Phase II Water Quality Improvement Plan for

Silver Lake

Delaware County, Iowa

Total Maximum Daily Load
for Nuisance Algal Growth, pH, Turbidity and Ammonia

Iowa Department of Natural Resources
Watershed Improvement Section
2008

Table of Contents

List of Figures	4
List of Tables	5
General Report Summary	6
Technical Elements of the TMDL	8
1. Introduction	10
2. Description and History of Silver Lake	12
2.1. Silver Lake	14
Morphometry and Hydrology.	15
2.2. The Silver Lake Watershed	15
Land Use	15
Soils, climate, and topography.	15
3. Total Maximum Daily Load (TMDL) for Phosphorus	16
3.1. Problem Identification	16
Applicable water quality standards.	16
Data sources.	17
Interpreting Silver Lake data.	17
Carlson's Trophic State Index:	20
3.2. TMDL Target	21
General description of the pollutant.	21
Water body pollutant loading capacity (TMDL).	22
Decision criteria for water quality standards attainment.	22
3.3. Pollution Source Assessment	23
Existing load.	23
Departure from load capacity.	24
Identification of pollutant sources.	24
Allowance for increases in pollutant loads.	24
3.4. Pollutant Allocation	25
Wasteload allocation.	25
Load allocation.	25
Margin of safety.	25
3.5. TMDL Summary	25
4. Implementation Plan	26
4.1 General Approach and Reasonable Timeline	26
4.2. Best Management Practices (BMPs)	26
5. Future Monitoring	27
5.1. Monitoring Plan to Track TMDL Effectiveness	27
5.2. Idealized Plan for Future Watershed Projects	27
6. Public Participation	28
6.1. Public Meetings	28
6.2. Written Comments	28
7. References	29
8. Appendices	31
Appendix A --- Glossary of Terms and Acronyms	31

Appendix B --- General and Designated Uses of Iowa's Waters 37
Appendix C --- Calculating a Daily Expression For Phosphorus 40
Appendix D --- Using WiLMS, the Vollenweider 1982 Combined OECD and Nurnberg Models to Predict Water Quality 42
Appendix E --- Using RUSLE to Predict Changes in Soil Loss with Future BMPs 46
E-1. Methods 46
E-2. Results 52
Appendix F --- Public Comments 53

List of Figures

Figure 1 Silver Lake Delaware County with watershed boundary outlined in black 14
Figure 2. RUSLE sheet and rill erosion map depicting areas of higher and lower erosion within the watershed 18
Figure 3. Current land uses and their corresponding soil losses in Silver Creek Watershed 19
Figure 4. Combined ISU and UHL TSI values over time 21
Figure D-1 Lake response model ran for existing condition of 309 ug/l and resulting Nurnberg external internal loading. 42
Figure D-2. The value in cell B17 of the Nurnberg model is the load if it were all from external watershed sources. 45
Figure D-3. Results of target Modeling. 45
Figure E-1. Estimated erosion within Silver Lake watershed with current land use and conservation practices 48
Figure E-2. Estimated erosion within Silver Lake watershed with contour farming practices adopted. 49
Figure E-3. Estimated erosion within Silver Lake watershed with no-till farming practices adopted 50
Figure E-4. Estimated erosion within Silver Lake watershed with a combination of contour and no-till farming practices adopted. 51

List of Tables

Table 1. Comparison of 1979 and current water quality 12
Table 2. Landuse in Silver Lake watershed (2006) 15
Table 3. Changes in temperate lake attributes according to trophic state (modified from U.S. EPA 2000, Carlson and Simpson 1995, and Oglesby et al. 1987). 20
Table 4. Summary of ranges of TSI values and measurements for chlorophyll-a and Secchi depth used to define Section 305(b) use support categories for the 2004 reporting cycle. 20
Table 5. Silver Lake Existing vs. Target TSI Values 22
Table 6. Acute Ammonia Water Criterion for listed classes. 23
Table 7. Idealized monitoring plan for Silver Lake Delaware. 27
Table B-1. Designated use classes for Iowa water bodies. 38
Table C-1 Multipliers used to convert an LTA to MDL 40
Table E-1. Export Coefficients for RUSLE TP in lbs/acre/year 47
Table E-2. Simulated effects of different land management scenarios within Silver Lake Watershed. 52

General Report Summary

What is the purpose of this report?

This report serves two major purposes. First, this report satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) report for all impaired 303(d) waterbodies. Second, this report should serve as a resource for locally-driven water quality improvements to Silver Lake in an effort to improve the water body and successfully restore the lake.

What's wrong with Silver Lake?

Silver Lake is not supporting the designated Class A (primary contact recreation) and Class B(LW) aquatic life uses. This is due to high nutrients within the lake, specifically phosphorus leading to organic enrichment. Through the recycling of phosphorus and the resulting organic enrichment, dissolved oxygen decreases and pH increases to levels that violate water quality standards. Results of a monitoring survey conducted by Iowa State University indicate Silver Lake has some of the poorest water quality of any lake in the state.

