Water Quality Improvement Plan
for

Silver Lake

Dickinson County, Iowa

Total Maximum Daily Load
for Turbidity

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General Report Summary

What is the purpose of this report?

This report serves multiple purposes. First, it is a resource for guiding locally-driven water quality improvements in Silver Lake. Second, it satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) report for all federally impaired waterbodies. Silver Lake is an important water resource, and as an impaired waterbody, it is eligible for financial assistance to improve water quality. This document is meant to help guide watershed improvement efforts to remove Silver Lake from the federal 303(d) list of impaired waters.

What's wrong with Silver Lake?

Silver Lake is not supporting its Class A1 (primary contact recreation) designated use. Primary contact recreation includes activities that involve human contact with the water such as swimming, wading, and water skiing. This use is not supported in Silver Lake due to poor water transparency, which violates the narrative water quality criterion for surface waters to be free of "aesthetically objectionable conditions."

What is causing the problem?

The primary cause of poor water clarity in Silver Lake is the high concentration of suspended solids. Although poor water clarity in Silver Lake is frequently caused by inorganic suspended solids, high levels of phosphorus and algal blooms also contribute to water quality problems. Inorganic suspended solids, phosphorus, and other substances contributing to poor water transparency are caused by sediment and phosphorus loads to the lake from surrounding land and from sediment resuspended from the bottom of the lake. If phosphorus loads to the lake are reduced, sediment reduction will also occur. Additionally, if only non-algal turbidity were reduced, algal blooms could actually worsen due to decreased light limitation. For these reasons, this TMDL targets phosphorus reductions for water quality improvement in Silver Lake.

Sediment and phosphorus can originate from point or nonpoint sources, or a combination of both. Point sources of pollution are easily identified sources that enter a stream or lake at a distinct location, such as a wastewater treatment outfall. Nonpoint sources of pollution are discharged in a more indirect and diffuse manner, and are often more difficult to locate and quantify. Nonpoint source pollution is usually carried by rainfall or snowmelt over the land surface and into a nearby lake or stream. The area of land that drains to a lake or stream is called a watershed. Watershed runoff often carries pollutants with it that can degrade water quality. There are no permitted point sources of pollution in the Silver Lake watershed. Therefore, sediment and phosphorus are generated by nonpoint sources that include wildlife, livestock, pets, and humans that live, work, and play in and around the lake. Once sediment and phosphorus enter a lake and settle to the bottom, they can be recycled between the bottom of the lake and the water column for many years, which causes ongoing water clarity problems.

What can be done to improve Silver Lake?

To improve water quality and the overall health of Silver Lake, the amount of sediment and phosphorus entering the lake must be reduced. A combination of land and animal management practices must be implemented in the watershed to obtain necessary reductions. Potential watershed improvement measures include:

- increased use of conservation tillage,
- adoption of manure and fertilizer application strategies to reduce phosphorus loss,
- construction of grass waterways, buffer strips, and sediment control basins, and
- restoration of wetlands that filter sediment and nutrients and restore hydrologic functions of the watershed.

In addition to controlling watershed sources, phosphorus and sediment resuspended from the bottom of the lake must be reduced. This internal or recycled source of phosphorus can be reduced by adopting a variety of shallow lake management techniques. These include:

- fisheries management,
- water level management to establish aquatic vegetation,
- shoreline stabilization projects, and
- minimal dredging targeted to provide deep-water habitat.

Managing the fishery of Silver Lake will reduce populations of bottom-feeding fish species, such as common carp, which stir up sediment and contribute to poor water transparency. Water level management will help establish rooted vegetation in shallow areas, which increases water clarity by stabilizing bottom-sediments to prevent resuspension, and by competing with algae for phosphorus needed for growth. Shoreline stabilization projects will help the development of rooted vegetation, and reduce turbidity caused by shoreline erosion. Minimal dredging may have some limited water quality benefits. Dredging should be focused to address severe sediment deposition, and to provide deep-water habitat to compliment fisheries management. It is important to note that Silver Lake is a naturally shallow lake, and widespread dredging is neither feasible nor recommended.

Who is responsible for a cleaner Silver Lake?

Everyone who lives, works, or plays in the Silver Lake watershed has a role in water quality improvement. Because there are no regulated point sources in the watershed, voluntary management of land and animals will be required to see positive results. Much of the land draining to the lake is in agricultural production, and financial assistance is often available from government agencies to individual landowners willing to adopt changes in tillage practices and manure management. Financial assistance may also be available for the restoration of wetlands that naturally filter sediment and nutrients from water before it enters the lake. Funding opportunities also exist for in-lake improvement strategies to reduce internal recycling of sediment and phosphorus after external watershed loads have been controlled.

Homeowners can have their septic systems inspected to ensure they function properly. Residents with shoreline property can implement a variety of practices to help prevent shoreline erosion and sediment and phosphorus from running off their property to the lake. Examples of such practices include establishment of vegetative buffers along the shore, stabilizing the shoreline, and use of fertilizer that does not contain phosphorus. Improving water quality in Silver Lake will require a collaborative effort of citizens and agencies with a genuine interest in protecting the lake now and in the future.

Technical Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Silver Lake, Waterbody ID IA 06-LSR-03105-L_0, located in S28, T100N, R38W, on the west edge of the City of Lake Park in Dickinson County.
Surface water classification and designated uses:	A1 – Primary contact recreation B(LW) – Aquatic life (lakes/wetlands) C – Drinking water supply HH – Human health (fish consumption)
Impaired beneficial uses:	Class A1 – Primary contact recreation
TMDL priority level:	High
Identification of the pollutant and applicable water quality standards (WQS):	Carlson's Trophic State Indices (TSI) for total phosphorus (TP) and Secchi depth place Silver Lake in the hypereutrophic range, with very poor water transparency. This violates the narrative water quality criterion for "aesthetically objectionable conditions" per the Iowa WQS.
Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	The turbidity impairment is associated with the total phosphorus (TP) load. For attainment of the TSI targets, the allowable average annual TP load = 8,499 lbs/yr; the allowable maximum daily TP load = 45.9 lbs/day
Quantification of the amount or degree by which the current pollutant load in the waterbody, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain water quality standards:	The existing TP load is 19,980 lbs/yr. To meet the TSI targets, the annual TP load must be reduced by 11,481 lbs/yr, or 57.5 percent; the daily maximum TP load must be reduced by 61.9 lbs/day.

Identification of pollution source categories:	There are no permitted point sources of phosphorus in the watershed. Nonpoint sources of phosphorus, which are contributing to high turbidity levels, include erosion from agricultural land, livestock manure application, geese and other wildlife, septic systems, phosphorus fertilizer, internal loading, and atmospheric deposition.
Wasteload allocations for pollutants from point sources:	Because there are no permitted point sources, the total WLA is zero.
Load allocations for pollutants from nonpoint sources:	The total allowable average annual TP LA is 7,649 lbs/year, and the allowable maximum daily LA is 41.3 lbs/day.
A margin of safety:	The margin of safety is an explicit 10 percent of modeled allowable loads. The MOS for the allowable annual load is 850 lbs/yr, and 4.6 lbs/day for the daily maximum load.
Consideration of seasonal variation:	This TMDL was developed based on the allowable annual phosphorus loading that will result in attainment of TSI targets for the growing season.
Allowance for reasonably foreseeable increases in pollutant loads:	Because there are no permitted point sources in the watershed, and significant land use change is unlikely, there is no allowance for reasonably foreseeable increases in pollutant loads.
Implementation plan:	An implementation plan is outlined in Chapter 4 of this TMDL. Phosphorus loading and turbidity will be addressed through a variety of voluntary land management, manure application, structural BMPs, and in-lake water quality improvement strategies.

1. Introduction

The Federal Clean Water Act requires all states to develop lists of impaired waterbodies that are not meeting water quality standards (WQS) and designated uses. This list of impaired waterbodies is referred to as the state's 303(d) list. In addition to developing the 303(d) list, a Total Maximum Daily Load (TMDL) report must also be developed for each impaired waterbody included on the list. A TMDL is a calculation of the maximum amount of pollution that a waterbody can tolerate without exceeding WQS and impairing the waterbody's designated uses. The TMDL calculation is represented by the following general equation:

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

Where:
TMDL = total maximum daily load
LC = loading capacity
Σ WLA = sum of wasteload allocations (point sources)
Σ LA = sum of load allocations (nonpoint sources)
MOS = margin of safety (to account for uncertainty)

One purpose of this Water Quality Improvement Plan for Silver Lake, located in Dickinson County in northwest Iowa, is to serve as the TMDL for turbidity. The second purpose of the plan is to provide local stakeholders and watershed managers with a tool to promote awareness of water quality issues, guide watershed improvement efforts, and assist the development of funding applications for water quality improvement projects. The water quality parameter addressed is turbidity, which is impairing primary contact recreation in Silver Lake. The plan outlines a phased approach to TMDL development and implementation. A phased approach is helpful when the origin, interaction, and quantification of pollutants contributing to water quality problems are complex and difficult to fully understand and predict.

The TMDL includes an assessment of existing pollutant loads to the lake and a determination of how much of a specific pollutant the lake can tolerate and still meet water quality standards and support its designated uses. The allowable amount of pollutant the lake can receive is the loading capacity, also called the TMDL target load. The TMDL also includes a description of potential solutions to the water quality problem. This group of solutions is more precisely defined as a system of best management practices (BMPs) that will improve water quality in Silver Lake, with the ultimate goal of supporting all designated uses. These BMPs are outlined in the implementation plan in Chapter 4. A water quality monitoring plan designed to help assess water quality improvement and BMP effectiveness is provided in Chapter 5.

This Water Quality Improvement Plan will be of little value to real water quality improvement unless watershed improvement activities and BMPs are implemented. This will require the active engagement of local stakeholders and the collaboration of several state and local agencies. Completion of the TMDL should also be followed by several other actions, including:

- collection of water quality data as part of the ongoing monitoring plan,
- evaluation of collected data, and
- modification of the targets and/or implementation plan (if necessary).

Monitoring is a crucial element in assessing attainment of water quality standards and designated uses, determining if water quality is improving, degrading, or remaining unchanged, and assessing the effectiveness of implementation activities and the possible need for additional BMPs.

2. Description and History of Silver Lake (Dickinson County)

Silver Lake is a natural lake that borders the west edge of the City of Lake Park, located in Dickinson County in northwest Iowa. Trappers Bay State Park borders the northeast corner of the lake. The Iowa Department of Natural Resources (IDNR) owns and operates the Silver Lake Wildlife Management Area (WMA), which is also adjacent to the lake. The Center for Agricultural and Rural Development (CARD) at Iowa State University estimates that between 2002 and 2005, Silver Lake averaged over 47,000 annual visitors, which is well below the state average for Iowa lakes over the same period (CARD, 2008). The number of annual visitors to the lake and water quality have both decreased in recent years. Table 1 lists some of the general characteristics of Silver Lake and its watershed.

Table 1. Silver Lake watershed and lake characteristics.

IDNR Waterbody ID	IA 06-LSR-03105-L_0
10 Digit Hydrologic Unit Code (HUC)	1023000302
10 Digit HUC Name	West Fork Little Sioux River
Location	Dickinson County, S28, T100N, R38W
Latitude	43.5
Longitude	-95.3
Designated Uses	A1 – Primary contact recreation B(LW) – Aquatic life (lakes and wetlands) C – Drinking water supply HH – Human health (fish consumption)
Tributaries	West Branch Little Sioux River and one unnamed tributary
Receiving Waterbody	West Branch Little Sioux River
Lake Surface Area	1,032 acres (excludes Trappers Bay)
Maximum Depth	9.8 feet
Mean Depth	6.7 feet (excludes Trappers Bay)
Lake Volume	6,894 acre-feet
Length of Shoreline	9.61 miles (50,730 feet)
Watershed Area (excludes lake)	17,025 acres
Watershed:Lake Ratio	16.5:1
Lake Residence Time	121 days (estimated)

2.1. Silver Lake

Hydrology. Silver Lake is a natural lake that lies within the Little Sioux Hydrologic Unit Code eight-digit watershed (HUC-8). Major inflows to Silver Lake include West Branch Little Sioux River and one unnamed tributary. The lake outlet discharges on the east side of the lake through a man-made weir structure, as shown in Figure 1. Lake outflow continues east through West Branch Little Sioux for approximately 3.4 miles before joining the Little Sioux River, which flows south towards the Missouri River.

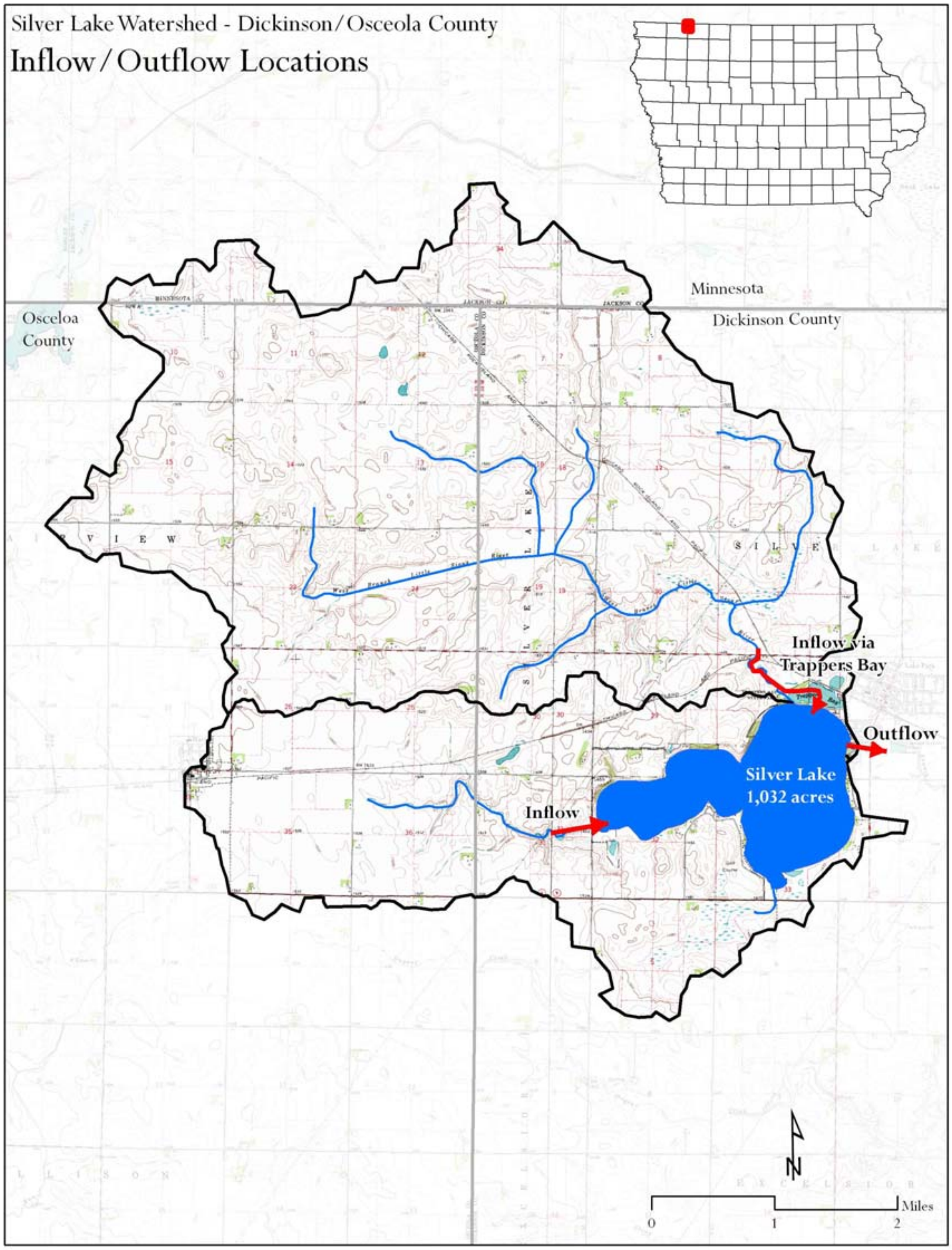


Figure 1. Silver Lake surface water inflows and outflow locations.

Morphometry & Substrate. The total surface area of Silver Lake is 1,066 acres, which includes approximately 34 acres of a marshy-wetland in the northeast corner of the lake known as Trappers Bay. For the purposes of this TMDL, Trappers Bay is not considered part of the main lake. However, the sediment and phosphorus load to the lake from Trappers Bay is accounted for in the TMDL. The effective lake area is 1,032 acres, based on bathymetric survey work completed in 2008. An aerial photograph of the lake and adjacent area is shown in Figure 2. Excluding Trappers Bay, the volume of Silver Lake is 6,894 acre-feet, with a mean depth of 6.7 feet (J. Sholly, personal communication). The lake is a natural lake, but the water surface elevation has been manipulated by construction of a man-made dam and overflow structure, shown in Figure 3. The shoreline development index of the lake, which measures irregularity or convolution of the shoreline, is 2.11 (Bachman, 1993). Values greater than 1.0 suggest the shoreline is highly dissected and indicative of a high degree of watershed influence (Dodds, 2000), resulting in increased lake productivity.

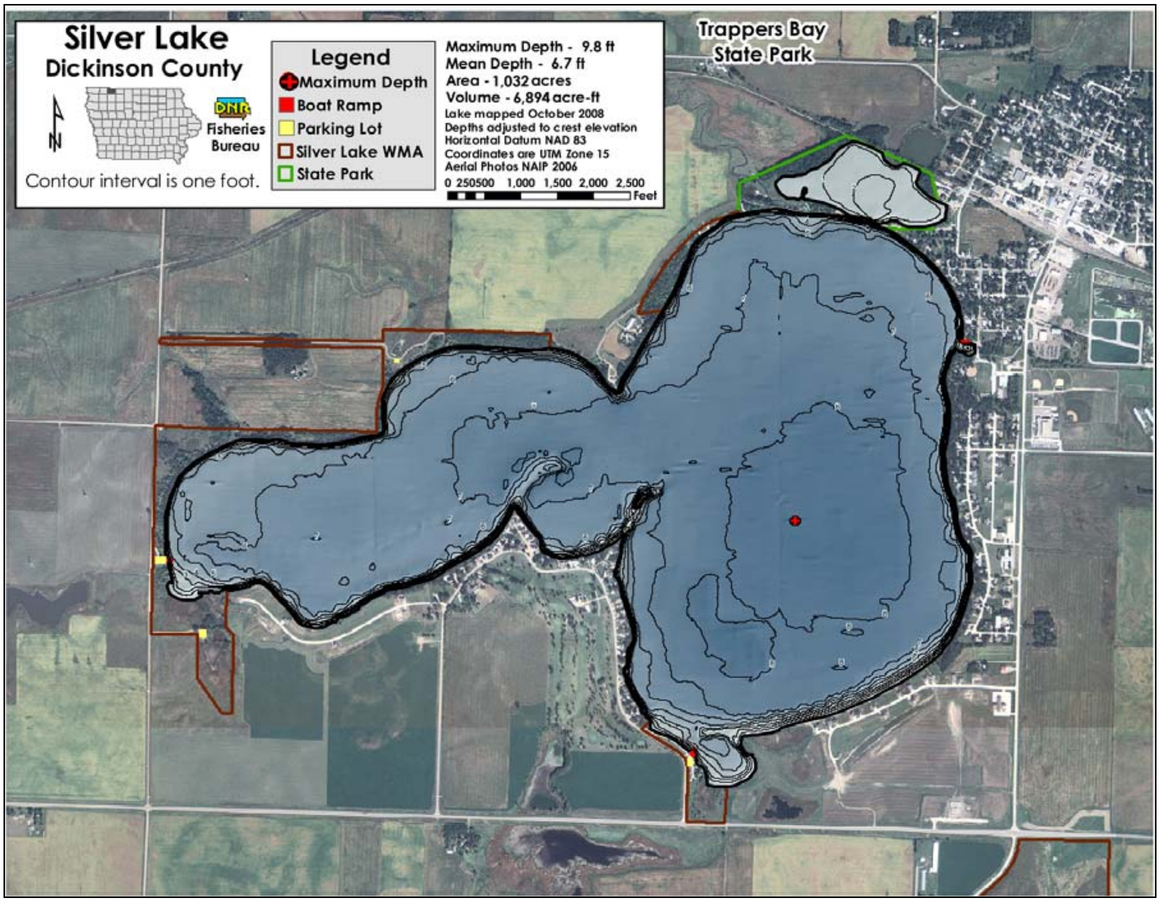


Figure 2. Aerial photograph of Silver Lake.

Silver Lake was formed in a region of glacial till in the Des Moines Lobe landform region. The lake was dredged sometime prior to the 1970s, but silt, loam, and clay sediments have accumulated on the bottom of the lake. This sediment is enriched with organic material, which increases turbidity when it (and attached nutrients) becomes resuspended to the water column. Because Silver Lake is shallow, bottom sediments are subject to resuspension by wind action, power boating, and bottom-feeding fish.

Figure 3. Silver Lake outlet structure to West Branch Little Sioux River.

