots within the Lake Leven Watershed under average flow conditions is approximately 203 lbs/yr.

Table 40. Phosphorus Contributing to Lake Leven from Open Lot Feedlots Not Requiring NPDES Permit Coverage

Animal	Animal Units	Phosphorus contributing to surface waters during average flow year (lbs/yr)
Beef	986.6	143
Dairy	403	58.5
Horse	29	1.2
Sheep	0.5	0.1
Poultry	0.7	0.1
Goats	0.5	0.1
Total	**1,420.3**	**203**

Atmospheric Deposition

The TP load from atmospheric deposition is 66 lbs/yr (Table 41).

Table 41. Lake Leven Wet and Dry Atmospheric Deposition

Source	Phosphorus Deposition (lbs/yr)
Wet Deposition	46
Dry Deposition	19
Total	**66**

Subsurface Sewage Treatment Systems

There are 26 houses on Lake Leven that use an SSTS. Of these systems, it is estimated that 27% are failing and that 90% of the homes are permanent residences. The total estimated TP load from SSTS to Lake Leven is 30 lbs/yr.

7.3 TMDL Loading Capacity and Allocations

The phosphorus loading capacity of Lake Leven is 1,560 lbs/yr, to be split among allocations according to Table 42. The permitted sources in the Lake Leven Watershed receive individual WLAs (Table 43).

Table 42. Lake Leven Allocation Summary

Allocation	lbs/yr	lbs/day
TMDL	1,560	4.3
MOS	156	0.43
WLA	7.3	0.020
LA	1,397	3.8

Table 43. Lake Leven WLAs

Source	Permit #	WLA	
		lbs/yr	lbs/day
Construction stormwater	Various	0.27	0.00074
Industrial stormwater	No current regulated sources	7.0	0.019

7.4 Implementation Strategy

7.4.1 Approach to Lake Restoration

Lake restoration activities can be grouped into two main categories: those practices aimed at reducing external nutrient loads and those practices aimed at reducing internal loads. The focus of restoration activities depends on the lake's nutrient balance and opportunities for restoration. For Lake Leven, previous work conducted by Pope County resulted in an implementation plan (Pope County 2004b), which will serve as the basis of this strategy. A reduction of 836 lbs of TP annually is needed to achieve the Lake Leven TMDL and meet water quality standards.

This discussion separates the management strategies into practices addressing watershed load and internal load. The total cost for implementation is estimated to be $400,000 to $600,000. Implementation costs do not take into account existing programs and are assumed to be spent over the next 20 to 30 years.

7.4.2 Watershed Load Reduction Activities

Overall watershed loadings will be reduced through a variety of mechanisms including expansion of existing programs to encourage and promote agricultural BMPs such as conservation tillage, alternative tile inlets, and buffers. Enhanced feedlot BMPs and nutrient management plans will need to be developed and implemented. Wetland restoration can also be used to provide water quality treatment in the watershed.

Due to the predominance of the JD4 system within the Leven Watershed, emphasis should be placed on restoring and enhancing this ditch to provide water quality improvements though the use of alternative ditch designs (two stage ditches), wetland restoration, streambank stabilization, cattle exclusion, and buffers. Groundwater contributions to JD4 could also be further evaluated, as existing data suggest that groundwater phosphorus concentrations are high. Phosphorus within groundwater is typically a result of fertilizer and waste management practices coupled with sandy soils. The East Lateral of JD4 downstream of West Ellen Lake has exhibited very high dissolved phosphorus concentrations and should be a focus of investigation to determine the source.

Monitoring of water quality parameters within West Ellen Lake will provide additional data to understand the potential impact of West Ellen and the JD4 ditch system on Lake Leven water quality and also identify potential opportunities for activities that will improve water quality. Monitoring at several locations along JD4 will also help to focus implementation activities within the subwatersheds that contribute the majority of pollutants to Leven. Monitoring along JD4 should include both flow and water quality sampling in order to establish loadings.

Upstream management in West Ellen Lake that could include modifications to the existing outlet may also lead to water quality improvements. Increasing set aside lands though programs including Reinvest in Minnesota (RIM) and Conservation Reserve Program (CRP), as well as improving management activities on currently enrolled lands, can also help to achieve water quality goals.

7.4.3 Internal Load Reduction Activities

Reductions in internal loading to Lake Leven will focus on establishing a healthy macrophyte community through management of curlyleaf pondweed. In addition, in-lake activities could also include chemical treatment to precipitate phosphorus out of the water column, water level manipulation, and fisheries management to achieve water quality standards.

8 MALMEDAL LAKE TMDL

8.1 Lake Assessment

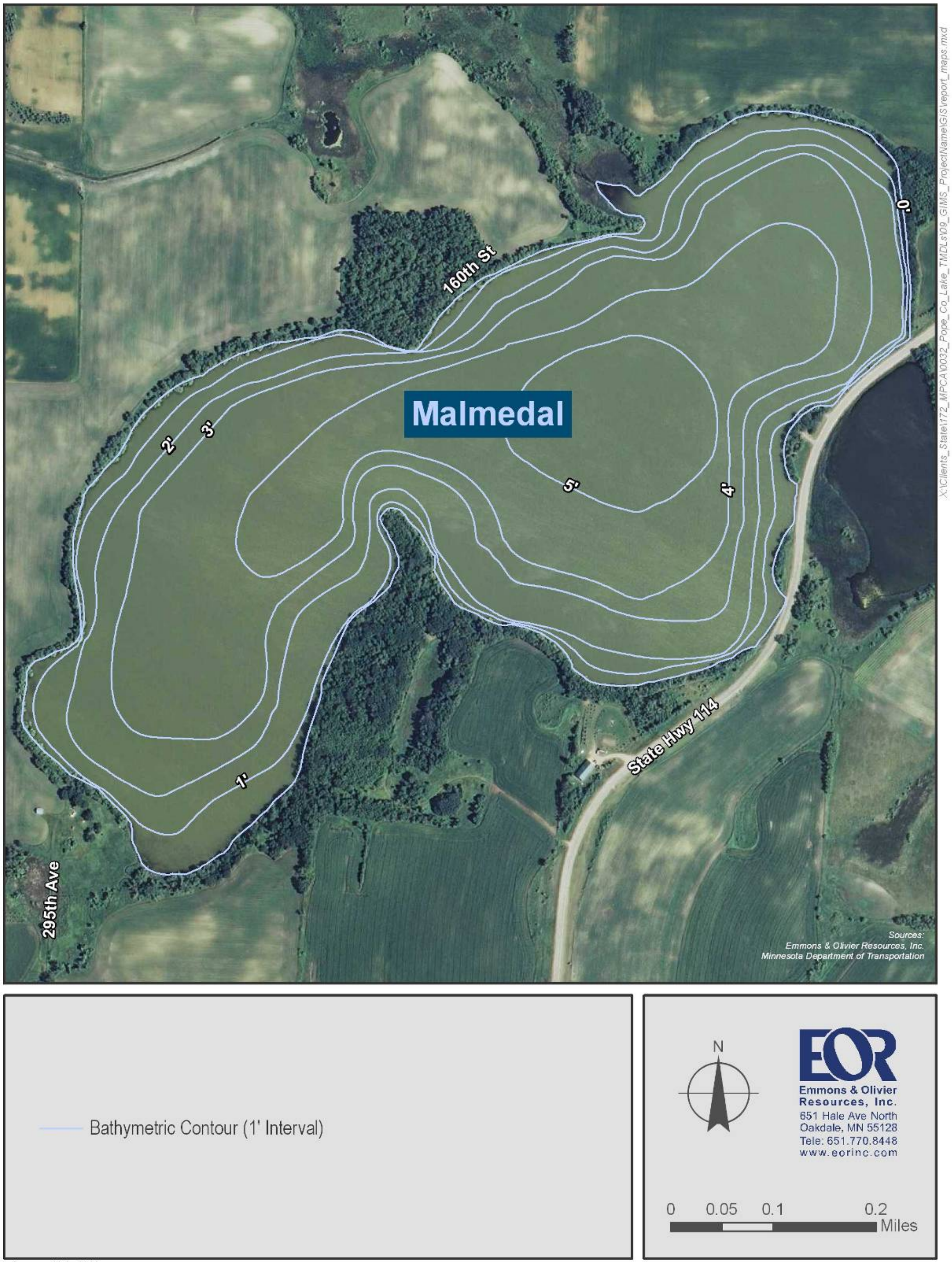
8.1.1 Physical Characteristics

Malmedal Lake, 197 acres in size (Figure 52 and Table 44), is located in north central Pope County. Malmedal outlets to Peopple's wetland, a 303(d) listed impaired wetland that drains to Strandness Lake and Trapper's Run Creek. Trapper's Run Creek flows through Pelican Lake and discharges to Lake Minnewaska. Malmedal Lake is 100% littoral (less than 15 feet deep) and is classified as a shallow lake.

Table 44. Malmedal Lake Characteristics

Characteristic	Value	Source
Lake total surface area (ac)	197	MPCA Minnesota Inventory of Impaired Lakes database (July 2008)
Percent lake littoral surface area	100%	Bathymetry
Lake volume (ac-ft)	610	Calculated (mean depth x surface area)
Mean depth (ft)	3	Bathymetry
Maximum depth (ft)	5	Bathymetry
Drainage area (acres)	6,584	DNR Waters Lakesheds (2004), Pope County (1996)
Watershed area : lake area	33	Calculated

Figure 52. Malmedal Lake Bathymetry, 2009



January 19th, 2010

Land Use

The watershed of Malmedal is dominated by agriculture. Approximately 88% of the land is categorized as cultivated crop and pasture/hay land. The 5% developed land includes the city of Lowry. There is one home along the shores of the lake. Table 45 shows the total acres and percent of the watershed for each type of land use.

Table 45. Malmedal Lake Land Use

Land Use	Total Acres	% of Watershed
Barren Land (Rock/Sand/Clay)	0	0%
Cultivated Crops	5,409	83%
Deciduous Forest	72	1%
Developed, High Intensity	1	0%
Developed, Low Intensity	27	0%
Developed, Medium Intensity	0	0%
Developed, Open Space	302	5%
Emergent Herbaceous Wetlands	245	4%
Evergreen Forest	3	0%
Grassland/Herbaceous	31	0%
Mixed Forest	4	0%
Open Water	90	1%
Pasture/Hay	398	6%
Shrub/Scrub	0	0%
Woody Wetlands	1	0%
Total	**6,584**	**100%**

Source: NLCD 2001, USGS.

8.1.2 Biological Characteristics

Fisheries

Malmedal Lake is classified as a natural environment lake by the DNR shoreland management lake classifications and managed as a waterfowl and wildlife lake by the DNR fisheries department. The lake has no public access. The fishery of the lake is not currently being managed. No stocking efforts of any kind are being undertaken. In 1995. a fish community assessment was completed on Malmedal Lake as part of the Trapper's Run Watershed Water Resource Study. The gamefish captured were northern pike and pumpkinseed sunfish. Black bullheads were found to be abundant. Bullheads are benthivorous fish; they forage in the lake sediments, which physically disturbs the sediments and causes high rates of phosphorus release from the sediments to the water column. A fish kill in the winter of 1991 to 1992 was noted by citizen at a public meeting for the Trapper's Run Project in 1992. At a public meeting in May 2009, a citizen noted a fish kill on the lake during the winter of 2007 to 2008.

Macrophytes

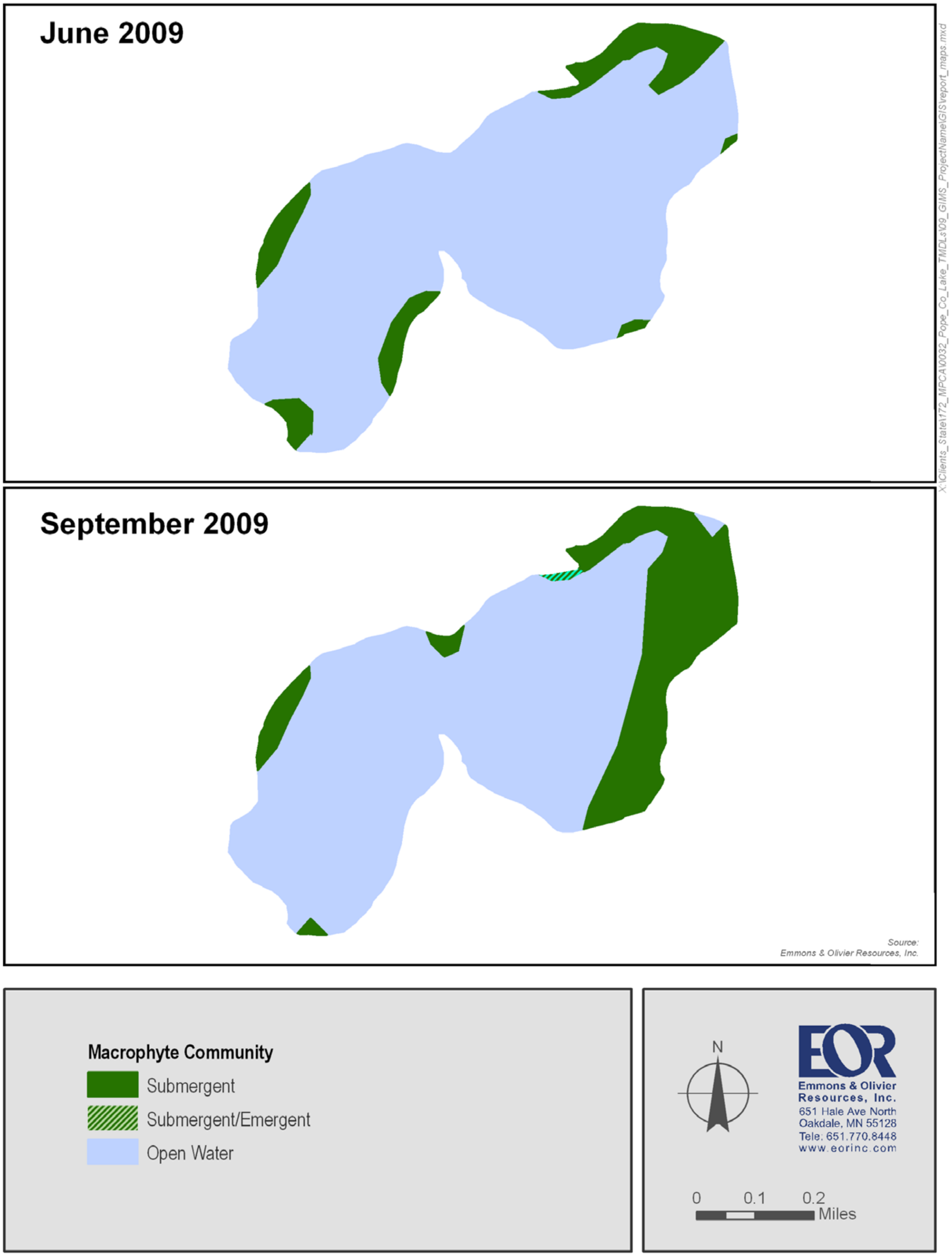
The most current data available on macrophytes within Malmedal Lake is from a DNR aquatic plant survey done in July 1995, as part of the Trapper's Run Watershed Water Resource Study. This survey reported that the dominant plant species was sago pondweed.

A macrophyte survey was conducted in the summer and fall of 2009, as part of this TMDL study to obtain additional information (Table 46 and Figure 53). In June, there were very few submergent plants present throughout the lake. In the fall, a higher diversity of submergent plants was encountered, including sago pondweed, coontail, and muskgrass.

Table 46. Plant Species Observed During 2009 Malmedal Lake Macrophyte Surveys

Scientific Name	Common Name	Summer	Fall
Ceratophyllum demersum	Coontail		X
Chara vulgaris	Muskgrass	X	X
Potamogeton pectinatus	Sago pondweed	X	X
Vallisneria americana	Wild Celery		X

Figure 53. Malmedal Lake Macrophytes, 2009



8.1.3 Existing Studies and Monitoring

Trapper's Run Creek Watershed Project

In 1994, a water resources study of Trapper's Run Creek was completed by the DNR to analyze the physical, biological, and chemical characteristics of the creek and identify point and non-point sources of pollution. Lake Minnewaska and Pelican Lake are two of the most aesthetically and economically valuable water resources within Pope County and are directly impacted by the poor water quality draining from Trapper's Run Creek. The study identified high nutrient concentrations, low biodiversity, and low DO levels within the creek.

In 1995, the study continued by looking at the runoff to the creek, collecting additional flow data along the stream, evaluating the status of contributing lakes including Malmedal, and starting inventories of the tile systems within the watershed, feedlots, and septic systems. At that time, Malmedal Lake was found to be hypereutrophic with a mean TP concentration of 153.5 µg/L. A fish survey and macrophyte survey were done on Malmedal Lake as part of the study; see the *Fisheries* and *Macrophytes* sections above.

The project report published by Pope County Environmental Services in 1996, provided a comprehensive look at all of the inventoried data on the creek and identified goals and objectives to prevent further degradation of the water quality and protect Pelican and Minnewaska. The report identified additional monitoring that could be done, programs to implement, and BMPs that could be used throughout the watershed. The problems within the creek's watershed were diagnosed in 1996, and the largest contributors included feedlot runoff, extensive tiling, non-code septic systems, and fertilizer runoff. The data collected within the subwatersheds of the creek that fall within the Malmedal Watershed were analyzed and it was concluded that the absence of BMPs and drained wetlands caused by tiling and ditching were the main causes of pollution to the creek in that area.

From 2000 to 2004, with grant assistance from the MPCA, the Trapper's Run Creek Watershed Project implemented programs to identify and upgrade non-compliance feedlots, set-up a manure management planning program, conduct additional water quality monitoring and data assessment on the watershed, and to start an incentive-based program for septic system upgrades.

8.1.4 Impairment Assessment

Monitoring data are available from as far back as 1992. Malmedal Lake has had frequent sampling since 1994. The last 10 years of data were used to calculate the water quality data means (Table 47).

Malmedal Lake is a hypereutrophic lake, with similar TSI values for the three standard monitoring parameters (Table 47). TP concentration growing season means in the years 1992 to 2007 exceeded the standard of 60 µg/L every year, with means ranging from 107 µg/L to 221 µg/L (Figure 54). Chlorophyll-*a* concentration growing season means ranged from to 46 µg/L to 141 µg/L in the years 1996 to 2007 (Figure 55), never meeting the standard of 20 µg/L. The Secchi depth growing season means ranged from 0.3 m to 0.5 m in 1994 to 2007 (Figure 56), never meeting the standard of 1.0 m.

Water quality in Malmedal Lake is poor throughout the growing season, with the poorest water quality observed in August (Figure 57). There is a positive relationship between TP and chlorophyll-*a* (Figure 58), and a slight negative relationship between TP and Secchi depth (Figure 59) and between chlorophyll-*a* and Secchi depth (Figure 60).

Table 47. Surface Water Quality Means, Malmedal Lake, 1998 to 2007

Parameter	Growing Season Mean (June – September)	Trophic Status Index	NCHF Shallow Lakes Standard
TP	166 µg/L	78	< 60 µg/L
Chlorophyll-*a*	97 µg/L	75	< 20 µg/L
Secchi depth	0.4 m	73	> 1.0 m