What is causing the problem?

Although Silver Lake suffers from many impairments, all of these can be tied to excessive nutrient levels, specifically phosphorus. A study conducted in 2001 by the University of Northern Iowa demonstrated that water entering the lake is mostly runoff and with only a small amount directly from precipitation. As the runoff enters the lake it carries sediment. Phosphorus sorbed to this sediment is the main source of the phosphorus in the lake. Silver Lake has no physical mechanism to remove the phosphorus so it continually recycles between sediment and biomass. Overtime, excess phosphorus has built up within the lake which, in turn, supports exceedingly high amounts of biomass. The life cycles of the biomass, mostly composed of blue-green algae, are what lead to the additional impairments of nuisance algal growth, pH, turbidity and ammonia.

What can be done to improve Silver Lake?

In 2001 a TMDL for Silver Lake was prepared and an annual total maximum load of 60 pounds of phosphorus per year was assigned to the lake. However, a 2006 assessment indicated water quality was not improving and now included violations for nuisance algal growth, pH and turbidity. A draft list for 2008 will also indicate an ammonia impairment. Although reducing phosphorus loads entering the lake is a step in the right direction it does not directly address the current phosphorus load within the lake that continues to recycle. To improve Silver Lake water quality a physical mechanism allowing phosphorus to be removed from the lake must be instated. Because the phosphorus is either contained within the biomass or attached to the sediment, removing both via dredging would be the best solution.

Who is responsible for a cleaner Silver Lake?

Everyone who lives and works nearby, or wishes to utilize a healthy Silver Lake has an important role to play in improving and maintaining the lake. The future of Silver Lake depends on citizens and landowners adopting land use changes on a voluntary basis. The best chance for success in improving Silver Lake lies with private citizens working with government agencies that can provide technical and in some cases financial support of efforts. Citizens interested in making a difference in Silver Lake should contact their local soil and water conservation district or the Iowa DNR Watershed Improvement Section for information on how to get involved.

Delaware County Soil and Water Conservation District
Keith Krause, District Conservationist
200 S 12TH ST
Manchester, IA
Phone: (563) 927-4590
Fax: 563-927-4535

Iowa DNR Watershed Improvement Section
Allen Bonini, Supervisor
502 East 9th Street
Des Moines, IA
Phone: (515) 281-5107
Fax: (515) 281-8895

Technical Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Silver Lake, Delaware Co. (Sec 16, T88N, R4W) IA 01-MAQ-00680-L_0
Surface water classification and designated uses:	A (primary contact recreation) B(LW) (aquatic life), HH (fish consumption)
Impaired beneficial uses:	A (primary contact recreation) B(LW) (aquatic life)
Identification of the pollutants and applicable water quality standards:	Excessive phosphorus has caused nuisance algal growth, pH, turbidity and ammonia (2008 303(d) draft).
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	The target phosphorus load is 154 lbs/year with a maximum daily load of 1.2 lbs/day.
Quantification of the amount or degree by which the current pollutant loads in the waterbody, including the pollutants from upstream sources that are being accounted for as background loading, deviate from the pollutant loads needed to attain and maintain water quality standards:	Existing phosphorus load is estimated at 457 lbs/year. A 67 percent reduction in phosphorus delivery is called for.
Identification of pollution source categories:	Major: Excessive fertilizer and manure delivered from cropland and internal nutrient recycling Minor: Urban stormwater and failed septics.
Wasteload allocations for pollutants from point sources:	There are no point sources discharging into Silver Lake, therefore the Wasteload Allocation is zero.
Load allocations for pollutants from nonpoint sources:	LA of 138.6 lbs/yr (based on attaining TSI (TP) of 70 or in-lake TP concentration of 96.2 ug/l). This target

	concentration results in a Maximum Daily Load (MDL) of 1.2 lbs/day.
A margin of safety (MOS):	An explicit margin of safety (MOS) of 10 percent is used yielding a MOS of 15.4 lbs/year
Consideration of seasonal variation:	Seasonal variation is accounted for in the calculation of the MDL via a statistical analysis including a coefficient of variation.
Reasonable assurance that load allocations and wasteload allocations will be met:	Load allocations can be achieved voluntarily via watershed/water quality assistance grants and through public participation. There are no wasteload allocations in the watershed.
Allowance for reasonably foreseeable increases in pollutant loads:	Nearly all available land for intensive agriculture is currently under such use and human and livestock populations appear stable. Therefore no allowance for an increase in pollutant loads was given.
Implementation plan:	Although not required by the Clean Water Act, a general Implementation Plan is included in this report to assist managers in removing this lake from the 303(d) List.