2.2. The Silver Lake Watershed

The drainage area to Silver Lake is a 17,025-acre watershed, not including the surface area of the lake. The moderately large lake to watershed ratio of 16.5 to 1 indicates that watershed characteristics have a significant potential impact on the water quality of the lake.

Land Use. The land cover information for this TMDL was collected via a windshield survey in 2007. The predominant land use is row crop agriculture, most of which is in a corn-soybean rotation. There is some cropland in a corn-soybean-oats-meadow rotation, but this accounts for only five percent of the total cropland in the watershed. Conservation Reserve Program (CRP) ground makes up a very small portion (less than one percent) of the area typically in crop production. Other land uses include farmsteads, timber, grasslands, wildlife area, urban, and roads. Table 2 reports the generalized land uses by acre and by percentage of watershed. Figure 4 shows a more detailed classification of land uses distributed throughout the watershed.

Many of the natural wetlands that were once common in the watershed have been drained. Loss of wetlands and introduction of agricultural tile drains have affected watershed hydrology and nutrient loads to the lake. The biggest impact to the lake is the loss of surface water storage, which causes lake water level to remain high for longer periods compared to pre-settlement conditions. This prevents the establishment of aquatic vegetation along the shore. Additionally, nutrient loads to the lake are increased when wetlands are removed and watershed storage is lost.

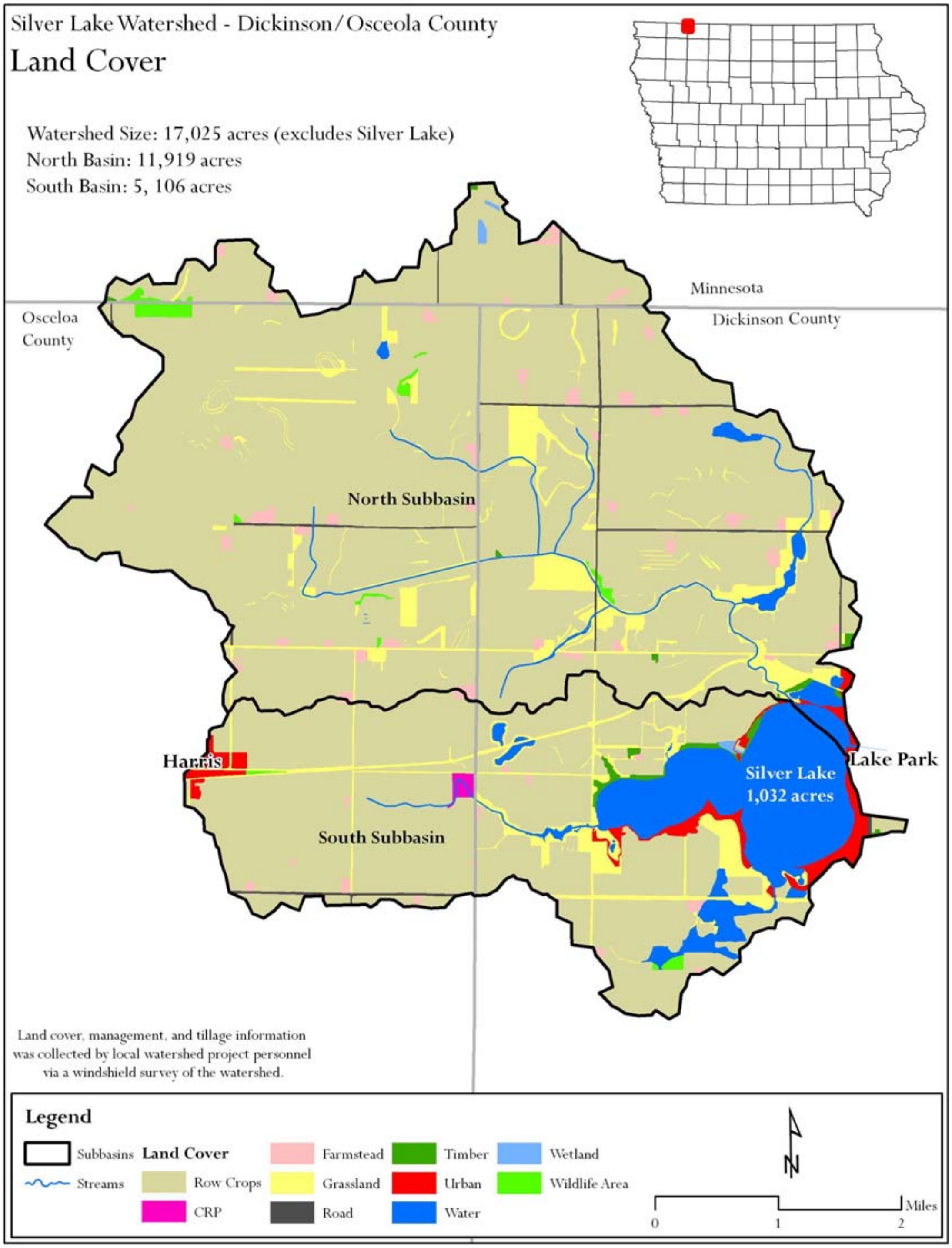


Figure 4. Land cover distribution map based on 2002 IDNR windshield survey

Table 2. Generalized land use composition of Silver Lake watershed.

General Land Use	Description	Area (Acres)	% of Watershed
Row Crops	corn, beans, oats, alfalfa, CRP	14,521.1	85.3
Conservation Areas	timber, grassland, wildlife areas	1,471.3	8.6
Farmsteads	homes, yards	269.3	1.6
Water	wetlands, ponds (excludes lake)	320.5	1.9
Urban/Roads	residential, commercial, roads	442.8	2.6
Total		**17,025**	**100.0**

Soils, climate, and topography. Soils in the Silver Lake watershed are derived from Wisconsin glacial till within the Des Moines Lobe landform region. Depressional and calcareous soils are common in the region. Commonly found soil types, brief descriptions, and typical slopes are reported in Table 3. The topography of the region is relatively flat, with some gently rolling hills and depressed areas that form isolated basins within the watershed. In its natural state, the watershed contained many wetlands in these low-lying depressed areas. However, due to its topography and poorly drained soils, approximately 85 percent of the watershed is tile drained, which enables the land to be agriculturally productive.

Table 3. Predominant soils in the Silver Lake watershed.

Soil Name	Description	Typical Slopes (%)
Nicollet	loam, somewhat poorly drained	1-3
Okoboji	silty clay loam, very poorly drained	0-1
Clarion	loam, moderately eroded, well drained	2-9
Webster	silty clay loam, poorly drained	0-2
Canisteo	silty clay loam, poorly drained	0-2

Source: USDA-NRCS, 2008

The climate is typical of the Midwest, with most of the annual rainfall occurring from late spring through early fall. Spring and summer rainfall can be intense, with large amounts of rain occurring in short time spans. High intensity rainfall increases the potential for localized flooding and soil erosion. Annual precipitation is lower in the northwest corner of Iowa than for most of the state. From April 2001 to March 2008, average annual precipitation at National Weather Service (NWS) COOP station located in Lake Park was 32.3 inches (IEM, 2008).

3. Total Maximum Daily Load (TMDL) for Turbidity

A Total Maximum Daily Load (TMDL) is required for Silver Lake (Dickinson County) by the Federal Clean Water Act. This chapter quantifies the maximum amount of total phosphorus (TP) that Silver Lake can tolerate without violating the state's water quality standards.

3.1. Problem Identification

Silver Lake is a Significant Publicly Owned Lake, and is protected for the following designated uses:

- Primary contact recreation – Class A1
- Aquatic life – Class B(LW)
- Drinking water – Class C
- Fish consumption – Class HH

The 2006 Section 305(b) Water Quality Assessment Report states that primary contact recreation in Silver Lake is "not supported" due to poor water transparency caused primarily by high levels of inorganic suspended solids. This chapter details the development of the TMDL for turbidity. The 2006 305(b) report can be accessed at http://wqm.igsb.uiowa.edu/wqa/305b.html.

Applicable water quality standards. The State of Iowa Water Quality Standards (WQS) are published in the Iowa Administrative Code (IAC), Environmental Protection Rule 567, Chapter 61. Although the State of Iowa does not have numeric criteria for sediment or nutrients, narrative water quality criteria do apply. Chapter 61.3(2) of the WQS contains the general water quality criteria, which are applicable to all surface waters. These narrative criteria require that waters be free of "aesthetically objectionable conditions." The WQS can be accessed on the web at http://www.iowadnr.com/water/standards/files/chapter61.pdf.

Problem statement. The 2006 305(b) report assesses water quality in Silver Lake as follows:

> *"…SUMMARY: The Class A (primary contact recreation) uses are assessed (monitored) as "not supporting" due to very poor water transparency caused primarily by high levels of inorganic suspended solids. The Class B(LW) aquatic life uses are assessed (evaluated) as "fully supporting". The Class C (drinking water) uses are "not assessed" due to the lack of recent information upon which to base an assessment. Fish consumption uses remain assessed (evaluated) as "fully supported" based on results of fish contaminant monitoring in 1999. The sources of data for this assessment include (1) results of the statewide survey of Iowa lakes sponsored by IDNR and conducted by Iowa State University (ISU) from 2000 through 2004, (2) surveys by IDNR Fisheries Bureau, (3) information on plankton communities collected at Iowa lakes from 2000 through 2005 as part*

> *of the ISU lake survey, and (4) results of U.S. EPA/IDNR fish contaminant monitoring in 1999."*

The 305(b) assessment continues with the following explanation of the water transparency problems in Silver Lake:

> *"…Results from the ISU statewide survey of Iowa lakes suggest that high levels of primarily non-algal turbidity adversely affect the Class A and Class B(LW) uses of Silver Lake. Using the median values from this survey from 2000 through 2004 (approximately 15 samples), Carlson's (1977) trophic state indices for total phosphorus, chlorophyll-a, and secchi depth are 76, 54, and 70, respectively. According to Carlson (1977), the index values total phosphorus and secchi depth place this lake in the range of hyper-eutrophic lakes; the index value for chlorophyll-a is in the middle range of eutrophic lakes. These index values suggest extremely high levels of phosphorus in the water column, very low (and much less than expected) levels of chlorophyll-a, and very poor water transparency.*
>
> *According to Carlson (1991), the occurrence of a low chlorophyll-a TSI value relative to those for total phosphorus and secchi depth indicate non-algal particles or color dominate light attenuation. The ISU lake data suggest that non-algal particles do likely limit algal production at Silver Lake. The median level of inorganic suspended solids [ISS] in the 131 lakes sampled for the ISU lake survey from 2000 through 2004 was 5.2 [milligrams per litre] mg/l. Of 131 lakes sampled, Silver Lake had the 28th highest median level of inorganic suspended solids (10.5 mg/l), thus suggesting that non-algal turbidity is the primary factor that limits the production of algae and that contributes to the turbidity-related impairments of both the primary contact recreation and aquatic life uses.*
>
> *Nitrogen limitation does not appear to limit algal production at this lake. Based on median values from ISU sampling from 2000 through 2004, the ratio of total nitrogen to total phosphorus for this lake is 20. This ratio suggests that algal production at Silver Lake is limited by the availability of phosphorus.*
>
> *The presence of very large populations of zooplankton at Silver Lake that graze on algae, however, may explain the majority of the discrepancy between the TSI value for total phosphorus (76) and that for chlorophyll-a (54). In terms of all Iowa lakes sampled, data from the ISU survey show large populations of zooplankton species at this lake that graze on algae. Sampling from 2000 through 2005 showed that Cladoceran taxa (e.g., Daphnia) comprised approximately 60% of the dry mass of the zooplankton community of this lake. The average per summer sample mass of Cladoceran taxa over the 2000-2005 period (169 mg/l) was the 25th highest of the 131 lakes sampled. This population of zooplankton grazers suggests the potential for this type of non-phosphorus limitation on algal production at Silver Lake.*

The levels of nuisance (=noxious) algal species (i.e., bluegreen algae) at this lake do not suggest an impairment of Class A uses. While data from the ISU survey from 2000 through 2004 suggest that bluegreen algae (Cyanophyta) comprise a significant portion (almost 80%) of this lake's summertime phytoplankton community, sampling from 2000 through 2004 showed that the median per summer sample mass of bluegreen algae at Silver Lake (4.7 mg/l) was the 23rd lowest of the 131 lakes sampled. This level is in the lowest 25% of the 131 Iowa lakes sampled. The presence of a relatively small population of bluegreen algae at this lake does not suggest a potential violation of Iowa's narrative water quality standard protecting against occurrence of nuisance aquatic life. This assessment, however, is based strictly on a distribution of the lake-specific median bluegreen algae values for the 2000-2004 monitoring period. Median levels less than the 75th percentile of this distribution (~29 mg/l) were arbitrarily considered by IDNR staff to not represent an impairment of the Class A uses of Iowa lakes. No criteria exist, however, upon which to base a more accurate identification of impairments due to bluegreen algae. Thus, while the ability to characterize the levels of bluegreen algae at this lake has improved over that of the previous (2004) assessment due to collection of additional data, the assessment category for assessments based on level of bluegreen algae nonetheless remains, of necessity, "evaluated" (indicating an assessment with relatively lower confidence) as opposed to "monitored" (indicating an assessment with relatively higher confidence)…"

Data sources. Sources of data used in the development of this TMDL include those used in the 2006 305(b) report, several sources of additional water quality data, and non-water quality related data used for model development. These sources are summarized in the following list:

- Results of statewide survey of Iowa lakes sponsored by IDNR and conducted by ISU from 2000-2007
- Water quality data collected by the University of Iowa Hygienic Laboratory (UHL) from 2005-2007 as part of the Ambient Lake Monitoring Program
- Water quality data collected in several tributaries and in Trappers Bay funded by the Dickinson County Soil and Water Conservation District (SWCD)
- Water quality data collected by the Cooperative Lakes Area Monitoring Project (CLAMP)
- Surveys by the IDNR Fisheries Bureau
- Information on plankton communities collected at Iowa lakes from 2000-2005 as part of the ISU lake survey
- Results of the U.S. Environmental Protection Agency (EPA) and IDNR fish tissue monitoring in 1996
- National Weather Service (NWS) precipitation data accessed through the Iowa Environmental Mesonet (IEM)
- Land cover and land use data collected via windshield survey in 2007

Water quality data was grouped into two primary data sets for statistical analysis and water quality modeling: (1) ISU data collected from 2001-2004, and (2) UHL data collected from 2005-2007. These data are provided in Appendix C of this report, along with tributary and Trappers Bay data collected by the SWCD. ISU data from 2000 was not considered due to suspected data problems, specifically TP concentrations measured in 2000. UHL data is used in favor of ISU data from 2005-2007 because it is more complete (less null sample values) than ISU data collected during that time span. Statistical analysis and water quality trends were developed using both data sets lumped together. The water quality model was developed and calibrated using the 2005-2007 UHL data. After calibration, the model was applied to the 2001-2004 ISU data to validate model performance for a different timeframe. SWCD data was not utilized in model development because there was no approved Quality Assurance Project Plan (QAPP) at the time this TMDL was developed. Modeling assumptions and methodology are discussed in further detail in Appendix D.

Interpreting Silver Lake data. The 2006 305(b) assessment reports that poor water transparency in Silver Lake is caused primarily by non-algal turbidity. Important transparency-related terms and their definitions are provided in Table 4.

Table 4. Transparency-related terms and their definitions.

Parameter	Definition
Turbidity	Properties of the water column that cause light to be scattered and absorbed, resulting in low water clarity. Primarily caused by algae and/or inorganic TSS.
Secchi Depth (SD, m)	A measure of water column transparency that is often used as a translator for turbidity.
Total Suspended Solids (TSS, mg/L)	Solids residue captured on a 0.45 micrometer (um) filter and dried at 105 degrees Celsius. Represents all particles suspended in the water column larger than the filter size (0.45 um).
Inorganic Suspended Solids (ISS, mg/L)	The portion of TSS remaining after heating at 550 degrees Celsius. Represents suspended particles that are not composed of matter originating from plants/animals.
Volatile Suspended Solids (VSS, mg/L)	Quantified as the difference between TSS and ISS. VSS is the organic fraction of suspended particles (those particles originating from plants/animals).
Chlorophyll-a (Chl, ug/L)	Chlorophyll-a is a specific pigment found in algae, and used as a measure of algae concentration in water.
Total Phosphorus (TP, ug/L)	In the absence of light limitation (from non-algal turbidity), TP is often the limiting factor for algal growth in lakes.

Although the 305(b) assessment attributed poor transparency to non-algal turbidity using the 2000-2004 ISU data set, additional statistical analyses were performed in the development of this TMDL using the updated data set (ISU 2001-2004 and UHL 2005-2007). The purpose of additional analysis was to gain more insight to the probable cause(s) of poor water clarity in Silver Lake, investigate more recent water quality trends, and to confirm or qualify the conclusions made in the 2006 assessment.

Secchi depth (SD) was plotted against a variety of other water quality parameters related to transparency. The regression analysis resulted in several key observations. Not surprisingly, there is a strong correlation between TSS and Secchi depth, as illustrated in Figure 5. This strong correlation reveals that suspended particles are causing light limitation and reduced water clarity in Silver Lake. However, there is no observable correlation between chlorophyll-a and Secchi depth, as shown in Figure 6. The absence of a relationship between chlorophyll-a and Secchi depth suggests transparency problems in Silver Lake are not usually driven by excess algae growth, but by inorganic suspended solids.

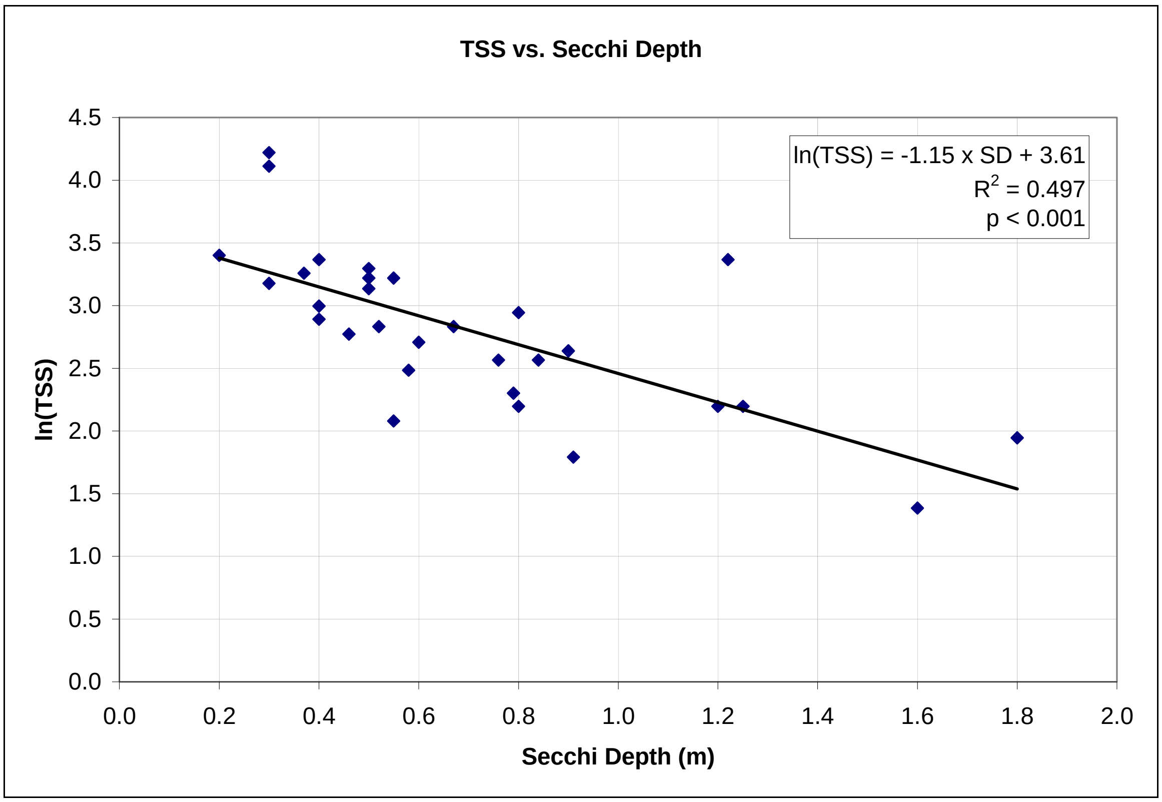


Figure 5. Regression of ln(TSS) versus Secchi depth.