Figure 54. TP Monitoring Data, Malmedal Lake

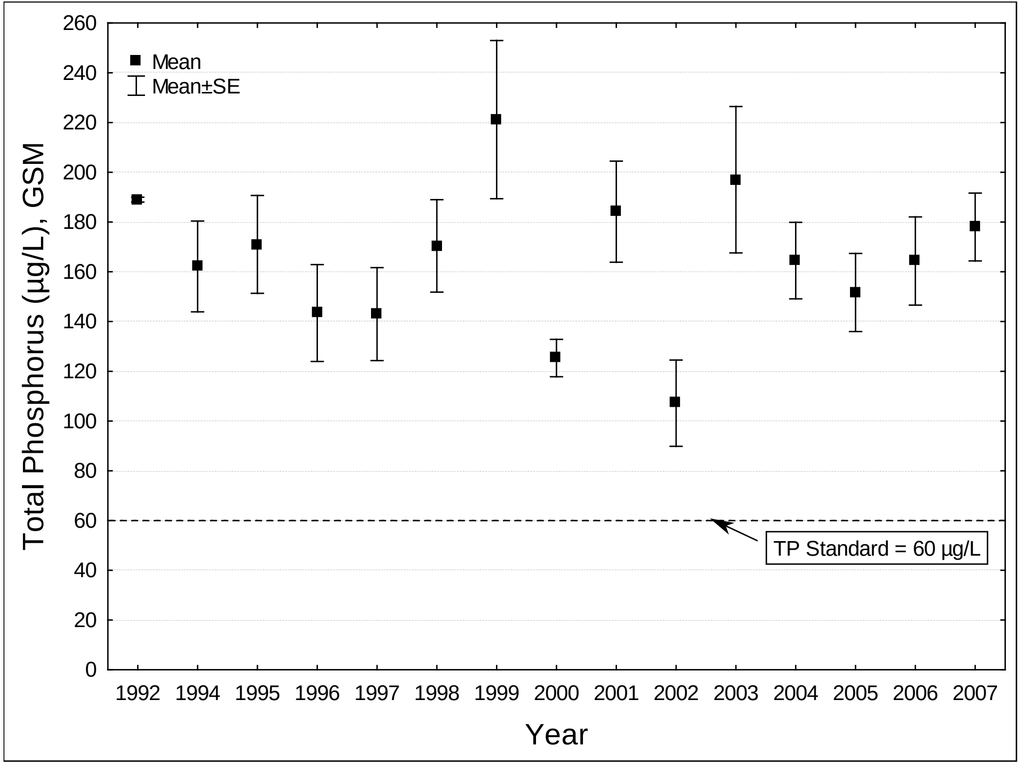


Figure 55. Mean Chlorophyll-*a* Monitoring Data, Malmedal Lake

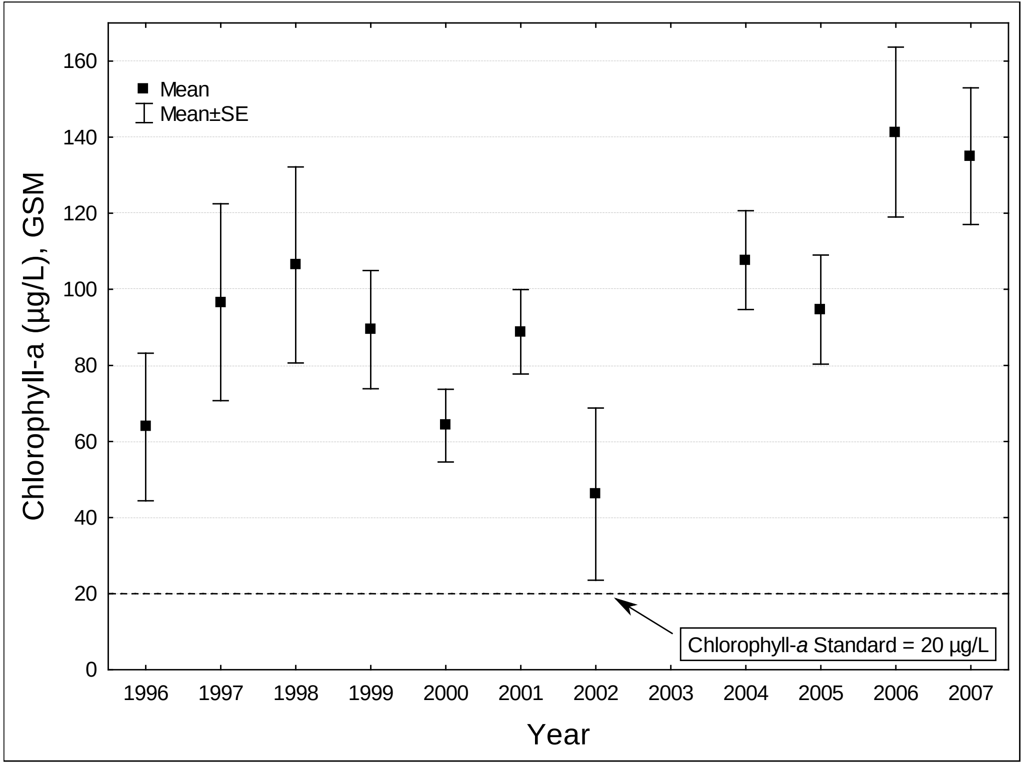


Figure 56. Secchi Depth Monitoring Data, Malmedal Lake

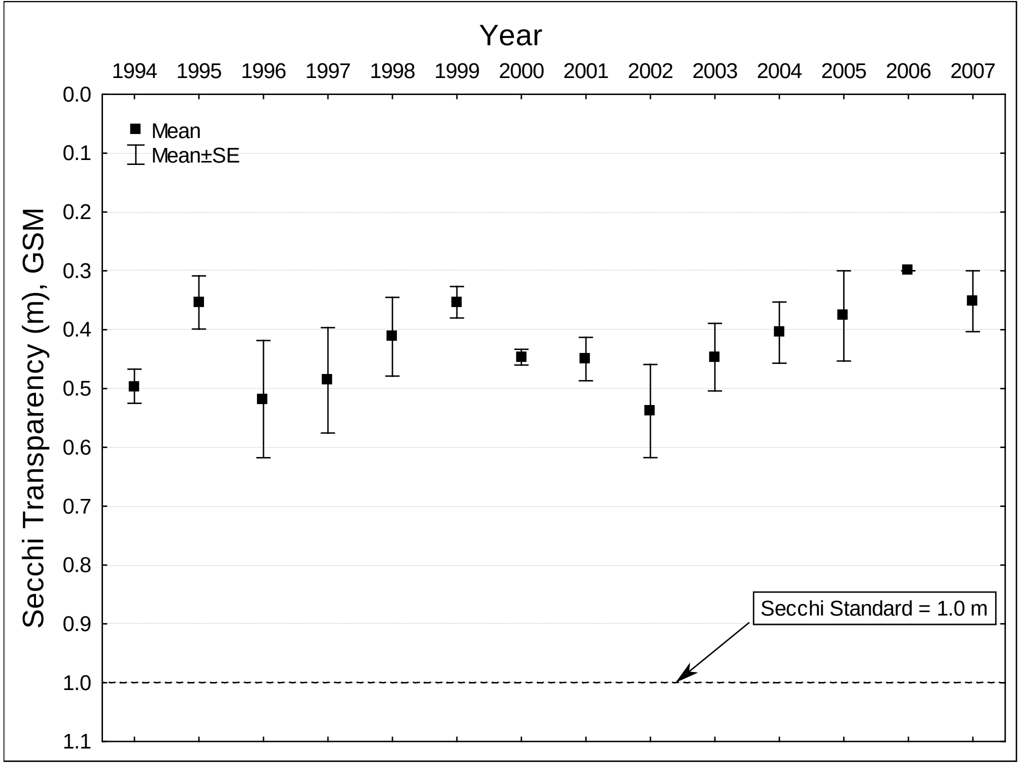


Figure 57. Malmedal Lake Seasonal Chlorophyll-*a* Patterns, 1998 to 2007

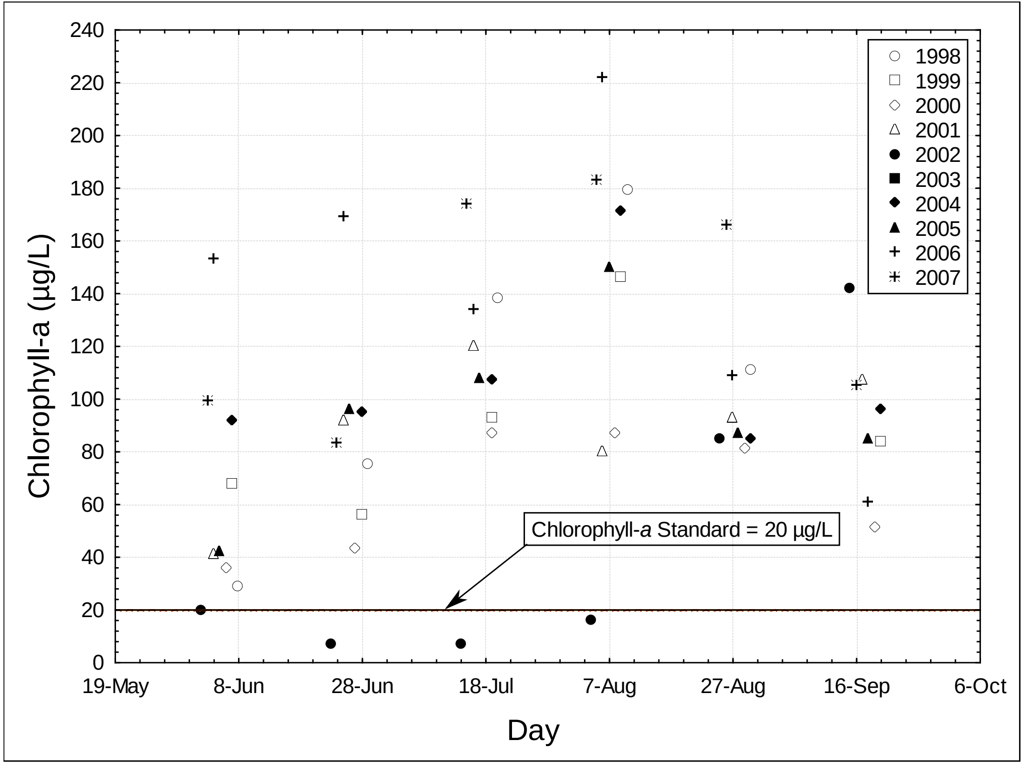


Figure 58. Relationship of Chlorophyll-*a* to TP in Malmedal Lake, 1998 to 2007

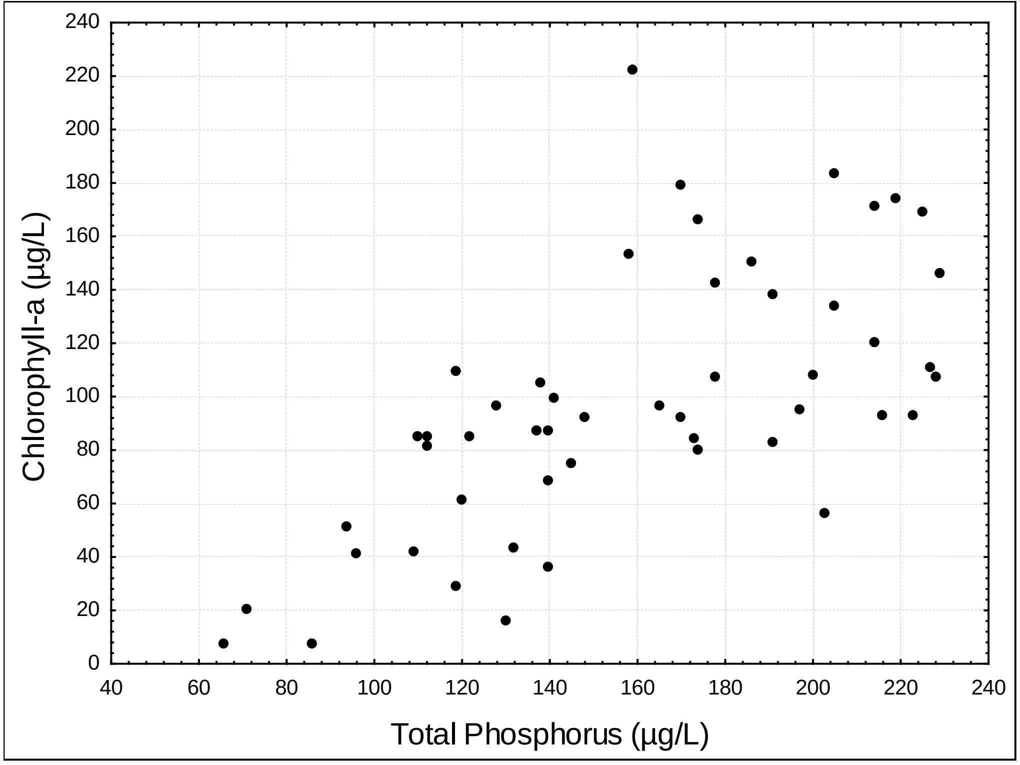


Figure 59. Relationship of Secchi Depth to TP in Malmedal Lake, 1998 to 2007

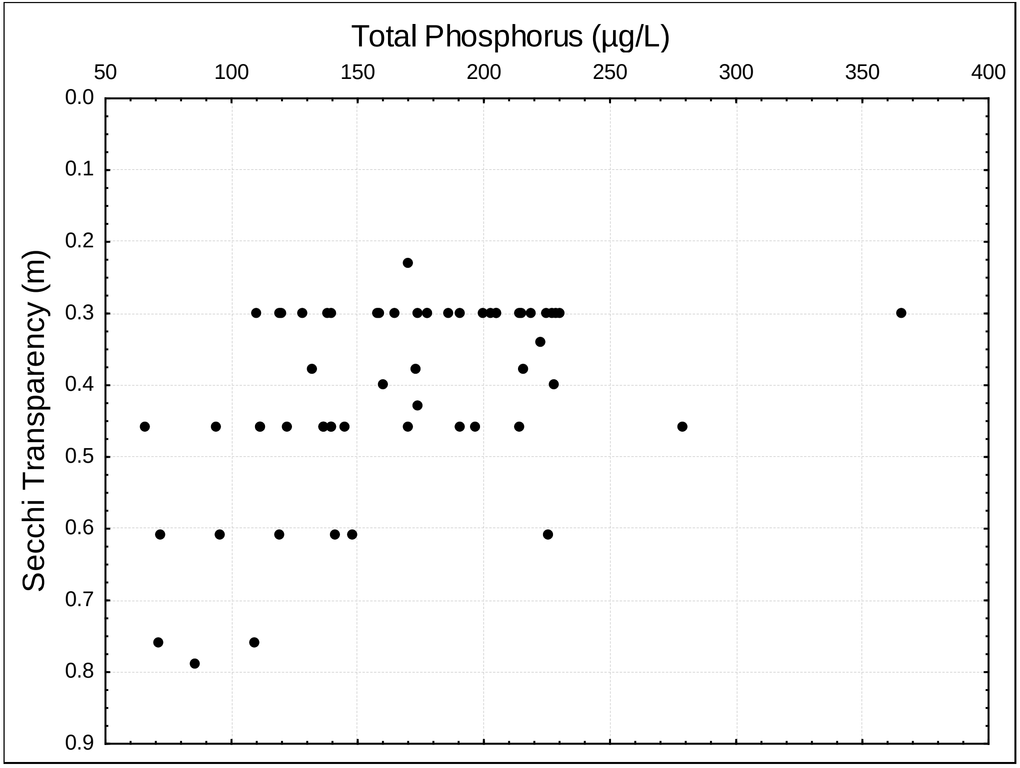
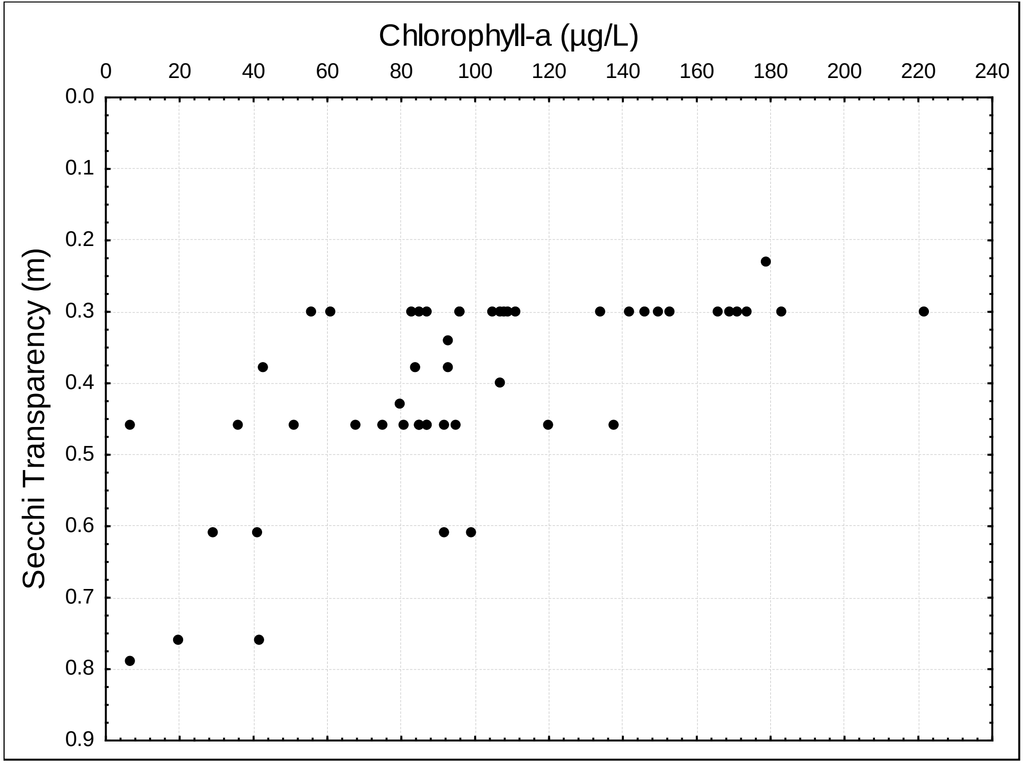


Figure 60. Relationship of Secchi Depth to Chlorophyll-*a* in Malmedal Lake, 1998 to 2007



8.2 Phosphorus Source Assessment

It is estimated that Malmedal Lake receives 1,467 lbs of phosphorus annually from external sources. The majority of the external phosphorus to Malmedal Lake is coming from stormwater runoff (Figure 61, Table 48). Internal loading accounts for an additional 124 to 816 lbs/year of TP loading to the lake.

Figure 61. Malmedal Lake Phosphorus Inventory

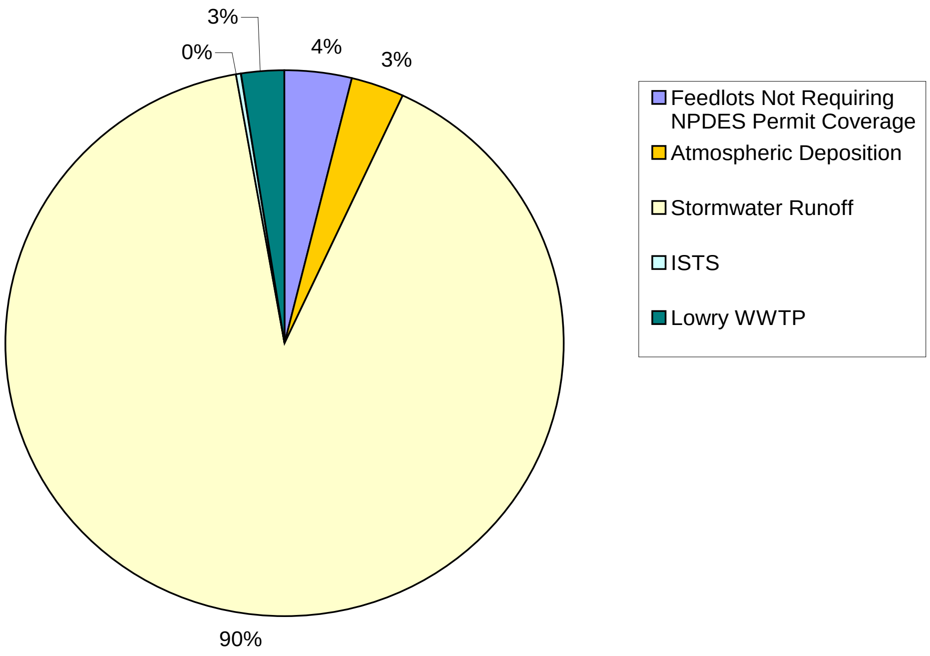


Table 48. Malmedal Lake Phosphorus Source Summary

Phosphorus Source	Annual TP Load [lbs/yr]
Stormwater Runoff	1,325
Feedlots Not Requiring NPDES Permit Coverage	56.5
Atmospheric Deposition	46
SSTS	2
Lowry WWTF	37.9
Total	**1,467.4**

8.2.1 Sources of Phosphorus Requiring NPDES Permit Coverage

Municipal and Industrial Wastewater Treatment Systems

One permitted WWTF is located within the Malmedal Lake Watershed and discharges treated wastewater from the city of Lowry. A total of 37.9 lbs/year are discharged into Malmedal Lake from this point source (Table 48).

8.2.2 Sources of Phosphorus Not Requiring NPDES Permit Coverage

Stormwater Runoff

The entire drainage area to Malmedal Lake (6,584 acres) was modeled using the Simple Method. A total of 1,356 lbs of phosphorus per year are generated by stormwater runoff. Approximately 31 lbs of phosphorus per year is removed from runoff due to buffers throughout the watershed.

Loading from Upstream Waters

There is no upstream waters tributary to Malmedal Lake with sufficient data to evaluate.

Feedlots Not Requiring NPDES Permit Coverage

Within the Malmedal Lake Watershed there are four registered feedlots under 1,000 AUs in size, all of which are open lot feedlots. The open lot feedlots house a total of 454.7 AUs of beef cattle (Table 49). The estimated TP load coming from these feedlots within the Malmedal Watershed under average flow conditions is approximately 56.5 lbs/yr.

Table 49. Phosphorus Contributing to Malmedal Lake from Open Lot Feedlots Not Requiring NPDES Permit Coverage.

Animal	Animal Units	Lbs/yr Phosphorus contributing to surface waters during average flow year
Beef	454.7	56.50

Atmospheric Deposition

The TP atmospheric deposition is 46 lbs/yr (Table 50).

Table 50. Malmedal Lake Wet and Dry Atmospheric Deposition

Source	Phosphorus Deposition (lbs/yr)
Wet Deposition	33
Dry Deposition	13
Total	**46**

Subsurface Sewage Treatment Systems

There is one home on Malmedal Lake that uses an SSTS. It is assumed that this is a permanent residence and that the SSTS is a failing system. The total estimated TP load from the SSTS to Malmedal Lake is 2.0 lbs/yr.

8.3 TMDL Loading Capacity and Allocations

The phosphorus loading capacity of Malmedal Lake is 416 lbs/yr, to be split among allocations according to Table 51. The permitted sources in the Malmedal Lake Watershed receive individual WLAs (Table 52). Watershed scale pollutant load modeling was conducted and analyzed on an annual basis to establish this TMDL at a level necessary to attain and maintain applicable water quality standards. Daily WLAs were derived from this analysis. See Section 8.4 for alternative, non-daily, pollutant load expressions recommended for the development of WQBEL based on EPA (2006).

Table 51. Malmedal Lake Allocation Summary

Allocation	lbs/yr	lbs/day
TMDL	416	1.14
MOS	42	0.12
WLA	134	0.37
LA	240	0.65

Table 52. Malmedal Lake WLAs

Source	Permit #	WLA	
		lbs/yr	lbs/day
Construction stormwater	**Various**	**0.125**	**0.00034**
Industrial stormwater	No current regulated sources	1.9	0.0052
Lowry WWTF	MNG580123	134	0.37

8.4 Implementation Strategy

8.4.1 Approach to Lake Restoration

Lake restoration activities can be grouped into two main categories: those practices aimed at reducing external nutrient loads, and those practices aimed at reducing internal loads. The focus of restoration activities depends on the lake's nutrient balance and opportunities for restoration. A reduction of 1,052 lbs of TP annually is needed to achieve the Malmedal Lake TMDL and meet water quality standards.

Malmedal Lake has a fairly small watershed, with one point source contributing TP to the lake. During the TMDL analysis, water quality in the lake was determined to be driven primarily by in-lake processes. Evaluation of data following winter fish kills indicates that water quality is much improved, although the TP load associated with benthic fish populations is uncertain. Implementation for Malmedal will therefore focus on in-lake management activities that will control the carp and benthic fish populations and establish a healthy macrophyte community. It is anticipated that these activities will limit the amount of watershed load reductions needed, and should be conducted early in the implementation process.

This discussion separates the management strategies into practices addressing point sources, watershed load, and internal load. The total cost for implementation is estimated to be $250,000 to $500,000. Implementation costs do not take into account existing programs or the Lowry WWTF upgrade and are assumed to be spent over the next 20 to 30 years.

8.4.2 Point Source Reduction Activities

The Lowry WWTF recently upgraded their facility. The new facility improves treatment capacity and eliminates many issues with the previous system including storm water inflows.

Although the TMDLs individual WLAs are expressed in terms of both daily (lbs/day) and annual (lbs/yr) loads, for implementation purposes, WQBELs developed for NPDES Permits do not necessarily have to be expressed in terms of a daily limit (EPA 2006). WQBELs should be consistent with the time increment assumptions upon which the TMDL was established. Additional considerations for the development of permit limits include the type of facility, the nature and frequency of the discharge, and compatibility with any other applicable effluent limits.

8.4.3 Watershed Load Reduction Activities

Overall watershed loadings will be reduced through a variety of mechanisms including expansion of existing programs to encourage and promote agricultural BMPs such as conservation tillage, alternative tile inlets, and buffers. Enhanced feedlot BMPs and nutrient management plans will need to be developed and implemented. Conversion of row crop agricultural land to forest and prairie will also reduce the phosphorus loading from the watershed and should be focused along perennial and intermittent streams.

Small and large scale water quality BMPs including ponds, raingardens, permeable pavements, and other low impact techniques could be considered in areas where there is development and along roadways.

Wetland and stream restoration has the ability to provide water quality and habitat improvements within the watershed. Priority wetland restoration sites will be identified within the TMDL implementation plan.

8.4.4 Internal Load Reduction Activities

Reductions in internal loading to Malmedal Lake will focus on the establishment of a healthy macrophyte community and removal of carp and other rough fish. A lake drawdown could achieve many objectives including controlling the rough fish populations, consolidating the bottom sediments, and creating an environment for macrophytes to establish. An investigation into upstream and downstream water bodies will be needed to determine the need for fish barriers. It is anticipated that once the rough fish are controlled, macrophytes will be reestablished within the lake, creating a healthy shallow lake ecosystem.

9 PELICAN LAKE TMDL

9.1 Lake Assessment

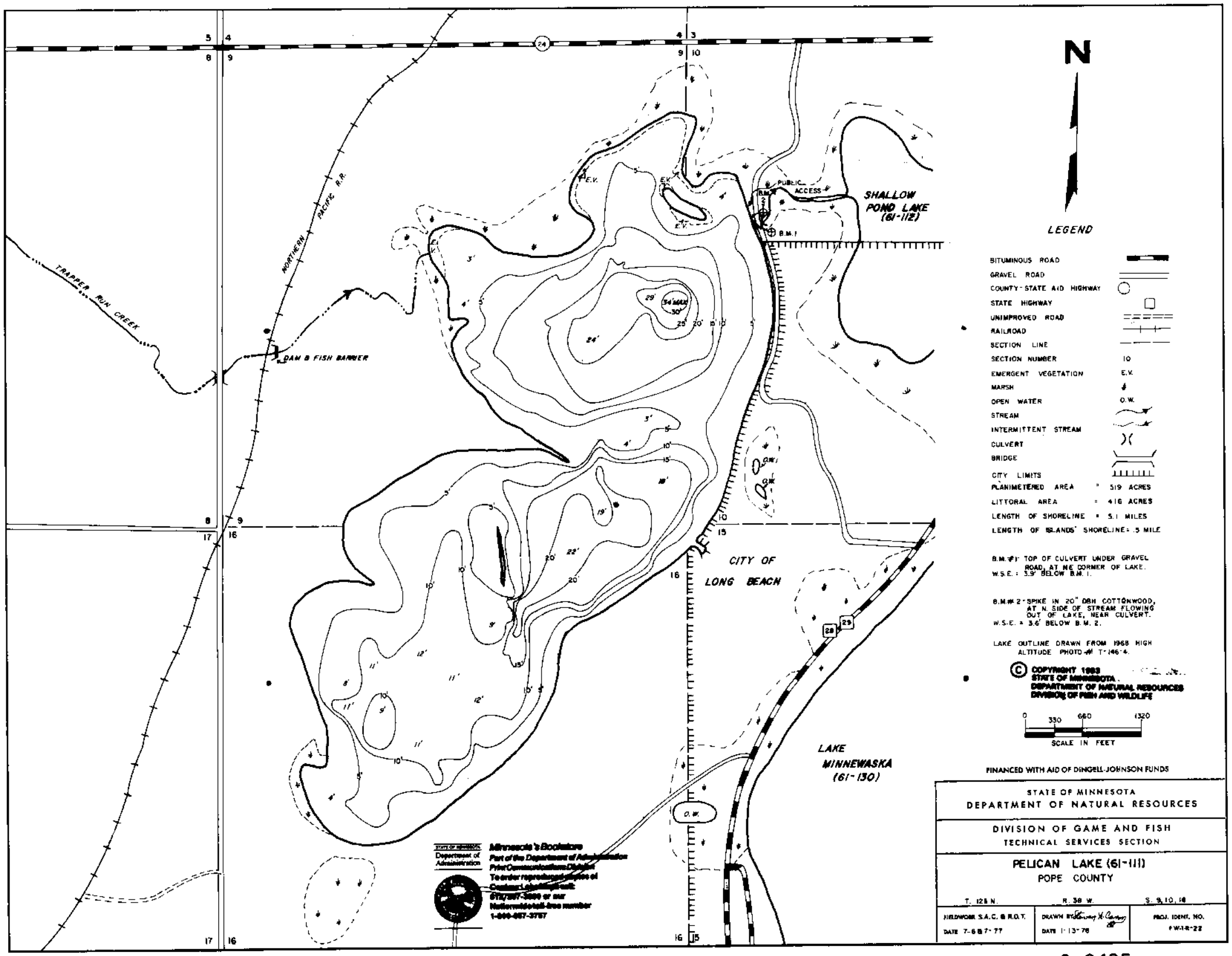
9.1.1 Physical Characteristics

Pelican Lake is located along Trapper's Run Creek in North Central Pope County. The creek stretches six miles, starting at Malmedal Lake, flows through Pelican, and discharges at Lake Minnewaska. Tiling in the Trapper's Run Creek Watershed is extensive; almost every section in this watershed contains some tile according to the tile inventory (see Figure 6 of the Trapper's Run Creek Watershed Project report (PCES 1996). Pelican Lake has a surface area of 511 acres (Table 53 and Figure 62) and lies between Lake Minnewaska and Strandness Lake along the creek.

Table 53. Pelican Lake Characteristics

Characteristic	Value	Source
Lake total surface area (ac)	511	MPCA Minnesota Inventory of Impaired Lakes database (July 2008)
Percent lake littoral surface area	80%	DNR Lake Finder
Lake volume (ac-ft)	9,198	Calculated (mean depth x surface area)
Mean depth (ft)	18	COLA (2005)
Maximum depth (ft)	34	DNR Lake Finder
Drainage area (acres)	19,720	DNR Waters Lakesheds (2004), Pope County (1996)
Watershed area : lake area	39	Calculated

Figure 62. Pelican Lake Bathymetry



C-0495

Land Use

Land use throughout the watershed is primarily agriculture. Approximately 79% of the land is used for cultivated crops and pasture/hay. The lake has approximately 72 homes along its shore. Table 54 summarizes the total acres and the percent of the watershed of the different land uses.

Table 54. Pelican Lake Watershed Land Use

Land Use	Total Acres	% of Watershed
Barren Land (Rock/Sand/Clay)	0	0%
Cultivated Crops	13,430	68%
Deciduous Forest	1078	5%
Developed, High Intensity	1	0%
Developed, Low Intensity	69	0%
Developed, Medium Intensity	0	0%
Developed, Open Space	888	5%
Emergent Herbaceous Wetlands	614	3%
Evergreen Forest	15	0%
Grassland/Herbaceous	513	3%
Mixed Forest	15	0%
Open Water	979	5%
Pasture/Hay	2,111	11%
Shrub/Scrub	0	0%
Woody Wetlands	7	0%
Total	**19,720**	**100%**

Source: NLCD 2001, USGS.

9.1.2 Biological Characteristics

Fisheries

Pelican Lake is classified as a recreational development lake by the DNR shoreland management lake classifications. A public access is located on the northeast corner of the lake. Black bullhead, bluegill, and yellow perch are the dominant fish species within the lake (2005 DNR fish survey). Common carp were also caught in the trap net surveys in low abundance. Walleye have been stocked in various amounts since 1982. In the past 10 years, walleye have been stocked in the lake in 1998, 2000, 2001, 2003, and 2005, and northern pike fry were stocked in 1999. According to the DNR survey report, limited natural reproduction in game fish takes place in the lake due to poor water quality and poor spawning areas. A viable fishery is only possible through the stocking efforts of the DNR. The lake has experienced winter kills in the past, and an aeration system was installed in 1989.