1. Introduction

The Federal Clean Water Act of 1972 requires that each state develop a list of impaired waters which are not meeting designated water quality standards. This list is commonly called the 303(d) List. A Total Maximum Daily Load (TMDL) report must also be developed for each impaired waterbody that appears on the list.

A TMDL is a calculation of the maximum amount of pollution a waterbody can tolerate without exceeding its water quality standards. The report must allocate portions of the total maximum daily load to point sources (called wasteload allocation or WLA) and nonpoint sources (called load allocation or LA), allow for a margin of safety, and account for seasonal variations in hydrology and pollutant loading. Usually, TMDLs are expressed in units of mass per day. This is a phase II TMDL which is developed to reflect updates to a previous TMDL. In the case of Silver Lake, a more sophisticated model along with additional monitoring data has been applied to improve the original TMDL.

Silver Lake was first listed as impaired in 1998. An EPA-approved TMDL was completed in December of 2001 and addressed the impairment due to excessive nutrients (specifically phosphorus) and organic enrichment (blue-green algae blooms). This resulted in this site being moved to the Integrated Report (IR) Category 4a (TMDL approved) in the 2004 assessment listing cycle. However, an assessment completed in 2006 found the lake to be impaired for algal growth, pH and turbidity. Additionally, the 2008 303(d) draft lists the lake as impaired for ammonia. Since pH and turbidity were not addressed in the original TMDL the lake was moved back to the Category 5a (impaired, TMDL required) during the 2006 assessment listing cycle. This report will also address the impairment of ammonia that appears on the 2008 listing cycle draft.

The TMDL completed in 2001 set a LA of 60 pounds of phosphorus delivered to Silver Lake each year. Since there are no point sources within the watershed the WLA was set to zero. However, this TMDL was derived using a general calculation accounting for only lake volume and a desired target concentration of 100 ug/l Total Phosphorus (TP). In 2006, an in-house study was completed by the Iowa DNR (Herring 2006) that employed a more sophisticated modeling method, the Vollenweider 1982 Combined Organization for Economic Cooperation and Development (OECD). Both documents described Silver Lake as hypereutrophic and unlikely to respond to anything less than extreme reductions in nutrient load, specifically phosphorus, for an extended period of time. For the purpose of this TMDL, the model used by Herring 2006 will be expanded upon in order to use phosphorus as a surrogate contaminate for the impairments of algal growth, pH, turbidity and ammonia.

This TMDL report will be most useful as a resource to coordinate and target efforts to improve water quality. Public involvement is of the utmost importance in restoring the water quality in Silver Lake which is a reflection of the surrounding land and land management practices. Since local landowners, tenants, and businesses have the most influence in deciding how this land is used, they also have the most influence in improving the water quality of Silver Lake. Government action alone can not restore

Silver Lake. A successful restoration effort will require citizen action and involvement, with this document serving as a tool for guiding how to best proceed.

2. Description and History of Silver Lake

Silver Lake is a natural lake located in northeastern Iowa on the southeast edge of Delhi, Iowa. Silver Lake is located at the Silver Lake County Park and managed by the Delaware County Conservation Board. Silver Lake has designated uses of Class A (primary contact recreation) and Class B(LW) (aquatic life). The lake provides facilities for fishing, boating and picnicking. Park use is approximately 1,650 visits per year.

Clean Lakes Classification Studies completed in 1979 to 1990 indicated total phosphorus levels in Silver Lake doubled in that period. High phosphorus levels have remained consistent from 1990 on. Suspended solids and chlorophyll–a values also increased substantially from 1979 to 1990 and have remained very high since 1990. Secchi disk depth data have been reflective of the water quality in Silver Lake. The highest Secchi depths were recorded in 1979 when total phosphorus, suspended solids, and chlorophyll-a values were at their lowest. As the values for these parameters have increased, the Secchi depth has decreased to just a few inches. Table 1 compares the 1979 data to data collected since 2001.

Table 1. Comparison of 1979 and current water quality

Parameter	1979 annual mean	2001-2007 mean
Secchi Depth (m)	1.75	0.6
Chlorophyll-a (ug/l)	15	112.1
Total Phosphorus (ug/l)	175	309.4

A Summer Lakes Study conducted by the University of Northern Iowa (2000) measured several water quality parameters that included chlorophyll-a, nitrate, dissolved oxygen, phosphate, phytoplankton, bacteria, and insects. The chlorophyll-a values in 1999 ranged from 40 to 530 ug/l. Total phosphorus values are not available from the 2000 study, but total dissolved phosphorus ranged from 50 to 225 ug/l. Dissolved phosphorus is a part of the total phosphorus value. The study also estimated the biomass concentration for Silver Lake at 23 to 49 mg biomass/l. An aerobic lake with dissolved oxygen levels of around 9 mg/l can decompose about 8.5 mg biomass/l. The concentrations observed in Silver Lake are exceedingly high and would normally suggest anaerobic conditions (UNI, 2000).