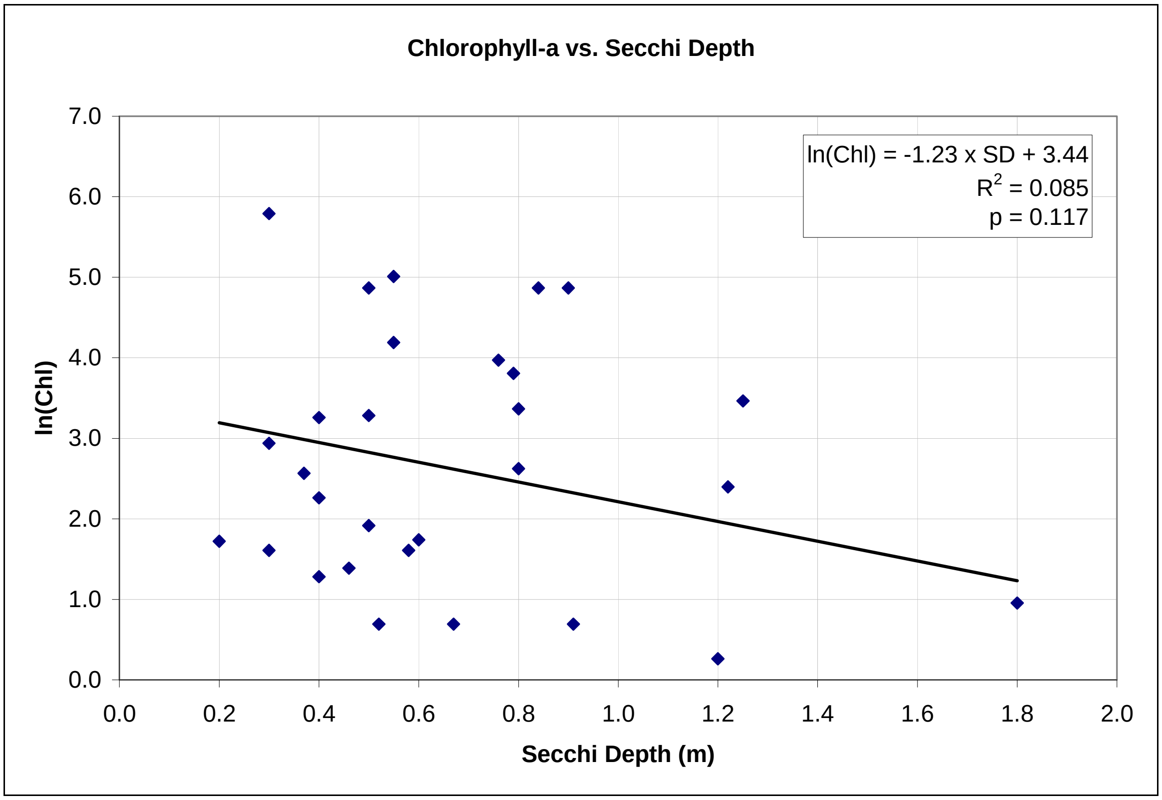


Figure 6. Regression of ln(Chl) versus Secchi depth.

Table 5 reports regression statistics for Secchi depth and TSS, ISS, VSS, TP, and chlorophyll-a. The R-squared value is an indicator of how much of the variability in Secchi depth is explained by the regression model. The higher the R-squared value, the better the regression model, with a value of R-squared equal to one being a "perfect" correlation. The p-value is defined as the level of significance, which is the probability that the variability is random. The smaller the p-value, the more confidence there is that the variation in Secchi depth is significantly correlated to the predictor variable and not random. A p-value less than or equal to 0.05 indicates statistical significance for regressions developed in this TMDL.

Table 5. Secchi depth regression statistics.

Predictor Parameter	R-squared	p-value
ln (TSS)	0.497	< 0.001
ln (ISS)	0.197	0.057
ln (VSS)	0.402	< 0.001
ln (Chl)	0.085	0.117
ln (TP)	0.105	0.076

Secchi depth is significantly correlated to TSS and VSS. Correlations with TP and ISS are stronger than for chlorophyll-a, but weaker than for VSS and TSS, and not statistically significant. One would expect a positive and significant correlation between Secchi depth and ISS if non-algal turbidity were the sole cause of poor water clarity.

Carlson's Trophic State Index (TSI) was used to evaluate the relationships between TP, algae (chlorophyll), and transparency (Secchi depth) in Silver Lake. If the TSI values for the three parameters are the same, the relationships between the three are strong. If the TP TSI values are higher than chlorophyll TSI, it suggests there are limitations to algal growth besides phosphorus. Figure 7 illustrates each of the individual TSI values throughout the sampling period. The general trend that TP TSI values are the highest of the three, and chlorophyll TSIs are the lowest, supports the notion that algae is not the primary cause of turbidity in Silver Lake. However, there are several instances of very high chlorophyll-a values (greater than 75), indicating algal blooms do occur.

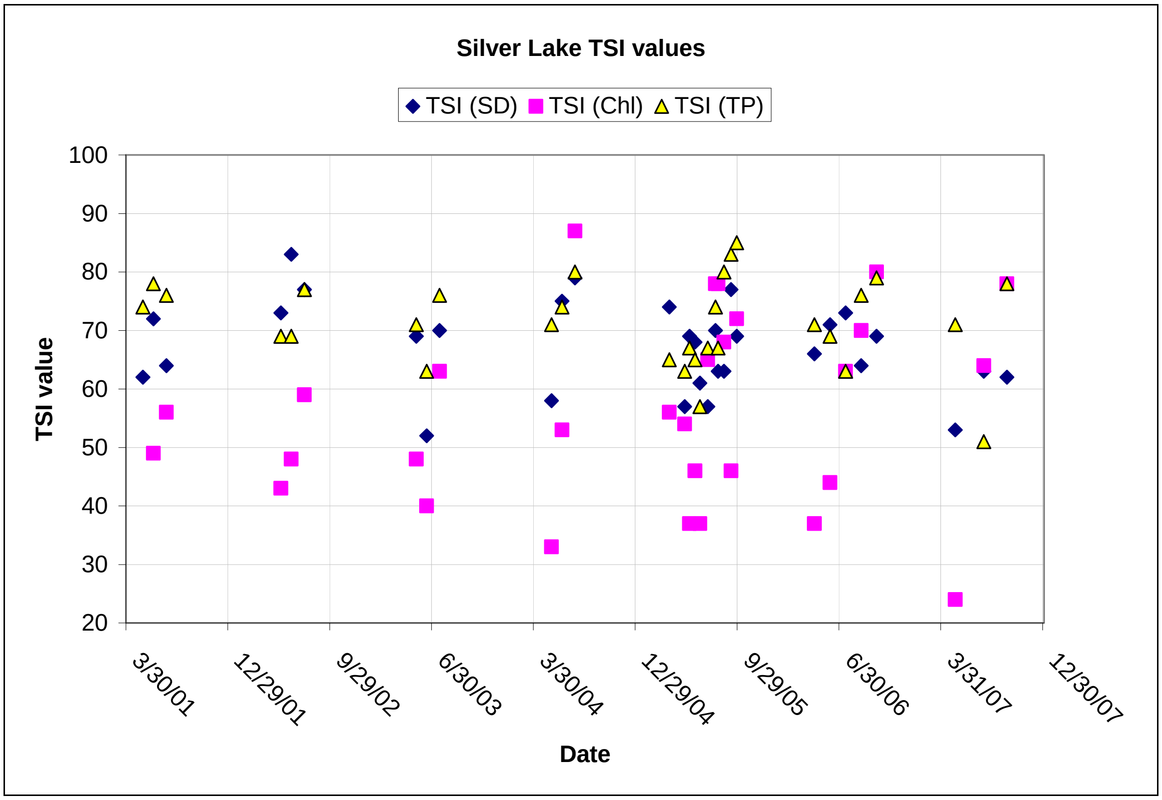


Figure 7. Silver Lake TSI values (2001-2004 ISU and 2005-2007 UHL data sets).

Figures 8 and 9 illustrate a method for interpreting the meaning of the deviations between TSI values. The quadrant on the right side of the figure indicates factors that may limit algal growth in a lake. A detailed description of this approach is available in *A Coordinator's Guide to Volunteer Lake Monitoring Methods* (Carlson and Simpson, 1996). If the deviation between the chlorophyll-a TSI and TP TSI (Chl TSI minus TP TSI) is less than zero, the data point will fall below the X-axis, which suggests that phosphorus may not be limiting algal growth. Points above the X-axis would indicate that phosphorus is the limiting factor. Points to the left of the Y-axis (Chl TSI < SD TSI) represent conditions in which transparency is reduced by non-algal turbidity, whereas points to the right reflect situations in which transparency is greater than chlorophyll levels would suggest.

The quadrant on the left of Figure 8 plots the deviations based on the TSI values computed using median concentration and Secchi depth data for Silver Lake. Figure 9 illustrates the deviations considering mean data values. Note that using median data is consistent with the 305(b) assessment, corresponding deviations reveal that chlorophyll-a is under-predicted by TP, and non-algal turbidity is the limiting factor. However, if mean values are used, the deviations suggest that zooplankton grazing, also discussed in the 305(b) report, may be limiting algal growth. TSI values for Silver Lake are reported in Table 6. The fact that the TSI for mean chlorophyll-a concentration is much higher than for median concentration suggests that algal blooms may be a problem, even though non-algal turbidity is the more frequent cause of poor water clarity. Because the water quality model uses and simulates average concentrations, data based on mean concentrations are emphasized in the remainder of this TMDL.

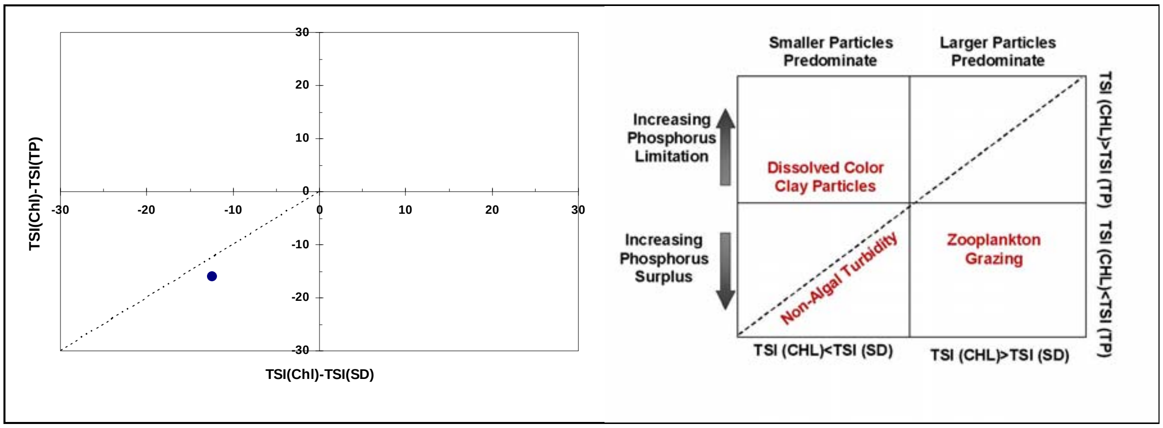


Figure 8. TSI deviations based on median concentrations and Secchi depth.

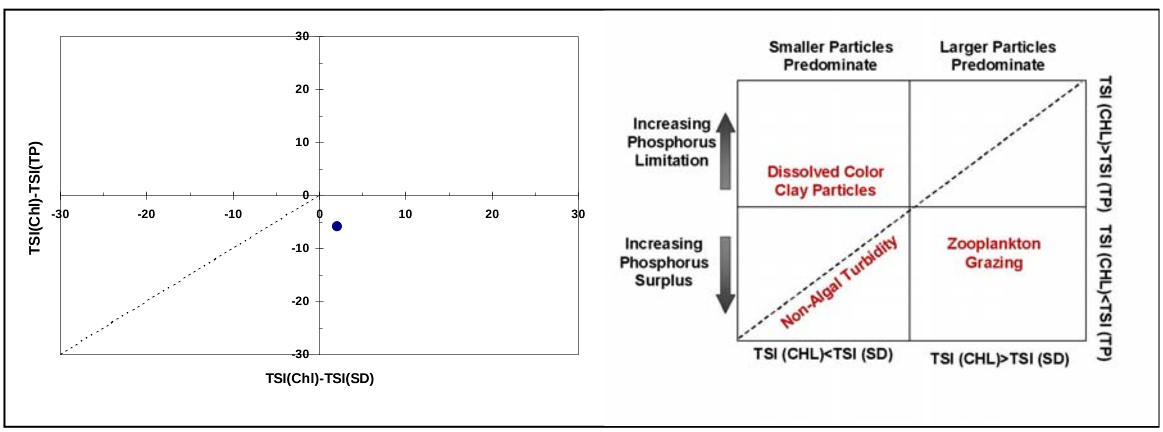


Figure 9. TSI deviations based on mean concentrations and Secchi depth.

Table 6. TSI values using mean and median concentrations.

	TSI (SD)	TSI (Chl)	TSI (TP)
Mean Values	65	67	73
Median Values	68	55	71

Table 7 describes likely attributes related to primary contact recreation and aquatic life for lakes that fall into one of several ranges in TSI values. Silver Lake is considered eutrophic to hyper-eutrophic based on TSI values for mean Secchi depth, mean chlorophyll-a concentration, and mean total phosphorus.

Table 7. Implications of TSI values on lake attributes.

TSI Value	Attributes	Primary Contact Recreation	Aquatic Life (Fisheries)
50-60	eutrophy: anoxic hypolimnia; macrophyte problems possible	[none]	warm water fisheries only; percid fishery; bass may be dominant
60-70	blue green algae dominate; algal scums and macrophyte problems occur	weeds, algal scums, and low transparency discourage swimming and boating	Centrarchid fishery
70-80	hyper-eutrophy (light limited). Dense algae and macrophytes	weeds, algal scums, and low transparency discourage swimming and boating	Cyprinid fishery (e.g., common carp and other rough fish)
>80	algal scums; few macrophytes	algal scums, and low transparency discourage swimming and boating	rough fish dominate; summer fish kills possible

Note: Modified from Carlson and Simpson (1996).

3.2. TMDL Target

General description of the pollutant. The 305(b) assessment and the regression analysis described in Chapter 3.1 both indicate non-algal turbidity is the primary cause of poor water clarity in Silver Lake. However, further investigation using Carlson's trophic state index methodology suggests that algae, as represented by chlorophyll-a, can also lead to transparency problems. For this reason, the TMDL considers in-lake targets for Secchi depth, chlorophyll-a, and TP. If only non-algal turbidity were reduced, algal blooms could actually worsen due to decreased light limitation. In-lake water quality targets for mean Secchi depth, chlorophyll-a and TP concentrations, and corresponding TSI values are reported in Table 8.

Table 8. Silver Lake existing TSI values and water quality targets.

Parameter	2001-07 TSI	Target TSI	2001-07 Mean	Target Mean	Improvement Needed
Secchi depth	65	60	0.7 m	1.0 m	Increase 43%
Chlorophyll-a	67	65	41.9 ug/L	34 ug/L	Decrease 19%
Total Phosphorus	73	65	119.8 ug/L	68 ug/L	Decrease 43%

Reductions in both TSS and TP loading are needed to meet the in-lake targets for Secchi depth, chlorophyll-a, and total phosphorus. Because most of the total phosphorus in lakes is associated with soil particles (sediment), controlling TP will require reduction of sediment loading and TSS. In other words, adequate reduction of TP loads should result in reduction of both algal and non-algal turbidity. Future monitoring will be required to determine if the target TP reductions and corresponding reductions in suspended solids (sediment) result in achievement of the in-lake targets set forth in this TMDL

Selection of environmental conditions. Both non-algal turbidity and occasional algal blooms cause poor water transparency in Silver Lake. The critical period for the occurrence of high non-algal turbidity and/or algal blooms resulting from high phosphorus levels in the lake is the growing season (April through September). However, sediment and phosphorus accumulate in reservoirs over time and are recycled within the system, so annual average sediment and phosphorus loading must be controlled. Existing and allowable TP loads to Silver Lake will be expressed as daily maximums to comply with EPA guidance, and as annual averages to help guide water quality improvement efforts.

Waterbody pollutant loading capacity (TMDL). This TMDL for turbidity establishes in-lake targets for Secchi depth, chlorophyll-a, and TP using analysis of existing water quality data and Carlson's trophic state index methodology. The water quality targets are aggressive, but are also reasonably achievable. If these targets are met, the narrative water quality criteria applicable to Silver Lake should be attained.

The allowable in-lake targets were translated to the TP loading capacity by performing water quality simulations using the BATHTUB model. BATHTUB is a steady-state water quality model that performs empirical eutrophication simulations in lakes and reservoirs (Walker, 1999). The BATHTUB model was calibrated to water quality data collected by UHL from 2005 through 2007, using watershed hydrology and sediment and nutrient loads predicted by the Generalized Watershed Loading Function (GWLF) model. GWLF input included local soil, land cover, and climate data for the calibration period (2005-2007). The annual TP loading capacity of 8,499 pounds per year (lbs/yr) was obtained by adjusting the tributary and internal TP loads in the calibrated BATHTUB model until the target Secchi depth, chlorophyll-a, and TP concentrations were attained. A detailed discussion of the parameterization of the GWLF and BATHTUB models is provided in Appendix D.

In November of 2006, The U.S. Environmental Protection Agency (EPA) issued a memorandum entitled *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.* In the context of the memorandum, EPA

> *"…recommends that all TMDLs and associated load allocations and wasteload allocations include a daily time increments. In addition, TMDL submissions may include alternative, non-daily pollutant load expressions in order to facilitate implementation of the applicable water quality standards…"*

As recommended by EPA, the loading capacity of Silver Lake for TP is expressed as a daily maximum load, in addition to the allowable average annual load of 8,499 lbs/yr obtained above. The annual average load is more applicable to the assessment of in-lake water quality and water quality improvement actions, while the daily maximum load expression satisfies the legal uncertainty addressed in the EPA memorandum.

The maximum daily load was estimated from the annual average load using a statistical approach that is outlined in more detail in Appendix D. This approach uses a lognormal distribution to calculate the daily maximum from the long-term (e.g., annual) average load. The methodology for this approach is taken directly from a follow-up guidance document entitled *Options for Expressing Daily Loads in TMDLs* (EPA, 2007), and was issued shortly after the November 2006 memorandum cited previously. This methodology can also be found in EPA's 1991 *Technical Support Document for Water Quality Based Toxics Control*. Using the approach, the allowable maximum daily load (loading capacity) for TP in Silver Lake is calculated to be 45.9 lbs/day.

Decision criteria for water quality standards attainment. The narrative criteria in the water quality standards require that Silver Lake be free from "aesthetically objectionable conditions." There are no numeric criteria associated with water clarity, therefore attainment of the standard is based on maintaining relatively good water clarity compared to other Iowa lakes. The primary metric for water quality standards attainment set forth in this TMDL is obtaining/maintaining a Secchi depth of at least 1.0 meter.

Carlson's Trophic State Index provides insight to the complex relationships between transparency (as measured by Secchi depth), chlorophyll-a, and total phosphorus in lakes. TSI values for Secchi depth, chlorophyll-a, and TP should be assessed to evaluate water quality trends and relationships. Achieving the target TSI values and associated in-lake measurements reported in Table 7 will result in standards attainment.

3.3. Pollution Source Assessment

Existing load. Existing TP load to Silver Lake has not been monitored, therefore long-term simulations of loading were developed using the GWLF model, within the BasinSim windows-based interface. GWLF has been used nationally for research and TMDL development, and is particularly useful for simulating sediment, nitrogen, and phosphorus loading from a mixed-use watershed. Key model inputs include parameters that are based on soil information, land use, and land practice management (Haith et al., 1996). GWLF includes the ability to simulate point sources, septic tanks, and manure applied to croplands, which are often important considerations in TMDL development.

Using GWLF, the existing annual average TP load to Silver Lake from April 2005 through March 2008 was estimated to be 19,980 lbs/yr, or 54.7 lbs/day. This period was selected for two primary reasons: (1) annual GWLF simulations must begin on April 1 and end on March 31, and (2) water quality monitoring data from UHL during the 2005-07 growing seasons were utilized in the calibration of the BATHTUB water quality model. The existing daily maximum load is estimated at 107.8 lbs/day. For consistency, the existing maximum daily load was estimated from the annual average load (GWLF output) using the same statistical approach described for the loading capacity in Chapter 3.2. See Appendix D for more details.