Macrophytes

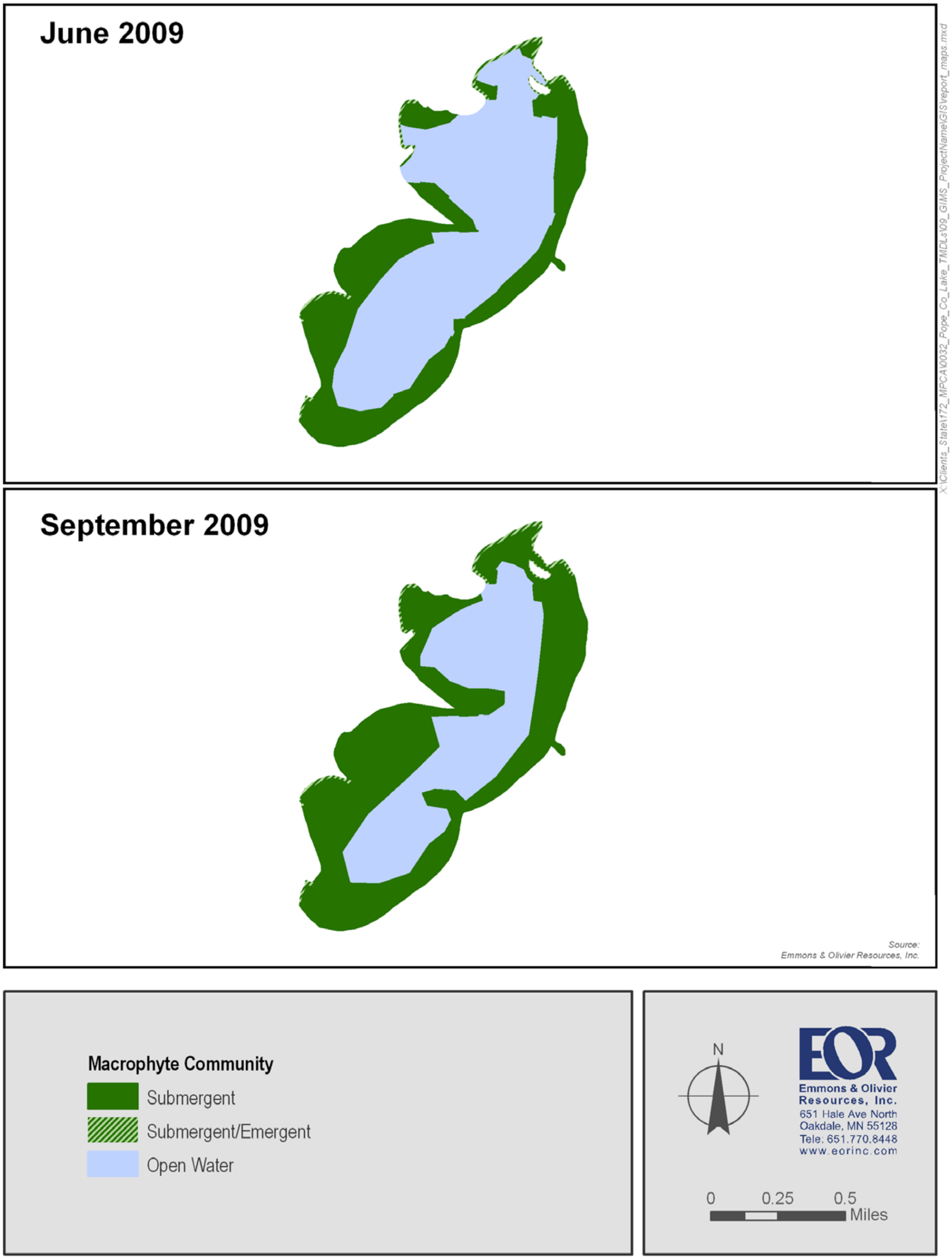
The 2005 DNR fish survey states that aquatic vegetation is very dense and has the potential to limit recreational activities during the summer. A formal aquatic plant survey has not been performed on Pelican Lake in the past 10 years. In a DNR fish survey performed in July 2004, the aquatic plant community was observed to be dominated by muskgrass and coontail.

In 2009, a macrophyte survey was completed in the summer and fall as part of TMDL development (Table 55 and Figure 63). A similar extent of submergent plants and a ring of emergents around most of the lake were present in the summer and fall. In the fall, the lake was dominated by a large diversity of submergent plants, including muskgrass, coontail, northern water milfoil (native), bladderwort, and water naiad.

Table 55. Plant Species Observed During 2009 Pelican Lake Macrophyte Surveys

Scientific Name	Common Name	Summer	Fall
Ceratophyllum demersum	Coontail	X	X
Chara vulgaris	Muskgrass	X	X
Myriophyllum exalbescens	Northern water milfoil		X
Najas marina	spiny naiad		X
Potamogeton pectinatus	Sago pondweed	X	X
Utricularia macrorhiza	Bladderwort		X

Figure 63. Pelican Lake Macrophytes, 2009



9.1.3 Existing Studies and Monitoring

The Pelican Lake Association is an active member of the Pope County Coalition of Lakes Association which in turn is a member of Minnesota Waters http://minnesotawaters.org/popecountycoalitionoflakes/, a non-profit organization engaging citizens in the protection and restoration of Minnesota lakes and organizing volunteer citizen monitoring programs around the state. The Pelican Lake Sportsmen's Club is an organized group that participated in the 1994 LAP for Pelican Lake.

Trapper's Run Creek Watershed Project

In 1994, a water resources study of Trapper's Run Creek was completed by the DNR to analyze the physical, biological, and chemical characteristics of the creek and identify point and non-point sources of pollution. Lake Minnewaska and Pelican Lake are two of the most aesthetically and economically valuable water resources within Pope County and are directly impacted by the poor water quality draining from Trapper's Run Creek. The study identified high nutrient concentrations, low biodiversity, and low DO levels within the creek.

In 1995, the study continued by looking at the runoff to the creek, collecting additional flow data along the stream, evaluating the status of contributing lakes, and starting inventories of the tile systems within the watershed, feedlots, and septic systems. At that time, Pelican Lake was found to be eutrophic with a mean TP concentration of 51 µg/L.

The project report published by Pope County Environmental Services in 1996, provided a comprehensive look at all of the inventoried data on the creek and identified goals and objectives to prevent further degradation of the water quality and protect Pelican and Minnewaska. The report identified additional monitoring that could be done, programs to implement, and BMPs that could be used throughout the watershed. The problems within the creek watershed were diagnosed in 1996, and the largest contributors included feedlot runoff, extensive tiling, non-code septic systems, and fertilizer runoff. The data collected within the subwatersheds of the creek that fall within the Pelican Lake Watershed were analyzed and it was concluded that the absence of BMPs, feedlots, and drained wetlands caused by tiling and ditching were the main causes of pollution to the creek in that area.

From 2000 to 2004, with grant assistance from the MPCA, the Trapper's Run Creek Watershed Project implemented programs to identify and upgrade non-compliant feedlots, set up a manure management planning program, conduct additional water quality monitoring and data assessment on the watershed, and start an incentive based program for septic system upgrades.

Pelican Lake: Lake Assessment Program

In 1994, a LAP was completed by the MPCA for Pelican Lake in cooperation with the DNR, Pope County Environmental Services, and the Pelican Lake Sportsmen's Club to determine the baseline water quality status of the lake. Through water quality data collection, the study concluded that Pelican Lake was in a mesotrophic state. TP concentrations in 1994 were observed at 42 µg/L, chlorophyll-*a* at 24 µg/L, and the Secchi depth transparency was 4.6 feet. The Reckhow and Simpson lake model was used to further analyze the state of the lake and the model concluded that 91% of the phosphorus loading to the lake was from the watershed. The remaining 9% was from atmospheric deposition and failing septic systems. The LAP concluded that additional monitoring needed to occur within the lake and the watershed to continue to develop specific relationships between the water quality and land use. The LAP recommended that the Pelican Lake Sportsmen's Club focus on the development of a lake management plan. The lake management plan should include working with homeowners to ensure properly installed and maintained septic systems, establishment of naturally vegetated shorelines, and proper use of fertilizers and pesticides. The LAP suggested continued participation in the Citizen's Lake Monitoring Program and cooperating with Pope County SWCD and the COLA. Finally, the LAP suggested the need for voluntary participation in the implementation of BMPs such as grassed waterways, minimum tillage, septage and manure management, contour plowing, vegetative buffer strips, and other conservation and erosion control practices.

Trapper's Run Creek Monitoring, 2009

In 2009, additional water quality data were collected along Trapper's Run Creek as part of this TMDL study. Monitoring occurred at three locations along the creek at crossings with County Highway 24, 270th Avenue, and 260th Avenue. An automatic flow station was set up at the 270th Avenue crossing and collected data between July 20, 2009, and October 6, 2009. Water quality grab samples were taken at each of the sites six times during the monitoring season. Results for TP ranged from 0.059 to 0.179 mg/L and TSS concentrations ranged from 2 to 15 mg/L. Data collected as part of this work has been entered into the STORET database.

9.1.4 Impairment Assessment

Monitoring data are available from as far back as 1986. However, there were only one or two samples taken per year in the initial years and some years were missed; therefore, conclusions should not be drawn from the initial years of data. Sampling frequency increased in 1994. The 10 years of data (1998 through 2007) were used to calculate the water quality data means (Table 56).

Pelican Lake is a eutrophic lake, with similar TSI values for TP and chlorophyll-*a* and a relatively lower value for Secchi depth (Table 56). The TP standard for lakes in the NCHF ecoregion is 40 µg/L. TP concentration growing season means in the years 1994 to 2007 exceeded the standard every year except 2006 with concentrations ranging from 35 µg/L to 72 µg/L (Figure 64). Chlorophyll-*a* concentration growing season means ranged from to 11 µg/L to 32 µg/L in the years 1994 to 2007 (Figure 65), meeting the standard in approximately one-third of the years monitored. The Secchi depth growing season means ranged from 0.9 m to 1.9 m in 1990 to 2007 (Figure 66), meeting the standard during approximately half of the years.

There is not a clear seasonal pattern in TP or chlorophyll-*a.* Transparency data are available from earlier in the season than the TP and chlorophyll-*a* data, and data from May indicate that transparency is quite high during May and then quickly worsens and remains low throughout the remainder of the growing season (Figure 67). There are no clear relationships among TP, chlorophyll-*a*, and Secchi depth (Figure 68 through Figure 70).

Water quality sampling and DO depth profiles were taken at the deepest point in Pelican Lake. The DO depth profiles from 1996 indicate that the lake was stratified in August of that year (Figure 71).

However, with data from only three dates, it is not known how long the stratification remained. The TP concentration in the hypolimnion is at times substantially higher than the surface TP (Figure 72), suggesting that the lake does remain stratified during at least a portion of the growing season and that internal loading is a source of phosphorus in Pelican Lake.

Table 56. Surface Water Quality Means, Pelican Lake, 1998 – 2007

Parameter	Growing Season Mean (June – September)	Trophic Status Index	NCHF Lakes Standard
TP	56 µg/L	62	< 40 µg/L
Chlorophyll-*a*	21 µg/L	60	< 14 µg/L
Secchi depth	1.3 m	53	> 1.4 m

Figure 64. TP Monitoring Data, Pelican Lake

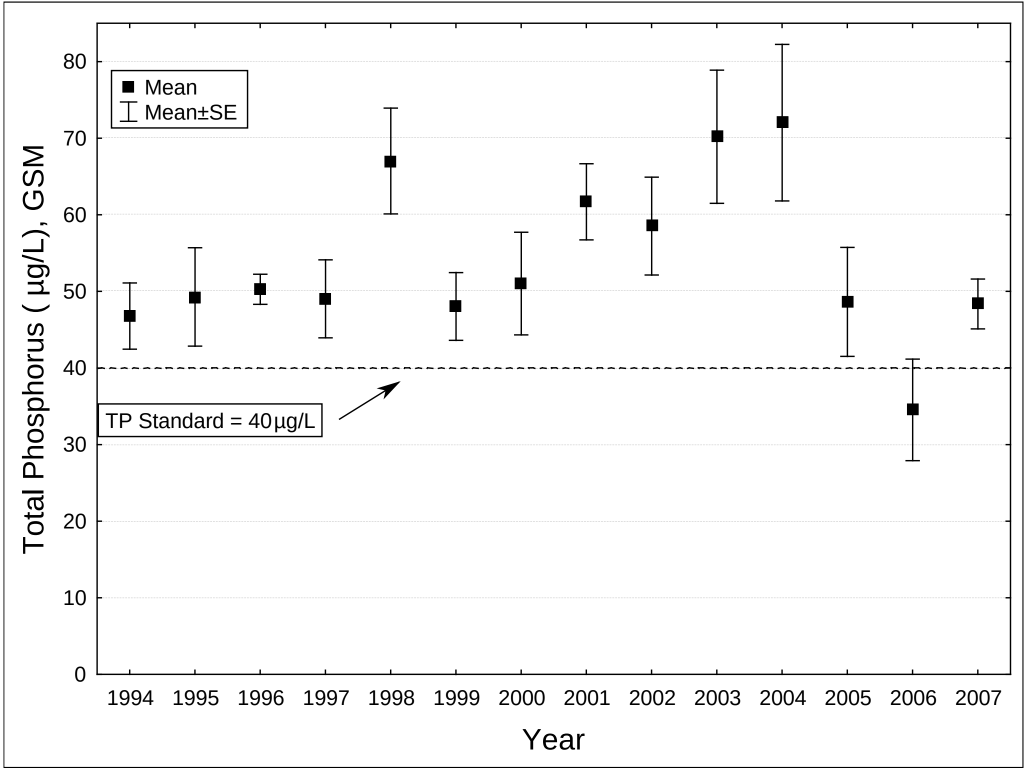


Figure 65. Mean Chlorophyll-*a* Monitoring Data, Pelican Lake

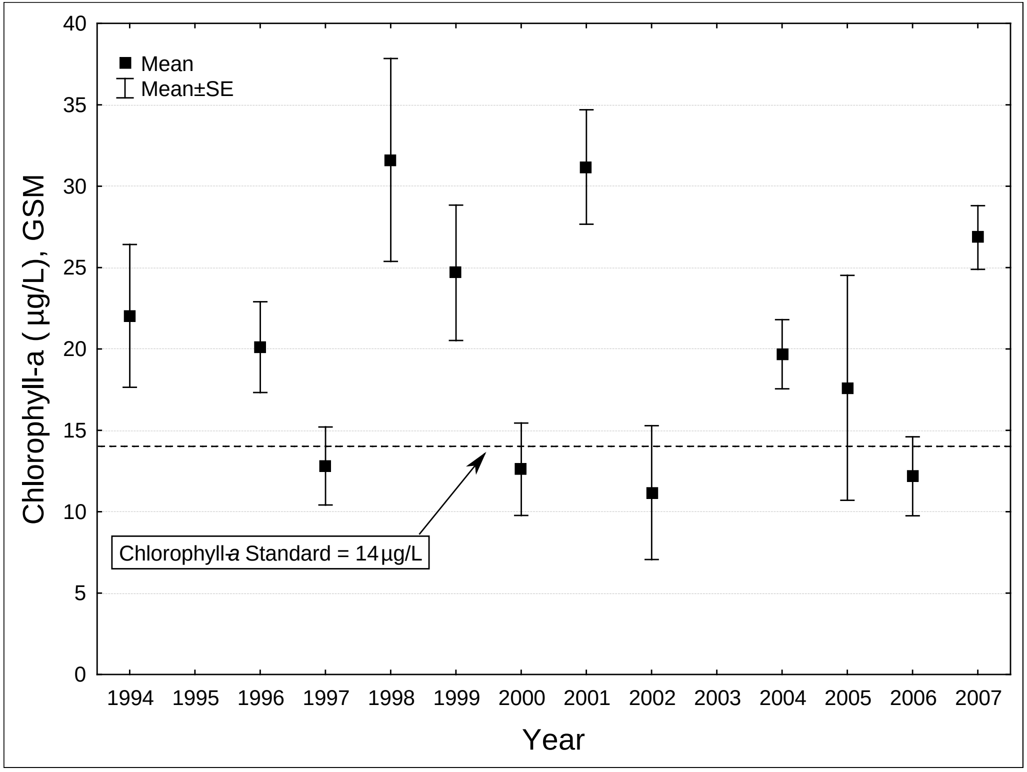


Figure 66. Secchi Depth Monitoring Data, Pelican Lake

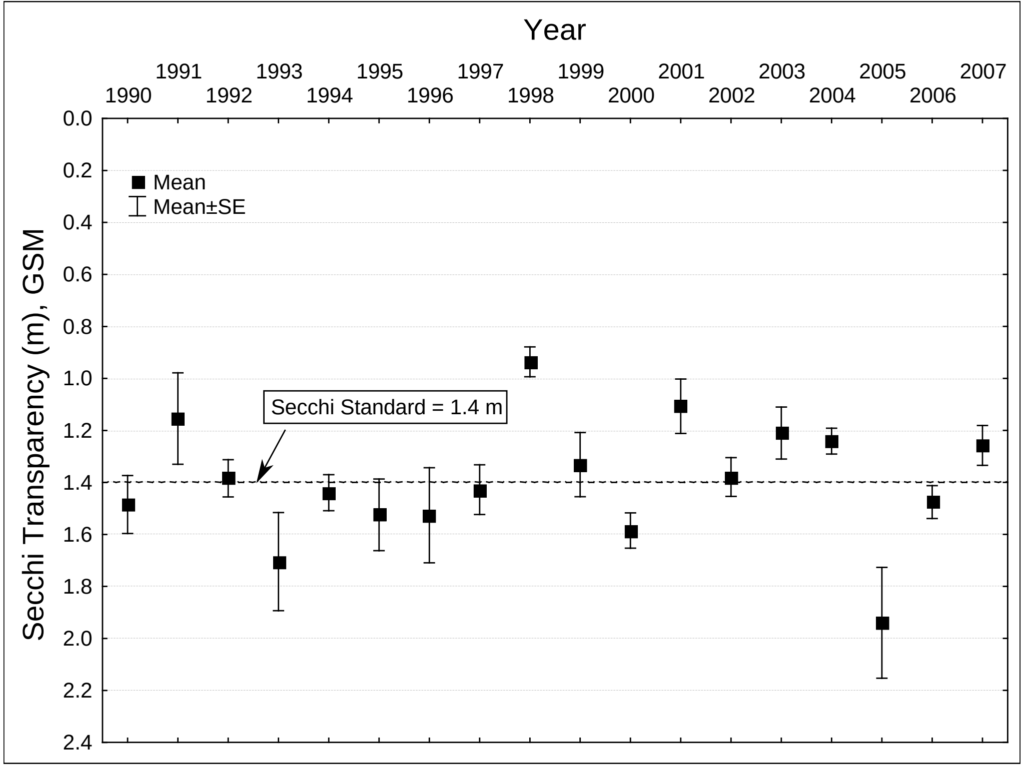


Figure 67. Pelican Lake Seasonal Transparency Patterns, 1998 to 2007

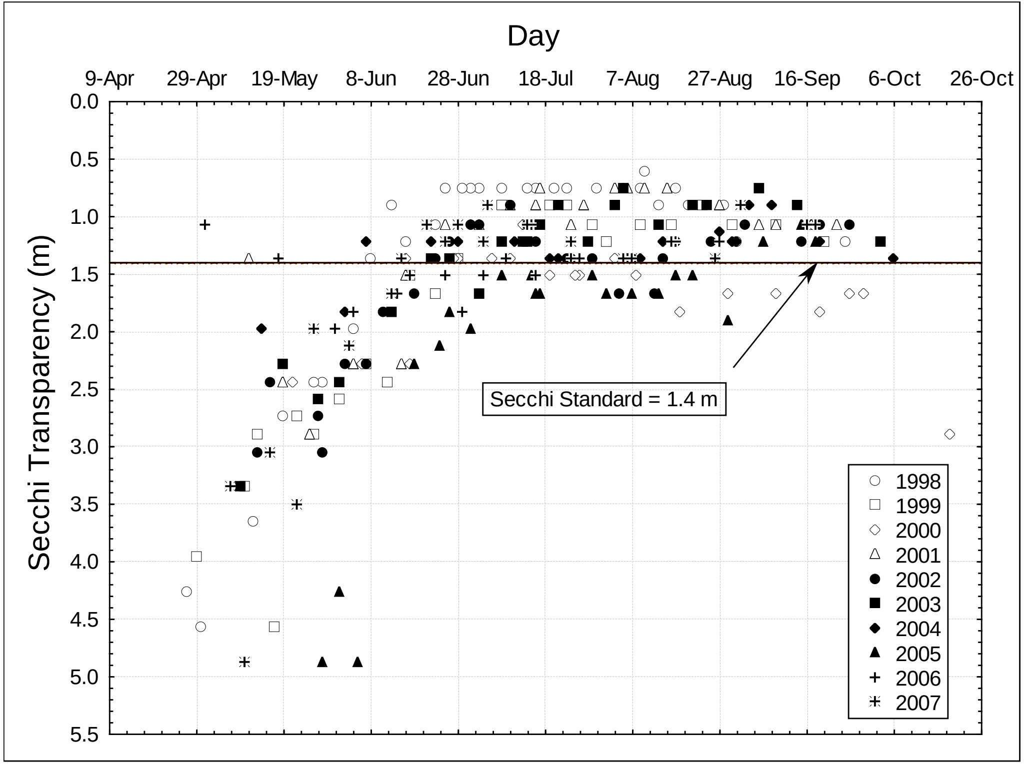


Figure 68. Relationship of Chlorophyll-*a* to TP in Pelican Lake, 1998 to 2007

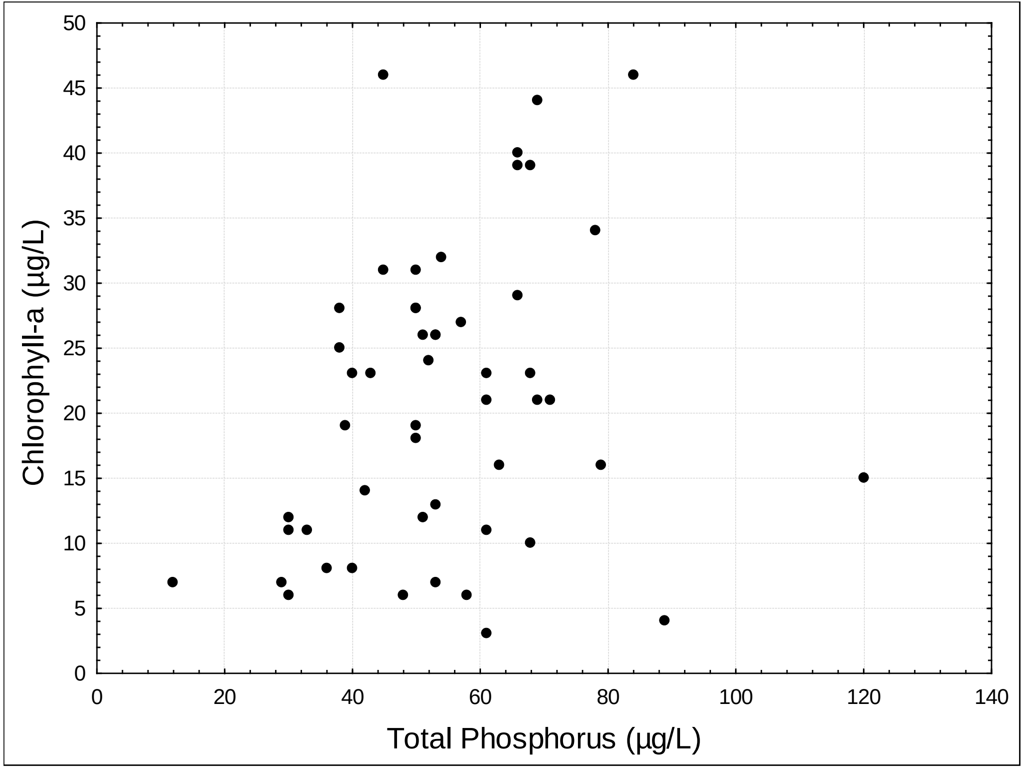


Figure 69. Relationship of Secchi Depth to TP in Pelican Lake, 1998 to 2007

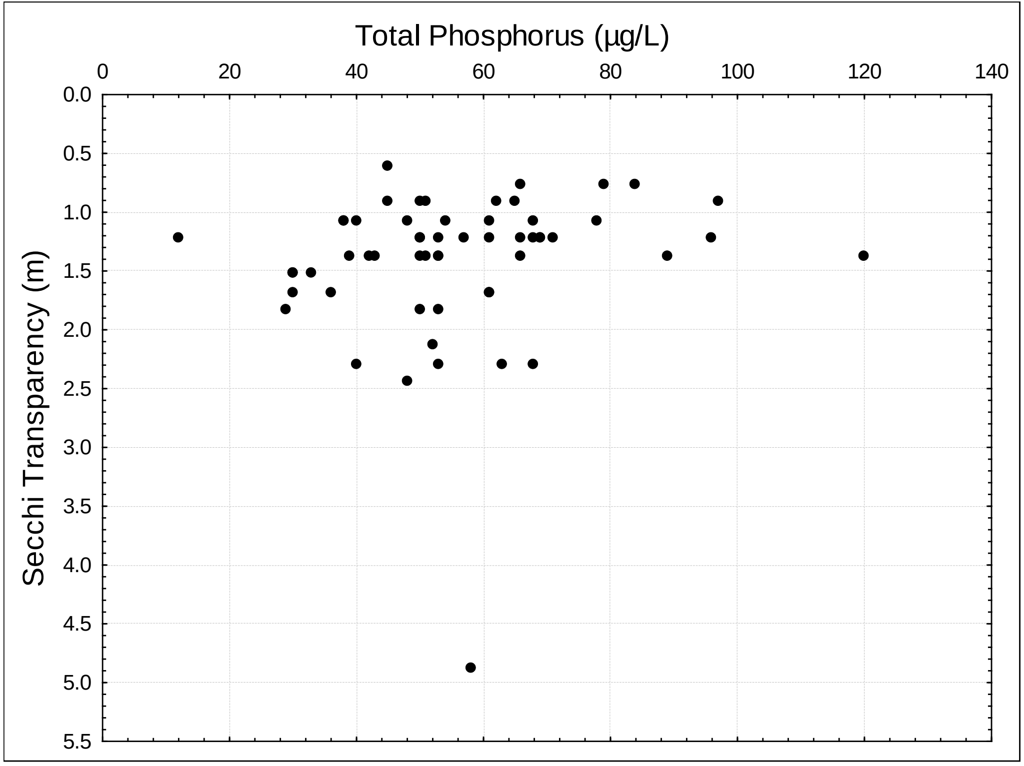


Figure 70. Relationship of Secchi Depth to Chlorophyll-*a* in Pelican Lake, 1998 to 2007