Because there is enough phosphorus in the lake to support exceedingly high levels of biomass, Silver Lake does not appear to be phosphorus limited. This would hold true even if all inputs of phosphorus were ceased today because Phosphorus has no chemical mechanism by which it can be vented from the lake. Instead it is continually recycling between the sediments and the biomass.

Results from a Subsurface Exploration of Silver Lake (DNR, 2001) indicated there is a generalized flow of water from the lake rather than groundwater flowing into the lake and recharging it. As a result, the majority of the water entering Silver Lake is from overland runoff with a small amount directly from precipitation.

The results of sediment cores taken from Silver Lake (Garrison, 2001) indicated there was a dramatic change in the water quality of Silver Lake during the time span of the sediment cores. During the time period at the bottom of the core (30-50 years ago), the lake level was lower and in a clear-water macrophyte phase. Phosphorus levels were dramatically lower than the levels at the top of the core, which represents current conditions. Lower phosphorus levels are indicated by the vegetation dominant diatoms as well as planktonic diatoms which also indicate lower phosphorus levels. The presence of fossils in addition to diatoms support the hypothesis of lower phosphorus levels. These include sponge spicules and chrysophyte cysts. Although it is difficult to estimate the phosphorus concentrations during the time period represented at the bottom of the core, phosphorus levels were likely less than 100 ug/l. The tops of the cores indicate the lake has shifted to a turbid algal dominated phase. This happens when nutrient levels become high, resulting in algae out competing macrophytes for light. The dominant diatom community at the top of the core is composed of species that are indicative of very high phosphorus levels including the taxa *C.* cf. *tholiformis*, S. *hantzschi*i, and *S. minutulus*.

Silver Lake has a history of periodic winterkills caused by dissolved oxygen depletion since the early 1960's. These are due to a combination of factors: high levels of nutrients in the lake that result in excessive growth of aquatic vegetation or algae, a relatively shallow lake basin, and periodic low lake water levels during dry periods. Winterkills in the 1960's and early 1970's were infrequent enough that bass, bluegill and channel catfish populations could be established, providing fair to good fishing for a few years between winterkills.

The frequency of fishkills started to increase in the early 1970's. Following a severe winterkill in February, 1975, an aeration system was installed and operated each year in an attempt to reduce or prevent winterkills. In spite of aeration, winterkills became even more frequent in the early 1980's. Fisheries managers decided in 1987 attempt establishing northern pike as the primary sport fish due to their faster growth rate and tolerance of lower dissolved oxygen levels. Northern pike were stocked from 1987 until 1995, but resulted in only brief periods of good fishing.

In the mid-1990's, in spite of continuous aeration, the lake was experiencing winter and summer kills every year, preventing the establishment of any type of viable sport fishery. Therefore, the aeration was stopped. The only sportfish species present in the lake from the mid-1990’s to present is black bullhead, a species that is extremely tolerant of oxygen depletions. Without a consistent predator fish species in the lake, the bullhead population density has increased so that most are only six to seven inches long and their body condition is very poor. Annual fishing activity on Silver Lake is almost zero (Personal Communication Dan Kirby Fisheries Delaware County).

In 2001, a TMDL was developed for Silver Lake for the impairments of nutrients and organic enrichment. This TMDL set a target of 60 lbs of phosphorus per year. This was calculated using a volumetric equation and desired water concentration of 100 ug/l.

An assessment completed in 2006 found the lake to be impaired for nuisance algal growth, pH and turbidity. The 2008 303(d) draft indicated the lake will be impaired for ammonia. Since nuisance algal growth, pH, turbidity and ammonia were not addressed in the original TMDL, the lake was moved to the Category 5a (impaired, TMDL required) assessment listing.

The additional impairment listings along with improved modeling techniques and updated monitoring data have prompted the development of a phase II TMDL for Silver Lake.