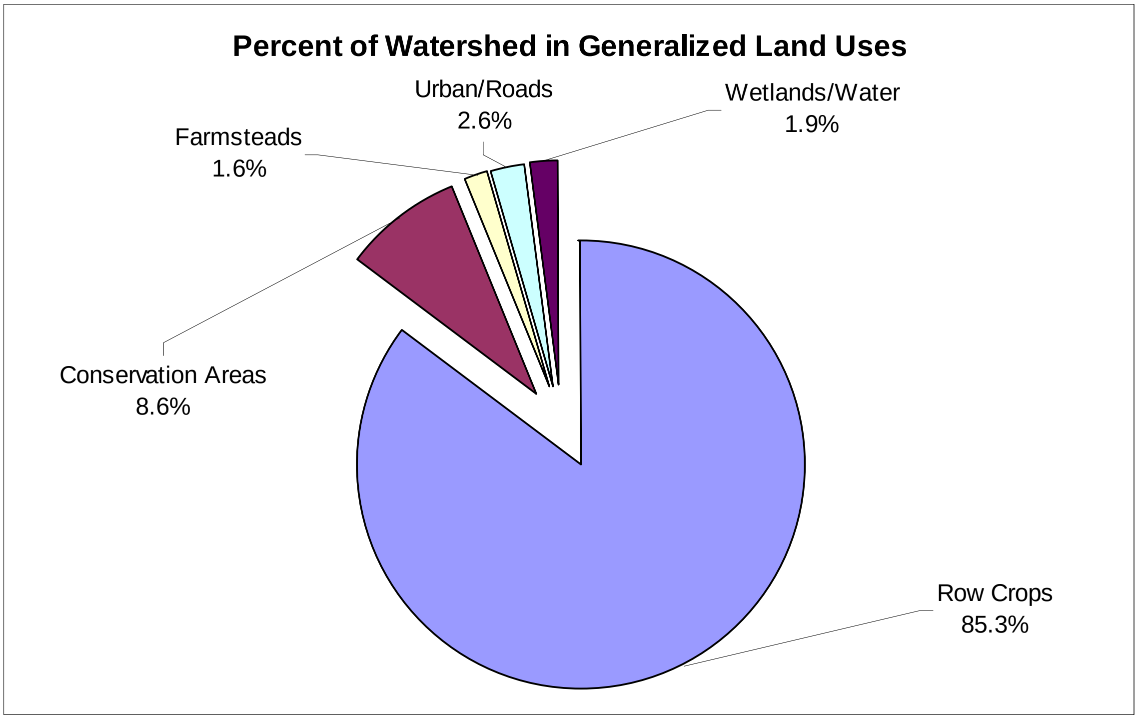
Departure from load capacity. The existing average annual TP load to Silver Lake is an estimated 19,980 lbs/year. The TP target load, also referred to as the loading capacity, is 8,499 lbs/yr (average annual) and 45.9 lbs/day (maximum daily). To meet the target loads, a reduction of 11,481 lbs/yr, or 57.5 percent, is required. This is an aggressive goal, and will require a comprehensive package of BMPs and other water quality improvement activities to be implemented in the watershed. The implementation plan included in Chapter 4 describes recommended BMPs and outlines a preliminary implementation schedule.

Identification of pollutant sources. The existing TP load to Silver Lake stems from nonpoint sources of pollution. Figure 10 illustrates the percent of generalized land uses that make up the watershed, as well as the relative TP contributions from various sources. Table 9 reports existing TP loads from each source, as simulated using GWLF and 2005-2007 climate data input. The two largest sources of phosphorus loading to Silver Lake are runoff from row crop agriculture (46.1 percent) and phosphorus recycled within the lake, also referred to as the internal load (39.0 percent).

Runoff from agricultural land contains phosphorus bound to small soil particles, and phosphorus in manure or synthetic fertilizer applied to cropland. Soil erosion, over-application of manure or fertilizer, and improper timing of application can all exacerbate phosphorus loading to the lake from agricultural runoff. Sediment and phosphorus from these sources can cause water clarity problems immediately upon entering the lake, or they can accumulate over time and lead to clarity issues from internal loading.

Many Iowa lakes have an internal source of phosphorus in addition to external sources from the watershed. In shallow lakes with large areas of open water and a lack of aquatic vegetation, this problem is magnified. Lakes with no aquatic vegetation are wind swept, have loosely consolidated bottom sediments, and can have high densities of common carp. In large numbers, the feeding habits of common carp can stir up significant amounts of sediment and phosphorus, which further magnifies the internal load.

Water quality modeling and anecdotal data analyzed in the development of this TMDL indicate internal phosphorus loading is a significant source of the TP load to the lake. Silver Lake is shallow, and because of a lack of aquatic vegetation (submergent and shoreline), it is susceptible to wind-induced mixing. Sustained high water levels resulting from major changes in the hydrology of the watershed, the proliferation of common carp, and increased siltation all perpetuate this condition. All of these facts support the assumption that internal TP loading is problematic and should be considered in the TMDL.



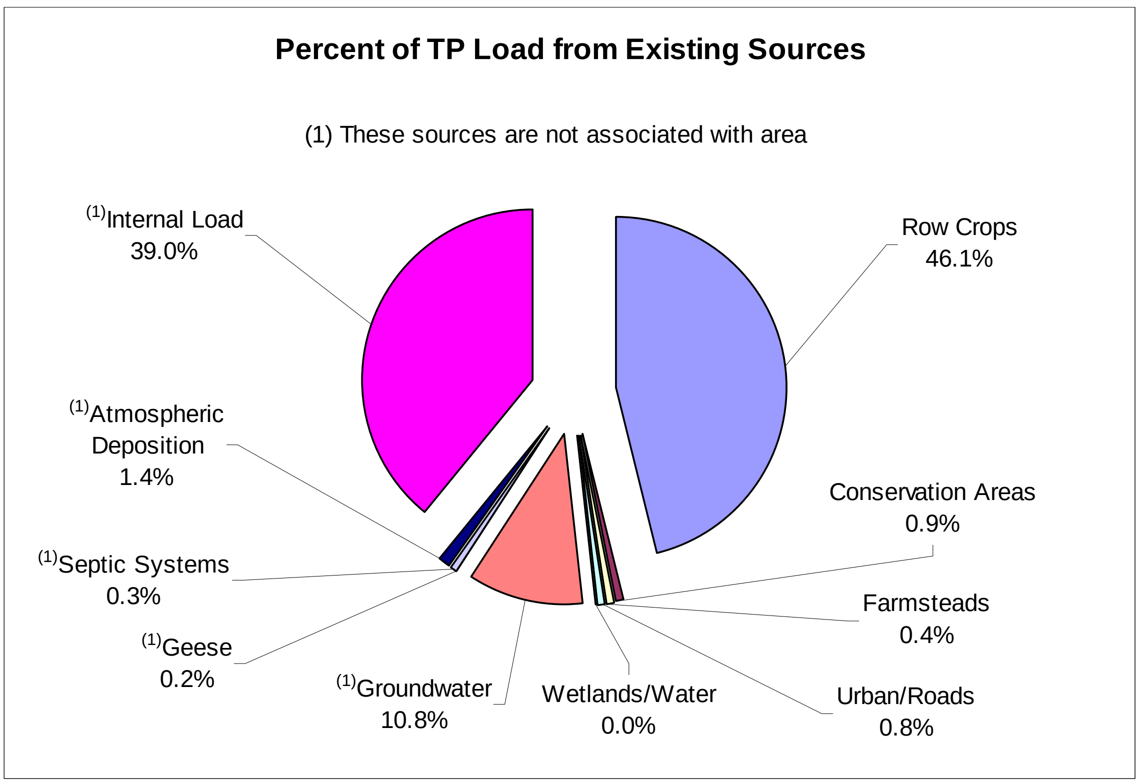


Figure 10. Percent of watershed in generalized land uses compared with relative TP load contributions.

The water quality model for Silver Lake indicated internal loading comprises approximately 39 percent of the existing TP load. This relative contribution is consistent with internal loading rates estimated for other shallow lakes in Iowa, which report internal contributions generally between 25 and 60 percent of the overall TP load. The TMDL for Lower Gar Lake, another shallow lake in Dickinson County, assumes an internal loading contribution of 42.5 percent of the overall TP load (IDNR, 2003). It should be noted that these internal loading estimates are based on modeling results and not direct observations. More direct methods of calculating internal loads are available, but results are varied, and methods are costly, time-intensive, and require complex field sampling and laboratory analysis.

The Silver Lake TMDL partitions external loads to various sources and accounts for an overall internal load (Figure 10). However, with available data and modeling methods, it is not possible to partition internal loads to individual contributions from wind-induced mixing, common carp, and power boating. It is important to consider all three factors when developing lake management strategies.

In addition to row crops and internal loading, smaller sources of TP to Silver Lake exist. These include sediment and phosphorus from non-agricultural land uses, groundwater sources, failing septic systems, and natural or background sources. Background sources include wildlife in the watershed, geese at the lake, and atmospheric deposition. There are no regulated point sources of phosphorus in the watershed. However, geese residing at the beach were considered point sources for modeling purposes only.

Groundwater sources of phosphorus are in the form of dissolved phosphorus (DP), and can result from fertilizer application and transformations that occur in the soil as part of the phosphorus cycle. The GWLF model associates a groundwater DP concentration with land uses in the watershed. These input groundwater concentrations are available in the GWLF user manual, and parameterization is discussed in detail in Appendix D. The largest source of DP is groundwater beneath cropland.

There are 49 septic systems in the Silver Lake watershed. Conversations with the Dickinson and Osceola County sanitarians revealed that as many as 80 to 90 percent of these systems are not currently permitted (D. Kohlhaase and D. Davids, personal communication). For the purposes of this TMDL, it was assumed that 75 percent of septic systems are not functioning properly, and that only those systems within a quarter mile of the nearest stream or drain-tile intake contribute loads to the lake. This results in 30 percent of septic systems in the watershed contributing phosphorus to the lake, as reported in Table 9.

Allowance for increases in pollutant loads. There is no allowance for increased TP loading included as part of this TMDL. A majority of the watershed is in agricultural row crop production, and is likely to remain in cropland in the future. The City of Lake Park, which borders the east edge of the lake, may grow in population in the future. However, it is highly unlikely that population growth would trigger the City's storm sewer system to be considered a municipal separate storm sewer system (MS4), which would require a wasteload allocation as part of Phase 2 NPDES permitting requirements. There are no known unsewered communities in the watershed; therefore, it is unlikely that a future WLA would be needed for a permitted wastewater discharge. There may be an increase in residential construction in the watershed in the future. Transition from agriculture to residential land use would change the nature and the source of loading, but not the total LA as set forth in the TMDL.

Table 9. Simulated TP source loads for existing conditions.

TP Source (land uses and other inputs)	Descriptions and Assumptions	Existing Load (lb/yr)	TP Load (%)
Row Crops	corn, beans, oats, alfalfa	9,217	46.1
Conservation Areas	forest, grassland, wildlife areas, CRP	180	0.9
Farmsteads	Farmsteads	76	0.4
Urban/Roads	residential lands use, roads	164	0.8
Septic Systems	49 septic systems, 30% contributing TP	66	0.3
Geese	150 geese (Oct-Apr); 100 geese (May-Sep)	45	0.2
Groundwater	TP inputs based on land use	2,158	10.8
Atmospheric	atmospheric deposition to lake	276	1.4
Internal Load	recycled from bottom of lake	7,798	39.0
Total		**19,980**	**100**

3.4. Pollutant Allocation

Wasteload allocation. There are no permitted point source dischargers in the Silver Lake watershed, therefore, the TMDL wasteload allocation is set to zero.

Load allocation. The entire TP load to Silver Lake is attributed to nonpoint sources, including internal and external loading. Table 10 shows a potential load allocation scheme for the Silver Lake watershed that would meet the overall target TP load. These individual reductions are provided as a guide. There are many combinations of reductions from individual sources that would result in attainment of water quality standards. Development of an allocation scheme such as the one in Table 10 will be a key component of future implementation planning.

The sum of the load allocations in the allocation scheme must not exceed 7,649 lbs/yr. Note that in the example allocation scheme in Table 10, the resulting LA is equal to the required annual TP load allocation of 7,649 lbs/yr. Using EPA's methodology for expressing annual loads as daily loads, the maximum daily TP load allocation is 41.3 lbs/day (based on the annual LA of 7,649 lbs/yr). Both internal and external loads must be reduced to meet the required load allocations and water quality standards. The solid line in Figure 11 illustrates potential combinations of internal and external loading reductions to meet the annual allocation of 7,649 lbs/yr. The dashed lines indicate the limits of acceptable combinations (i.e., the minimum internal and external reductions). Note that 5.5 percent of the internal load must be removed even if 100 percent of the external load is controlled. Similarly, 38.1 percent of the external load must be removed if 100 percent of the existing internal load is eliminated.

Table 10. Potential allocation scheme to meet the load allocation.

TP Source	Existing Load (lb/yr)	LA (lb/yr)	Load Reduction (%)
Row Crops	9,217	3,244	64.8
Conservation Areas	180	162	10
Farmsteads	76	76	0
Urban/Roads	164	126	23
Groundwater	2,158	2,158	0
Geese	45	45	0
Septic Systems	66	2	97
Atmospheric Deposition	276	276	0
Internal Load	7,798	1,560	80
Total	**19,980**	**7,649**	**61.7**

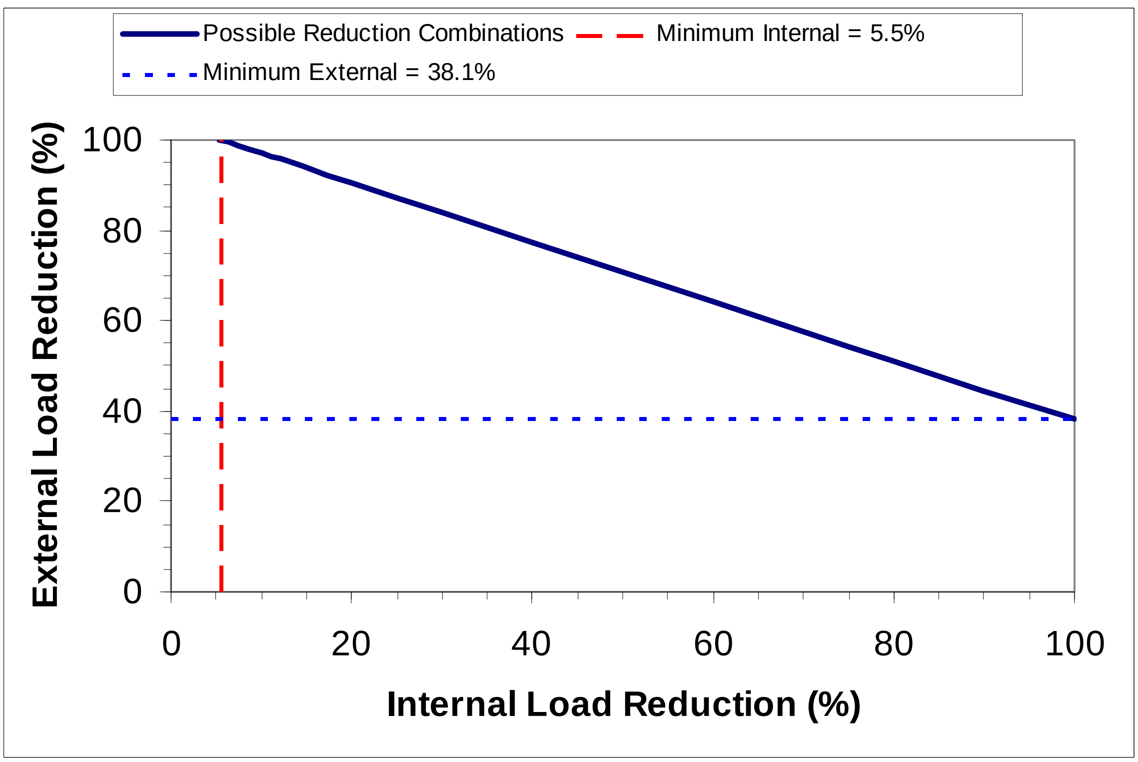


Figure 11. Possible combinations of internal and external load reductions to meet the TMDL load allocation.

Margin of safety. To account for uncertainties in data and modeling, a margin of safety (MOS) is a required component of all TMDLs. An explicit MOS of 10 percent was utilized in the development of this TMDL. The 10 percent MOS is equivalent to 850 lbs/yr, or 4.6 lbs/day when expressed in terms of a daily maximum load.

3.5. TMDL Summary

The following equation represents the total maximum daily load (TMDL) and its components for Silver Lake (Dickinson County):

TMDL = LC = Σ WLA + Σ LA + MOS

Where: TMDL = total maximum daily load
LC = loading capacity
Σ WLA = sum of wasteload allocations (point sources)
Σ LA = sum of load allocations (nonpoint sources)
MOS = margin of safety (to account for uncertainty)

Once the loading capacity, wasteload allocations, load allocations, and margin of safety have all been determined for the Silver Lake watershed, the general equation above can be expressed for the Silver Lake TMDL for turbidity.

Expressed as the maximum annual average, which is helpful for water quality assessment and watershed management:

TMDL = LC = Σ WLA (0 lbs-TP/yr) + Σ LA (7,649 lbs-TP/yr)
+ MOS (850 lbs-TP/yr) = **8,499 lbs-TP/yr**

Expressed as the maximum daily load:

TMDL = LC = Σ WLA (0 lbs-TP/day) + Σ LA (41.3 lbs-TP/day)
+ MOS (4.6 lbs-TP/day) = **45.9 lbs-TP/day**

4. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources recognizes that technical guidance and support are critical to achieving the goals outlined in this Water Quality Improvement Plan. Therefore, this plan is included to be used by local professionals, watershed managers, and citizens for decision-making support and planning purposes. The best management practices (BMPs) listed below represent a package of tools that will help achieve water quality goals if appropriately utilized. It is up to land managers, citizens, and local conservation professionals to determine exactly how best to implement them.

4.1. General Approach & Timeline

Collaboration and action by residents, landowners, lake patrons, and local agencies will be required in order to improve water quality in Silver Lake to support all designated uses. Locally-driven efforts have proven to be the most successful in obtaining real and significant water quality improvements. Improved water quality in Silver Lake would have economic and recreational benefits for people that live, work, and play in the watershed. Therefore, each group of people have a stake in promoting awareness and educating others about Silver Lake, working together to adopt a comprehensive watershed improvement plan, and applying BMPs and land practice changes in the watershed. This large and diverse group of stakeholders provides the opportunity for an effective network of partnerships to be built.

General approach. The TMDL for turbidity utilizes a phased approach to improving water quality. The existing loads, loading targets, a general listing of BMPs needed to improve water quality, and a monitoring plan to assess progress, are established in this TMDL. Ideally, the TMDL would be followed by the development of a watershed management plan. The watershed plan should include more comprehensive and detailed actions to better guide the implementation of specific BMPs. Other ongoing tasks required to obtain real and significant water quality improvements include continued monitoring, assessment of water quality trends, assessment of WQS attainment, and adjustment of proposed BMP types, locations, and implementation schedule.

Timeline. Development of a comprehensive watershed management plan may take one to three years. Implementation of watershed BMPs could take upwards of five to ten years, depending on funding, willingness of landowner participation, and time needed for design and construction of any structural BMPs. Realization and documentation of water quality benefits may take 10 years or longer, depending on weather patterns, amount of water quality data collected, and the successful location, design, construction, and maintenance of BMPs. Utilization of the monitoring plan as outlined in Chapter 5 should begin immediately to establish a baseline, and should continue throughout implementation of BMPs and beyond.

4.2. Best Management Practices

No single BMP will be able to sufficiently reduce pollutant loads to Silver Lake. Rather, a comprehensive package of BMPs will be required to address poor water transparency that has caused “aesthetically objectionable conditions” and impaired primary contact recreation. The majority of the phosphorus and sediment that enter Silver Lake is from agricultural land uses and internal recycling; however, some urban area drains to the lake as well. Therefore, potential BMPs for water quality improvement in Silver Lake are grouped into three components: agricultural, urban, and in-lake. Tables 11 through 13 identify some potential BMPs in each of these respective groups. These lists are not all-inclusive, and further investigation may reveal some alternatives are more or less feasible and applicable to site-specific conditions than others. Development of a more detailed watershed management plan would be helpful in selecting, locating, and implementing the most effective and comprehensive package of BMPs practicable, and would maximize opportunities for future technical and funding assistance.

Agricultural BMPs. One of the primary sources of existing total phosphorus (TP) loads to Silver Lake is runoff from row crop agriculture (Figure 10 and Table 9). Many agricultural BMPs are designed to reduce erosion and/or capture sediment before it reaches a stream or lake. Because a large portion of TP is adsorbed to sediment, BMPs that reduce erosion and sediment transport will also reduce TP loads. Water quality improvement alternatives implemented in row crop areas should include structural BMPs such as sediment control structures, wetlands restoration, and grass waterways. Nonstructural conservation practices such as cross-slope farming, no-till and strip-till farming, diversified crop rotation methods, and use of a winter cover crop are also recommended. To obtain reductions in TP load necessary to meet water quality targets, these practices should be focused where they are needed most (i.e., in areas with the highest potential to contribute sediment and phosphorus loads to the lake.

Figure 12 illustrates areas in the watershed most prone to high erosion rates. Figure 13 shows the relative sediment deliver ratio (SDR) in smaller drainage basins, called catchments. Prioritization and location of sediment and erosion control practices should be guided by these figures because they show the areas in which BMPs will provide the largest potential TP reductions. Highest priority should be given to areas that exhibit high erosion rates, high SDR, and do not currently have a sediment reduction BMP in place. Additionally, widespread adoption of BMPs and techniques that implement multiple BMPs in series (treatment-train approach) will enhance reductions in TP loading to the lake.