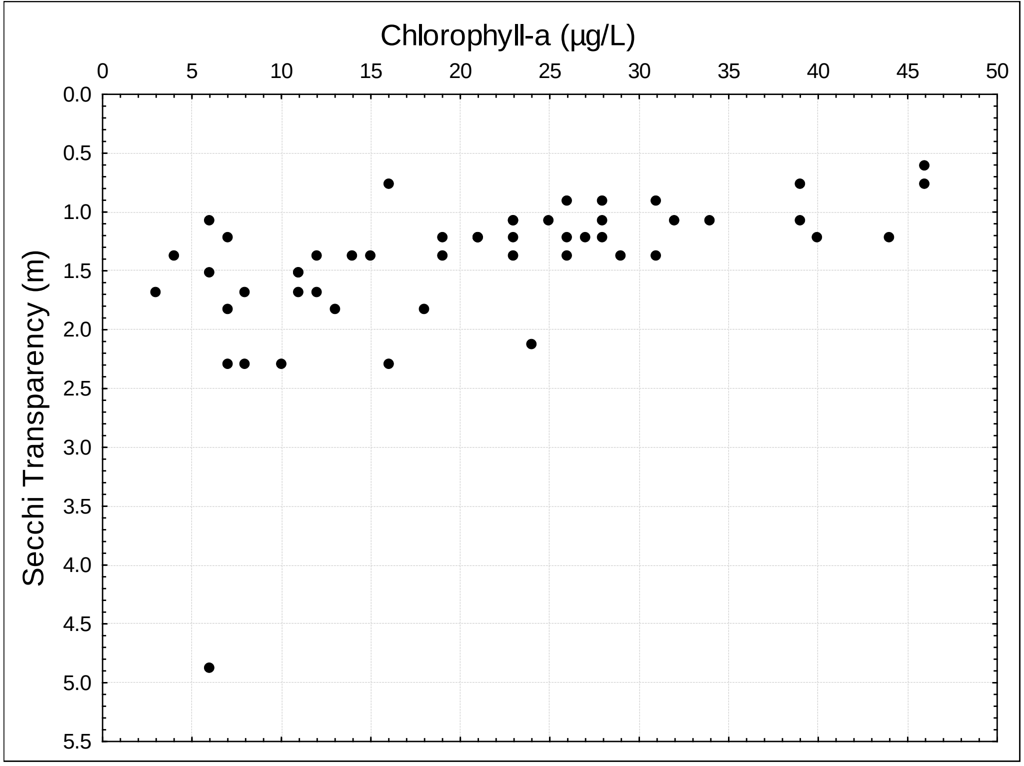


Figure 71. Pelican Lake Temperature and DO, 1996

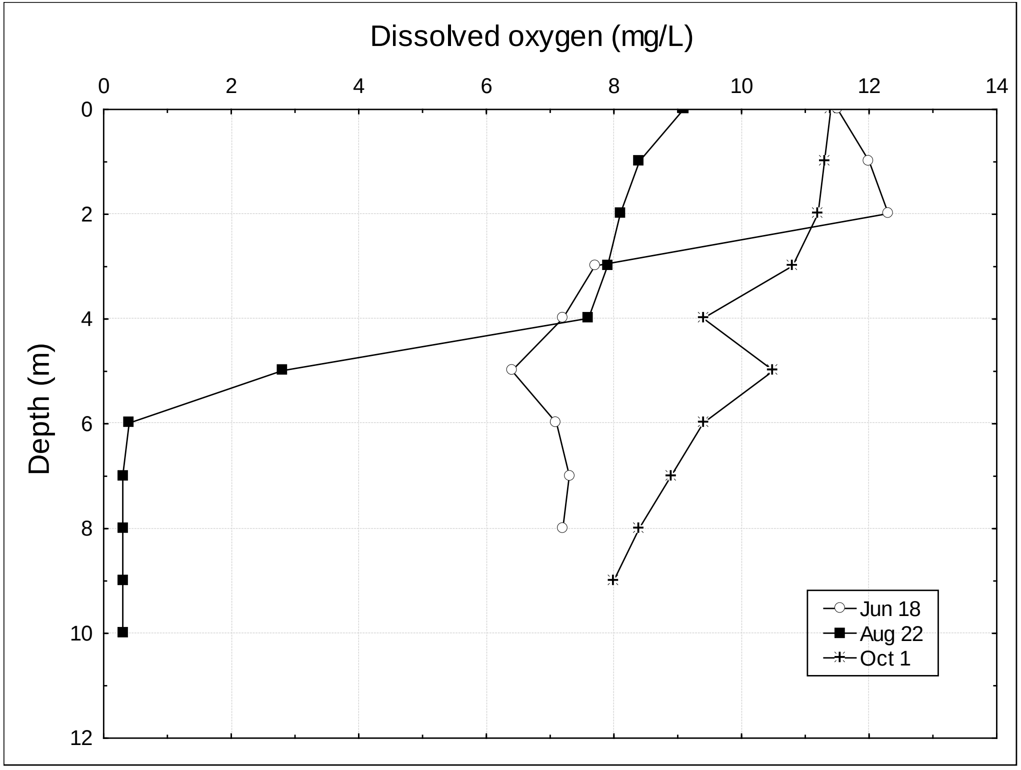
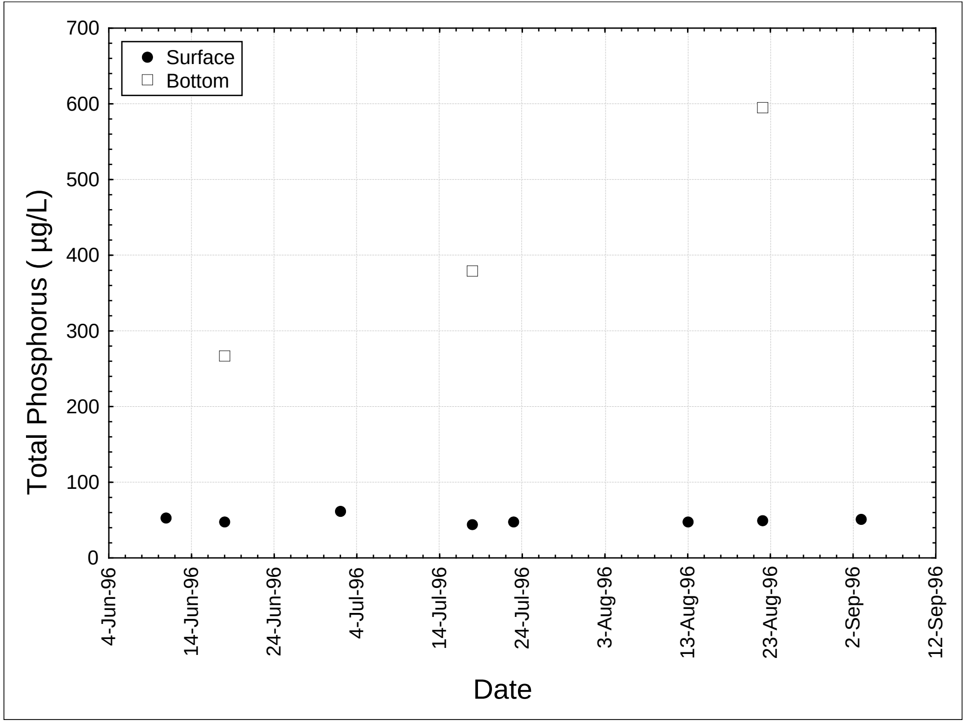


Figure 72. Pelican Lake Surface vs. Bottom TP, 1996



9.2 Phosphorus Source Assessment

The Pelican Lake Watershed (19,720 acres) includes the direct drainage area to the lake (7,811 acres) and the drainage area to Strandness Lake and the lake itself (11,909 acres), which includes Lake Malmedal. It is estimated that Pelican Lake receives 2,580 lbs of phosphorus annually from external sources within the entire watershed. The majority of the external phosphorus to Pelican Lake is coming from runoff from the direct drainage area and the loading from Strandness Lake (Figure 73, Table 57). Internal loading accounts for an additional 264 to 1,453 lbs/year of TP loading to the lake.

Figure 73. Pelican Lake Phosphorus Inventory

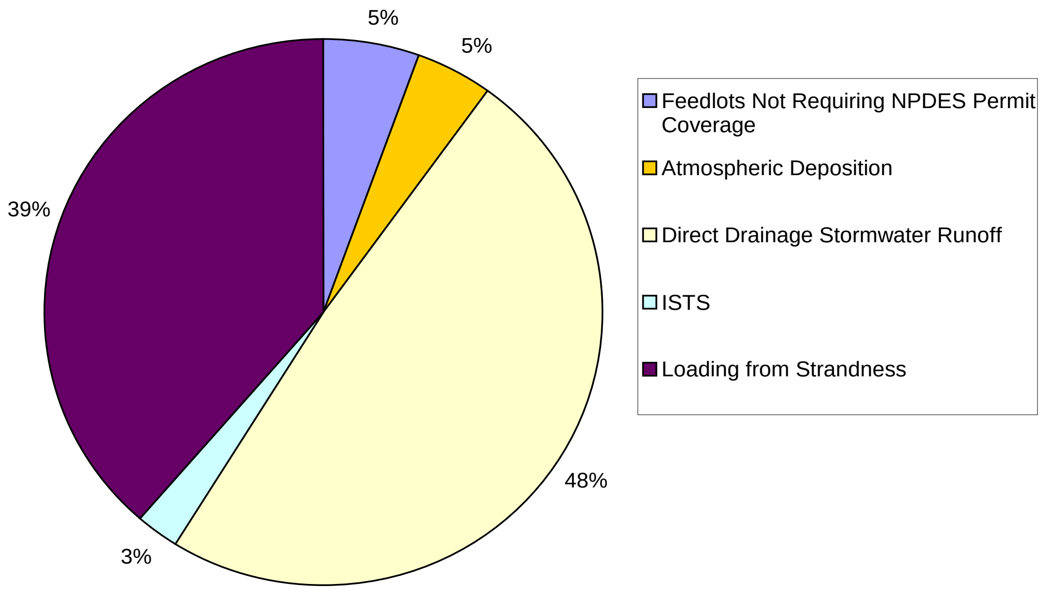


Table 57. Pelican Lake Phosphorus Source Summary

Phosphorus Source	Annual TP Load [lbs/yr]
Direct Drainage Stormwater Runoff	1,257
Feedlots Not Requiring NPDES Permit Coverage	140
Atmospheric Deposition	119
SSTS	70
Loading from Strandness Lake	994
Total	**2,580**

9.2.1 Sources of Phosphorus Requiring NPDES Permit Coverage

Municipal and Industrial Wastewater Treatment Systems

One permitted WWTF is located within the Pelican Lake Watershed and discharges treated wastewater from the city of Lowry. The average annual load of TP from the Lowry WWTF is 37.9 lbs/year (Table 4). In the phosphorus source summary above, the calculated load from the WWTF is not listed but is accounted for in the loading from Strandness Lake.

9.2.2 Sources of Phosphorus Not Requiring NPDES Permit Coverage

Stormwater Runoff

A Simple Method model was used to quantify a TP load of 1,296 lbs/yr coming from the direct drainage area to Pelican Lake. Approximately 39 lbs/yr of phosphorus are removed from runoff due to buffers throughout the watershed.

Loading from Upstream Waters

In-lake data collected in Strandness were used to determine an average annual TP load (between 1998 and 2007) of 994 lbs/yr contributing to Pelican Lake from the Strandness Lake Watershed.

Feedlots Not Requiring NPDES Permit Coverage

Within the Pelican Lake Watershed there are 14 registered feedlots under 1,000 AUs in size, all of which are labeled as open lots. The feedlots house a total of 1139.7 AUs consisting mainly of beef and dairy cattle (Table 58). The estimated TP load coming from registered feedlots within the Pelican Lake Watershed under average flow conditions is 139.9 lbs/yr. Additional feedlots exist within the Strandness Watershed and are accounted for in the loading from Strandness.

Table 58. Phosphorus Contributing to Pelican Lake from Open Lot Feedlots Not Requiring NPDES Permit Coverage

Animal	Animal Units	Phosphorus contributing to surface waters during average flow year (lbs/yr)
Beef	706.6	87.8
Dairy	414.1	51.6
Horse	13.0	0.5
Total	**1,139.7**	**139.9**

Atmospheric Deposition

The TP atmospheric deposition to Pelican Lake is 119 lbs/yr (Table 59).

Table 59. Pelican Lake Wet and Dry Atmospheric Deposition

Source	Phosphorus Deposition (lbs/yr)
Wet Deposition	85
Dry Deposition	35
Total	**119**

Subsurface Sewage Treatment Systems

There are 72 homes on Pelican Lake that use an SSTS. It is estimated that 25% are failing systems and that 70% are permanent residences. The total estimated TP load from SSTS to Pelican Lake is 69.9 lbs/yr.

9.3 TMDL Loading Capacity and Allocations

The phosphorus loading capacity of Pelican Lake is 1,669 lbs/yr, to be split among allocations according to Table 60. The permitted sources in the Pelican Lake Watershed receive individual WLAs (Table 61). Watershed scale pollutant load modeling was conducted and analyzed on an annual basis to establish this TMDL at a level necessary to attain and maintain applicable water quality standards. Daily WLAs were derived from this analysis. See Section 9.4 for alternative, non-daily, pollutant load expressions recommended for the development of WQBEL based on EPA (2006).

Table 60. Pelican Lake Allocation Summary

Allocation	lbs/yr	lbs/day
TMDL	1,669	4.6
MOS	167	0.46
WLA	141.8	0.39
LA	1,360	3.73

Table 61. Pelican Lake WLAs

Source	Permit #	WLA	
		lbs/yr	lbs/day
Construction stormwater	Various	0.29	0.00079
Industrial stormwater	No current regulated sources	7.5	0.021
Lowry WWTF	MNG580123	134	0.37

9.4 Implementation Strategy

9.4.1 Approach to Lake Restoration

Lake restoration activities can be grouped into two main categories: those practices aimed at reducing external nutrient loads, and those practices aimed at reducing internal loads. The focus of restoration activities depends on the lake's nutrient balance and opportunities for restoration. A reduction of 911 lbs of TP annually is needed to achieve the Pelican Lake TMDL and meet water quality standards.

Pelican Lake is located downstream of Strandness Lake, which is also listed as impaired and part of this multi-lake TMDL (see *Section 11 Strandness TMDL*). Improvements within Strandness will have a positive impact on the water quality of Pelican Lake.

This discussion separates the management strategies into practices addressing point sources, watershed load, and internal load. The total cost for implementation is estimated to be $400,000 to $800,000. Implementation costs do not take into account existing programs and are assumed to be spent over the next 20 to 30 years.

9.4.2 Point Source Reduction Activities

The Lowry WWTF is currently in the process of upgrading their facility. The new facility will improve treatment capacity and eliminate many issues with the previous system including stormwater inflows. No phosphorus reductions are planned for the Lowry WWTF.

Although the TMDLs individual WLAs are expressed in terms of both daily (lbs/day) and annual (lbs/yr) loads, for implementation purposes, WQBELs developed for NPDES Permits do not necessarily have to be expressed in terms of a daily limit (EPA 2006). WQBELs should be consistent with the time increment assumptions upon which the TMDL was established. Additional considerations for the development of permit limits include the type of facility, the nature and frequency of the discharge and compatibility with any other applicable effluent limits.

9.4.3 Watershed Load Reduction Activities

Overall watershed loadings will be reduced through a variety of mechanisms including expansion of existing programs to encourage and promote agricultural BMPs such as conservation tillage, alternative tile inlets, livestock exclusion along Trapper's Run Creek, and buffers. Wetland restoration can also be used to provide water quality treatment in the watershed.

Improvements to the water quality in Strandness Lake upstream of Pelican will result in better water quality within Pelican. Additional analysis for Pelican Lake determined that when Strandness water quality is set to the water quality standard (60 µg/L TP), with no other reductions, the in-lake TP concentration of Pelican Lake would be reduced to 47 µg/L. Achieving the TMDL for Strandness will be important to achieving the TMDL for Pelican Lake. In addition, improvement and protection strategies for other upstream lakes including Wallin (Wollen), John, Troen, and White Star (Star) should also be implemented.

The high level of developed lakeshore around Pelican Lake can contribute nutrients to the lake. Educational campaigns directed at lakeshore property owners should focus on the benefit of natural buffers, fertilizer use, and yard waste disposal. The county land use controls govern application of commercial fertilizer near waterbodies, in most cases a 200-foot separation from the lake is required. A buffer survey of the lakeshore would provide focus to this educational campaign by identifying the most likely areas of nutrient runoff to the lake. As properties are developed in the future, additional restrictions could be considered to further prevent manipulations to the natural shoreline. Restoration of shorelines to natural conditions would contribute to improved water quality.

Resources should be focused on upgrading existing septic systems to comply with current regulations. Community wastewater facilities or larger scale decentralized wastewater treatment could be explored. As new homes and cabins are built near the lake, additional restrictions should be considered to place sewage treatment facilities at the greatest distance possible from the lake.

9.4.4 Internal Load Reduction Activities

Reductions in internal loading to Pelican Lake will focus on removal of rough fish and treating in-lake phosphorus concentrations. Fish barriers and commercial harvesting may be needed to manage carp populations.

Chemical treatment of Pelican Lake could also provide water quality improvement in the lake. Aluminum sulfate (alum) is a chemical addition that binds with phosphorus to form a non-toxic precipitate (floc), settling out precipitated phosphorus. This alternative is relatively inexpensive and can provide immediate results. The treatment of Pelican Lake should cover all areas deeper than 20 feet where stratification occurs during the growing season. These are the areas most likely to experience sustained low oxygen concentrations near the sediments, which leads to internal loading.

10 RENO LAKE TMDL

10.1 Lake Assessment

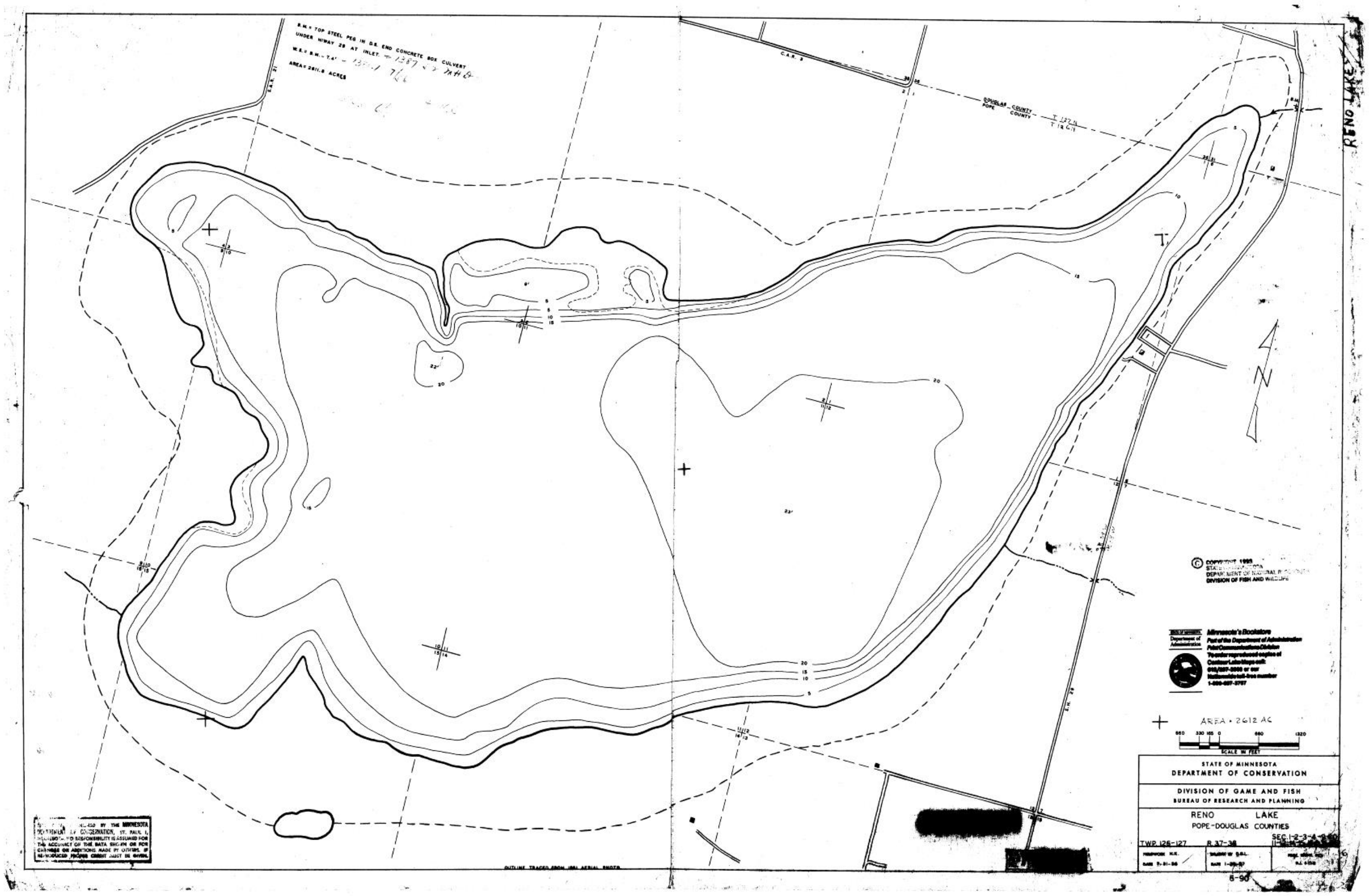
10.1.1 Physical Characteristics

Reno Lake, the largest lake in this study, is located in north-central Pope County with a small portion crossing into Douglas County. Reno is located approximately 10 miles south of the city of Alexandria, Minnesota, the largest city in Douglas County. Reno Lake has a surface area of 3,509 acres (Figure 74 and Table 62) and outlets into Maple Lake to the north. Reno Lake has also been known to periodically receive inflow from Maple Lake, depending on lake elevations. Maple Lake has very good water quality, with a 10-year GSM TP concentration of 17 µg/L. Maple is typically below its runoff elevation so water rarely outlets from Reno and Maple.

Table 62. Reno Lake Characteristics

Characteristic	Value	Source
Lake total surface area (ac)	3,509	MPCA Minnesota Inventory of Impaired Lakes database (July 2008)
Percent lake littoral surface area	34%	DNR Lake Finder
Lake volume (ac-ft)	52,635	Calculated (mean depth x surface area)
Mean depth (ft)	15	COLA (2005)
Maximum depth (ft)	23	DNR Lake Finder
Drainage area (acres)	5,497	DNR Waters Lakesheds (2004)
Watershed area : lake area	2	Calculated

Figure 74. Reno Lake Bathymetry



[redacted]

[redacted]

Land Use

Land use throughout the watershed is primarily agriculture. Urban and residential developed areas make up only 4% of the watershed while 82% of the land is used for cultivated crops and pasture and hay. Approximately 114 homes are on the shores of the lake. Table 63 summarizes the total acres and the percent of the watershed of the different land uses.

Table 63. Reno Lake Watershed Land Use

Land Use	Total Acres	% of Watershed
Barren Land (Rock/Sand/Clay)	0	0%
Cultivated Crops	3,680	67%
Deciduous Forest	319	6%
Developed, High Intensity	0	0%
Developed, Low Intensity	76	1%
Developed, Medium Intensity	0	0%
Developed, Open Space	185	3%
Emergent Herbaceous Wetlands	78	1%
Evergreen Forest	7	0%
Grassland/Herbaceous	31	1%
Mixed Forest	0	0%
Open Water	292	5%
Pasture/Hay	829	15%
Shrub/Scrub	0	0%
Woody Wetlands	0	0%
Total	**5,497**	**100%**

Source: NLCD 2001, USGS.

10.1.2 Biological Characteristics

Fisheries

Reno Lake has two public access sites, one on the southwest shore and one on the northeast tip of the lake. The lake is classified as a recreational development lake by the DNR shoreland management lake classifications. Reno Lake is known for quality walleye and angler fishing and is used for boating, swimming, and other lake recreation. A number of resorts and rental properties with private sandy beaches exist on the shores of Reno, making it a common vacation destination. Reno Lake is stocked with walleye. The gamefish populations have benefited from the slight increase in water and habitat quality with the fishery reverting back to a more diverse fishery (2006 DNR fish survey). Some rough fish are present in Reno Lake but their populations are on the low end of the normal range for similar lakes.

Macrophytes

An aquatic vegetation survey was performed by the DNR in July 1994. This survey listed filamentous algae and narrowleaf cattail as the most common macrophytes. The study concluded that submergent vegetation was dense in limited areas around the lake. The 2006 DNR fish survey discusses how an extended period of high water levels in the mid-1980s greatly reduced the submergent and emergent vegetation abundance and diversity.

In 2009, a macrophyte survey was conducted as part of this TMDL study (Table 64 and Figure 75). The survey was conducted in September and found a healthy population of aquatic macrophytes including both submergents and emergents within the entire littoral area. Submergent plant species were dominated by sago pondweed and also included coontail, muskgrass, bushy pondweed, other native pondweeds, and one incidence of curlyleaf pondweed. Emergents include bulrushes and cattail beds.