2.1. Silver Lake

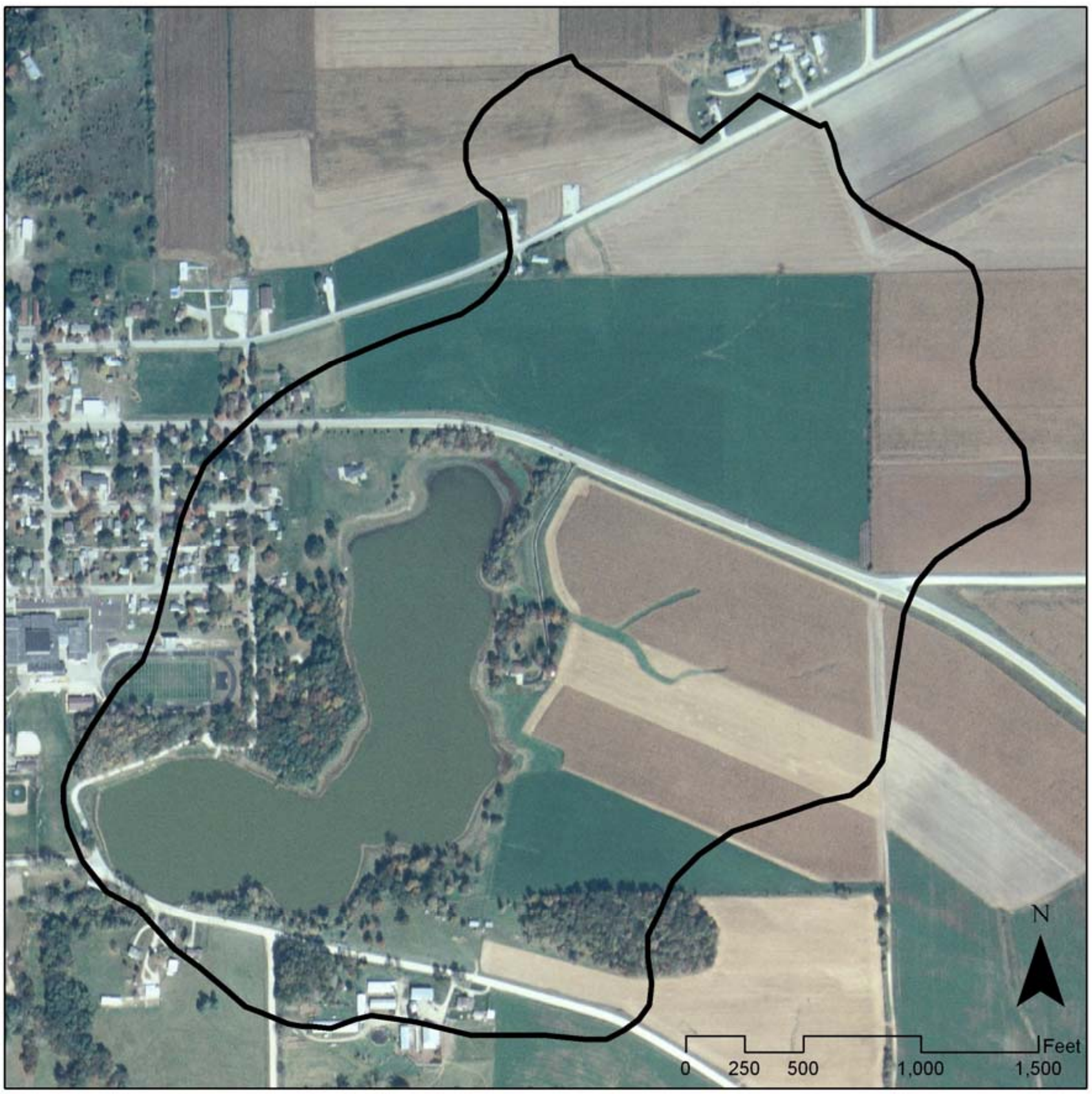


Figure 1 Silver Lake Delaware County with watershed boundary outlined in black

Morphometry and Hydrology. Silver Lake has a surface area of 31.1 acres, a mean depth of 6 feet, a maximum depth of 15 feet, and a storage volume of 219 acre-feet. A dam constructed across the southwest end of this natural lake has raised the water level higher than the natural high water line.

2.2. The Silver Lake Watershed

Land Use. The Silver Lake watershed has a land area of approximately 238.9 acres and has a watershed to lake ratio of 6.7:1 (Figure 1). The landuses and associated areas for the watershed are shown in the Table 2.

Table 2. Landuse in Silver Lake watershed (2006)

Land Cover	Acres	%
Farmstead	5.3	2.22%
Grass/Timber	20.2	8.46%
Pasture	1.5	0.63%
Road	16.4	6.86%
Row Crop	151.3	63.33%
Urban Residential	13.1	5.48%
Water	31.1	13.02%
Total	238.9	100.00%

Soils, climate, and topography. Topography of the watershed varies from gently to steeply sloping (2-14%) terrain. Soils of the watershed are primarily forest-derived, which were developed from pre-Wisconsin till or loess and prairie-derived soils from alluvium and include Chelsea, Olin Variant, Lamont, and Schley soils. Permeability of these soils is moderately rapid and runoff is slow to medium. These soils typically have low to very low amounts of available phosphorus (UDSA-SCS, 1986).

Average rainfall in the area is 34 inches/year, with the greatest monthly amount typically occurring in July.