Management of livestock manure and synthetic fertilizer is another agricultural BMP that would significantly reduce TP loads to Silver Lake. Incorporation of applied manure and fertilizer into the soil by knife injection equipment reduces phosphorus levels, as well as nitrogen and bacteria levels, in runoff from application areas. Strategic timing of manure and fertilizer application and avoiding over-application may have even greater benefits to water quality. Application of manure on frozen ground should be avoided, as should application prior to likely periods of heavy rainfall. The Osceola and Dickinson County

Soil and Water Conservation Districts (SWCDs) and the Iowa State University (ISU) Extension can help local producers determine how and when to best apply manure to row crops. Another potential manure management practice may be to export most of the manure produced in the watershed out of the drainage area for land application. The feasibility of this practice will depend on the availability of land and ensuring that other water resources are not compromised for the sake of improving Silver Lake.

Table 11. Potential agricultural BMPs for water quality improvement.

BMP or Activity	(1) Potential TP Reduction
Conservation Tillage:	
Moderate vs. Intensive Tillage	50%
No-Till vs. Intensive Tillage	70%
No-Till vs. Moderate Tillage	45%
Cover Crops	50%
Diversified Cropping Systems	50%
In-Field Vegetative Buffers	50%
Terraces	50%
Pasture/Grassland Management:	
Livestock Exclusion from Streams	75%
Rotational Grazing vs. Constant Intensive Grazing	25%
Seasonal Grazing vs. Constant Intensive Grazing	50%
Phosphorus Nutrient Application Techniques	
(2)Deep Tillage Incorporation vs. Surface Broadcast	-15%
(2)Shallow Tillage Incorporation vs. Surface Broadcast	-10%
Knife/Injection Incorporation vs. Surface Broadcast	35%
Phosphorus Nutrient Application Timing and Rates:	
Spring vs. Fall Application	30%
Soil-Test P Rate vs. Over-Application Rates	40%
Application: 1-month prior to runoff event vs. 1-day	30%
Riparian Buffers	45%
(3)Wetlands	20%

(1) Source: IDNR and USDA-ARS (2004). Actual reduction percentages may vary widely across sites and runoff events.
(2) Note: Tillage incorporation can increase TP in runoff.
(3) Note: TP reductions in wetlands vary greatly depending on site-specific conditions. Increasing surface area, implementing multiple wetlands in series, and managing vegetation can result in significantly higher TP reductions.

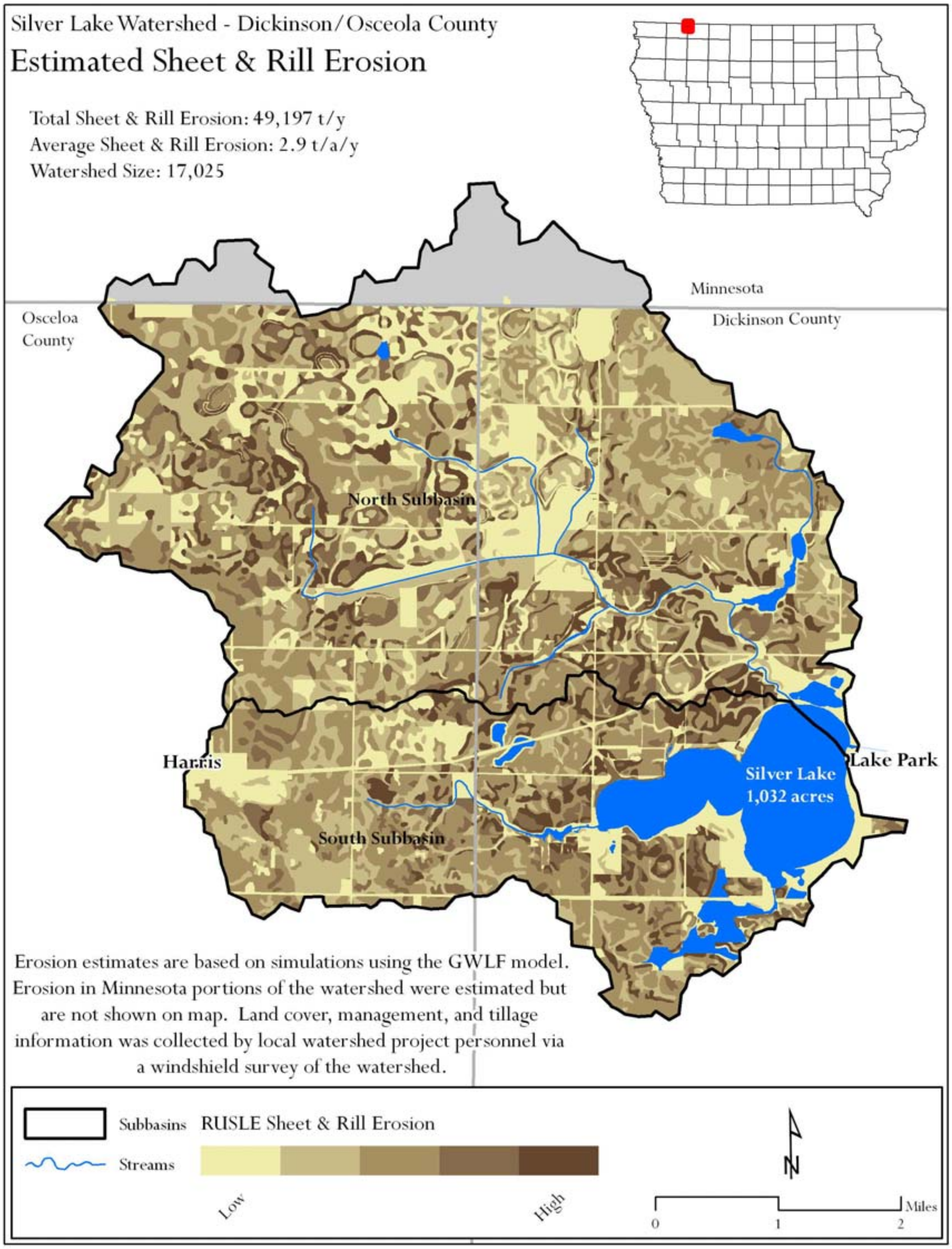


Figure 12. Relative sheet and rill erosion rates in the Silver Lake watershed.

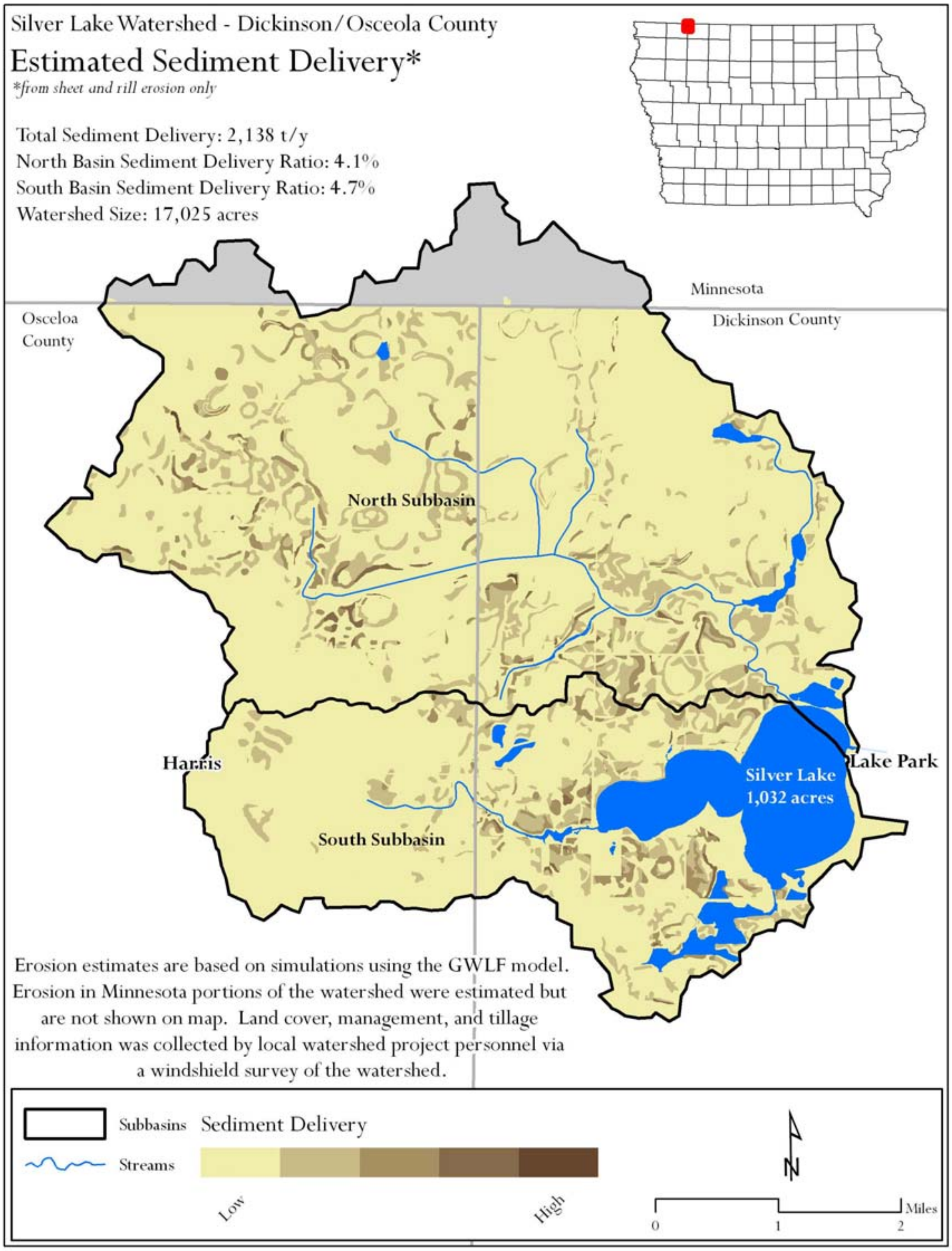


Figure 13. Relative sediment delivery ratio (SDR) in the Silver Lake watershed.

Urban BMPs. Phosphorus loads to Silver Lake generated from urban land uses account for a small portion of the overall load. However, some water quality BMPs for urban stormwater are relatively inexpensive and offer secondary benefits such as reduction of other pollutants, wildlife habitat, and aesthetic benefits. In addition, implementation of urban BMPs in combination with public information and education programs can promote awareness among citizens and lake patrons that everyone plays a role in improving water quality. Although residential development along the shores of Silver Lake is a relatively small source of phosphorus, adoption of BMPs by homeowners can provide localized improvements in water quality and gives citizens a sense of ownership over not only water quality problems, but also solutions. A list of potential BMPs for urban areas and shoreline property owners is provided in Table 12 below. Some of these BMPs may not be feasible or practical for Silver Lake. Local decision makers should evaluate all potential BMPs to select those most applicable to site-specific conditions.

Table 12. Potential BMPs for urban areas and shoreline properties.

BMP or Activity	(1) Potential TP Reduction
Dry Detention Basin	26%
Extended Wet Detention Basin	68%
Wetland Detention	44%
Grass Swales	25%
Infiltration Basin	65%
Bioretention Facility	80%
Vegetated Filter Strips	45%
Water Quality Inlets	9%
Weekly Street Sweeping	6%
Low Impact Development (LID) Techniques	20-80%
Pet Waste Programs (Public Information/Education)	Medium to High
No/Low Phosphorus Fertilizer Programs (Voluntary or Ordinance)	Medium to High
Shoreline buffer strips	Low to Medium
Shoreline stabilization/landscaping	Low to Medium

(1) Percent reductions taken from the EPA Region 5 STEPL model.

In-Lake BMPs. Along with runoff from cropland, phosphorus recycled between the bottom sediment and water column of the lake is a major contributor of the TP load to Silver Lake. Even if all external TP load from the watershed could be eliminated, which is not possible, it would take many years for significant water quality improvement to be observed in Silver Lake due to sediment and attached phosphorus that has accumulated in this shallow lake over the years. To meet the water quality goals established in this TMDL, the internal load must be reduced.

Restoration of Silver Lake will require shallow lake restoration techniques. Over the past decade, IDNR has gained valuable insight into the mechanisms that drive water quality and the quality of fisheries in Iowa's shallow lakes. Restoration of these ecosystems requires an adaptive management approach utilizing a combination of complimentary techniques. Restoration techniques are geared towards emulating pre-settlement conditions. The goal is to shift the lake from a turbid system with little to no aquatic plants, to a clear water system dominated by macrophytes (aquatic plants). Shallow lake restoration techniques include:

- wetlands restoration to emulate natural lake hydrology,
- water level management to establish rooted aquatic vegetation,

- shoreline stabilization to reduce erosion and establish and sustain aquatic plants,
- fisheries management to reduce bottom-feeding fish species (common carp),
- creation of sediment forebays at the mouth of tributary streams to filter sediment and nutrient loads, and
- limited dredging to remove known sediment deposits and create deep-water habitat to compliment fisheries management.

Table 13. Potential in-lake BMPs for water quality improvement.

In-Lake BMPs	Comments	(1) Relative TP Reduction
Wetland/Vegetation Establishment	Rooted vegetation competes with algae for nutrients; overall impact of large wetland/marsh areas on water quality can be significant; vegetation may require annual harvesting to remove accumulated nutrients; reduces a portion of open water areas of the lake, requires water level manipulation.	Med to High
Water Level Management	Helps establish rooted vegetation in shallow areas to stabilize sediments and provide a nutrient sink; requires altering watershed hydrology through wetlands restoration in the watershed; may require lake outlet modification; low water periods may inconvenience lake users at times.	Med to High
Shoreline Stabilization (Public Areas)	Helps establish and sustain vegetation, which competes with algae for nutrients. Impacts of individual projects may be small, but cumulative effects of widespread stabilization projects can be significant.	Med
Fisheries Management	Moderate reductions in internal TP load are possible; existing fish population must be manipulated, which may take several years; in some cases, the lake must be partially drawn down to kill undesirable fish.	Med
Sediment Forebays	Only captures external loads that watershed BMPs fail to remove; requires periodic maintenance.	Low to Med
Dredging	Dredging is seldom cost-effective on a large scale and as a stand-alone measure; disposal of dredged material is often a challenge; dredging should be focused on areas of known sediment deposition or to create deep-water habitat as part of fisheries management.	Low

(1) Reductions (High/Med/Low) are and relative to each other and based on numerous research studies and previous IDNR projects.

Some advantages and disadvantages of shallow lake restoration methods are included in Table 13, along with relative TP reductions. Actual reduction percentages of each alternative vary and depend on a number of site-specific factors. It is virtually impossible to determine how much of the internal load is due to each of the contributing factors, and equally difficult to predict TP reductions associated with individual improvement strategies. A combination of multiple internal load reduction strategies should be utilized to achieve the required internal load reduction. Past lake restorations have shown that this is generally achievable with a combination of wetlands restoration/creation, water level management, creation of sediment forebays, fisheries management, and minimal dredging targeted to specific areas. Conceptual development of these alternatives is best accomplished within the context of a full-scale watershed management plan.

5. Future Monitoring

Water quality monitoring is critical for assessing the status of water resources and historical and future trends. Furthermore, monitoring is necessary to track the effectiveness of BMPs implemented in the watershed and document the status of the waterbody in terms of achieving total maximum daily loads (TMDLs).

Future monitoring in the Silver Lake watershed can be agency-led, volunteer-based, or a combination of both. The Iowa Department of Natural Resources (IDNR) Watershed Monitoring and Assessment Section administers a water quality monitoring program that provides training to interested volunteers. This program is called IOWATER, and more information can be found at the program web site: http://www.iowater.net/Default.htm

It is important that volunteer-based monitoring efforts include an approved water quality monitoring plan, called a Quality Assurance Project Plan (QAPP), in accordance with Iowa Administrative Code (IAC) 567-61.10(455B) through 567-61.13(455B). The IAC can be viewed here: http://www.iowadnr.com/water/standards/files/chapter61.pdf Failure to prepare an approved QAPP will prevent data from being used to assess a waterbody's status on the state's 303(d) list – the list that assesses waterbodies and their designated uses as impaired.

5.1. Monitoring Plan to Track TMDL Effectiveness

Given current resources and funding, future water quality data collection in Silver Lake to assess water quality trends and compliance with water quality standards (WQS) is expected to include monitoring conducted as part of the IDNR Ambient Lake Monitoring Program. Unless there is local interest in collecting additional water quality data, the ambient program will comprise the vast majority of future sampling efforts by IDNR.

The Ambient Lake Monitoring Program was initiated in 2000 in order to better assess the water quality of Iowa lakes. Currently, 132 of Iowa's lakes are being sampled as part of this program, including Silver Lake. Typically, one sample location near the deepest part of the lake is sampled, and many chemical, physical, and biological parameters are measured. Sampling parameters are reported in Table 14. At least three sampling events are scheduled every summer, typically between Memorial Day and Labor Day.

Table 14. Ambient Lake Monitoring Program water quality parameters.

Chemical	Physical	Biological
• Total Phosphorus • Soluble Reactive Phosphorus • Total Nitrogen • Total Kjeldahl Nitrogen • Ammonia • Un-ionized Ammonia • Nitrate + Nitrite Nitrogen • Alkalinity • pH • Silica • Total Organic Carbon • Total Dissolved Solids • Dissolved Organic Carbon	• Secchi Depth • Temperature • Dissolved Oxygen • Turbidity • Total Suspended Solids • Total Fixed Suspended Solids • Total Volatile Suspended Solids • Specific Conductivity • Lake Depth • Thermocline Depth	• Chlorophyll a • Phytoplankton (mass and composition) • Zooplankton (mass and composition)

5.2. Idealized Plan for Future Watershed Projects

Data available from the IDNR Ambient Lake Monitoring Program will be used to assess general water quality trends and WQS violations/attainment. More detailed monitoring data will be required to reduce the level of uncertainty associated with water quality trend analysis, gain a better understanding of the impacts of implemented watershed projects, and guide future water quality modeling and BMP implementation efforts.

The availability of existing IDNR staff and resources will not allow the collection of more detailed monitoring data as part of normal IDNR activities. Only through the interest and action of local stakeholders will funding and resources needed to acquire this important information become available. Table 15 outlines the idealized monitoring plan by listing the components in order, starting with the highest priority. Proposed monitoring locations are illustrated in Figure 14.

Table 15. Idealized monitoring plan.

Parameter(s)	Intervals	Duration	Location(s)
Continuous flow	15-60 minute	Year-round	O1
TSS, TP, SRP, flow	Daily	10-day periods (multiple wet and dry periods)	T1, N1, N2, N3, N4, S1, S2, O1
TSS, TP, SRP, flow	Hourly	24 to 48-hour periods (curing runoff events)	N1, T1, S1, S2, O1
Aquatic vegetation (macrophytes)	Monthly to Seasonally	Every growing season for at least 5 years	Multiple shoreline areas around the lake

Daily monitoring for TSS, TP, SRP, and flow (at tributary sites) for multiple 10-day periods during wet and dry conditions would help confirm and/or reveal information helpful in locating and scheduling BMP construction. Potentially helpful information from this monitoring includes:

- Observed relationships between phosphorus levels and flow: are levels high during times of low flow, high flow, or both?
- Locations of the highest phosphorus and levels in the watershed to confirm priority sources.
- More extensive flow and concentration data to allow calculation of observed pollutant loads under wet and dry conditions.
- Confirmation of water quality improvement, or lack of improvement, resulting from implementation of BMPs throughout the watershed.

In addition to daily data, several occasions of hourly data would provide a more complete picture of water quality. Hourly data during runoff events would reveal how pollutant levels change throughout the storm event. If hourly monitoring shows that concentrations spike quickly towards the beginning of a storm, then BMP implementation should focus on capturing the first flush of runoff. Hourly data would also allow calculation of the total pollutant load for several storm events, which could guide BMP selection and design. Finally, proposed flow and water quality monitoring information would assist in the development and calibration of more complex watershed and water quality models to guide future efforts to simulate various scenarios and watershed response to BMP implementation.

Quantifying the amount of aquatic vegetation is another important component of the monitoring plan. Establishing a healthy aquatic plant population is one of the keys to improving water clarity in Silver Lake. Plant abundance will be one measure of success, and documenting a correlation to water quality improvement will provide strong evidence in support of this management option for future projects.

Monitoring parameters and locations should be continually evaluated. Adjustment of parameters and/or stations should be based on BMP placement, newly discovered or suspected pollution sources, and other dynamic factors. Several locally-led groups have collected water quality data in tributaries to Silver Lake and in Trappers Bay. The IDNR Watershed Improvement Section can provide technical support to locally led efforts in collecting further water quality and flow data in the Silver Lake watershed.