Table 64. Plant Species Observed During 2009 Reno Lake Macrophyte Surveys

Scientific Name	Common Name	Fall
Ceratophyllum demersum	Coontail	X
Chara vulgaris	Muskgrass	X
Myriophyllum exalbescens	Northern water milfoil	X
Najas flexilis	Bushy pondweed	X
Potamogeton pectinatus	Sago pondweed	X
Potamogeton richardsonii	Claspingleaf pondweed	X
Potamogeton zosteriformis	Flat-stemmed pondweed	X
Scirpus acutus	Hardstem bulrush	X
Typha sp	Cattails	X
Utricularia macrorhiza	Bladderwort	X

Figure 75. Reno Lake Macrophytes, 2009

10.1.3 Existing Studies and Monitoring

Status and Trend Monitoring Summary for Selected Pope and Douglas County, Minnesota Lakes

In 2000, the MPCA produced the "Status and Trend Monitoring Summary for Selected Pope and Douglas County, Minnesota Lakes." Reno Lake was included in the report. Water quality samples were collected from Reno Lake monthly from June through September of 2000. The lake water quality summer-mean for TP was 49 µg/L, chlorophyll-*a* was 34 µg/L, and Secchi depth was 1.6 meters. The algae community was dominated by blue-green algae throughout the summer leading to nuisance algal blooms and classifying the lake as having "partial support" for swimming use. As part of the study, a MNLEAP model was used to predict the lake's TP, chlorophyll-*a*, and Secchi values. The observed values were higher than the predicted values, suggesting that the loading to the lake is greater than expected just by looking at the lake's area, depth, and watershed size (MPCA 2001a). The report can be found at https://www.pca.state.mn.us/sites/default/files/lar-61-0122.pdf.

10.1.4 Impairment Assessment

Monitoring data are available from as far back as 1991, although there were only a few samples taken per year in the first few years and conclusions should not be drawn from sampling at this low frequency. Sampling frequency increased in 1994. The last 10 years of data were used to calculate the water quality data means (Table 65).

Reno Lake is a eutrophic lake, with similar TSI values for TP and chlorophyll-*a* and a relatively lower TSI for Secchi depth (Table 65). TP concentration growing season means in the years 1994 to 2007 exceeded the standard every year except for four years, with means ranging from 31 µg/L to 93 µg/L (Figure 76). Chlorophyll-*a* concentration growing season means ranged from 6.4 µg/L to 50 µg/L (Figure 77), only exceeding the standard in three of the monitored years. The Secchi depth growing season means ranged from 1.6 m to 3.4 m in 1991 to 2007 (Figure 78), meeting standard in all years, and meeting the overall standard with a 10-year mean of 2.3 m (Table 65).

Water quality generally worsens throughout the growing season (Figure 79). There is a positive relationship between TP and chlorophyll-*a* (Figure 80), and weaker positive relationships between TP and Secchi depth (Figure 81) and between chlorophyll-*a* and Secchi depth (Figure 82).

Water quality sampling and DO depth profiles were taken at the deepest point in Reno Lake. The DO depth profile from 2000 indicates only one date when the DO was lower in the bottom of the lake (Figure 83). However, it did not reach anoxic conditions, and therefore anoxic release of phosphorus is likely not a substantial source of internal loading in the lake. Due to the large fetch of Reno Lake and its shallow depth, internal loading due to wind mixing may be a source of phosphorus to the lake.

Table 65. Surface Water Quality Means, Reno Lake, 1998 to 2007

Parameter	Growing Season Mean (June – September)	Trophic Status Index	NCHF Lakes Standard
TP	52 µg/L	62	< 40 µg/L
Chlorophyll-*a*	17 µg/L	59	< 14 µg/L
Secchi depth	2.3 m	47	> 1.4 m

Figure 76. TP Monitoring Data, Reno Lake

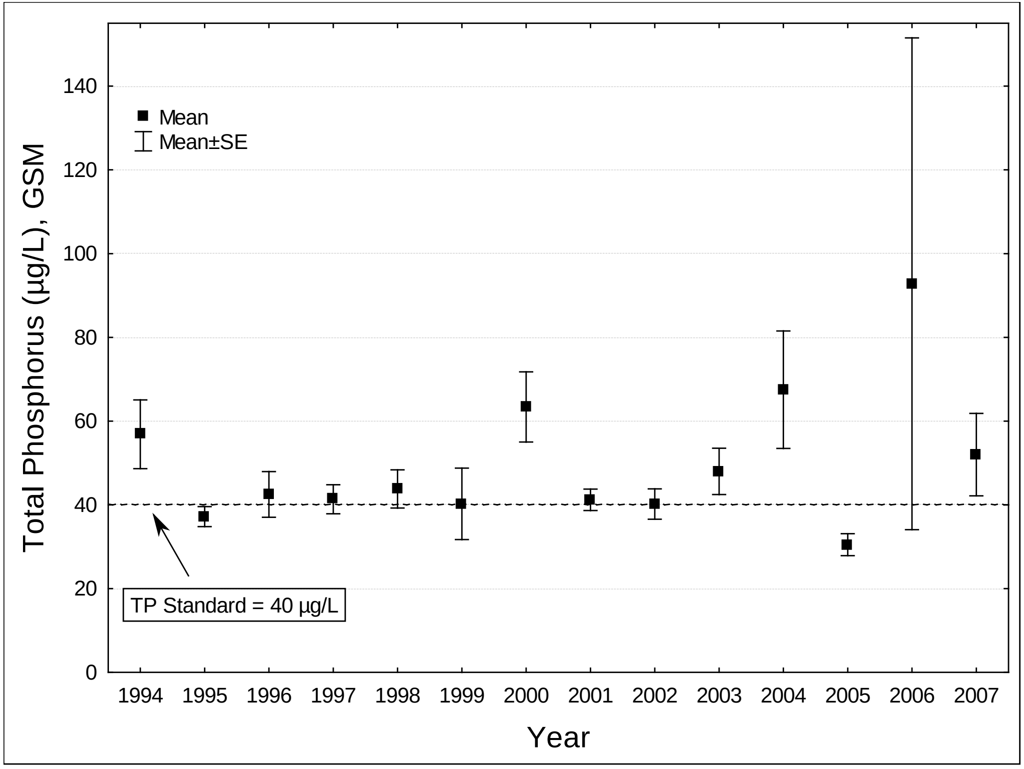


Figure 77. Mean Chlorophyll-*a* Monitoring Data, Reno Lake

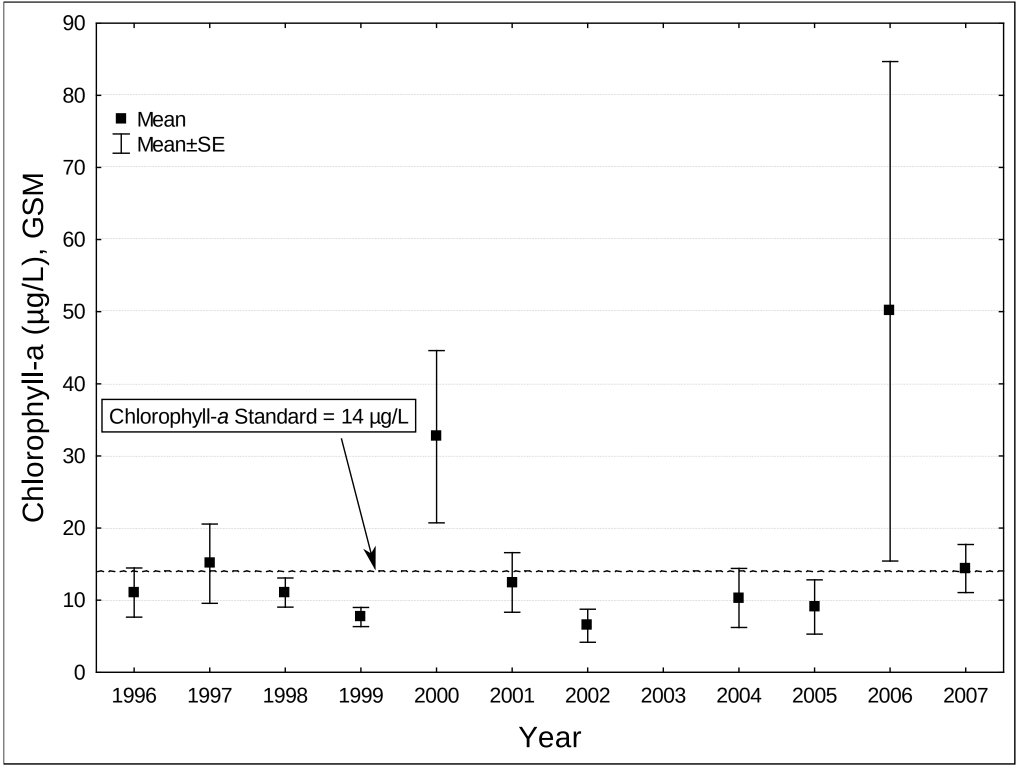


Figure 78. Secchi Depth Monitoring Data, Reno Lake

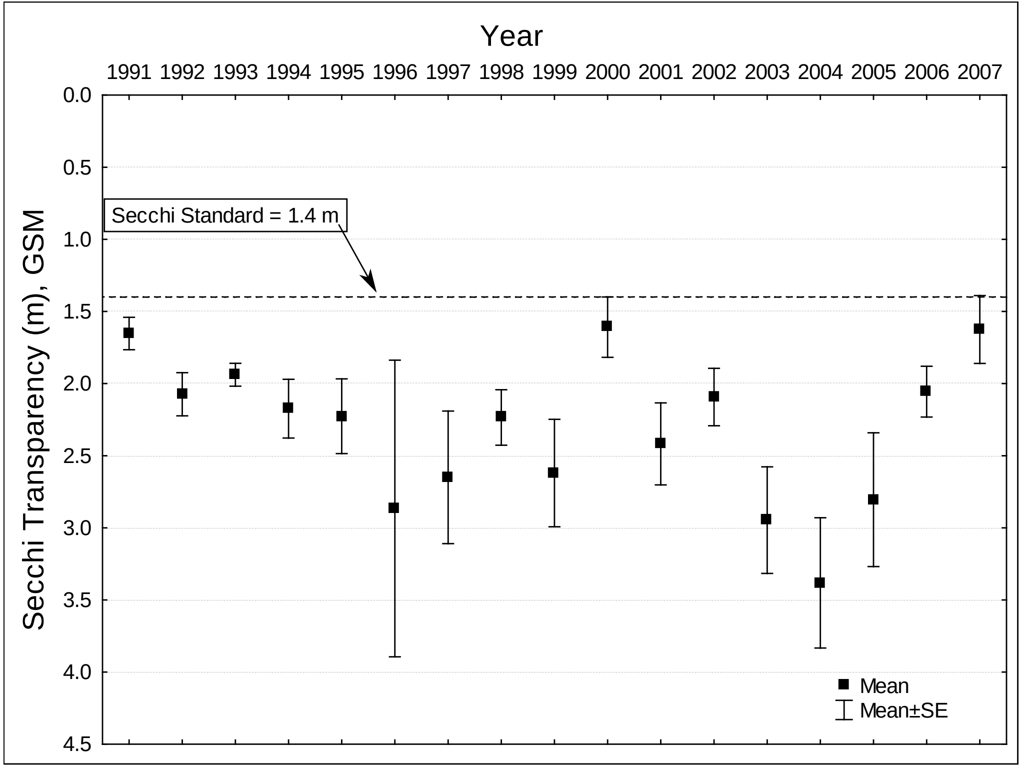


Figure 79. Reno Lake Seasonal Chlorophyll-*a* Patterns, 1998 to 2007

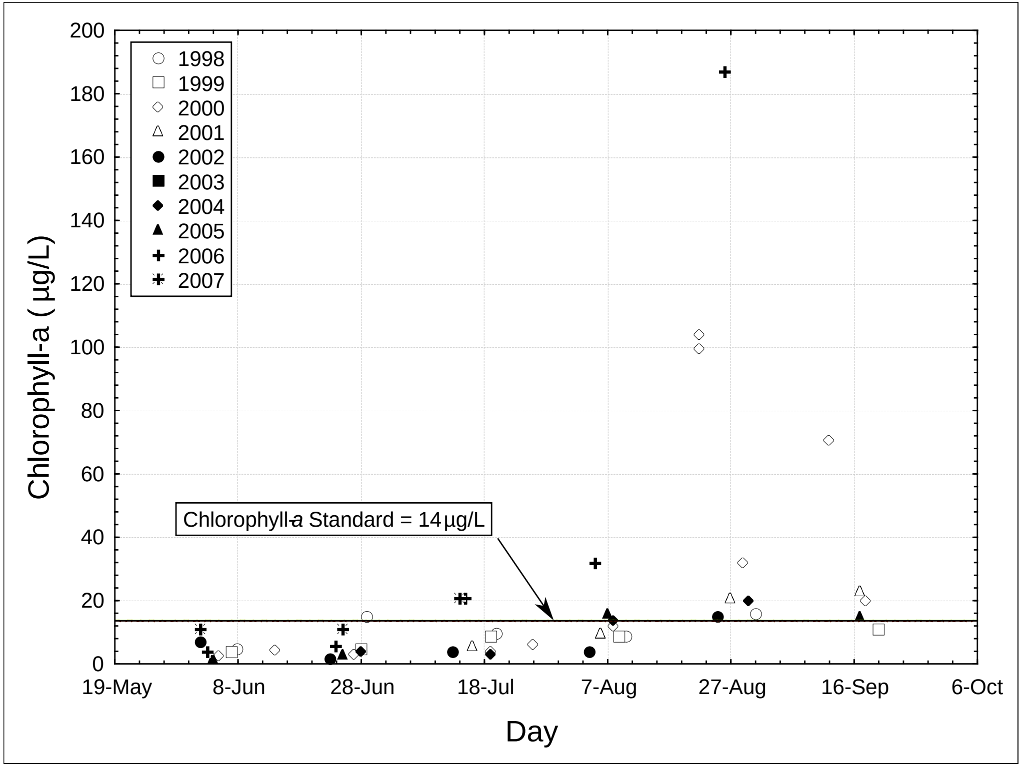


Figure 80. Relationship of Chlorophyll-*a* to TP in Reno Lake, 1998 to 2007

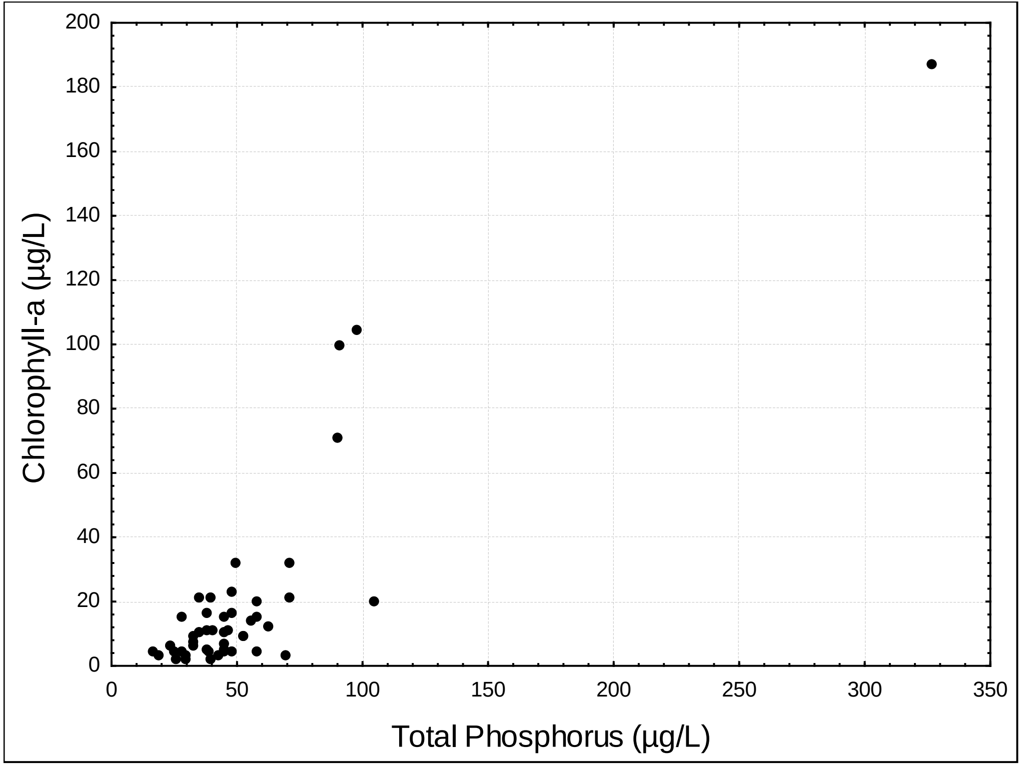


Figure 81. Relationship of Secchi Depth to TP in Reno Lake, 1998 to 2007

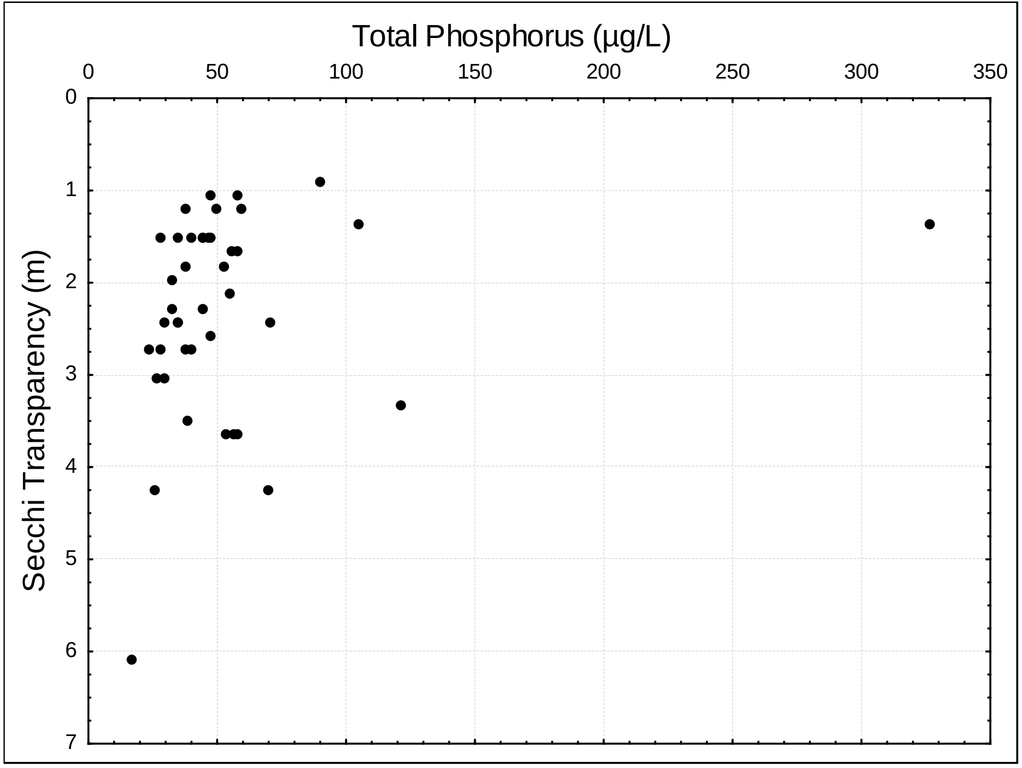


Figure 82. Relationship of Secchi Depth to Chlorophyll-*a* in Reno Lake, 1998 to 2007

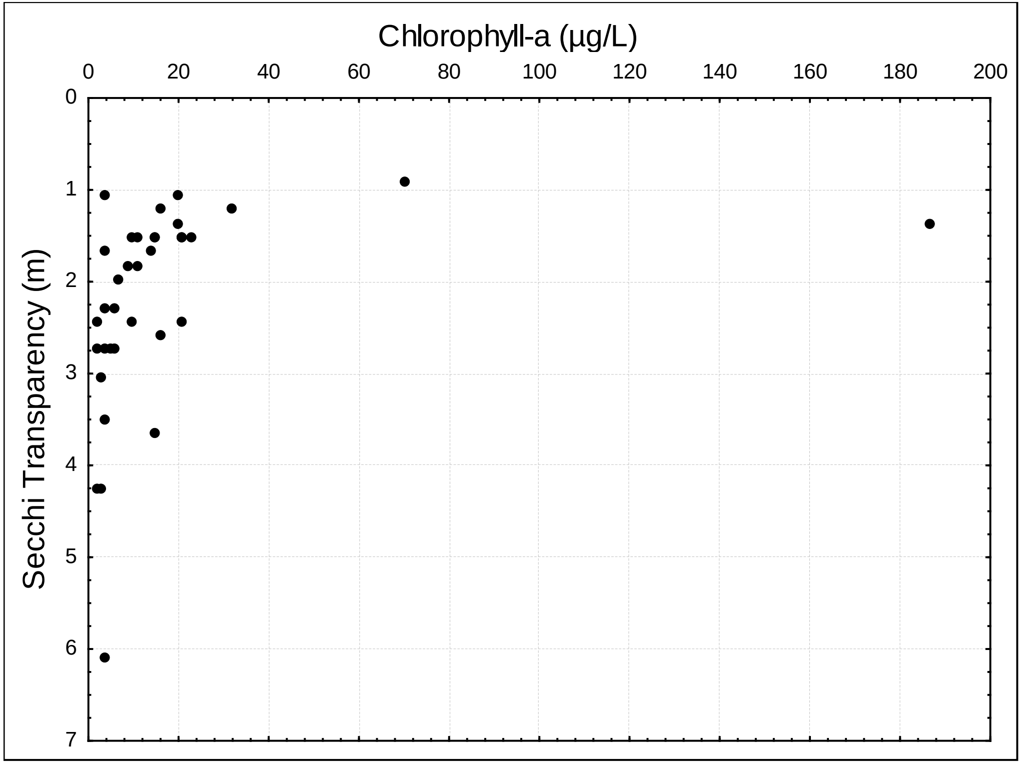
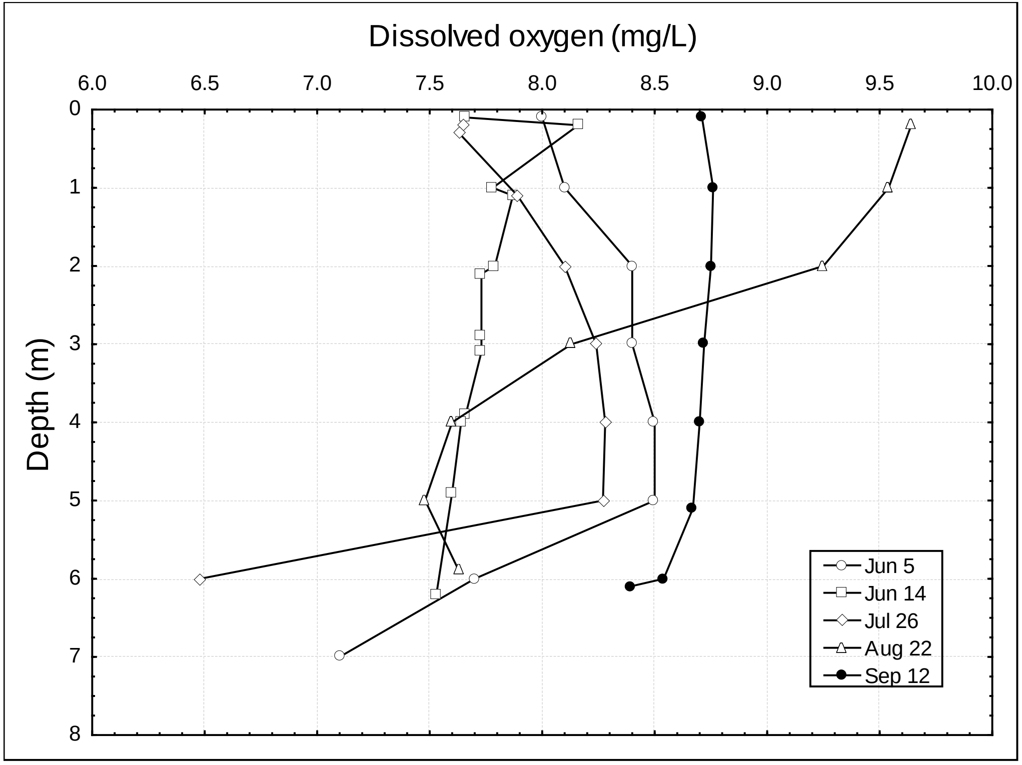


Figure 83. Reno Lake Temperature and DO, 2000



10.2 Phosphorus Source Assessment

It is estimated that Reno Lake receives 2,064 lbs of phosphorus annually from external sources. The majority of the external phosphorus to Reno Lake is coming from the watershed and atmospheric deposition (Figure 84, Table 67). Internal loading accounts for an additional 1,209 to 12,883 lbs/year of loading to the lake.

Figure 84. Reno Lake Phosphorus Inventory

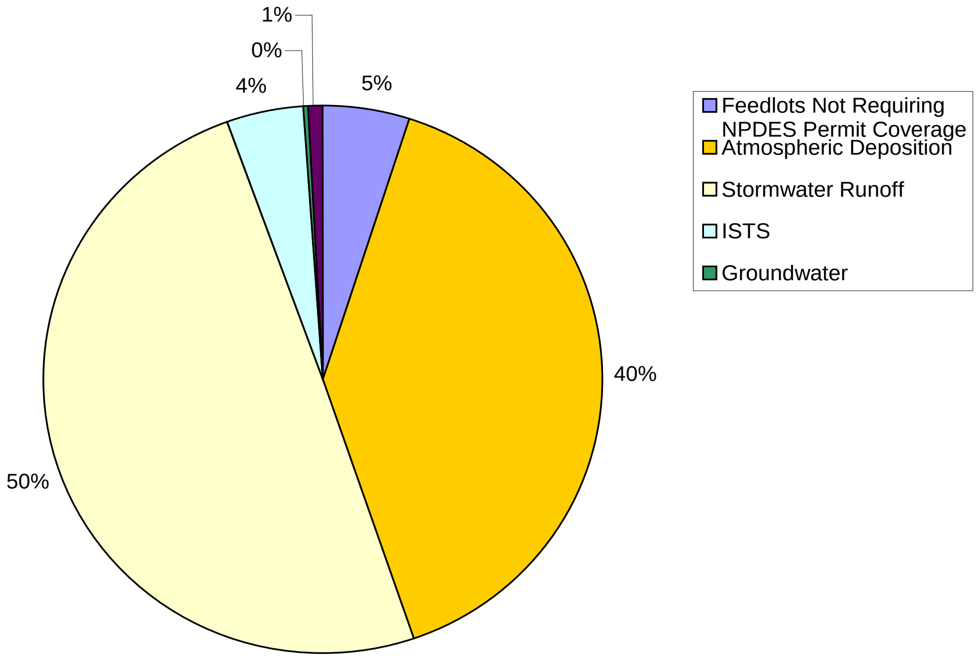


Table 66. Reno Lake Phosphorus Source Summary

Phosphorus Source	Annual TP Load [lbs/yr]
Stormwater Runoff	1,023
Feedlots Not Requiring NPDES Permit Coverage	106
Atmospheric Deposition	818
SSTS	92
Groundwater	10.1
Loading from Maple	15
Total	**2,064.2**

10.2.1 Sources of Phosphorus Requiring NPDES Permit Coverage

Feedlots

From 2003 to 2008, there was one NPDES Permitted feedlot within the TMDL study area: Blair Farms Inc. (Permit #MN0066273) located within the Ann Lake and Reno Lake Watersheds.