3. Total Maximum Daily Load (TMDL) for Phosphorus

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

3.1. Problem Identification

Applicable water quality standards. The 2006 Iowa 305(b) report states the Class A (primary contact recreation) uses were assessed (monitored) as "not supported" due to (1) extremely poor water transparency that violates Iowa's narrative water quality standard protecting against aesthetically objectionable conditions and (2) frequent violations of Iowa's water quality criterion for pH. In addition, the presence of very large populations of nuisance aquatic life (bluegreen algae) likely represents an additional impairment to the Class A uses. The Class B(LW) aquatic life uses were assessed (monitored) as "not supported" due to violations of state water quality criteria for dissolved oxygen and pH. The Class B(LW) uses were also assessed (evaluated) as "not supported" due to excessive nutrient loading to the water column, nuisance blooms of algae, and re-suspension of sediment. A TMDL was completed in 2001 for the impairments of excessive nutrients (phosphorus) and organic enrichment (dissolved oxygen). However, a TMDL has not been developed to cover nuisance algal growth, pH and turbidity.

The ISU lake survey data for chemical water quality of Silver Lake also suggest "nonsupport" of the Class B(LW) uses. Four violations of the Class B(LW) criteria for dissolved oxygen occurred in the 12 samples (33%) collected during summers of 2000 through 2004 (violations were 2.8 mg/l on August 13, 2003, 2.0 mg/l on June 9, 2004, 4.0 mg/l on July 14, 2004, and 4.7 mg/l on August 11, 2004). Interestingly, these four violation occurred in the last four samples collected during the 2000-2004 period. Based on IDNR's assessment methodology, these results suggest that significantly more than 10% of the samples exceed Iowa's criterion for dissolved oxygen and thus suggest an impairment of the Class B(LW) uses of this lake.

The impairments due to violations of Iowa's Class A and Class B(LW) pH criterion are new for this lake. Fish consumption remained assessed (evaluated) as "fully supported" based on results of fish contaminant monitoring in 1999. These assessments are consistent with those developed for the 2000, 2002, and 2004 integrated reports.

Problem statement. Results of monitoring conducted by ISU from 2000 through 2004 as part of the statewide survey of Iowa lakes suggest that the Class A (primary contact) uses are "not supported" due to the extremely poor water transparency caused by algal blooms and by high levels of non-algal turbidity. 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 88, 79, and 82, respectively, for Silver Lake. According to Carlson (1977), these index values place this lake in the range of hyper-eutrophic lakes and suggest (1) extremely high levels of phosphorus in the water column (third highest of the 131 lakes sampled), (2) extremely high levels of chlorophyll-a (second highest of the 131 lakes), and (3) extremely poor water transparency (third poorest of the 131 lakes sampled). These TSI values suggest that Silver Lake continues to have some of the poorest water quality of any lake in the state.

Data sources. 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 EPA/IDNR fish contaminant monitoring in 1999.

Interpreting Silver Lake data. Although Silver Lake is impaired due to excessive algal blooms, organic enrichment, DO and pH, most of these if not all can be related to excessive phosphorus delivered via sediment. Water entering Silver Lake is mostly runoff and with only a small amount directly from precipitation. However, very little water flows out of the lake, trapping the sediment and phosphorus within the lake. This sets up for a cycle that can include algal blooms, periods of low DO, high pH, increased turbidity and high levels of ammonia.

When phosphorus is applied to fields, either as fertilizer or manure, it clings to soil until used by crops. Depending on several factors such as best management practices, plant cover, slope, rainfall, etc., soil loss will vary from area to area within a watershed. This variation can be seen using Revised Universal Soil Loss Equation (RUSLE) to estimate soil loss (Figure 2) and then compared to land uses (Figure 3). When this soil is washed away during heavy rains, the phosphorus ultimately goes with it. In many cases, a portion of this sediment will be delivered into the lake. Based on the landform region and watershed size of Silver Lake this delivered portion is estimated to be approximately 21 percent of total erosion (NRCS 1998). This would result in about 114 tons of sediment per year is washing into Silver Lake during a year of average rainfall. This amount can be less or more depending on above or below average precipitation. After delivery into the lake, the phosphorus serves as a nutrient source for algal blooms. These blooms can lead to numerous water quality problems for the lake.

One of the largest problems caused by the algal blooms is a by-product of plant respiration. This process removes dissolved oxygen (DO) from the water. Lower DO concentrations stress fish populations, with larger predatory fish suffering the most. These conditions can and often do lead to fish kills. Reduced predatory fish populations allow smaller fish to reproduce unchecked. Generally, smaller fish feed on zooplankton which feed on algae. If the increased small fish population greatly reduces the zooplankton population, algal blooms increase in biomass. As these blooms die, the phosphorus they used and stored in their biomass is re-released to the lake. The decomposition of algal blooms can also lead to ammonia being released into the water. If this occurs during periods of warm water temperatures and high pH, the lake may experience toxic levels of ammonia. These conditions occurred in late July of 2004 and early August of 2005 and resulted in acute ammonia violations.