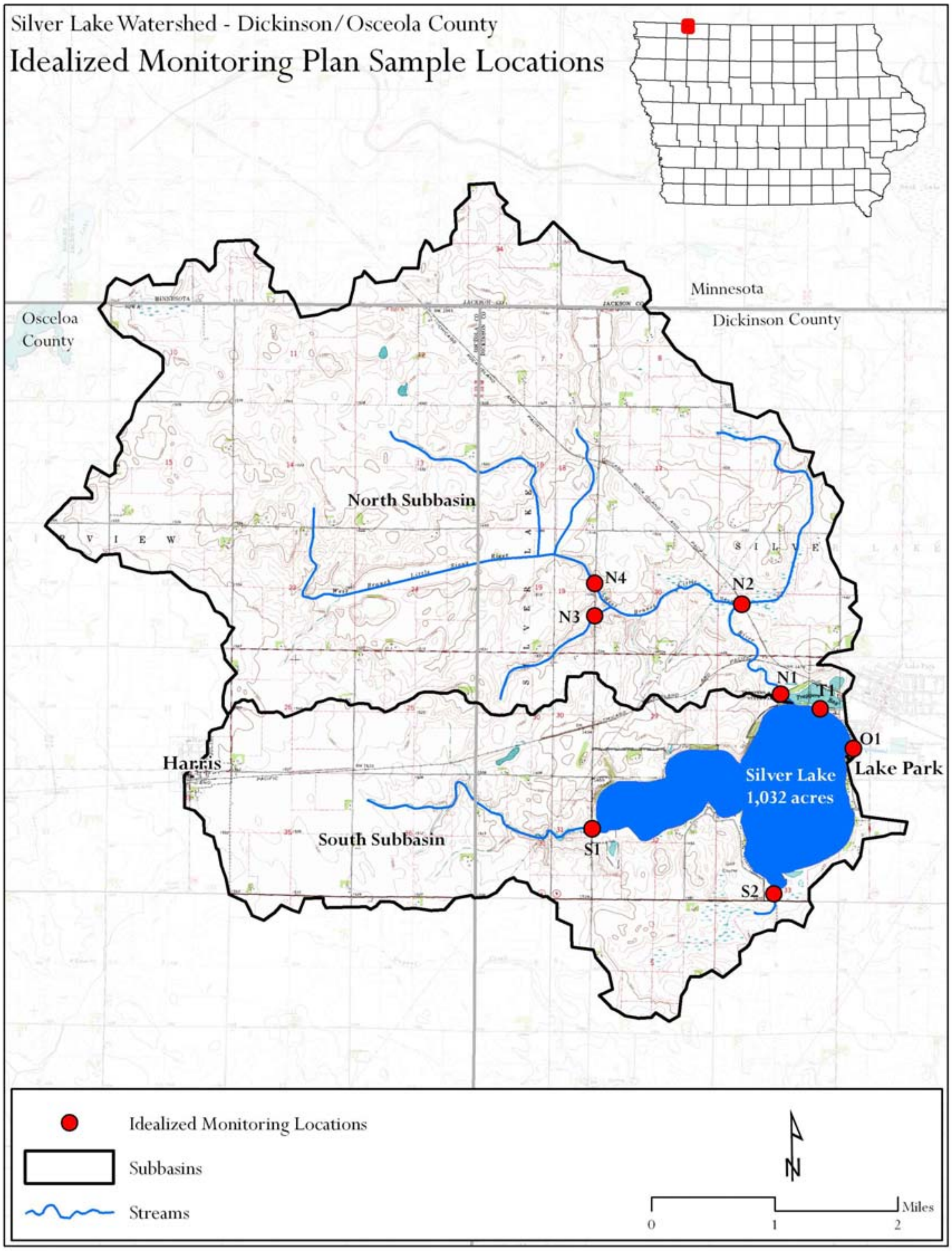


Figure 14. Idealized monitoring plan sample locations.

6. Public Participation

Public involvement is important in the TMDL process since it is the land owners, tenants, and citizens who directly manage land and live in the watershed that determine the water quality in Silver Lake. During the development of this TMDL, considerable effort was made to ensure that local stakeholders were involved in the decision-making process to agree on feasible and achievable goals for the water quality in Silver Lake.

6.1. Silver Lake Technical Advisory Committee Meeting

In the early stages of TMDL development, Iowa Department of Natural Resources (IDNR) staff met with the Silver Lake Technical Advisory Committee. The advisory committee is a key stakeholder group comprised of landowners in the watershed and staff from the Clean Water Alliance and the local Soil and Water Conservation District (SWCD). The committee serves an advising role in watershed improvement projects underway outside of the scope of the TMDL. Specifically, the advisory committee was involved in development of a watershed assessment project that was funded through a watershed development and planning assistance grant, administered by the Iowa Department of Agriculture and Land Stewardship (IDALS). The advisory committee participated in data collection efforts that were helpful in TMDL development, as well as BMP planning efforts to reduce erosion and nonpoint source pollution from agricultural practices in the watershed.

IDNR met with the Silver Lake Technical Advisory Committee on February 19, 2008. The advisory committee was presented with an overview of the TMDL process, including why a TMDL was required, the goals and objectives of the TMDL, and the projected timeline for completion of the TMDL. Input from the advisory committee was also obtained, which proved helpful during TMDL development. Feedback included insights regarding available information, manure application practices, and ongoing activities in the watershed.

6.2. Silver Lake Park Improvement Association Meeting

IDNR met with the Silver Lake Park Improvement Association on April 8, 2008. The improvement association is comprised of residents of Lake Park and staff from the Clean Water Alliance and the SWCD. IDNR explained the TMDL process to the improvement association, including the goals, objectives, and timeline for completion. The improvement association provided input to IDNR in the form of local knowledge of potential pollutant sources and ongoing activities of the association. The association is involved in water quality data collection, the development of city ordinances to protect the lake, and advising the watershed development and planning assistance grant administered through IDALS.

6.3. Public Meeting

A formal public meeting was held at the Lake Park Community Center in Lake Park, Iowa, from 6:00 to 8:00 pm on February 17, 2009. Nearly 50 citizens attended, indicating that there is outstanding local support of water quality improvement efforts. The primary purposes of the meeting were to present the draft of the Silver Lake TMDL for Turbidity to the public, and to provide stakeholders with an opportunity to ask questions and offer input. Additionally, IDNR personnel explained the next steps required to improve water quality in Silver Lake, and stakeholders were informed of technical assistance and possible funding opportunities available through IDNR. A community-based planning process for watershed improvement and lake restoration was also discussed.

Key agency attendees included:

- IDNR – Watershed Improvement Section (TMDL)
- IDNR – Section 319 Program
- IDNR – Fisheries Bureau
- IDALS – Division of Soil Conservation (Regional Coordinator)
- Dickinson County SWCD
- Clean Water Alliance

Key stakeholder groups represented included:

- Rural residents, land owners, and agricultural producers
- Citizens from Lake Park, including owners of shoreline properties
- Silver Lake patrons
- City of Lake Park
- Local businesses
- Silver Lake Park Improvement Association
- Silver Lake Technical Advisory Committee

6.4. Written Comments

IDNR received no public comments on the Silver Lake TMDL for Turbidity.

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8. Appendices

Appendix A --- Glossary of Terms and Acronyms

303(d) list: Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface waterbodies (creeks, rivers, wetlands, and lakes) that do not support their general and/or designated uses. Also called the state's "Impaired Waters List."

305(b) assessment: Refers to section 305(b) of the Federal Clean Water Act, it is a comprehensive assessment of the state's public waterbodies ability to support their general and designated uses. Those bodies of water which are found to be not supporting or just partially supporting their uses are placed on the 303(d) list.

319: Refers to Section 319 of the Federal Clean Water Act, the Nonpoint Source Management Program. Under this amendment, States receive grant money from EPA to provide technical & financial assistance, education, & monitoring to implement local nonpoint source water quality projects.

AFO: Animal Feeding Operation. A livestock operation, either open or confined, where animals are kept in small areas (unlike pastures) allowing manure and feed become concentrated.

Base flow: The fraction of discharge (flow) in a river which comes from ground water.

BMIBI: Benthic Macroinvertebrate Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of bottom-dwelling invertebrates.

BMP: Best Management Practice. A general term for any structural or upland soil or water conservation practice. For example terraces, grass waterways, sediment retention ponds, reduced tillage systems, etc.

CAFO: Confinement Animal Feeding Operation. An animal feeding operation in which livestock are confined and totally covered by a roof, and not allowed to discharge manure to a water of the state.

Credible data law: Refers to 455B.193 of the Iowa Administrative Code, which ensures that water quality data used for all purposes of the Federal Clean Water Act are sufficiently up-to-date and accurate.

Cyanobacteria (blue-green algae): Members of the phytoplankton community that are not true algae but can photosynthesize. Some species can be toxic to humans and pets.

Designated use(s): Refer to the type of economic, social, or ecologic activities that a specific waterbody is intended to support. See Appendix B for a description of all general and designated uses.

DNR (or IDNR): Iowa Department of Natural Resources.

Ecoregion: A system used to classify geographic areas based on similar physical characteristics such as soils and geologic material, terrain, and drainage features.

EPA (or USEPA): United States Environmental Protection Agency.

FIBI: Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.

FSA: Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.

General use(s): Refer to narrative water quality criteria that all public waterbodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated uses.

GIS: Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.

Gully erosion: Soil movement (loss) that occurs in defined upland channels and ravines that are typically too wide and deep to fill in with traditional tillage methods.

HEL: Highly Erodible Land. Defined by the USDA Natural Resources Conservation Service (NRCS), it is land which has the potential for long term annual soil losses to exceed the tolerable amount by eight times for a given agricultural field.

Integrated report: Refers to a comprehensive document which combines the 305(b) assessment with the 303(d) list, as well as narratives and discussion of overall water quality trends in the state's public waterbodies. The Iowa Department of Natural Resources submits an integrated report to the EPA biennially in even numbered years.

LA: Load Allocation. The fraction of the total pollutant load of a waterbody which is assigned to all combined *nonpoint sources* in a watershed. (The total pollutant load is the sum of the waste load and load allocations.)

Load: The total amount (mass) of a particular pollutant in a waterbody.

MOS: Margin of Safety. In a total maximum daily load (TMDL) report, it is a set-aside amount of a pollutant load to allow for any uncertainties in the data or modeling.

MS4 Permit: Municipal Separate Storm Sewer System Permit. An NPDES license required for some cities and universities which obligates them to ensure adequate water quality and monitoring of runoff from urban storm water and construction sites, as well as public participation and outreach.

Nonpoint source pollution: A collective term for contaminants which originate from a diffuse source.

NPDES: National Pollution Discharge Elimination System, which allows a facility (e.g. an industry, or a wastewater treatment plant) to discharge to a water of the United States under regulated conditions.

NRCS: Natural Resources Conservation Service (United States Department of Agriculture). Federal agency which provides technical assistance for the conservation and enhancement of natural resources.

Periphyton: Algae that are attached to substrates (rocks, sediment, wood, and other living organisms).

Phytoplankton: Collective term for all self-feeding (photosynthetic) organisms which provide the basis for the aquatic food chain. Includes many types of algae and cyanobacteria.

Point source pollution:	A collective term for contaminants which originate from a specific point, such as an outfall pipe. Point sources are generally regulated by an NPDES permit.
PPB:	Parts per Billion. A measure of concentration which is the same as micrograms per liter (µg/l).
PPM:	Parts per Million. A measure of concentration which is the same as milligrams per liter (mg/l).
Riparian:	Refers to site conditions that occur near water, including specific physical, chemical, and biological characteristics that differ from upland (dry) sites.
RUSLE:	Revised Universal Soil Loss Equation. An empirical model for estimating long term, average annual soil losses due to sheet and rill erosion.
Secchi disk:	A device used to measure transparency in waterbodies. The greater the Secchi depth (measured in meters), the more transparent the water.
Sediment delivery ratio:	A value, expressed as a percent, which is used to describe the fraction of gross soil erosion which actually reaches a waterbody of concern.
Seston:	All particulate matter (organic and inorganic) in the water column.
Sheet & rill erosion	Soil loss which occurs diffusely over large, generally flat areas of land.
SI:	Stressor Identification. A process by which the specific cause(s) of a biological impairment to a waterbody can be determined from cause-and-effect relationships.
Storm flow (or stormwater):	The fraction of discharge (flow) in a river which arrived as surface runoff directly caused by a precipitation event. *Storm water* generally refers to runoff which is routed through some artificial channel or structure, often in urban areas.
STP:	Sewage Treatment Plant. General term for a facility that processes municipal sewage into effluent suitable for release to public waters.

SWCD:	Soil and Water Conservation District. Agency which provides local assistance for soil conservation and water quality project implementation, with support from the Iowa Department of Agriculture and Land Stewardship.
TMDL:	Total Maximum Daily Load. As required by the Federal Clean Water Act, a comprehensive analysis and quantification of the maximum amount of a particular pollutant that a waterbody can tolerate while still meeting its general and designated uses.
TSI (or Carlson's TSI):	Trophic State Index. A standardized scoring system (scale of 0-100) used to characterize the amount of algal biomass in a lake or wetland.
TSS:	Total Suspended Solids. The quantitative measure of seston, all materials, organic and inorganic, which are held in the water column.
Turbidity:	The degree of cloudiness or murkiness of water caused by suspended particles.
UAA:	Use Attainability Analysis. A protocol used to determine which (if any) designated uses apply to a particular waterbody. (See Appendix B for a description of all general and designated uses.)
UHL:	University Hygienic Laboratory (University of Iowa). Provides physical, biological, and chemical sampling for water quality purposes in support of beach monitoring and impaired water assessments.
USGS:	United States Geologic Survey (United States Department of the Interior). Federal agency responsible for implementation and maintenance of discharge (flow) gauging stations on the nation's waterbodies.
Watershed:	The land (measured in units of surface area) which drains water to a particular body of water or outlet.
WLA:	Waste Load Allocation. The fraction of waterbody loading capacity assigned to point sources in a watershed. Alternatively, the allowable pollutant load that an NPDES permitted facility may discharge without exceeding water quality standards.

WQS: Water Quality Standards. Defined in Chapter 61 of Environmental Protection Commission [567] of the Iowa Administrative Code, they are the specific criteria by which water quality is gauged in Iowa.

WWTP: Waste Water Treatment Plant. General term for a facility which processes municipal, industrial, or agricultural waste into effluent suitable for release to public waters or land application.

Zooplankton: Collective term for all animal plankton which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

Appendix B --- General and Designated Uses of Iowa's Waters

Introduction

Iowa's water quality standards (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code) provide the narrative and numerical criteria by which waterbodies are judged when determining the health and quality of our aquatic ecosystems. These standards vary depending on the type of waterbody (lakes vs. rivers) and the assigned uses (general use vs. designated uses) of the waterbody that is being dealt with. This appendix is intended to provide information about how Iowa's waterbodies are classified and what the use designations mean, hopefully providing a better general understanding for the reader.

All public surface waters in the state are protected for certain beneficial uses, such as livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and other incidental uses (e.g. withdrawal for industry and agriculture). However, certain rivers and lakes warrant a greater degree of protection because they provide enhanced recreational, economical, or ecological opportunities. Thus, all public bodies of surface water in Iowa are divided into two main categories: *general* use segments and *designated* use segments. This is an important classification because it means that not all of the criteria in the state's water quality standards apply to all water ways; rather, the criteria which apply depend on the use designation & classification of the waterbody.

General Use Segments

A general use segment waterbody is one which does not maintain perennial (year-round) flow of water or pools of water in most years (i.e. ephemeral or intermittent waterways). In other words, stream channels or basins which consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use waterbody, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

General use waters are protected for the beneficial uses listed above, which are: livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses. The criteria used to ensure protection of these uses are described in section 61.3(2) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Designated Use Segments

Designated use segments are waterbodies which maintain flow throughout the year, or at least hold pools of water which are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are a total of thirteen different designated use classes (Table B-1) which may apply, and a waterbody may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Table B-1. Designated use classes for Iowa waterbodies.

Class prefix	Class	Designated use	Brief comments
A	A1	Primary contact recreation	Supports swimming, water skiing, etc.
	A2	Secondary contact recreation	Limited/incidental contact occurs, such as boating
	A3	Children's contact recreation	Urban/residential waters that are attractive to children
B	B(CW1)	Cold water aquatic life – Type 2	Able to support coldwater fish (e.g. trout) populations
	B(CW2)	Cold water aquatic life – Type 2	Typically unable to support consistent trout populations
	B(WW-1)	Warm water aquatic life – Type 1	Suitable for game and nongame fish populations
	B(WW-2)	Warm water aquatic life – Type 2	Smaller streams where game fish populations are limited by physical conditions & flow
	B(WW-3)	Warm water aquatic life – Type 3	Streams that only hold small perennial pools which extremely limit aquatic life
	B(LW)	Warm water aquatic life – Lakes and Wetlands	Artificial and natural impoundments with "lake-like" conditions
C	C	Drinking water supply	Used for raw potable water
Other	HQ	High quality water	Waters with exceptional water quality
	HQR	High quality resource	Waters with unique or outstanding features
	HH	Human health	Fish are routinely harvested for human consumption

Appendix C --- Water Quality Data

The following tables summarize relevant water quality data collected from 2001-2004 by Iowa State University (ISU) as part of the Iowa Lakes Information System, and data collected from 2005-2007 by the Iowa Department of Natural Resources and University Hygienic Laboratory (UHL) as part of the Ambient Lake Monitoring Program.

Table C-1. ISU and UHL physical/chemical sampling data.(1)

Date	Secchi (m)	Chl-a (ug/L)	TP (ug/L)	ISS (mg/L)	VSS (mg/L)	TSS (mg/L)	TSI (SD)	TSI (Chl)	TSI (TP)
5/15/01	0.9	-	124	10	3	14	62	-	74
6/12/01	0.5	6.8	170	21	6	27	72	49	78
7/17/01	0.8	13.8	149	8	11	19	64	56	76
5/21/02	0.4	3.6	89	20	9	29	73	43	69
6/18/02	0.2	5.6	92	18	11	30	83	48	69
7/23/02	0.3	18.9	158	48	20	68	77	59	77
5/20/03	0.6	5.7	103	11	4	15	69	48	71
6/17/03	1.8	2.6	58	5	3	7	52	40	63
7/22/03	0.5	26.7	145	9	16	25	70	63	76
5/18/04	1.2	1.3	105	7	2	9	58	33	71
6/15/04	0.4	9.6	130	11	7	18	75	53	74
7/20/04	0.3	327.8	195	5	56	61	79	87	80
3/31/05	0.37	13	70	-	-	26	74	56	65
5/11/05	1.22	11	60	-	-	29	57	54	63
5/24/05	0.52	2	80	-	-	17	69	37	67
6/8/05	0.58	5	70	-	3	12	68	46	65
6/21/05	0.91	2	40	-	3	6	61	37	57
7/12/05	1.25	32	80	-	6	9	57	65	67
8/2/05	0.5	130	130	-	17	23	70	78	74
8/9/05	0.84	130	80	-	9	13	63	78	67
8/25/05	0.79	45	190	-	6	10	63	68	80
9/13/05	0.3	5	240	-	-	24	77	46	83
9/28/05	0.55	66	280	-	-	25	69	72	85
4/25/06	0.67	2	100	-	4	17	66	37	71
6/6/06	0.46	4	90	11	5	16	71	44	69
7/18/06	0.4	26	60	15	5	20	73	63	63
8/29/06	0.76	53	150	4	8	13	64	70	76
10/9/06	0.55	150	180	0.5	7	8	69	80	79
5/9/07	1.6	.5	100	2	1	4	53	24	71
7/25/07	0.8	29	25	4	4	9	63	64	51
9/25/07	0.9	130	170	3	11	14	62	78	78
Mean	**0.7**	**41.9**	**119.8**	**11.2**	**9.1**	**19.9**	**65(2)**	**67(2)**	**73(2)**
Median	**0.6**	**12.0**	**103.0**	**9.0**	**6.0**	**17.0**	**68(2)**	**55(2)**	**71(2)**
St Dev	**0.383**	**69.850**	**58.702**	**10.723**	**10.686**	**14.063**			
CV	**0.54**	**1.67**	**0.49**	**0.96**	**1.17**	**0.71**			

(1) ISU data from 2001-2004, UHL data from 2005-2007.
(2) TSI values calculated from mean and median depth and concentration.

Table C-2. ISU physical/chemical sampling data, 2001 to 2005.

Date	Secchi (m)	Chl-a (ug/L)	TP (ug/L)	ISS (mg/L)	VSS (mg/L)	TSS (mg/L)	TSI (SD)	TSI (Chl)	TSI (TP)
5/15/01	0.9	-	124	10	3	14	62	-	74
6/12/01	0.5	6.8	170	21	6	27	72	49	78
7/17/01	0.8	13.8	149	8	11	19	64	56	76
5/21/02	0.4	3.6	89	20	9	29	73	43	69
6/18/02	0.2	5.6	92	18	11	30	83	48	69
7/23/02	0.3	18.9	158	48	20	68	77	59	77
5/20/03	0.6	5.7	103	11	4	15	69	48	71
6/17/03	1.8	2.6	58	5	3	7	52	40	63
7/22/03	0.5	26.7	145	9	16	25	70	63	76
5/18/04	1.2	1.3	105	7	2	9	58	33	71
6/15/04	0.4	9.6	130	11	7	18	75	53	74
7/20/04	0.3	327.8	195	5	56	61	79	87	80
Mean	**0.7**	**38.4**	**126.5**	**14.4**	**12.3**	**26.8**	**66(1)**	**66(1)**	**74(1)**
Median	**0.5**	**6.8**	**127.0**	**10.5**	**8.0**	**22.0**	**70(1)**	**49(1)**	**74(1)**
St Dev	**0.460**	**96.290**	**39.019**	**11.912**	**14.810**	**19.154**			
CV	**0.70**	**2.51**	**0.31**	**0.83**	**1.20**	**0.71**			

(1) TSI values calculated from mean and median depth and concentration.