10.2.2 Sources of Phosphorus Not Requiring NPDES Permit Coverage

Stormwater Runoff

The entire drainage area to Reno Lake (5,497 acres) was modeled using the Simple Method. A total of 1,055 lbs of phosphorus per year are generated by stormwater runoff. Approximately 32 lbs of phosphorus per year are removed from runoff due to buffers throughout the watershed.

Loading from Upstream Waters

While constructing the in-lake response model for Reno Lake, it was determined that additional runoff or groundwater was entering the lake. After accounting for groundwater inputs (see *Groundwater* below), the remaining water was assumed to be coming from Maple Lake. The in-lake data collected in Maple Lake was used to determine an average annual TP load (between 1998 and 2007) of 15 lbs/yr contributing to Reno Lake from Maple Lake.

Feedlots Not Requiring NPDES Permit Coverage

Within the Reno Lake Watershed there are eight registered feedlots under 1,000 AUs in size and labeled as open lot feedlots. The feedlots house a total of 872.30 AUs consisting of mainly beef and dairy cattle. The estimated TP load coming from the feedlots within the watershed under average flow conditions is approximately 105.97 lbs/yr (Table 67).

Table 67. Phosphorus Contributing to Reno Lake from Open Lot Feedlots Not Requiring NPDES Permit Coverage

Animal	Animal Units	Phosphorus contributing to surface waters during average flow year (lbs/yr)
Beef	365.20	45.37
Dairy	477.10	59.43
Horse	30.00	1.17
Total	**872.30**	**105.97**

Atmospheric Deposition

The TP load from atmospheric deposition is 818 lbs/yr (Table 68).

Table 68. Reno Lake Wet and Dry Atmospheric Deposition

Source	Phosphorus Deposition (lbs/yr)
Wet Deposition	580
Dry Deposition	238
Total	**818**

Subsurface Sewage Treatment Systems

There are 114 houses on Reno Lake that use an SSTS. Of these systems, it is estimated that 25% are failing and 50% are permanent residences. The remaining 50% are seasonal residences used on average during approximately four months out of the year. The total estimated TP load from SSTS to Reno Lake is 92 lbs/yr.

Groundwater

While constructing the in-lake response model for Reno Lake, it was determined that additional runoff or groundwater was entering the lake. The groundwater analysis was used as described in the *Section 3: Methods* to account for 10.1 lbs/yr of TP from the groundwater system to Reno Lake.

10.3 TMDL Loading Capacity and Allocations

The phosphorus loading capacity of Reno Lake is 1,319 lbs/yr, to be split among allocations according to Table 69. The permitted sources in the Reno Lake Watershed receive individual WLAs (Table 70).

Table 69. Reno Lake Allocation Summary

Allocation	lbs/yr	lbs/day
TMDL	1,319	3.6
MOS	132	0.36
WLA	6.1	0.017
LA	1,181	3.2

Table 70. Reno Lake WLAs

Source	Permit #	WLA	
		lbs/yr	lbs/day
Construction stormwater	Various	0.23	0.00063
Industrial stormwater	No current regulated sources	5.9	0.016
Blair Farms Inc.	MN0066273	0	0

10.4 Implementation Strategy

10.4.1 Approach to Lake Restoration

Lake restoration activities can be grouped into two main categories: those practices aimed at reducing external nutrient loads, and those practices aimed at reducing internal loads. The focus of restoration activities depends on the lake's nutrient balance and opportunities for restoration. A reduction of 744 lbs of TP annually is needed to achieve the Reno Lake TMDL and meet water quality standards.

Reno Lake is influenced by a very small watershed and an uncertain connection to Maple Lake. Due to the size of the lake, atmospheric loading contributes a significant portion (62%) of the allowable TP load to the lake under the TMDL scenario. Due to the fact that atmospheric loading cannot be controlled or reduced, efforts will need to be focused on reducing inputs from the remaining sources to the extent practical.

This discussion separates the management strategies into practices addressing watershed load and internal load. The total cost for implementation is estimated to be $400,000 to $800,000. Implementation costs do not take into account existing programs and are assumed to be spent over the next 20 to 30 years.

10.4.2 Watershed Load Reduction Activities

Overall watershed loadings will be reduced through a variety of mechanisms including expansion of existing programs to encourage and promote agricultural BMPs such as conservation tillage, alternative tile inlets, and buffers. Knowing the locations of drain tile inlets and outlets can also serve to identify focused implementation activities.

Enhanced feedlot BMPs and nutrient management plans will need to be developed and implemented. Due to the small size of the watershed, nutrient management plans should be developed for all of the farms within the watershed. In addition, BMPs such as sediment and water control basins should be used to treat runoff entering the lake. Wetland, ditch, and stream restoration can also be used to provide water quality treatment in the watershed.

The existing sewage treatment facilities on the lake should be inspected and evaluated to determine where upgrades are needed. Community wastewater facilities or larger scale decentralized wastewater treatment could be explored. As new homes and cabins are built near the lake, additional restrictions should be considered to place sewage treatment facilities at the greatest distance from the lake.

The high level of developed lakeshore around Reno can contribute nutrients to the lake through improper yard maintenance. Educational campaigns directed at lakeshore property owners should focus on the benefit of natural buffers, fertilizer use, and yard waste disposal. The county land use controls govern application of commercial fertilizer near waterbodies, in most cases a 200-foot separation from the lake is required. A buffer survey of the lakeshore would provide focus to this educational campaign by identifying the most likely areas of nutrient runoff to the lake. As properties are developed in the future, additional restrictions could be considered to further prevent manipulations to the natural shoreline. Restoration of shorelines to natural conditions would contribute to improved water quality.

Protection and improvement to Maple Lake should also be a high priority implementation activity. A review of Maple Lake's water quality indicates declining water quality over the past few years. An emphasis on protecting and improving the water quality in Maple Lake will serve to protect Reno Lake from future degradation. A watershed management plan should be developed and implemented for Maple Lake to ensure no further degradation and protection of this high quality lake.

10.4.3 Internal Load Reduction Activities

Internal loading within Reno Lake is estimated to be significant, due to the size of the lake. Additional monitoring is suggested to better understand the role that phosphorus in the sediments is having on the lake's water quality (see *Section 13 Monitoring Plan*). In-lake activities could include management of curlyleaf pondweed, chemical treatment, and fisheries management.

11 STRANDNESS LAKE TMDL

11.1 Lake Assessment

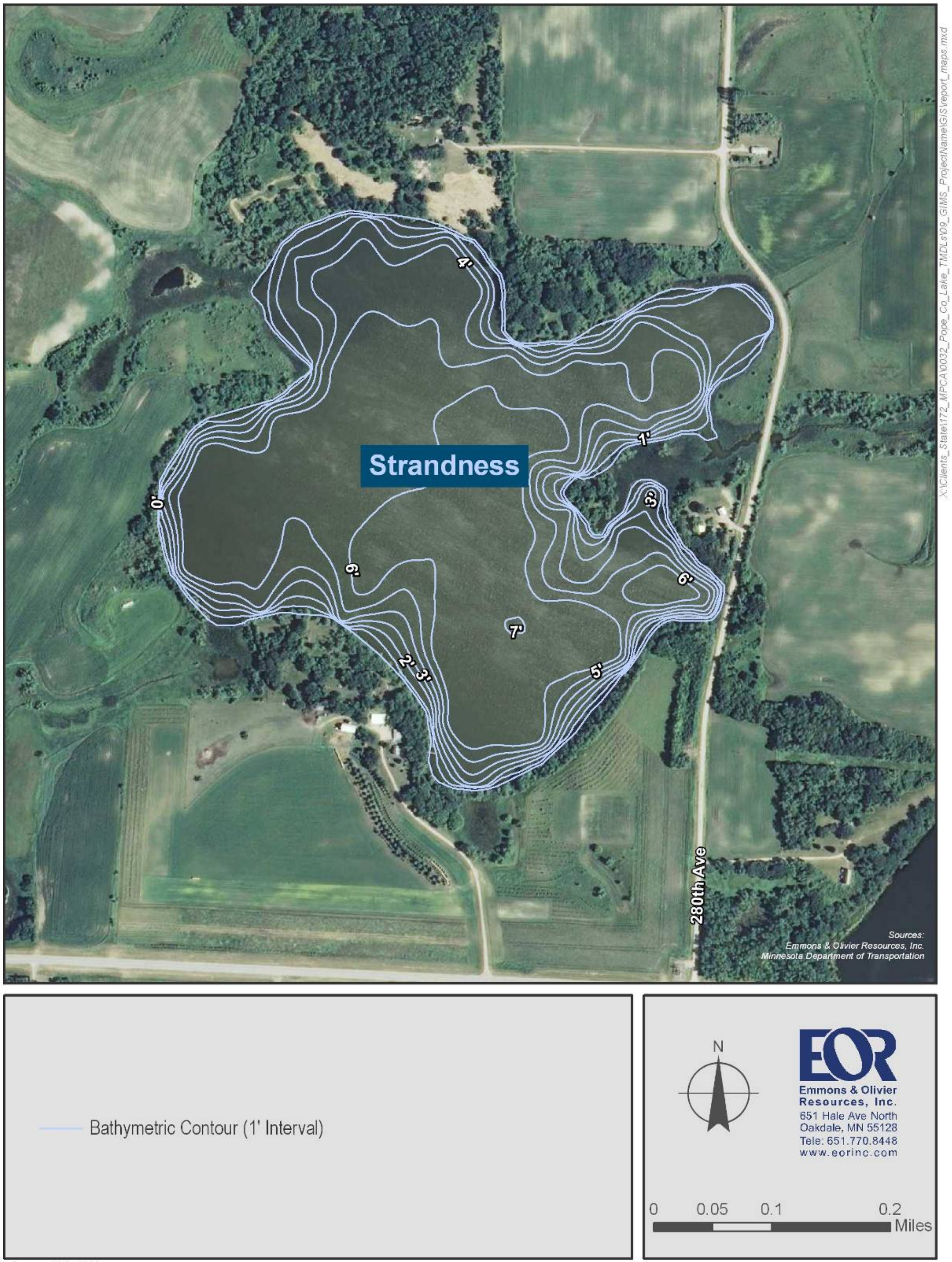
11.1.1 Physical Characteristics

Strandness Lake is located along Trapper's Run Creek in north central Pope County. The creek stretches 6.0 miles, starting at Malmedal Lake, flowing through Strandness and Pelican and discharging at Lake Minnewaska. Strandness Lake is 86 acres in size (Figure 85 and Table 71) and the entire watershed of 11,824 acres is highly tiled as recorded as part of the Trapper's Run Project in 1996. The watershed also contains Peopple's wetland; a 303(d) listed impaired wetland. The lake is 100% littoral (less than 15 feet deep), classifying it as a shallow lake.

Table 71. Strandness Lake Characteristics

Characteristic	Value	Source
Lake total surface area (ac)	86	MPCA Minnesota Inventory of Impaired Waters database (July 2008)
Percent lake littoral surface area	100%	Bathymetry
Lake volume (ac-ft)	402	Calculated (mean depth x surface area)
Mean depth (ft)	5	Bathymetry
Maximum depth (ft)	7	Bathymetry
Drainage area (acres)	11,824	DNR Waters Lakesheds (2004), Pope County (2004a)
Watershed area : lake area	137	Calculated

Figure 85. Strandness Lake Bathymetry



Sources:
Emmons & Olivier Resources, Inc.
Minnesota Department of Transportation

January 19th, 2010

Land Use

Land use throughout the watershed is primarily agriculture with 84% of the land categorized as cultivated crop land and pasture/hay land. There are two homes on the shore of the lake. Table 72 shows the total acres and percent of the watershed for each type of land use.

Table 72. Strandness Lake Watershed Land Use

Land Use	Total Acres	% of Watershed
Barren Land (Rock/Sand/Clay)	0	0%
Cultivated Crops	9,059	77%
Deciduous Forest	245	2%
Developed, High Intensity	1	0%
Developed, Low Intensity	46	0%
Developed, Medium Intensity	0	0%
Developed, Open Space	549	5%
Emergent Herbaceous Wetlands	360	3%
Evergreen Forest	8	0%
Grassland/Herbaceous	139	1%
Mixed Forest	8	0%
Open Water	590	5%
Pasture/Hay	817	7%
Shrub/Scrub	0	0%
Woody Wetlands	2	0%
Total	**11,824**	**100%**

Source: NLCD 2001, USGS.

11.1.2 Biological Characteristics

Fisheries

Strandness Lake is managed as a waterfowl and wildlife lake with no public access by the DNR fisheries department. According to the DNR's shoreland management lake classifications, the lake is a natural environment lake. Strandness Lake's fishery is not currently being managed; no stocking efforts of any kind are being undertaken. In 1995, a fish community assessment was completed on Strandness Lake as part of the Trapper's Run Creek Watershed Water Resource Study. The game fish captured were northern pike, walleye, and pumpkinseed sunfish. Of the six total species captured, none exceeded 4.5-inches in total length except for the northern pike, which was 8.1 inches. The survey also found that black bullheads are present in the lake.

Macrophytes

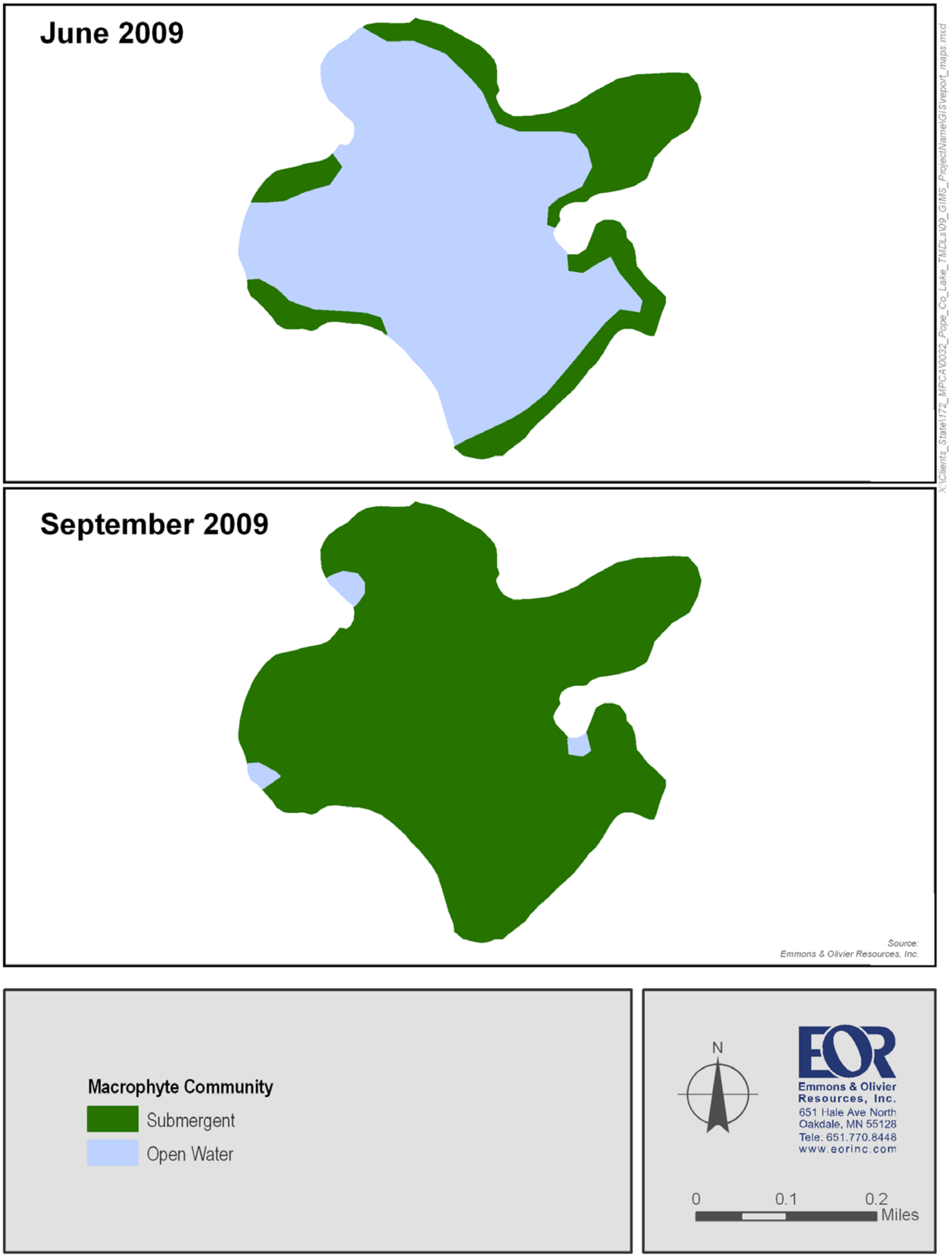
The most current data available on macrophytes within Strandness Lake is from a DNR aquatic plant survey done in July of 1995, as part of the Trapper's Run Creek Watershed Water Resource Study. This survey reported that the dominant plant species were muskgrass and sago pondweed. The report also identified less abundant populations of coontail, filamentous algae, and common cattail.

A macrophyte survey was conducted in 2009, as part of this TMDL study (Table 73 and Figure 86). Summer and fall survey were conducted. In June, the macrophyte community consisted mainly of muskgrass. In the fall, almost the entire lake was covered by a higher diversity of submergent plants. Submergents found in the fall were dominated by muskgrass and naiad, along with sago pondweed and coontail.

Table 73. Plant Species Observed During 2009 Strandness Lake Macrophyte Surveys

Scientific Name	Common Name	Summer	Fall
Chara vulgaris	Muskgrass	X	X
Potamogeton pectinatus	Sago pondweed		X
Najas marina	spiny naiad		X
Ceratophyllum demersum	Coontail		X

Figure 86. Strandness Lake Macrophytes, 2009



June 2009

September 2009

Source:
Emmons & Olivier Resources, Inc.

X:\Clients_State\172_MPCA\0032_Pope_Co_Lake_TMDLs\09_GIMS_ProjectName\GIS\report_maps.mxd

11.1.3 Existing Studies and Monitoring

Trapper's Run Creek Watershed Project

In 1994, a water resources study of Trapper's Run Creek was completed by the DNR to analyze the physical, biological, and chemical characteristics of the creek and identify point and non-point sources of pollution. Lake Minnewaska and Pelican Lake are two of the most aesthetically and economically valuable water resources within Pope County and are directly impacted by the poor water quality draining from Trapper's Run Creek. The study identified high nutrient concentrations, low biodiversity, and low DO levels within the creek.

In 1995, the study continued by looking at the runoff to the creek, collecting additional flow data along the stream, evaluating the status of contributing lakes including Strandness, and starting inventories of the tile systems within the watershed, feedlots, and septic systems. At that time, Strandness Lake was found to be eutrophic with a mean TP concentration of 110.33 µg/L. A fish survey and macrophyte survey were done on Strandness Lake as part of the study; see the *Fisheries* and *Macrophytes* sections above.

The project report published by Pope County Environmental Services in 1996, provided a comprehensive look at all of the inventoried data on the creek and identified goals and objectives to prevent further degradation of the water quality and protect Pelican and Minnewaska. The report identified additional monitoring that could be done, programs to implement, and BMPs that could be used throughout the watershed. The problems within the watershed were diagnosed in 1996, and the largest contributors included feedlot runoff, extensive tiling, non-code septic systems, and fertilizer runoff. The data collected within the subwatersheds of the creek that fall within the Strandness watershed were analyzed and it was concluded that the absence of BMPs, the number of drained wetlands, and the extensive tiling and drainage were the main causes of pollution to the creek in that area.

From 2000 to 2004, with grant assistance from the MPCA, the Trapper's Run Creek Watershed Project implemented programs to identify and upgrade non-compliant feedlots, set-up a manure management planning program, conducted additional water quality monitoring and data assessment on the watershed, and started an incentive based program for septic system upgrades.

Trapper's Run Creek Monitoring 2009

In 2009, additional water quality data were collected along Trapper's Run Creek as part of this TMDL study. Monitoring occurred at three locations along the creek at crossings with County Highway 24, 270th Avenue, and 260th Avenue. An automatic flow station was set up at the 270th Avenue crossing and collected data between July 20, 2009, and October 6, 2009. Water quality grab samples were taken at each of the sites six times during the monitoring season. Results for TP ranged from 0.059 to 0.179 mg/L and TSS concentrations ranged from 2 to 15 mg/L. Data collected as part of this work has been entered into the STORET database.

11.1.4 Impairment Assessment

Monitoring data are available from 1994, and Strandness Lake has had frequent sampling since then. The last 10 years of data were used to calculate the water quality data means (Table 74).

Strandness Lake is a highly eutrophic to hypereutrophic lake, with TSI values for TP in the hypereutrophic range and chlorophyll-*a* and Secchi depth in the eutrophic range (Table 74). The TP growing season means exceeded the standard every year, with concentrations ranging from 71 µg/L to 181 µg/L (Figure 87). Chlorophyll-*a* growing season means ranged from to 9.8 µg/L to 91 µg/L (Figure 88), meeting the standard of 20 µg/L in three of the years monitored. The Secchi depth growing season means ranged from 0.3 m to 1.4 m in 1994 to 2007 (Figure 89), meeting the standard in three of the monitored years.

There are no clear seasonal patterns in water quality, with water quality remaining poor throughout the growing season (Figure 90). In some years transparency is better during June (Figure 91).

There is a positive relationship between TP and chlorophyll-*a* (Figure 92), and weaker negative relationships between TP and Secchi depth (Figure 93) and between chlorophyll-*a* and Secchi depth (Figure 94).