Photosynthesis performed by algal blooms also increases the pH of water by removing carbon dioxide from the water. Removing carbon dioxide reduces the amount of carbonic acid within the water and raises the pH. The ability of sediment to retain phosphorus is highly dependent on pH, and higher pH (i.e. >6.5) causes more phosphorus to be released from the sediment to the water.

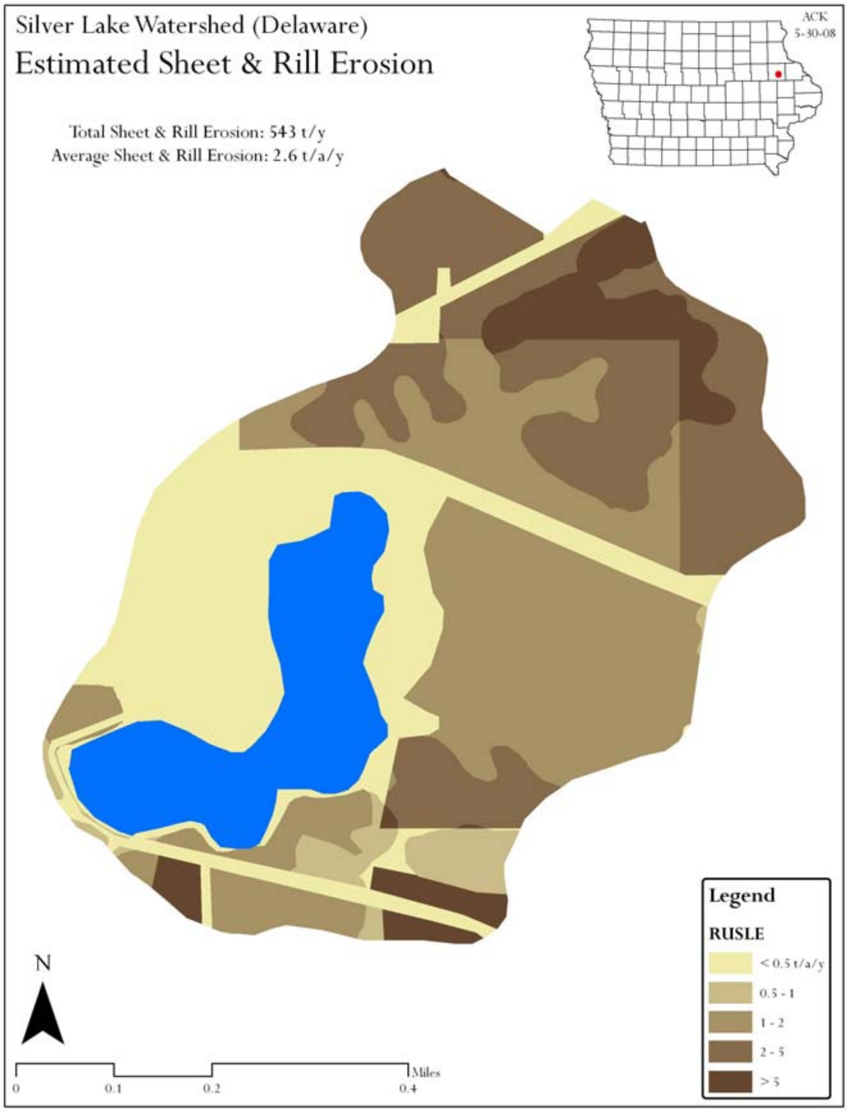
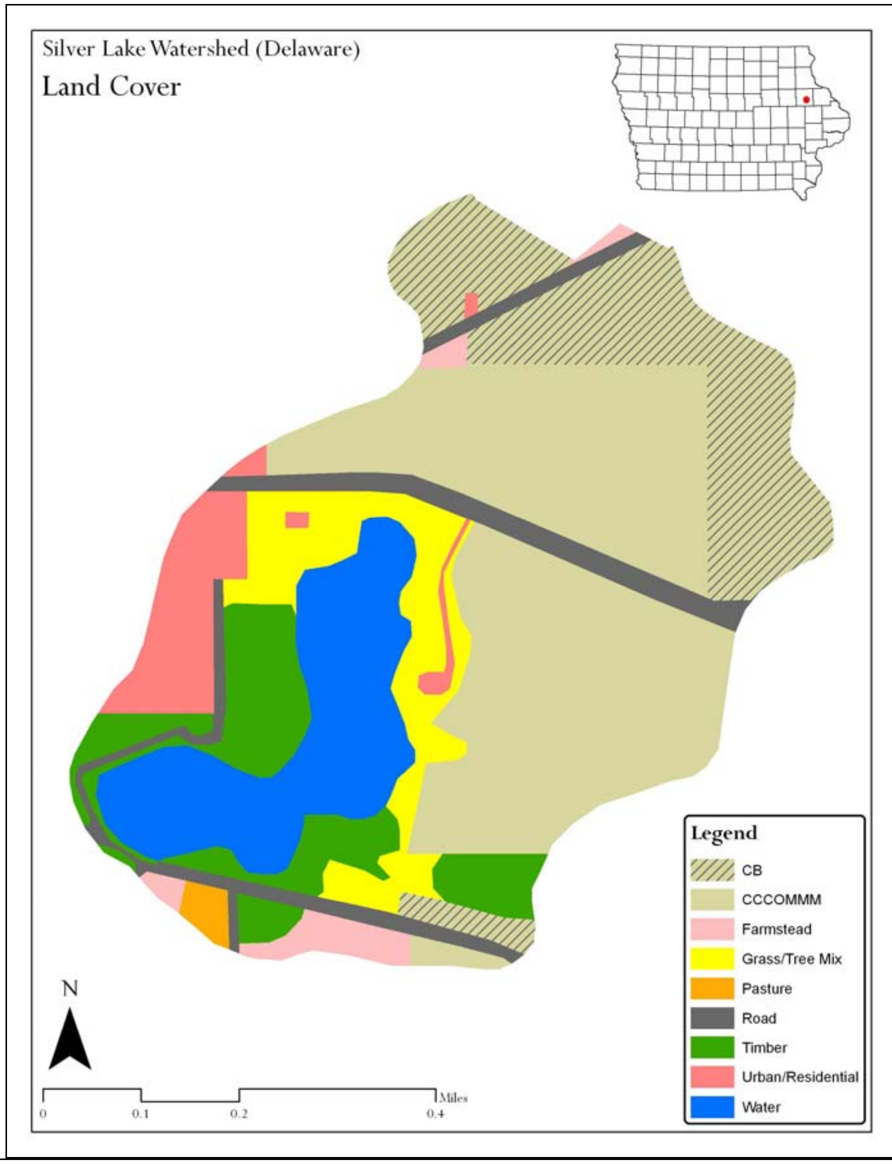