Table C-3. UHL physical/chemical sampling data, 2005 to 2007.

Date	Secchi (m)	Chl-a (ug/L)	TP (ug/L)	ISS (mg/L)	VSS (mg/L)	TSS (mg/L)	TSI (SD)	TSI (Chl)	TSI (TP)
3/31/05	0.37	13	70	-	-	26	74	56	65
5/11/05	1.22	11	60	-	-	29	57	54	63
5/24/05	0.52	2	80	-	-	17	69	37	67
6/8/05	0.58	5	70	-	3	12	68	46	65
6/21/05	0.91	2	40	-	3	6	61	37	57
7/12/05	1.25	32	80	-	6	9	57	65	67
8/2/05	0.5	130	130	-	17	23	70	78	74
8/9/05	0.84	130	80	-	9	13	63	78	67
8/25/05	0.79	45	190	-	6	10	63	68	80
9/13/05	0.3	5	240	-	-	24	77	46	83
9/28/05	0.55	66	280	-	-	25	69	72	85
4/25/06	0.67	2	100	-	4	17	66	37	71
6/6/06	0.46	4	90	11	5	16	71	44	69
7/18/06	0.40	26	60	15	5	20	73	63	63
8/29/06	0.76	53	150	4	8	13	64	70	76
10/9/06	0.55	150	180	0.5(1)	7	8	69	80	79
5/9/07	1.6	0.5(1)	100	2	1	4	53	24	71
7/25/07	0.8	29	25	4	4	9	63	64	51
9/25/07	0.9	130	170	3	11	14	62	78	78
Mean	**0.7**	**44.0**	**115.5**	**5.6**	**6.4**	**15.5**	**64(1)**	**68(1)**	**73(1)**
Median	**0.7**	**26.0**	**90.0**	**4.0**	**5.5**	**14.0**	**66(1)**	**63(1)**	**69(1)**
St Dev	**0.336**	**51.940**	**69.019**	**5.297**	**4.031**	**7.291**			
CV	**0.46**	**1.18**	**0.60**	**0.94**	**0.63**	**0.47**			

(1) TSI values calculated from mean and median depth and concentration.

Table C-4. ISU biological sampling data, 2000 to 2007.

Date	Cyanobacteria Wet Mass (mg/L)	Phytoplankton Wet Mass (mg/L)	Zooplankton Mass (mg/L)
6/13/00	1.00	1.56	--
7/12/00	36.07	36.07	6.42
8/3/00	26.45	26.45	86.48
5/15/01	0.03	0.04	183.91
6/12/01	0.19	0.53	78.21
7/17/01	0.20	0.20	690.22
5/21/02	0.00	1.29	217.76
6/18/02	294.91	294.98	206.23
7/23/02	913.54	918.09	81.60
5/20/03	0.00	0.72	129.50
6/17/03	4.72	4.76	104.97
7/22/03	52.00	52.09	679.27
5/18/04	1.96	2.04	323.71
6/15/04	22.66	22.76	380.13
7/20/04	37.54	37.86	328.75
5/24/05	0.05	0.45	65.09
6/21/05	0.26	2.14	165.78
7/26/05	20.07	21.11	260.19
5/23/06	220.20	391.13	38.31
6/21/06	38.88	38.88	82.09
7/26/06	206.98	207.29	173.26
5/22/07	26.3	37.4	85.6
6/19/07	31.4	31.8	67.9
7/23/07	5.7	5.7	760.5

Table C-5. [1]Dickinson County SWCD water quality data (2007).

Date	[2]Station	TP (ug/L)	TN (mg/L)	ISS (mg/L)	VSS (mg/L)	TSS (mg/L)	*E. coli* (cfu/100 mL)
6/19/07	1	55.3	15.3	--	--	--	56.3
	2	55.0	13.6	5.0	--	--	96.0
	3	70.7	14.8	--	--	--	137.6
	4	148.5	11.1	29.0	19.0	48.0	145.0
	5	38.5	12.1	4.0	--	--	13.2
	6	144.6	11.4	17.0	16.0	33.0	42.6
7/10/07	1	98.5	12.9	--	--	--	184
	2	69.9	14.0	--	--	--	> 2,419
	3	70.9	13.1	9.3	5.7	15.0	1,986
	4	362.4	3.3	60.0	28.8	88.8	11
	5	96.3	8.2	20.4	8.6	29.0	613
	6	367.3	3.1	20.8	22.8	43.6	2
7/24/07	1	247.7	4.4	--	--	--	479
	2	103.8	9.0	--	--	--	67
	3	--	--	--	--	--	--
	4	651.1	0.3	4.4	18.1	22.5	27
	5	--	--	--	--	--	--
	6	578.6	0.3	9.1	18.9	28.0	10
8/7/07	1	484.6	0.9	--	--	--	145
	2	267.4	7.1	5.1	--	7.9	345
	3	110.7	2.1	15.4	--	20.6	236
	4	472.0	0.8	18.3	20.0	38.3	26
	5	--	--	--	--	--	--
	6	511.4	2.2	35.0	35.6	70.6	48
8/15/07	1	618.2	1.5	4.0	--	8.7	2,420
	2	254.4	5.9	11.7	5.6	7.2	>2,420
	3	116.0	0.4	21.1	9.7	30.8	866
	4	411.9	1.4	22.8	27.8	50.6	26
	5	--	--	--	--	--	--
	6	--	--	--	--	--	--
8/21/07	1	220.6	7.1	6.7	--	10.6	58
	2	224.6	6.7	11.1	--	13.9	157
	3	287.7	5.5	29.2	5.9	35.1	291
	4	265.2	5.2	16.1	7.8	23.9	285
	5	240.6	2.7	37.8	11.4	49.2	> 2,420
	6	270.8	5.3	15.6	--	17.2	219
9/11/07	1	76.6	10.8	--	--	--	161
	2	71.8	11.1	5.0	--	6.1	117
	3	94.8	9.7	5.1	--	6.9	179
	4	113.6	8.0	12.8	7.8	20.6	81
	5	92.2	3.9	--	--	6--	12
	6	106.8	8.5	12.0	6.0	18.0	91

(1) SWCD data used for anecdotal purposes, but not model development.
(2) Station locations are illustrated in Figure C-1, which follows this table.

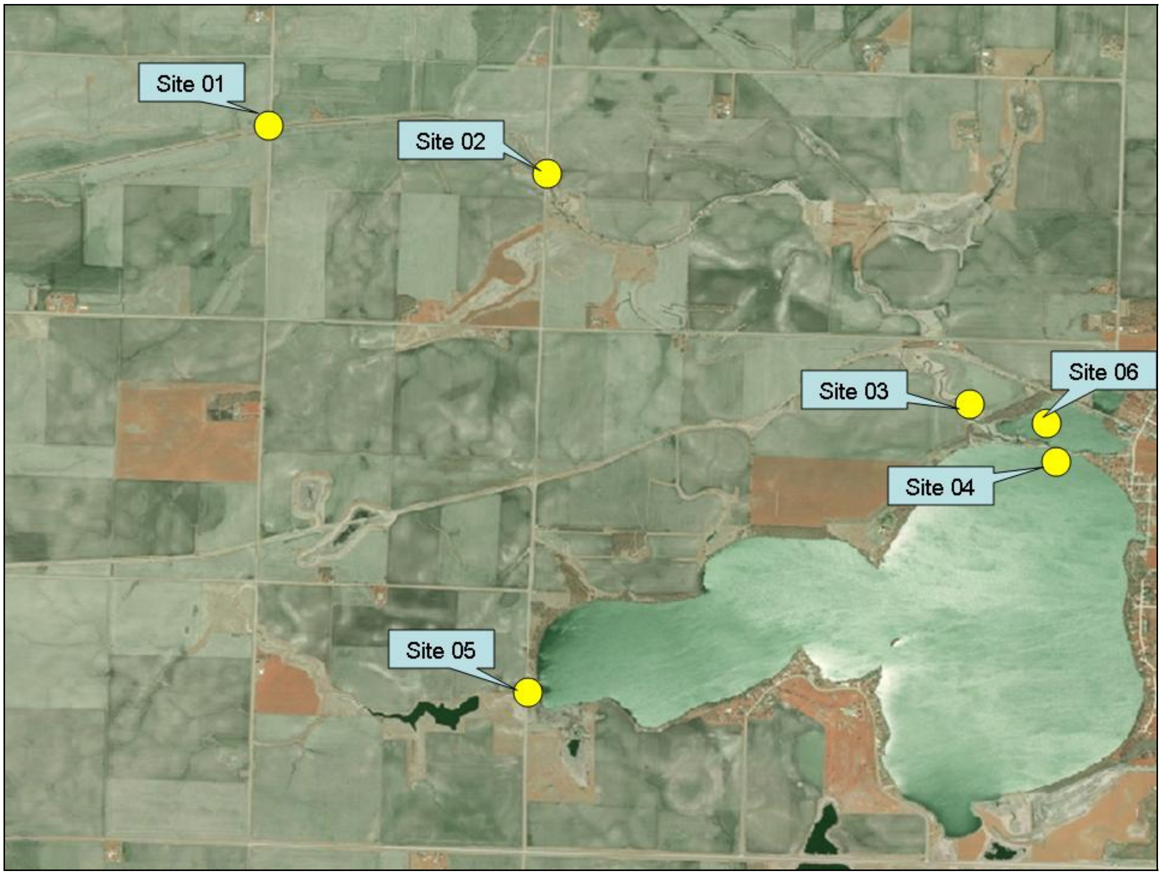

Figure C-1. Sampling stations for data collected by SWCD (2007).

Table C-6. (1)Dickinson County SWCD water quality data (2008).

Date	(2)Station	TP (mg/L)	NO_2/NO_3 (mg/L)	pH	DO (mg/L)	TSS (mg/L)	*E. coli* (cfu/100 mL)
7/1/08	W1	0.08	16	8	10	3	30
	W2	0.0	16	9	8	5	180
	W3	0.13	12	8	6	8	300
	W4	0.08	12	8.5	11	18	120
	W5	0.03	13	8.5	8	8	10
	W6	0.14	12	8	10	15	150
	W7	0.04	16	8.5	10	4	30
7/16/08	W1	0.10	14	7.5	7	< 1	110
	W2	0.08	14	7.5	5.5	2	130
	W3	0.51	2.5	6.5	5	260	1,700
	W4	0.24	5.9	7.5	7	68	90
	W5	0.03	11	7.5	6	22	130
	W6	0.39	7.5	6.5	7	76	70
	W7	0.04	16	8	8	1	50
8/1/08	W1	0.13	1	7	--	< 1	40
	W2	0.10	12	4.5	--	4	320
	W3	1.00	< 0.05	7	--	3,500	520
	W4	0.26	2.4	8.5	--	60	600
	W5	0.06	7.2	8	--	21	60
	W6	0.23	4.6	8.5	--	37	110
	W7	0.06	14	8	--	7	90
8/14/08	W1	0.12	8.2	8	7	9	90
	W2	0.12	9.5	8	7	7	270
	W3	2.20	0.14	6.5	--	3,100	1,400
	W4	0.20	0.05	8.5	5	29	110
	W5	0.05	4.9	8.8	4.5	17	400
	W6	0.02	0.79	9	5	79	580
	W7	0.24	15	7.5	8	40	370
9/10/08	W1	0.11	5.2	7.5	5.7	3	170
	W2	0.09	6.7	8	8.2	11	200
	W3	0.23	0.06	7.5	7.4	41	110
	W4	0.12	1.5	8	13.6	71	190
	W5	0.16	0.67	--	2.5	11	2,400
	W6	0.38	0.18	8	6.5	61	890
	W7	0.09	4.8	8.5	2.8	23	390
9/25/08	W1	0.18	3.8	7.6	3.5	12	540
	W2	0.08	5.9	8.1	6.3	13	2,200
	W3	0.18	0.05	8.2	5.0	8	1,100
	W4	0.20	0.27	8.6	5.6	43	31
	W5	0.31	0.06	8.6	8.4	50	24,000
	W6	0.61	0.05	8.8	9	64	540
	W7	0.08	2.4	8.1	7.0	22	4,100

(1) SWCD data used for anecdotal purposes, but not model development.
(2) Station locations are illustrated in Figure C-2, which follows this table.

Figure C-2. Sampling stations for data collected by SWCD (2008).

Appendix D --- Modeling and Methodology

D.1. Watershed and In-Lake Water Quality Model Development

A combination of spreadsheet tools and modeling software packages were used to develop the TMDL for turbidity in Silver Lake. Watershed hydrology and pollutant loading was simulated using the Generalized Watershed Loading Function (GWLF) model within the BasinSim 2.0 windows-based interface. In-lake water quality simulations were performed using BATHTUB 6.1.

GWLF has been used nationally for research and TMDL development, and is particularly useful for simulating sediment, nitrogen, and phosphorus loading from a mixed-use watershed. Key model inputs include parameters based on soil information, land use, and land practice management (Haith et al., 1996). GWLF includes the ability to simulate point sources, septic tanks, and manure applied to croplands, which are often important considerations in TMDL development. BATHTUB is a steady-state water quality model developed by the U.S. Army Corps of Engineers that performs empirical eutrophication simulations in lakes and reservoirs (Walker, 1999).

GWLF parameterization. The GWLF model consists of three main input files called the weather, transport, and nutrient files. The Silver Lake watershed was divided into two subbasins for modeling purposes. The north subbasin, or North Basin, is an 11,919-acre basin that drains to Trappers Bay via a drainage district ditch. The South Basin is a 5,106-acre basin that drains to the lake through the headwaters of the West Branch of the Little Sioux River. Simulation of both basins required the development of two transport and nutrient files (one for each subbasin). The same weather file was developed for both subbasins, and was populated with National Weather Service (NWS) Cooperative Observer Program (COOP) data obtained through the Iowa Environmental Mesonet (IEM). Daily temperature and precipitation for the Lake Park weather station (Station IA4561) was downloaded and formatted to meet GWLF requirements. The IEM can be accessed at the following web site: http://mesonet.agron.iastate.edu/COOP/

The transport file includes inputs that describe the watershed's soil, land use, erosion, and sediment delivery characteristics. These inputs include distinct land cover areas in the watershed, and Revised Universal Soil Loss Equation (RUSLE) parameters and hydrologic curve numbers (CN) to describe each land cover area. The RUSLE parameters are calculated based on land cover, soil type, slope, and other characteristics, and the RUSLE equation is summarized below:

$$A = R * K * LS * C * P$$

Where: A = Average annual soil loss in tons per acre per year
R = Rainfall/runoff erosivity
K = Soil erodibility
LS = Hillslope length and steepness
C = Cover management
P = Support practice

The rainfall (R) and hillslope (LS) factors are fixed for a given watershed; but factors such as cover management (C) and support practice (P) can be changed to reflect different land uses and/or best management practices (BMPs). For Silver Lake, the RUSLE parameters were calculated using current GIS land use coverages developed via a windshield survey in 2007, personal communications with local officials, and methodology described in the Agricultural Handbook 703 (USDA-NRCS, 1997). Key transport-related inputs for the North Basin and South Basin are reported in Tables D-1 and D-2, respectively. The watershed-wide R factor is 132, which is based on a county dataset compiled by NRCS.

Other transport parameters include monthly evapotranspiration (ET) coefficients based on land cover and growing season, typical daylight hours in each month, and the overall watershed sediment delivery ratio (SDR). The ET coefficients and daylight hours were estimated using the GWLF/BasinSim user's guide (Dai et al., 2000). The SDR for the Silver Lake watershed was calculated to be 4.1 percent in the north subbasin, and 4.7 percent in the south subbasin. The "Erosion and Sediment Delivery" method developed by the state geologist for Iowa NRCS (USDA-NRCS, 1998) was used to calculate the SDR.

The nutrient file is populated with inputs to calculate the nutrient loads generated by watershed sources. Parameters include sediment nutrient concentrations, information regarding runoff concentrations from row crops with and without manure applications, groundwater nutrient concentrations, number of people served by various types of septic systems, and point source inputs. Key nutrient inputs were derived using the GWLF/BasinSim user's guide (Dai et al., 2000), and are reported in Tables D-3 and D-4.

There are approximately 49 septic systems in the Silver Lake watershed. The GWLF model simulates four types of septic systems: normally functioning systems, ponded systems, short-circuited systems, and direct discharge systems. The latter three types are considered improperly functioning or illegal systems. Based on suspected malfunction rates (75 percent) and proximity to the nearest stream or tile drain (one-quarter mile), it is assumed that 30 percent of all septic systems contribute phosphorus to the lake. These contributing systems were distributed equally among the three failure types simulated by GWLF, as reported in Table D-5.

Geese have the potential to significantly contribute phosphorus to a lake if they congregate in large numbers. The GWLF model does not simulate nutrient inputs from geese directly. For modeling purposes, geese inputs were simulated as point sources, even though they are considered nonpoint sources under the Clean Water Act. The population varies seasonally due to migration patterns, and population estimates are based on visual counts by IDNR wildlife biologists. Assumptions used in modeling nutrient loads from geese are reported in Table D-6.

Table D-1. Key GWLF transport file parameters for the North Basin (existing conditions).

Land Use / Land Cover	Hectares	[(1)]K	[(1)]LS	[(1)]C x P	[(2)]K(LS)CP	[(3)]HSG	[(4)]CN
CB – Conventional Till	189.2	0.241	0.335	0.200	0.0161	B	80
CB – No Till	1,230.1	0.239	0.529	0.080	0.0101	B	74
CBOMMM – Conventional Till	73.9	0.237	0.662	0.200	0.0314	B	78
CB – Mulch Till	2,415.4	0.239	0.452	0.150	0.0162	B	78
CBOMMM – Mulch Till	10.3	0.213	0.833	0.150	0.0266	B	76
CCB – Conventional Till	34.8	0.236	0.570	0.200	0.0269	B	80
CCB – Mulch Till	227.1	0.236	0.570	0.150	0.0202	B	78
CCB – No Till	45.3	0.226	0.322	0.080	0.0058	B	74
CRP	0.0	--	--	--	--	--	--
Farmstead	90.0	0.218	0.645	0.039	0.0055	B	74
Grassland	332.3	0.233	0.853	0.009	0.0018	B	72
Timber	8.9	0.209	0.759	0.013	0.0021	B	66
Wildlife Area	32.3	0.245	1.596	0.003	0.0012	C	69
Wetland	4.3	0.000	0.000	0.000	0.0000	B	100
Water (excluding Silver Lake surface area)	48.6	0.117	0.106	0.000	0.0000	C	100
Road	69.9	0.228	0.743	0.003	0.0005	B	85
Urban	11.5	0.202	0.745	0.003	0.0005	B	89
Total Area =	**4823.8**						

(1) Individual RUSLE parameters from GIS coverage and Agricultural Handbook 703 calculations.
(2) Product of individual RUSLE parameters (GWLF input)
(3) HSG = hydrologic soil group
(4) Curve number based on land use and HSG (GWLF input)

Table D-2. Key GWLF transport file parameters for the South Basin (existing conditions).

Land Use / Land Cover	Hectares	(1)K	(1)LS	(1)C x P	(2)K(LS)CP	(3)HSG	(4)CN
CB – Conventional Till	162.6	0.224	0.468	0.200	0.0210	B	80
CB – No Till	144.9	0.226	0.451	0.080	0.0082	B	74
CBOMMM – Conventional Till	100.9	0.218	0.638	0.200	0.0278	B	78
CB – Mulch Till	1,121.6	0.225	0.430	0.150	0.0145	B	78
CBOMMM – Mulch Till	120.4	0.224	0.696	0.150	0.0234	B	76
CCB – Conventional Till	0.0	-	-	-	-	-	-
CCB – Mulch Till	0.0	-	-	-	-	-	-
CCB – No Till	0.0	-	-	-	-	-	-
CRP	10.1	0.239	1.028	0.003	0.0007	B	72
Farmstead	19.0	0.220	0.468	0.039	0.0040	B	74
Grassland	186.1	0.228	0.791	0.009	0.0016	B	72
Timber	19.4	0.239	3.500	0.013	0.0109	B	66
Wildlife Area	6.3	0.242	0.368	0.003	0.0003	B	69
Wetland	2.8	0.250	2.922	0.000	0.0000	B	100
Water (excluding Silver Lake surface area)	74.0	0.035	0.039	0.000	0.0000	D	100
Road	11.6	0.221	0.282	0.003	0.0002	B	85
Urban	86.2	0.214	0.558	0.003	0.0004	B	89
Total Area =	**2,066.0**						

(1) Individual RUSLE parameters from GIS coverage and Agricultural Handbook 703 calculations.
(2) Product of individual RUSLE parameters (GWLF input)
(3) HSG = hydrologic soil group
(4) Curve number based on land use and HSG (GWLF input)

Table D-3. Key GWLF nutrient file parameters for the North Basin (existing conditions).