Table 74. Surface Water Quality Means, Strandness Lake, 1998 to 2007

Parameter	Growing Season Mean (June – September)	Trophic Status Index	NCHF Shallow Lakes Standard
TP	114 µg/L	75	< 60 µg/L
Chlor-a	39 µg/L	67	< 20 µg/L
Secchi depth (m)	0.7 m	65	> 1.0 m

Figure 87. TP Monitoring Data, Strandness Lake

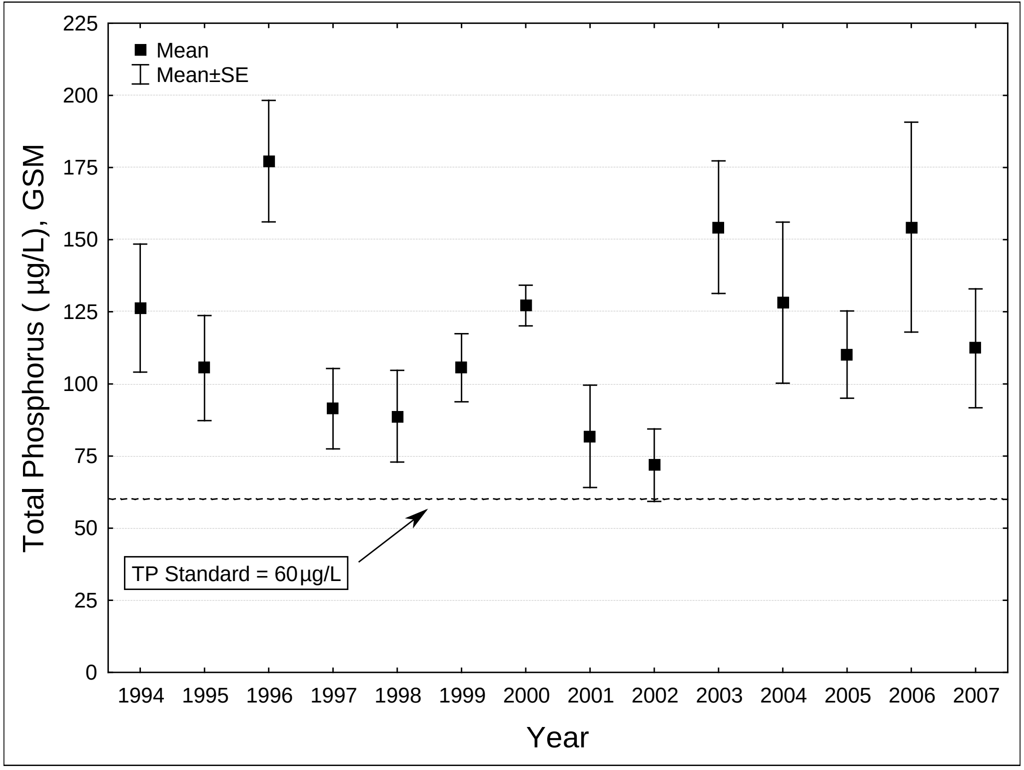


Figure 88. Mean Chlorophyll-*a* Monitoring Data, Strandness Lake

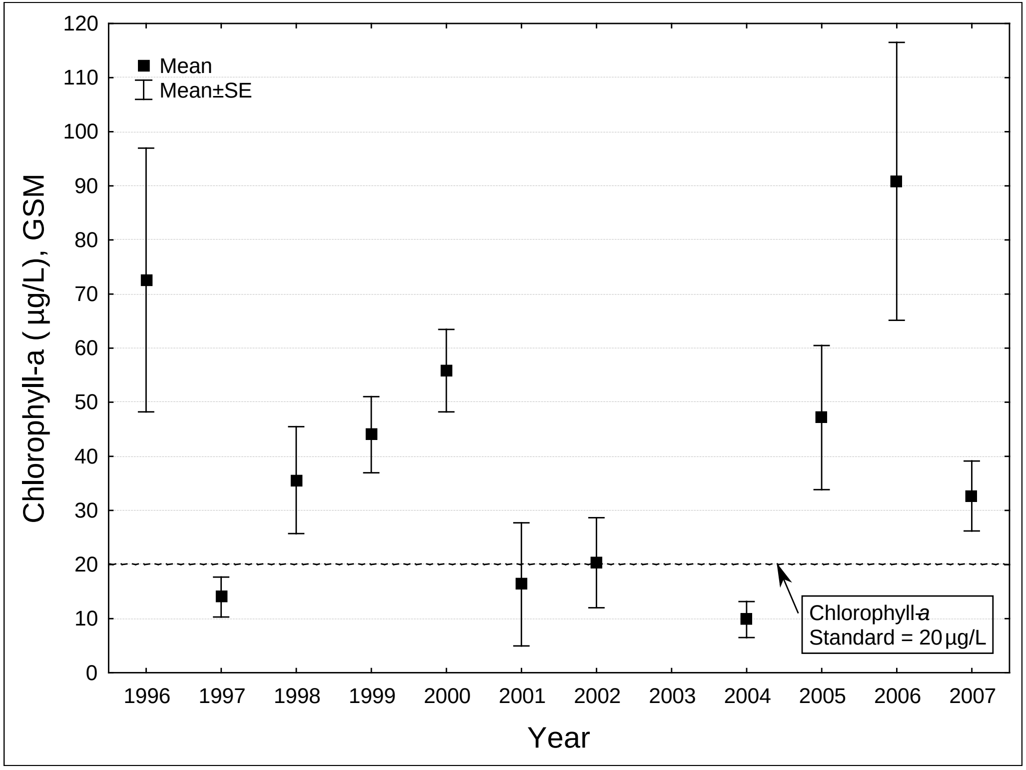


Figure 89. Secchi Depth Monitoring Data, Strandness Lake

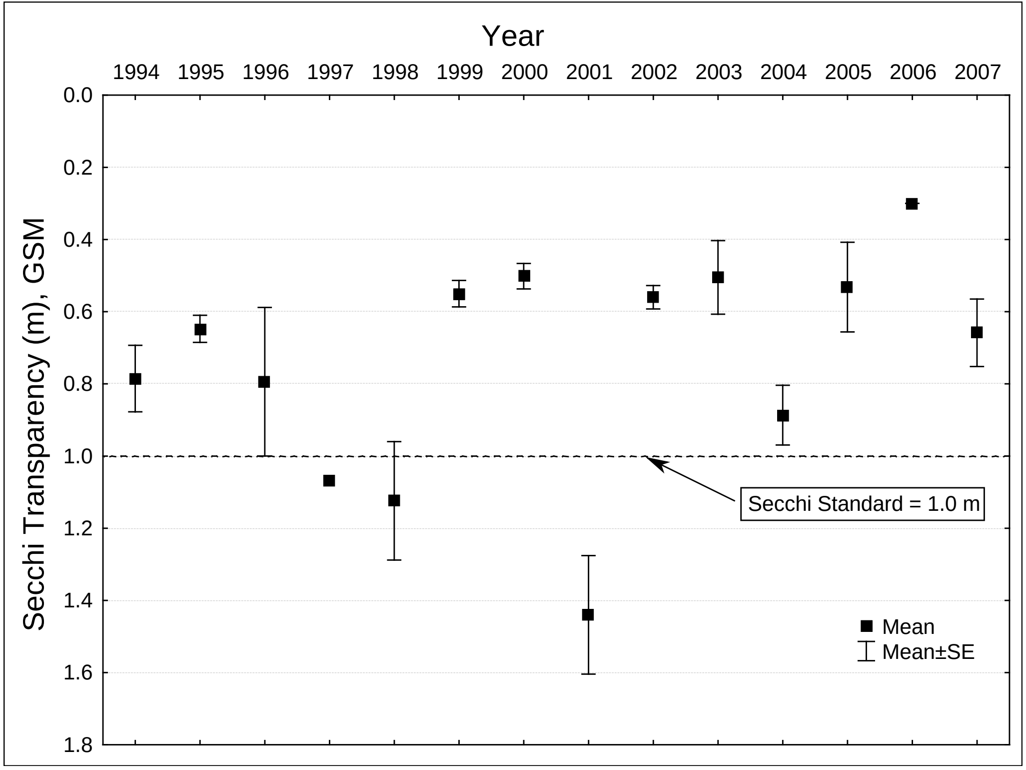


Figure 90. Strandness Lake Seasonal Chlorophyll-*a* Patterns, 1998 to 2007

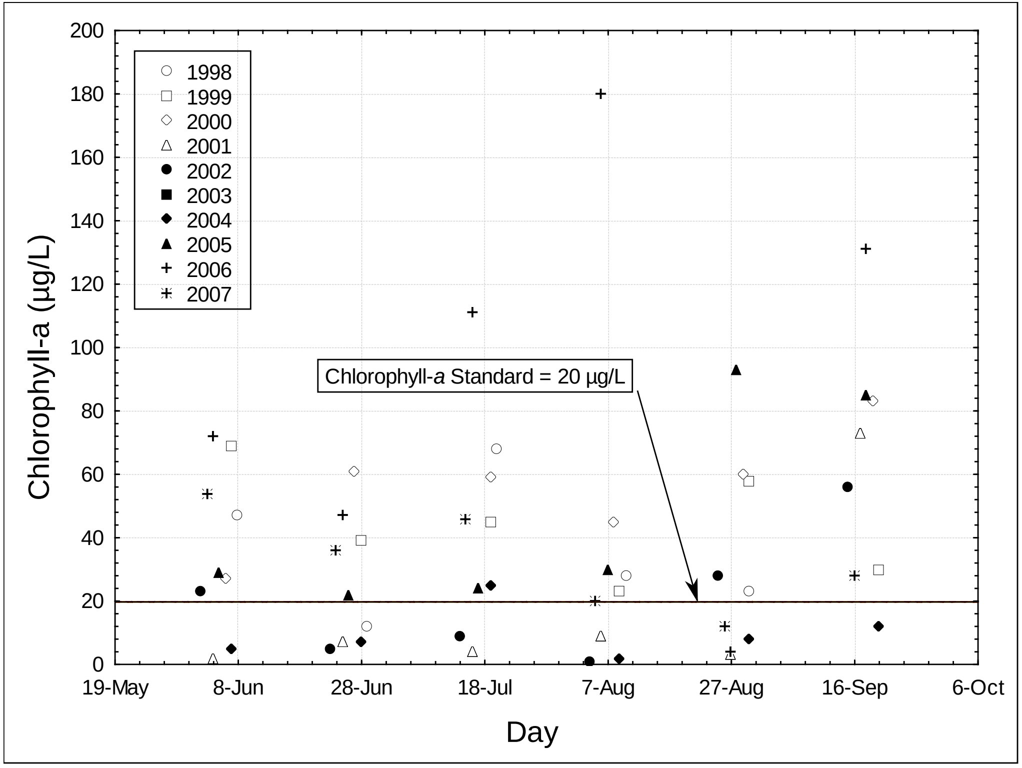


Figure 91. Strandness Lake Seasonal Transparency Patterns, 1998 to 2007

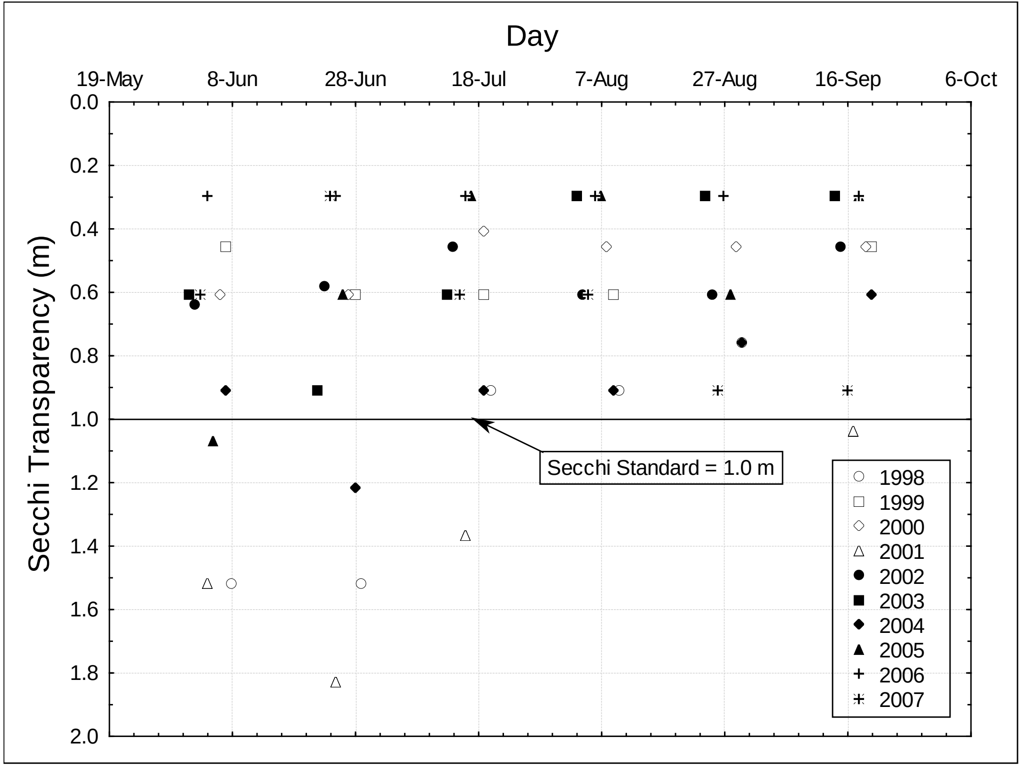


Figure 92. Relationship of Chlorophyll-*a* to TP in Strandness Lake, 1998 to 2007

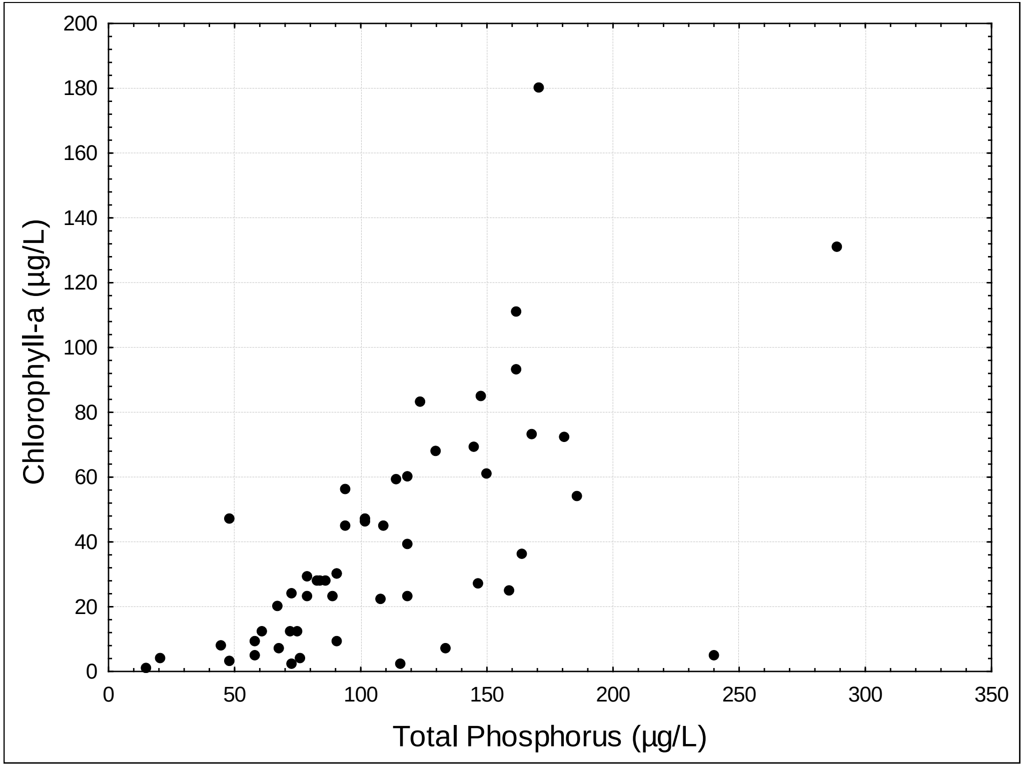


Figure 93. Relationship of Secchi Depth to TP in Strandness Lake, 1998 to 2007

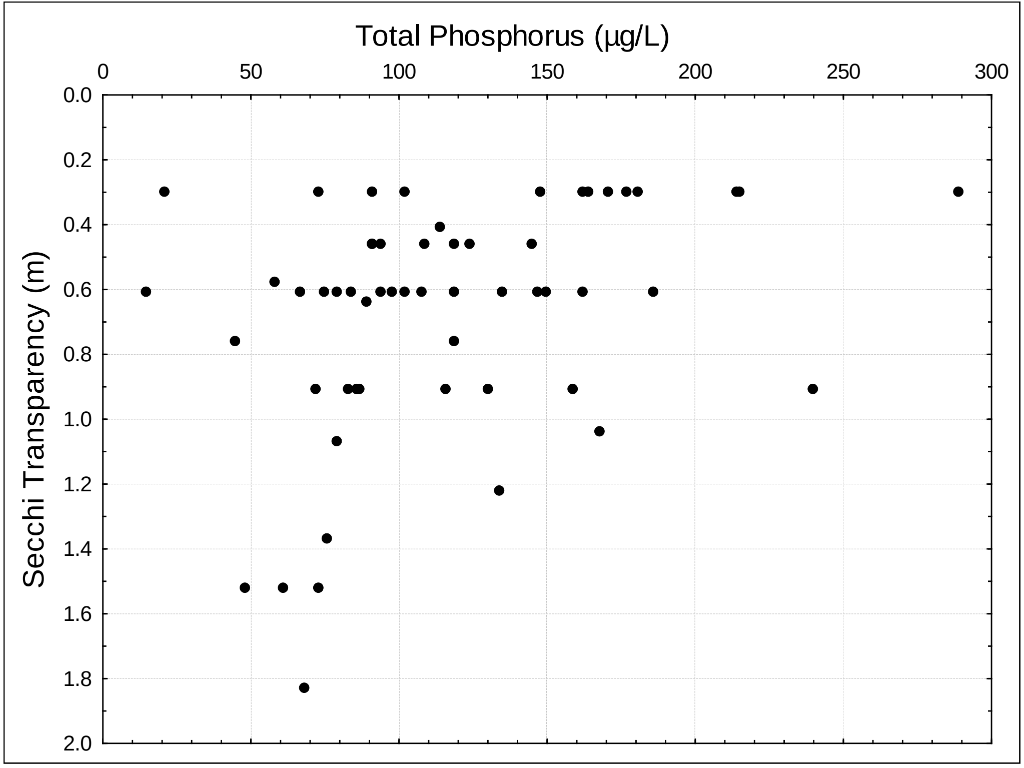
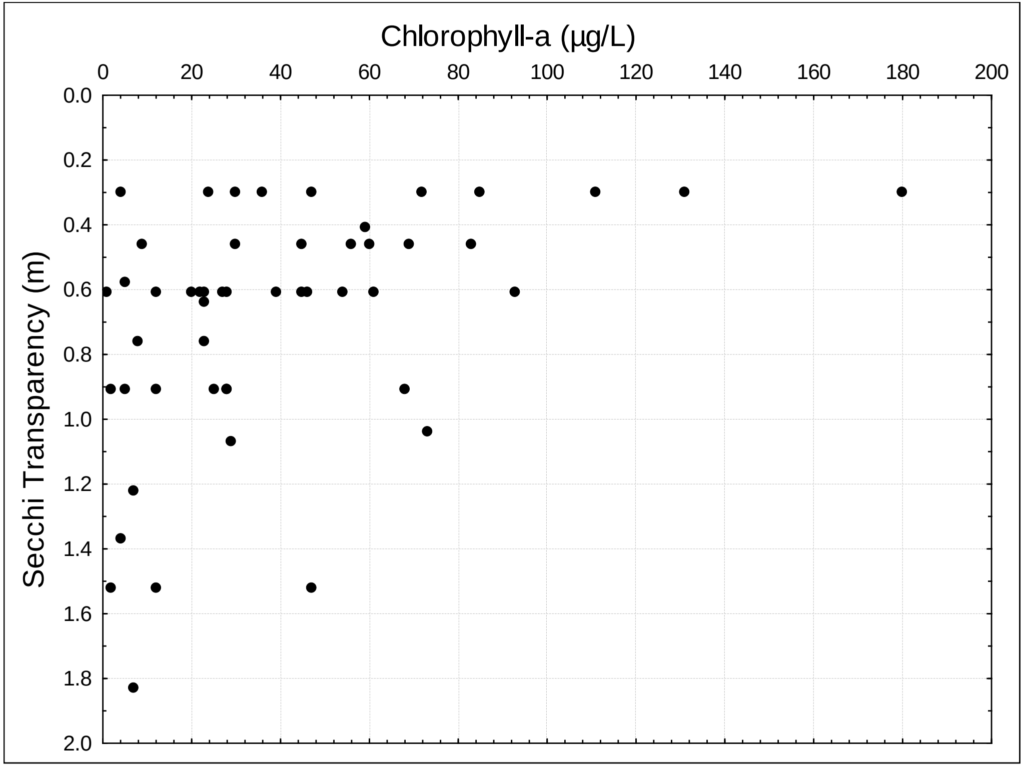


Figure 94. Relationship of Secchi Depth to Chlorophyll-*a* in Strandness Lake, 1998 to 2007



11.2 Phosphorus Source Assessment

The Strandness Lake Watershed (11,824 acres) includes the direct drainage area to the lake (5,044 acres) and the drainage area to Malmedal Lake and the lake itself (6,781 acres). It is estimated that Strandness Lake receives 1,838.6 lbs of phosphorus annually from external sources within the direct drainage watershed. The majority of the external phosphorus to Strandness Lake is coming from runoff from the direct drainage area and the loading from Malmedal Lake (Figure 95, Table 75). Internal loading accounts for an additional 49 to 304 lbs/year of TP loading to the lake.

Figure 95. Strandness Lake Phosphorus Inventory

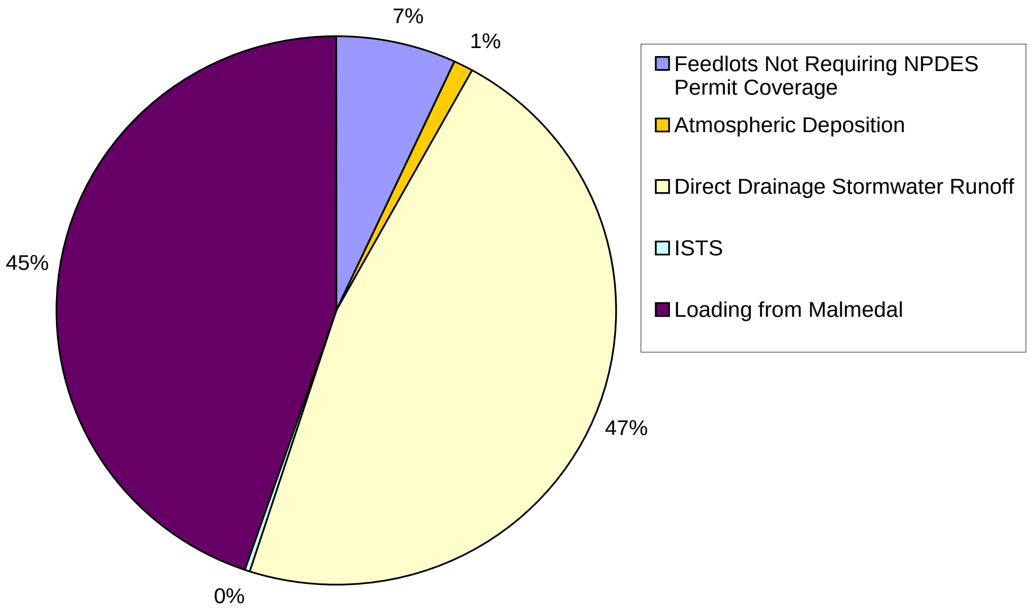


Table 75. Strandness Lake Phosphorus Source Summary

Phosphorus Source	Annual TP Load [lbs/yr]
Direct Drainage Stormwater Runoff	868
Feedlots Not Requiring NPDES Permit Coverage	125.6
Atmospheric Deposition	20
SSTS	4
Loading from Malmedal Lake	821
Total	**1,838.6**

11.2.1 Sources of Phosphorus Requiring NPDES Permit Coverage

Municipal and Industrial Wastewater Treatment Systems

One permitted WWTF is located within the Strandness Lake Watershed and discharges treated wastewater from the city of Lowry. The average annual load of TP from the Lowry WWTF is 37.9 lbs/year. In the phosphorus source summary above, the calculated load from the WWTF is accounted for in the loading from Malmedal Lake.

11.2.2 Sources of Phosphorus Not Requiring NPDES Permit Coverage

Stormwater Runoff

A Simple Method model was used to determine a TP load of 868 lbs/yr coming from the direct drainage area to Strandness Lake. Currently, approximately 27 lbs of phosphorus per year are removed from runoff due to buffers throughout the watershed.

Loading from Upstream Waters

The in-lake data collected in Malmedal was used to determine an average annual TP load (between 1998 and 2007) of 821 lbs/yr contributing to Strandness Lake from Malmedal Lake and its watershed.

Feedlots Not Requiring NPDES Permit Coverage

Within the direct drainage area of Strandness Lake Watershed, there are seven registered feedlots under 1,000 AUs in size, all of which are open lot feedlots. The feedlots house a total of 1012.0 AUs consisting mainly of beef cattle (Table 76). The estimated TP load coming from the feedlots within the watershed under average flow conditions is approximately 125.6 lbs/yr. Additional feedlots exist within the Malmedal Watershed and are accounted for in the loading from Malmedal.

Table 76. Phosphorus Contributing to Strandness Lake from Open Lot Feedlots Not Requiring NPDES Permit Coverage

Animal	Animal Units	Phosphorus contributing to surface waters during average flow year (lbs/yr)
Beef	876.0	108.8
Swine	105.0	12.6
Sheep	31.0	4.0
Horse	6.0	0.2
Total	**1012.0**	**125.6**

Atmospheric Deposition

The TP atmospheric deposition is 20 lbs/yr (Table 77).

Table 77. Strandness Lake Wet and Dry Atmospheric Deposition

Source	Phosphorus Deposition (lbs/yr)
Wet Deposition	16
Dry Deposition	6
Total	**20**

Subsurface Sewage Treatment Systems

There are two homes on Strandness Lake that use an SSTS. It is assumed that both houses are permanent residences and that they are both failing. The total estimated TP load from the SSTS to Strandness Lake is 4.0 lbs/yr.

11.3 TMDL Loading Capacity and Allocations

The phosphorus loading capacity of Strandness Lake is 840 lbs/yr, to be split among allocations according to Table 78. The permitted sources in the Strandness Lake Watershed receive individual WLAs (Table 79). Watershed scale pollutant load modeling was conducted and analyzed on an annual basis to establish this TMDL at a level necessary to attain and maintain applicable water quality standards. Daily WLAs were derived from this analysis. See Section 11.4 for alternative, non-daily, pollutant load expressions recommended for the development of WQBEL based on EPA (2006).

Table 78. Strandness Lake Allocation Summary

Allocation	lbs/yr	lbs/day
TMDL	840	2.3
MOS	84	0.23
WLA	137.9	0.38
LA	618	1.7

Table 79. Strandness Lake WLAs

Source	Permit #	WLA	
		lbs/yr	lbs/day
Construction stormwater	Various	0.14	0.00038
Industrial stormwater	No current regulated sources	3.8	0.0104
Lowry WWTF	MNG580123	134	0.37

11.4 Implementation Strategy

11.4.1 Approach to Lake Restoration

Lake restoration activities can be grouped into two main categories: those practices aimed at reducing external nutrient loads, and those practices aimed at reducing internal loads. The focus of restoration activities depends on the lake's nutrient balance and opportunities for restoration. A reduction of 998.6 lbs of TP annually is needed to achieve the Strandness Lake TMDL and meet water quality standards.

Strandness Lake is located downstream of Malmedal Lake, which is also listed as impaired and part of this multi-lake TMDL (see *Section 8 Malmedal TMDL*). Improvements within Malmedal will have a positive impact on the water quality of Strandness Lake. The direct watershed to Strandness is fairly small, with the majority of the tributary area draining through a wetland that is also listed as impaired. A TMDL has not been developed for that wetland, but it is likely that the wetland is acting as a phosphorus sink, treating runoff prior to discharging into Strandness Lake.

This discussion separates the management strategies into practices addressing point sources, watershed load and internal load. The total cost for implementation is estimated to be $200,000 to $300,000. Implementation costs do not take into account existing programs and are assumed to be spent over the next 20 to 30 years.

11.4.2 Point Source Reduction Activities

The Lowry WWTF is currently in the process of upgrading their facility. The new facility will improve treatment capacity and eliminate many issues with the previous system including stormwater inflows. No phosphorus reductions are planned for the Lowry WWTF.

Although the TMDL's individual WLAs are expressed in terms of both daily (lbs/day) and annual (lbs/yr) loads, for implementation purposes, WQBELs developed for NPDES Permits do not necessarily have to be expressed in terms of a daily limit (EPA 2006). WQBELs should be consistent with the time increment assumptions upon which the TMDL was established. Additional considerations for the development of permit limits include the type of facility, the nature and frequency of the discharge, and compatibility with any other applicable effluent limits.

11.4.3 Watershed Load Reduction Activities

Overall watershed loadings will be reduced through a variety of mechanisms including expansion of existing programs to encourage and promote agricultural BMPs such as conservation tillage, alternative tile inlets, and buffers. Enhanced feedlot BMPs and nutrient management plans will need to be developed and implemented. Wetland restoration can also be used to provide water quality treatment in the watershed.

Improvements to the water quality in Malmedal Lake upstream of Strandness and within the impaired wetland will result in better water quality within Strandness. Additional analysis for Strandness Lake determined that when Malmedal water quality is set to the water quality standard (60 µg/L TP), with no other reductions, the in-lake TP concentration of Strandness Lake would be reduced to 87 µg/L. Achieving the TMDL for Malmedal will be critical to achieving the TMDL for Strandness Lake.