Land Use / Land Cover	Hectares	(1)Runoff N (mg/L)	(2)Runoff P (mg/L)	(3)Manured N (mg/L)	(3)Manured P (mg/L)
CB – Conventional Till	189.2	2.9	0.26	12.2	1.9
CB – No Till	1,230.1	2.9	0.26	12.2	1.9
CBOMMM – Conventional Till	73.9	2.7	0.21	12.2	1.9
CB – Mulch Till	2,415.4	2.9	0.26		
CBOMMM – Mulch Till	10.3	2.7	0.21		
CCB – Conventional Till	34.8	2.9	0.26		
CCB – Mulch Till	227.1	2.9	0.26		
CCB – No Till	45.3	2.9	0.26		
CRP	0.0	2.8	0.15		
Farmstead	90.0	1.9	0.28		
Grassland	332.3	2.8	0.15		
Timber	8.9	0.8	0.06		
Wildlife Area	32.3	2.4	0.27		
Wetland	4.3	0	0		
Water (excluding Silver Lake surface area)	48.6	0	0		
Road	69.9	(4)0.0652	(5)0.0079		
Urban	11.5	(4)0.0652	(5)0.0079		
Total Area =	**4,823.8**				

(1) Groundwater N = 0.65 mg/L
(2) Groundwater P = 0.055 mg/L
(3) Assumed manure application on three land uses based on estimated application area
(4) Urban N buildup in kg/ha-day
(5) Urban P buildup in kg/ha-day

Table D-4. Key GWLF nutrient file parameters for the South Basin (existing conditions).

Land Use / Land Cover	Hectares	(1)Runoff N (mg/L)	(2)Runoff P (mg/L)	(3)Manured N (mg/L)	(3)Manured P (mg/L)
CB – Conventional Till	162.6	2.9	0.26	12.2	1.9
CB – No Till	144.9	2.9	0.26	12.2	1.9
CBOMMM – Conventional Till	100.9	2.7	0.21	12.2	1.9
CB – Mulch Till	1,121.6	2.9	0.26		
CBOMMM – Mulch Till	120.4	2.7	0.21		
CCB – Conventional Till	0.0	2.9	0.26		
CCB – Mulch Till	0.0	2.9	0.26		
CCB – No Till	0.0	2.9	0.26		
CRP	10.1	2.8	0.15		
Farmstead	19.0	1.9	0.28		
Grassland	186.1	2.8	0.15		
Timber	19.4	0.8	0.06		
Wildlife Area	6.3	2.4	0.27		
Wetland	2.8	0	0		
Water (excluding Silver Lake surface area)	74.0	0	0		
Road	11.6	(4)0.0652	(5)0.0079		
Urban	86.2	(4)0.0652	(5)0.0079		
Total Area =	**2,066.0**				

(1) Groundwater N = 0.65 mg/L for all land uses
(2) Groundwater P = 0.055 mg/L for all land uses
(3) Assumed manure application on three land uses based on estimated application area
(4) Urban N buildup in kg/ha-day
(5) Urban P buildup in kg/ha-day

Table D-5. Septic system assumptions used in nutrient file development.

System Type	Number of Systems	Persons per House	Number of Persons Served
NORTH BASIN			
Normal	27	2.4	65
Pond	4	2.4	10
Short-circuited	4	2.4	10
Direct discharge	4	2.4	10
North Basin Totals	39	-	95
SOUTH BASIN			
Normal	7	2.4	17
Pond	1	2.4	2
Short-circuited	1	2.4	2
Direct discharge	1	2.4	2
South Basin Totals	10	-	23
Watershed Totals	**49**		**118**

NOTE: 30 percent of septic systems contribute TP loads to Silver Lake, based on proximity to streams and tile drain intakes and an assumed 75 percent failure rate.

Table D-6. Goose population estimates and monthly nutrient loads.

Time Period	Goose population	kg-TN/month	kg-TP/month
October – April	150	6.4	2.0
May – September	100	4.3	1.4

Note: All goose loadings were input into the South Basin model.

GWLF calibration. Because neither watershed loads nor flows were monitored, it was not possible to calibrate the GWLF model to observed data. Nutrient inputs are based on literature values that designate runoff concentrations for each land use. These parameters are available in the GWLF model documentation (Haith et. al., 1996) and were previously discussed in this appendix.

Because the Silver Lake watershed has a significant amount of tile drainage, TP exports simulated using GWLF were compared with two studies conducted in agriculturally dominated watersheds with similar tile drain systems. A study of three watersheds in Illinois found that annual TP exports ranged from 0.1 to 2.1 kilograms per hectare (kg/ha), or 0.1 to 1.9 lbs/ac (Royer, et al., 2006). In an assessment of the Iowa River's South Fork watershed in central Iowa, researchers estimated average annual TP exports in the range of 0.4 to 0.6 lbs/ac (Tomer et al., 2008). The South Fork study area lies in the heart of the Des Moines Lobe ecoregion, the same ecoregion in which Silver Lake is located.

The Silver Lake GWLF model simulated a total TP export of 0.7 lbs/ac (including groundwater contributions), near the middle of the range of exports reported in the Illinois study, and just above the range reported for the South Fork of the Iowa River. The Silver Lake watershed has soils and slopes very similar to the South Fork watershed, hence, it is reasonable to expect that TP loads would compare favorably. The fact the

GWLF-simulated load for the Silver Lake watershed is greater is reasonable, considering the Silver Lake watershed is much smaller than the South Fork. As watershed size increases, the sediment delivery ratio decreases, resulting in a lower sediment (and phosphorus) exports. The slightly higher TP exports obtained using GWLF may suggest that existing load estimates are conservative, thus providing an additional factor of safety into the TMDL calculations. Table D-7 compares TP exports from the above studies with the TP load simulated using GWLF for the Silver Lake TMDL.

Table D-7. Comparison of TP exports and flows in tile-drained watersheds.

Watershed/Location	Source	TP Export (lb/ac)
East Central Illinois	Royer et al., 2006	0.1-1.9
South Fork Iowa River	Tomer et al., 2008	0.4-0.6
Silver Lake Watershed	IDNR (Silver Lake TMDL)	0.7

The TMDL load was derived statistically from the annual load, which is related to annual flow. Therefore, given the lack of adequate flow calibration data, it is appropriate to compare annual flows simulated using GWLF with observed or calibrated flows obtained in a similar watershed. IDNR developed a Soil and Water Assessment Tool (SWAT) model for the Des Moines River nitrate TMDL, which also lies in the Des Moines Lobe ecoregion (IDNR, unpublished data). The model was calibrated to observed flow data available through USGS. Subbasin sizes in the SWAT model range from 3,874 to 22,336 ha (9,573 to 55,193 ac), whereas the Silver Lake watershed is just over 17,000 acres not including the lake. The highest 25 percent of annual unit flows simulated by the calibrated SWAT model for subbasins in the Des Moines River basin in 2005 were between 285 and 435 mm/yr. For 2006, the upper quartile of flows ranged from 230 to 374 mm/yr. Annual flow simulated by the GWLF model used for the Silver Lake TMDL was 422 mm/r in 2005 and 304 mm/yr in 2006. In both years, GWLF estimates were near the upper end of flow estimates obtained from the calibrated SWAT model.

GWLF output was also compared to peak flow estimates from regional regression equations for several storm events that occurred during the GWLF simulation period. The regression equations were developed by the US Geological Survey (USGS), and published in WRIR 00-4233 (USGS, 2000). Table D-8 reports the regression equation results, as well as average daily flow simulated for several events using GWLF. Historical storms in Table D-8 approximate the 2-, 5-, and 10-year events. Events equal to or slightly less than the 2-year storm are likely responsible for the majority of sediment, and hence phosphorus loads, to the lake. Reasonable prediction of flows under these conditions would provide confidence that GWLF-simulated TP loads are reasonable.

The storm event on August 2, 2006, resulted in a GWLF daily flow of 201 cubic feet per second (cfs). The precipitation on this date was approximately 23 percent lower than a 2-year storm, and the simulated daily flow was approximately 31 percent lower than the peak flow predicted by the regression equation. This seems like a reasonable difference considering the regression equation is for peak flow and the GWLF output is a daily average. The storm event on September 25, 2005 is particularly noteworthy. Observed precipitation matched the 2-year 24-hr rainfall for this region of the state, and simulated flow was identical to that predicted by the corresponding USGS regression equation. Similar agreement was observed for the 2-year storm on May 6, 2007, and for larger events in July 2004 and August 2002. Comparison of simulated flows and flows predicted by the USGS regression equation increases the confidence level in the GWLF output. The comparisons of TP export, annual flow, and event-based flow above collectively indicate that the Silver Lake GWLF model performs adequately for the purposes of TMDL development.

Table D-8. Comparison of USGS regression equation and GWLF flows.

Regression Equation	Storm Frequency	Precipitation (in)	Peak Flow (cfs)
(1)$Q_2 = 33.8 \times DA^{0.656}$	2-year	3.1	291
(1)$Q_5 = 60.8 \times DA^{0.658}$	5-year	3.7	527
(1)$Q_{10} = 80.1 \times DA^{0.660}$	10-year	4.2	698
GWLF Simulation Date	**Approx. Frequency**	**Precipitation (in)**	**Daily Flow (cfs)**
8/2/2006	< 2-year	2.4	201
5/6/2007	< 2-year	2.9	282
9/25/2005	2-year	3.1	292
7/6/2004	5-year	(2)3.7	474
8/5/2002	> 10-year	(3)4.4	878

Notes:
(1) DA = drainage area = 26.6 square miles
(2) 2.4 inches of rainfall on 7/6/2004, with 1.3 inches falling the previous 3 days
(3) 4.4 inches of rainfall on 8/4/2002 and 8/5/2002 combined

BATHTUB parameterization. The BATHTUB model includes several data input menus/modules to describe lake characteristics and to set up water quality simulations. Data menus utilized to develop the BATHTUB model for Silver Lake include: model selections, global variables, segment data, and tributary data. The model selections menu allows the user to specify which modeling equations are to be used in the simulation of in-lake nitrogen, phosphorus, chlorophyll-a, transparency, and other parameters. Global variables describe parameters consistent throughout the lake such as precipitation and evaporation. The segment data menu is used to describe existing lake morphometry, observed water quality, calibration factors, and internal loads. GWLF hydrology and nutrient loads were converted to the appropriate BATHTUB input units and entered in the tributary data menu.

The BATHTUB model selections menu allows the user to specify one of several potential models for simulating a conservative substance, total phosphorus, total nitrogen, chlorophyll-a, and transparency in the lake/reservoir. Each of the models has advantages and disadvantages, with some models being more applicable to certain site-specific conditions than others. For the Silver Lake TMDL, the conservative substance model was not used. Each of the available phosphorus, nitrogen, chlorophyll-a, and transparency models were run to evaluate which provided the best fit to observed data.

The default model (Option 1) was selected for phosphorus simulation. This model provided a reasonable calibration to observed data, and as the default model, was developed based on a relatively large data set. For nitrogen simulations, the settling velocity model (Option 7) provided the best fit to observed data. Because Silver Lake is not nitrogen limited, the nitrogen model is not a critical element of the TMDL. The default model (Option 2) was selected for chlorophyll-a simulation. This model considers TP, light, and non-algal turbidity in predicting chlorophyll-a levels, and provided the best fit to observed data. The default model (Option 1) was also selected for transparency simulations, and is based on chlorophyll-a and non-algal turbidity.

Global input data for Silver Lake are reported in Table D-9, segment input is in Table D-10, and tributary data inputs obtained from 2005-2007 GWLF simulations are summarized in Table D-11. Data for all three tables are reported in units required by the BATHTUB model. The tributary data shown in Table D-11 was used to calibrate the model to observed water quality as measured by UHL from 2005-2007 and reported in Table D-10. Tributary inputs were modified to create subsequent BATHTUB simulations to validate the model to water quality data collected by ISU from 2001-2004, and to develop the in-lake targets for Secchi depth, chlorophyll-a, and TP.

Table D-9. Key global data for the Silver Lake BATHTUB model.

Parameter	Measured or Simulated Data	BATHTUB Input
Annual Precipitation	32.3 inches	0.82 m
Annual Evaporation	50 inches	1.27 m
(1)Atmospheric Loads:		
TP	0.3 kg/ha-yr	30 mg/m^2-yr
TN	7.7 kg/ha-yr	770.3 mg/m^2-yr

(1) From Anderson and Downing, 2006. Assumed all deposition is inorganic form.

Table D-10. Key segment data for the Silver Lake BATHTUB model.

Parameter	Measured or Monitored Data	(1)BATHTUB Input
Lake Surface Area	1,032 acres	4.18 km^2
Mean Depth	6.7 feet	2.04 m
Reservoir Length	2.4 miles	3.9 km
Mixed Layer Depth	6.7 feet	2.04 m
Hypolimnetic Depth	N/A	N/A
Total Phosphorus	115.5 ug/L	115.5 ppb
Total Nitrogen	3.35 mg/L	3,350 ppb
Chlorophyll-a	44.0 ug/L	44.0 ppb
Secchi Depth	0.7 m	0.7 m
Ammonia	200 ug/L	(2)N/A
Nitrate/Nitrite	1.8 mg/L	(2)N/A
Organic Nitrogen	1.35 mg/L	1,350 ppb
Ortho P	46 ug/L	(2)N/A
TP – Ortho P	69.5 ug/L	69.5 ppb
(3)Internal TP Load	7,798 lbs/yr	2.32 mg/m^2-day

(1) Measured or monitored data converted to units required by BATHTUB
ppb = parts per billion = micrograms per liter (ug/L)
(2) Not a BATHTUB input
(3) Internal load was adjusted until the simulated TP concentration matched the observed data, and is estimated as 39.0 percent of the total TP load.

Table D-11. Key tributary data for the Silver Lake BATHTUB model.

Parameter	Measured or Simulated Data	(1)BATHTUB Input
Watershed Area	17,025 acres	68.9 km^2
Flow Rate	27.5E+06 m^3/yr	(2)27.5 hm^3/yr
TP Concentration	(3)5.4 mtons	196.2 ppb
Ortho P Concentration	(3)2.9 mtons	104.5 ppb
Total N Concentration	(3)38.3mtons	1,390.9 ppb
Inorganic N Concentration	(3)29.9 mtons	1,087.8 ppb

(1) Measured data or GWLF output converted to units required by BATHTUB
(2) hm3/yr = cubic hectometers per year
(3) mtons = metric tons

BATHTUB calibration. The existing condition BATHTUB model was calibrated to 2005-2007 water quality data collected by UHL. The predicted and observed in-lake values, along with calibration coefficients, are reported in Table D-12.

The Silver Lake model calibrated well to TP, chlorophyll-a, and Secchi depth, as indicated by calibration coefficients near 1.00. It should be noted that the internal load estimate was technically treated as a calibration parameter because the internal load was adjusted until the predicted concentrations agreed with observed data. With the internal TP load adjustment, the model was able to predict chlorophyll-a with a small calibration adjustment, and Secchi depth with no calibration adjustment.

Table D-12. Calibration data for the Silver Lake BATHTUB model (2005-07).

Parameter	(1)Observed Data	BATHTUB Output	% Error	Calibration Coefficient
TP	115.5 ug/L	115.5 ug/L	0.0	1.00
TN	3.35 mg/L	3.35 mg/L	0.0	2.07
Chl-a	44.0 ug/L	44.1 ug/L	0.2	0.87
Secchi	0.7 m	0.7 m	0.0	1.00

(1) Collected by UHL from 2005 through 2007.

After the model was calibrated to UHL data from 2005-2007, it was validated against the water quality data collected by ISU from 2001-2004 using GWLF simulation output from the same period. Model validation results are reported in Table D-13. The model under-predicted TP by 3.3 percent, over-predicted chlorophyll-a by 19.3 percent, and predicted the observed Secchi depth to the nearest one-tenth of a meter. Considering the variability of natural systems such as lakes, this was determined to be a satisfactory validation result.

Table D-13. Validation data for the Silver Lake BATHTUB model (2001-04).

Parameter	(1)Observed Data	BATHTUB Output	% Error
TP	127.0 ug/L	122.8 ug/L	-3.3
TN	3.34 mg/L	3.79 mg/L	13.6
Chl-a	38.4 ug/L	45.8 ug/L	19.3
Secchi	0.7 m	0.7 m	0.0

(1) Collected by ISU from 2001 through 2004.

Use of BATHTUB to develop loading capacity. The tributary TP load is represented in BATHTUB by average concentration and annual flow. The internal TP load is a direct input within the segment data menu. The simulated TP load to Silver Lake was adjusted iteratively until simulations resulted in the desired targets. Water quality targets include a Secchi depth of at least 1.0 m, chlorophyll-a concentration 34 ug/L or lower, and TP concentration of 68 ug/L or lower. Attainment of the target TP concentration required the largest reduction in TP load of the three targets. This justifies utilizing TP as the basis for this turbidity TMDL, and is a conservative approach because it results in reduction chlorophyll-a and increase of Secchi depth beyond the targets. The maximum simulated TP load that meets the water quality targets is 8,499 pounds per year (lbs/year). This load represents the allowable annual average TP load to Silver Lake, and is the basis for developing the maximum daily load.

D.2. Expressing the Maximum Daily Load

In November of 2006, The U.S. Environmental Protection Agency (EPA) issued a memorandum entitled *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.* In the context of the memorandum, EPA

> *"…recommends that all TMDLs and associated load allocations and wasteload allocations include a daily time increments. In addition, TMDL submissions may*

> *include alternative, non-daily pollutant load expressions in order to facilitate implementation of the applicable water quality standards…"*

Per the EPA recommendations, the loading capacity of Silver Lake for TP is expressed as both a maximum annual average and a daily maximum load. The annual average load is more applicable to the assessment of in-lake water quality and water quality improvement actions, while the daily maximum load expression satisfies the legal uncertainty addressed in the EPA memorandum. The allowable annual average was derived using the BATHTUB model described previously in this appendix, and is 8,499 lbs/yr.

The maximum daily load was estimated from the allowable annual average load using a statistical approach. The methodology for this approach is taken directly from the follow-up guidance document titled *Options for Expressing Daily Loads in TMDLs* (EPA, 2007), which was issued shortly after the November 2006 memorandum cited previously. This methodology can also be found in EPA's 1991 *Technical Support Document for Water Quality Based Toxics Control*.

The *Options for Expressing Daily Loads in TMDLs* document presents a similar case study in which a statistical approach is considered the best option for identifying a maximum daily load that corresponds to the allowable average load. The method calculates the daily maximum based on a long-term average and considers variation. This method is represented by the equation:

$$MDL = LTA \times e^{[z\sigma - .05\sigma^2]}$$

Where: MDL = maximum daily limit
LTA = long term average
z = z statistic of the probability of occurrence
$\sigma^2 = \ln(CV^2 + 1)$
CV = coefficient of variation

The long-term average load (LTA) is 23.3 lbs/day, which is the allowable annual load derived using BATHTUB divided by the 365-day averaging period. The 365-day averaging period equates to a recurrence interval of 99.7 percent and corresponding z statistic of 2.778, as reported in Table D-14. The coefficient of variation (CV) is the ratio of the standard deviation to the mean of the simulated GWLF TP load data set for the 2005-2007 period, and is 0.26. The resulting σ^2 value is 0.065. This yields a final a daily TMDL of 45.9 lbs/day. This calculation is summarized in Table D-15.

Table D-14. Multipliers used to convert a LTA to an MDL.

Averaging period (days)	Recurrence interval	Z-score	Coefficient of variation								
			0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
30	96.8%	1.849	1.41	1.89	2.39	2.87	3.30	3.67	3.99	4.26	4.48
60	98.4%	2.135	1.50	2.11	2.80	3.50	4.18	4.81	5.37	5.87	6.32
90	98.9%	2.291	1.54	2.24	3.05	3.91	4.76	5.57	6.32	7.00	7.62
120	99.2%	2.397	1.58	2.34	3.24	4.21	5.20	6.16	7.06	7.89	8.66
180	99.4%	2.541	1.62	2.47	3.51	4.66	5.87	7.06	8.20	9.29	10.3
210	99.5%	2.594	1.64	2.52	3.61	4.84	6.13	7.42	8.67	9.86	11.0
365	99.7%	2.778	1.70	2.71	4.00	5.51	7.15	8.83	10.5	12.13	13.7

Table D-15. Summary of LTA to MDL calculation for Silver Lake.

Parameter	Value	Description
LTA	23.3 lbs/day	Annual avg. load (8,499 lbs/ 365 days)
Z Statistic	2.778	Based on 365-day averaging period
CV	0.26	Used CV from annual GWLF TP loads
σ^2	0.065	ln (CV^2 + 1)
MDL	**45.9 lbs/day**	**TMDL expressed as daily load**

D.3. References

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Appendix E --- Public Comments

IDNR received no public comments on the Silver Lake TMDL for Turbidity.