11.4.4 Internal Load Reduction Activities

There are no planned internal load reduction activities. Internal loading has not been identified as a significant source of TP to Strandness Lake. A healthy macrophyte community is present in the lake. Fisheries and macrophytes should be monitored periodically to determine the presence of benthic fish and invasives, which could contribute to declining water quality. If benthic fish are determined to be causing negative water quality impacts to the lake, the lake outlet could be modified to increase the likelihood of winterkill. An evaluation of the connection between Malmedal and Strandness should yield valuable information on fish passage between the lakes that can be used to manage the fishery and macrophytes in Strandness.

12 FUTURE GROWTH CONSIDERATIONS

12.1 New or Expanding Permitted MS4 WLA Transfer Process

Future transfer of watershed runoff loads in this TMDL may be necessary if any of the following scenarios occur within the project watershed boundaries:

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be transferred from the LA to the WLA to account for the growth.
2. One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more non-regulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of a U.S. Census Bureau Urban Area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an Urban Area at the time the TMDL was completed, but are now inside a newly expanded Urban Area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related point source is identified and is covered under a NPDES Permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL. Loads will be transferred on a simple land-area basis. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment.

13 SEASONAL VARIATION AND CRITICAL CONDITIONS

13.1 Seasonal Variation

In-lake water quality varies seasonally. In Minnesota lakes, the majority of the watershed phosphorus load often enters the lake during the spring. During the growing season months (June through September) in deep lakes, phosphorus concentrations may not change drastically if major runoff events do not occur. However, chlorophyll-*a* concentrations may still increase throughout the growing season due to warmer temperatures fostering higher algal growth rates. In shallow lakes, the phosphorus concentration more frequently increases throughout the growing season due to the additional phosphorus load from internal sources. This can lead to even greater increases in chlorophyll-*a* since not only is there more phosphorus but temperatures are also higher.

Some of these patterns are seen in the Pope County lakes. In all lakes, the highest monthly TP and chlorophyll-*a* means across the 10 years (1998 to 2007) of data occur in either August or September (Figure 96 through Figure 98). This seasonal variation is taken into account in the TMDL by using the eutrophication standards, which are based on growing season averages, as the TMDL goals. The eutrophication standards were set with seasonal variability in mind. The load reductions are designed so that the lakes will meet the water quality standards over the course of the growing season (June through September).

Seasonal variation will also be considered in the implementation plan. BMPs will be selected and designed to address high loading rates that typically occur in the spring and early summer from watershed runoff, when vegetative cover on the watershed is at a minimum.

Figure 96. Seasonal Variation in TP, Averaged over 1998 to 2007

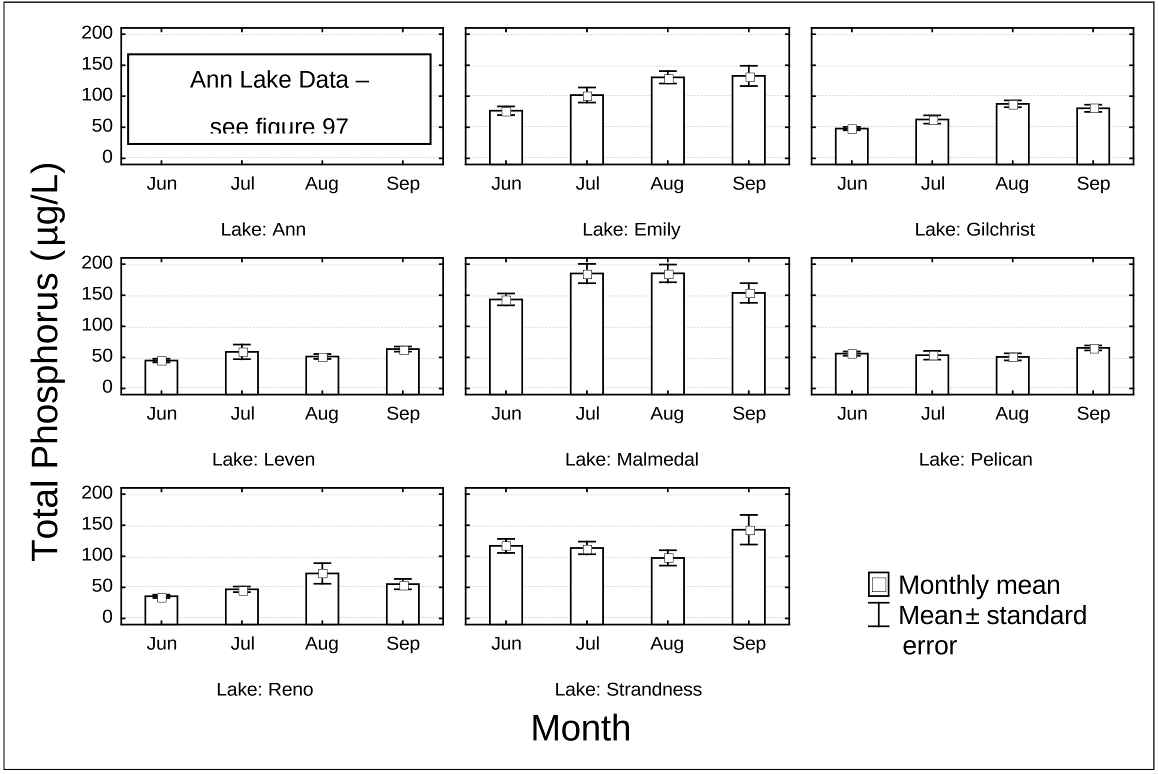


Figure 97. Seasonal Variation in TP, Ann Lake, Averaged over 1998to 2007

Shown separate from the other lakes in Figure 96 due to different scales.

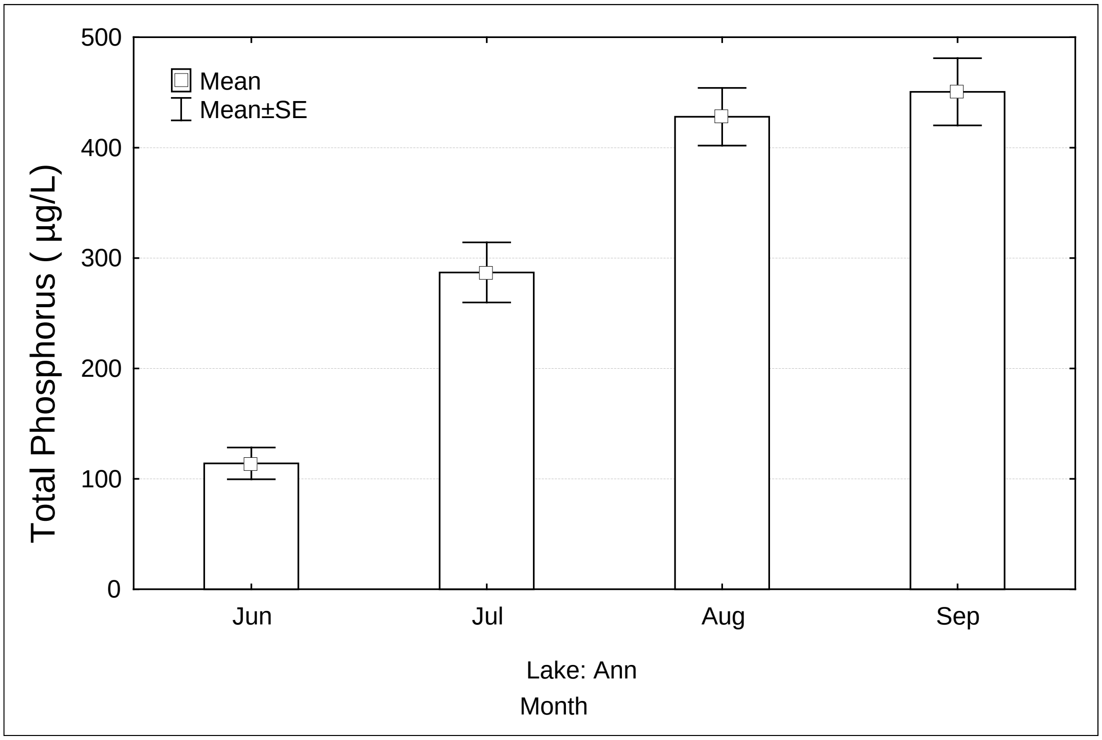
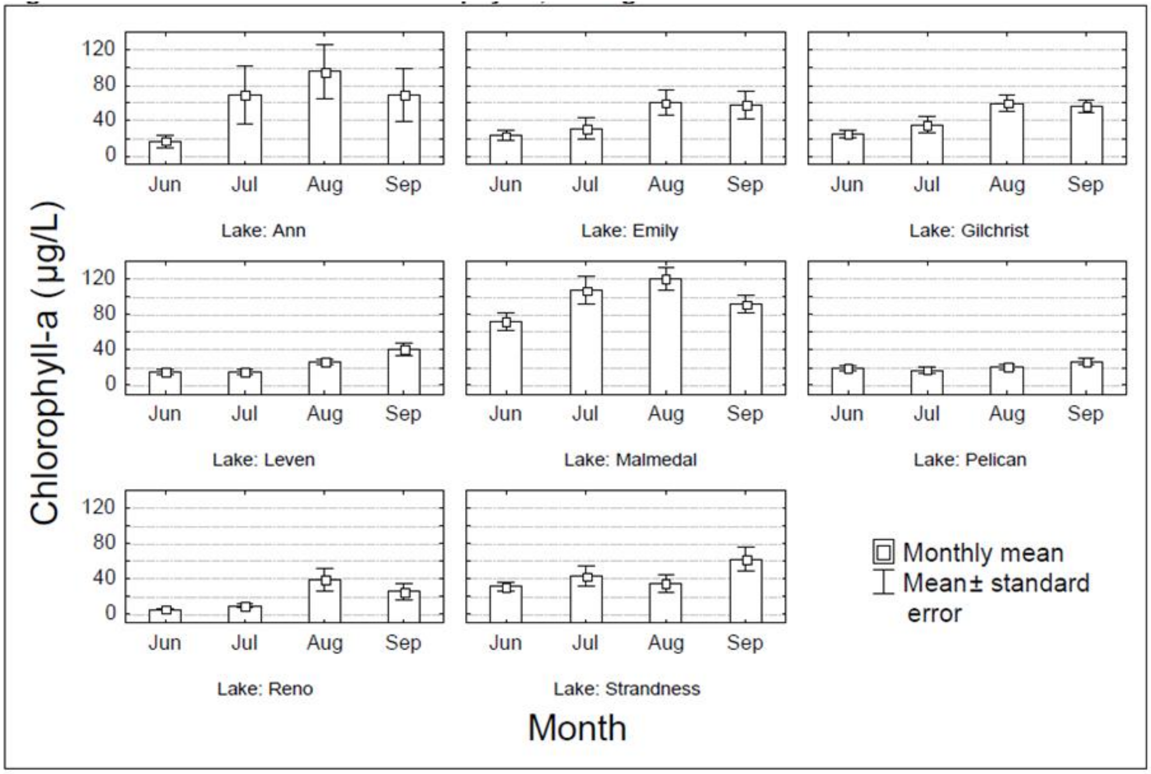


Figure 98. Seasonal Variation in Chlorophyll-*a*, Averaged over 1998 to 2007



13.2 Critical Conditions

Critical conditions in these lakes occur during the growing season, which is when the lakes are used for aquatic recreation. Similar to the manner in which the standards take into account seasonal variation, since the TMDL is based on growing season averages, the critical condition is covered by the TMDL.

14 MONITORING PLAN

14.1 Lake Monitoring

The COLA and Pope County have conducted comprehensive monitoring activities on each of the lakes, dating back to the early 1990s. Their programs have focused on providing nutrient sampling with periodic profiles for DO and temperature. Sampling is typically conducted four to six times per year during the summer months.

Efforts should be made to continue monitoring the impaired lakes into the future, as resources allow. At a minimum, each of the lakes should be monitored bi-annually with a minimum of four to six sample events per year to track changes in lake quality as a result of TMDL implementation. In addition, due to their proximity upstream of impaired lakes Emily and Gilchrist, respectively, Minnewaska and Amelia should continue to be monitored to ensure water quality is not degraded in these important water bodies. Additional lakes including Linka, Round, Swenoda, Marlu, Villard, Wallin, Troen, and White Star should also be monitored periodically to track decline or improvements in water quality, as resources allow.

Spring and fall aquatic macrophyte surveys should be completed in each of the lakes periodically to understand the role of curlyleaf pondweed in overall lake phosphorus dynamics and track the presence and establishment of macrophytes in the lakes. Monitoring of the fishery should continue for each of the lakes currently being managed. For unmanaged lakes including Malmedal and Strandness, fishery monitoring should be conducted as needed.

Plankton data can also provide useful input for understanding in-lake dynamics. In shallow lakes, where in-lake biological interactions can often drive water quality, plankton data can help to understand in-lake responses to nutrient inputs. Plankton data should be collected periodically as resources allow.

14.2 Watershed and BMP Monitoring

The CWRP also conducts water quality and flow monitoring within the Little Chippewa and the East Branch of the Chippewa River upstream of Emily and Gilchrist, respectively. As resources allow, flow and water quality should continue to be monitored in the Little Chippewa River until a project is implemented or a decision made regarding the reroute of the Little Chippewa River. Additional monitoring along Trapper’s Run Creek would provide more information on the loadings to Pelican Lake due to the Trapper’s Run Creek Watershed, helping to focus implementation activities. Monitoring of stream banks for erosion should also be conducted periodically, as resources allow.

The Chippewa River Watershed will be monitored with a comprehensive set of monitoring locations and parameters as part of the MPCA’s watershed approach to condition monitoring and assessment. Under this approach, watershed monitoring will occur every 10 years; the next monitoring and assessment for the Chippewa River Watershed will occur in 2019.

Monitoring of BMPs will be essential to track the effectiveness of watershed improvements on lake water quality. Monitoring of tile and ditch drainage within the Ann Lake Watershed could help to further refine the sources of TP to the lake. Monitoring and evaluation of septic systems to identify failing systems adjacent to lakes should take place within five years of TMDL completion and every 10 years following until lake standards are met. Evaluation of feedlots and compliance with nutrient management plans should be conducted annually until feedlots are upgraded to current state and county standards. Adaptive management may require additional monitoring when different BMPs are implemented.

15 REASONABLE ASSURANCES

As part of an implementation strategy, reasonable assurances provide a level of confidence that the TMDL allocations will be implemented by federal, state, or local authorities. Implementation of the Pope County 8 Lakes TMDL will be accomplished by both state and local action on many fronts, both regulatory and non-regulatory. Multiple entities in the watershed already work towards improving the lakes' water quality. Water quality restoration efforts will be led by Pope County, the Pope County SWCD, the CWRP, and through lake associations and the COLA. In addition, phosphorus reductions by point sources will be made through permit compliance.

15.1 Non-Regulatory

At the local level, Pope County, Pope SWCD, and CRWP currently implement many programs targeted at water quality improvement and have been actively involved in projects to improve water quality in the past. It is anticipated that their involvement will continue. Potential state funding of TMDL implementation projects includes Clean Water Fund grant funding. At the federal level, funding can be provided through Clean Water Act Section 319 grants that provide cost share dollars to implement activities in the watershed. Various other funding and cost-share sources exist, which will be listed in the Pope County Lakes TMDL Implementation Plan.

The implementation activities described in each lake TMDL have demonstrated to be effective in reducing nutrient loadings to lakes. Pope County, Pope SWCD, and the CRWP have programs in place to continue many of the recommended activities. Monitoring will continue and adaptive management will be in place to evaluate progress made towards achieving the beneficial use of each lake.

15.2 Regulatory

State implementation of the TMDL will be through action on NPDES Permits for WWTFs, feedlots, and regulated construction activities. Appendix A of the Stormwater Construction General Permit contains BMPs that must be implemented if a project is within one mile of an impaired water body. The DNR currently administers the state's shoreland rules, which will apply to this TMDL.

Pope County's current septic system ordinance is based on septic system inspection at the time of property transfer. Pope County is a MPCA delegated partner with the State Feedlot Program and employs a County Feedlot Officer. The County Feedlot Officer is responsible for conducting compliance checks on all registered feedlots and enforcing state rules if the feedlot is not in compliance.

16 PUBLIC PARTICIPATION

Public participation for the Pope County 8 Lake TMDL Study began in 2009, with a kick-off meeting and open house for the public on May 12, 2009. Prior to that meeting, meetings were held with Pope County, the Pope SWCD, and with DNR Area Fisheries staff to obtain initial input and feedback. The kick-off meeting was advertised in local papers, newsletters, and radio announcements and a number of specific individuals and organizations were personally invited. A total of 52 individuals attended this meeting. A Local Advisory Group (LAG) was then formed to provide continued input on the project. The LAG met on October 6, 2009, February 23, 2010 and September 14, 2010. The purpose of the first meeting was to report on the status of the project and obtain input in the early stages of TMDL development and potential implementation strategies. The next meetings were used to help derive and prioritize specific implementation activities. LAG representatives are identified in Table 80. A Technical Advisory Committee (TAC) was also convened to provide input and feedback on the TMDL. The TAC consisted of representatives from the MPCA, DNR, BWSR, MDA, NRCS, University of Minnesota Extension, CRWP, Pope County, Pope County SWCD, and the Pope County COLA. The TAC met in April 10, 2012, and May 8, 2012.

Table 80. LAG Members

Charles Ballou	Pope COLA
Jim Blair	Ann and Reno Watershed resident
Mike Blair	Ann and Reno Watershed resident
Bob and Louise Bowlen	Pope COLA
Bruce Brown	Pope COLA, Lake Leven
Ronald Burnham	Emily Watershed resident
Ron Cim	COLA, Lake Amelia
Ivie Cooley	Leven/Amelia Watershed resident
Jan Doebbert	Reno Watershed resident
Stan Erdman	Emily Watershed resident
Paul Gerde	Gilchrist Watershed resident
Mark Halls	Pope SWCD Commissioner, Gilchrist Watershed resident
Dennis Heieie	Pelican Watershed resident
Richard Heimkes	Gilchrist Watershed resident
David Hoffman	COLA, Lake Amelia
Mike Howe	Ann Watershed resident
Tim James	MPCA
Martin Jenniges	Gilchrist Watershed resident
Joan Jipson	Emily Watershed resident
Luan Johnsrud	Pope SWCD
Gary Koos	City of Starbuck
Nicholas Koos	Winseth, Smith & Nolting and city of Starbuck
Steve Lawrence	Pope Co. Land & Resource Mgmt
Jennifer Olson	EOR and Project Consultant
Kylene Olson	CWRP
Ralph Peterson	Pope SWCD Commissioner
Lowell Rasmussen	Pope COLA
Ryan Schulzetenberg	Reno Watershed resident

John Scott	Pelican Watershed resident
Jean Solheim	Reno Watershed resident
Nancy Tank	COLA, Lake Amelia
Larry VanHout	Winseth, Smith & Nolting and city of Starbuck
Greg Vold	Pope County Farm Bureau President
George Webster	Lake Emily Improvement Association, President
Gary & Nancy Wenzel	Reno Watershed resident

A draft TMDL report was put on public notice in the State Register for a 30-day comment period from July 23, 2012, to August 22, 2012. There was an extension of the public notice period from September 17 through October 17, 2012. Over 37 comments were received from eleven individuals and the report was revised where appropriate.

17 REFERENCES

Berg, J., 2006. Geologic Atlas of Pope County, Minnesota, Part B: Minnesota Department of Natural Resources County Atlas Series C-15, scales 1:100,000 and 1:150,000.

Canfield, D. and R. Bachmann, 1981. Prediction of Total Phosphorus Concentrations, Chlorophyll *a*, and Secchi Depths in Natural and Artificial Lakes. *Canadian Journal of Fisheries and Aquatic Science* 38:414-423.

Fang, F., P. Brezonik, D. Mulla, and L. Hatch, 2002. Estimating Runoff Phosphorus Losses from Calcareous Soils in the Minnesota River Valley. *Journal of Environmental Quality*, 31:1918-1929.

Harris, K. and A. Knaeble, 2003. Surficial Geology, Plate 3 *in* Harris, K.H. eds., Geologic Atlas of Pope County, Minnesota, Part A: Minnesota Geological Survey County Atlas Series C-15, scales 1:100,000 and 1:200,000.

Heiskary, S.A. and C.B. Wilson. 2005. Minnesota lake water quality assessment report:

Developing nutrient criteria. Minnesota Pollution Control Agency. St. Paul, Minnesota.

Lake Emily Improvement Association (LEIA), 2008. Lake Emily Management Plan. Prepared by the K. Olson, Chippewa River Watershed Project.

Midwest Plan Service (MWPS), 2004. Manure Characteristics: Manure Management Systems Series. MWPS-18 Section 1 Second Edition. Iowa State University

Minnesota Department of Natural Resources (DNR), 2008. Lake Emily, Pope County, Lake Water Budget.

Minnesota Department of Natural Resources (DNR), 2009. Personnel Communications with Julie Aadlund, Area Hydrologist.

Minnesota Pollution Control Agency (MPCA), 1994. Pelican Lake, Lake Assessment Program 1994. Prepared by the Water Quality Division and Northwest Regional Office.

Minnesota Pollution Control Agency (MPCA), 1995. Lake Emily, Lake Assessment Program 1995. Prepared by the Water Quality Division.

Minnesota Pollution Control Agency (MPCA), 1993. Gilchrist Lake, Lake Assessment Program 1993. Prepared by the Water Quality Division.

Minnesota Pollution Control Agency (MPCA), 2001a. Status and Trend Monitoring Summary for Selected Pope and Douglas County, Minnesota Lakes 2000. Prepared by the Environmental Outcomes Division Environmental Monitoring and Analysis Section.

Minnesota Pollution Control Agency (MPCA), 2001b. Effects of Liquid Manure Storage Systems on Groundwater Quality 2001. Prepared by the Ground Water and Toxics Monitoring Unit.

Minnesota Pollution Control Agency (MPCA), 2004a. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds. Prepared by Barr Engineering.

Minnesota Pollution Control Agency (MPCA), 2004b. Lower Minnesota River Dissolved Oxygen Total Maximum Daily Load Study. Prepared by the Regional Environment Management Division, May 2004.

Minnesota Pollution Control Agency (MPCA), 2009. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List. Prepared by the Environmental Outcomes Division.

Nürnberg, N., 1988. Prediction of Phosphorus Release Rates from Total and Reductant-Soluble Phosphorus in Anoxic Lake Sediments. *Can. J. Fish. Aquat. Sci.* 45:453-462.

Nürnberg, N., 1996. Trophic State of Clear and Colored, Soft- and Hardwater Lakes with Special Consideration of Nutrients, Anoxia, Phytoplankton and Fish. *Journal of Lake and Reservoir Management* 23(4):432-447.

Pope County, 1994. A Water Resources Study of Trapper's Run Creek. Prepared by DNR Area Fisheries.

Pope County, 1995. A Water Resource Study Trapper's Run Watershed.

Pope County, 1996. The Trapper's Run Watershed Project. Prepared by Pope County Environmental Services.

Pope County, 2004a. Trapper's Run Watershed Clean Water Partnership, Final Report. Prepared by Pope County Environmental Services.

Pope County, 2004b. Lake Leven Watershed Implementation Plan. Prepared by Bonestroo, Rosene, Anderlik & Associates.

Pope County Coalition of Lake Associations (COLA), 2005. Pope County COLA Monitoring Project, Update of tables & charts 1994-2004. Prepared by Bruce A. Brown.

Rosgen, D., 2006. Watershed Assessment of River Stability and Sediment Supply (WARSS). Fort Collins, CO; Wildland Hydrology Books.

Schueler, T., 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing urban BMPs. Publ. No. 87703. Metropolitan Washington Council of Governments, Washington D.C.

Soil Conservation Service (SCS), 1992. Hydrology Guide for Minnesota.

United States Environmental Protection Agency (U.S. EPA), 2006. Memorandum *Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth Inc. v. EPA, et al., No.05-5015, (April 25, 2006) and Implications for NPDES Permits*. November 15, 2006.

United States Geologic Survey (USGS), 2001. National Land Cover Database (NLCD).

Walker, W., 1999. Simplified Procedures for Eutrophication Assessment and Prediction: User Manual. Prepared for Headquarters, U.S. Army Corps of Engineers, Waterways Experiment Station Report W-96-2. http://wwwalker.net/BATHTUB/.

18 APPENDIX A: MODELING SUPPORT DATA

Table 81. BATHTUB Input Data

Lake Name	Global Data			Segment Data: Morphometry			Segment Data: Observed WQ			Tributary Data			
	Precip (m)	Evap (m)	Atm TP (mg/m2-yr)	Lake Surface Area (km2)	Mean Depth (m)	Length (km)	TP (µg/L)	Chl-A (µg/L)	Secchi (m)	Tributary	Watershed Area (km2)	Flow Rate (hm3/yr)	Total P (µg/L)
Ann	0.66	0.92	26.1	1.477	3.78	1.83	241	105	1.1	Ann	19.757	1.955	293.6
Emily	0.65	0.93	26.1	9.154	1.463	7.65	108	42	0.5	Emily	147.014	12.77	257
										Little Chippewa	188.826	15.45	272
										Minnewaska	201.687	17.32	33
Gilchrist	0.67	0.93	26.3	1.311	3.048	2.82	68	41	1.3	Gilchrist	163.772	15.82	222.6
										Linka	5.37	0.51	27
										Amelia	122.628	12.18	21
Leven	0.67	0.92	26.1	1.137	5.486	1.54	53	23	1.5	Leven	38.101	4.011	263.5
Malmedal	0.65	0.93	26.2	0.797	0.945	1.63	166	97	0.4	Malmedal	26.645	2.24	288
Pelican	0.65	0.93	26.1	2.068	5.486	2.76	56	21	1.3	Pelican	31.61	2.86	233
										Strandness	48.198	3.98	113.3
Reno	0.66	0.92	26.1	14.2	4.572	6.8	52	17	2.3	Reno	22.246	3.376	164.1
										Maple Lake	-	0.4	17
										Groundwater	-	0.05858	78.4
Strandness	0.65	0.93	26.1	0.348	1.432	0.85	113	39	0.7	Strandness	20.408	1.76	257
										Malmedal	27.442	2.24	166