Figure 2. RUSLE sheet and rill erosion map depicting areas of higher and lower erosion within the watershed



Cover	Acres	RUSLE (t/y)	Average RUSLE (t/a/y)
CB - Fall Chisle/Spring Disk	41.6	265.8	6.39
Corn Oat Meadow Rotation (CCCOMMM)	86.2	244.9	2.84
Farmstead	5.3	4.4	0.83
Grass/Timber Mix	20.2	2.6	0.13
Pasture	1.5	8.4	5.60
Road	16.4	0	0.00
Timber	23.5	14.5	0.62
Urban/Residential	13.1	2.5	0.19
Water	31.1	0	0.00
Total	**238.9**	**543.1**	

Figure 3. Current land uses and their corresponding soil losses in Silver Creek Watershed

Carlson's Trophic State Index: Carlson's trophic state index (TSI) can be used to relate algae (as measured by chlorophyll), transparency, and total phosphorus to one another. It can also be used as a guide to establish water quality improvement targets. Increasing TSI values generally correspond to decreasing water quality conditions (Table 3).

Table 3. Changes in temperate lake attributes according to trophic state (modified from U.S. EPA 2000, Carlson and Simpson 1995, and Oglesby et al. 1987).

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

A range of TSI values and measurements for chlorophyll-a and Secchi depth were used to define Section 305(b) use support categories for the 2004 reporting cycle for Iowa (Table 4).

Table 4. Summary of ranges of TSI values and measurements for chlorophyll-a and Secchi depth used to define Section 305(b) use support categories for the 2004 reporting cycle.

Level of Support	TSI value	Chlorophyll-a (ug/l)	Secchi Depth (m)
fully supported	<=55	*<=12*	*>1.4*
fully supported / threatened	55 → 65	*12 → 33*	*1.4 → 0.7*
partially supported (evaluated: in need of further investigation)	65 → 70	*33 → 55*	*0.7 → 0.5*
partially supported (monitored: candidates for Section 303(d) listing)	65-70	*33 → 55*	*0.7→ 0. 5*
not supported (monitored or evaluated: candidates for Section 303(d) listing)	>70	*>55*	*<0.5*

*TSI value equals the TSI for Chlorophyll-a at a given range of concentrations or the TSI value for a given range of depths. For example a chlorophyll-a concentration of 55 ug/l would yield a TSI (Chl-a) value of 70. Additionally a Secchi depth of .7 m would yield a TSI (Secchi) value of 65.

If the TSI values for the three variables are the same, the relationships between total phosphorus (TP) and algae and transparency are strong. TP TSI values that are higher than the chlorophyll values indicate there are limitations to algae growth besides phosphorus. Figure 4 shows a comparison of the Silver Lake TSI values for chlorophyll, Secchi depth and total phosphorus from the ISU data. The phosphorus values generally chart higher than both chlorophyll and Secchi depth. Instances when Secchi depth values are higher than chlorophyll indicates inorganic suspended solids in addition to algal suspended solids, limiting light penetration for algal photosynthesis

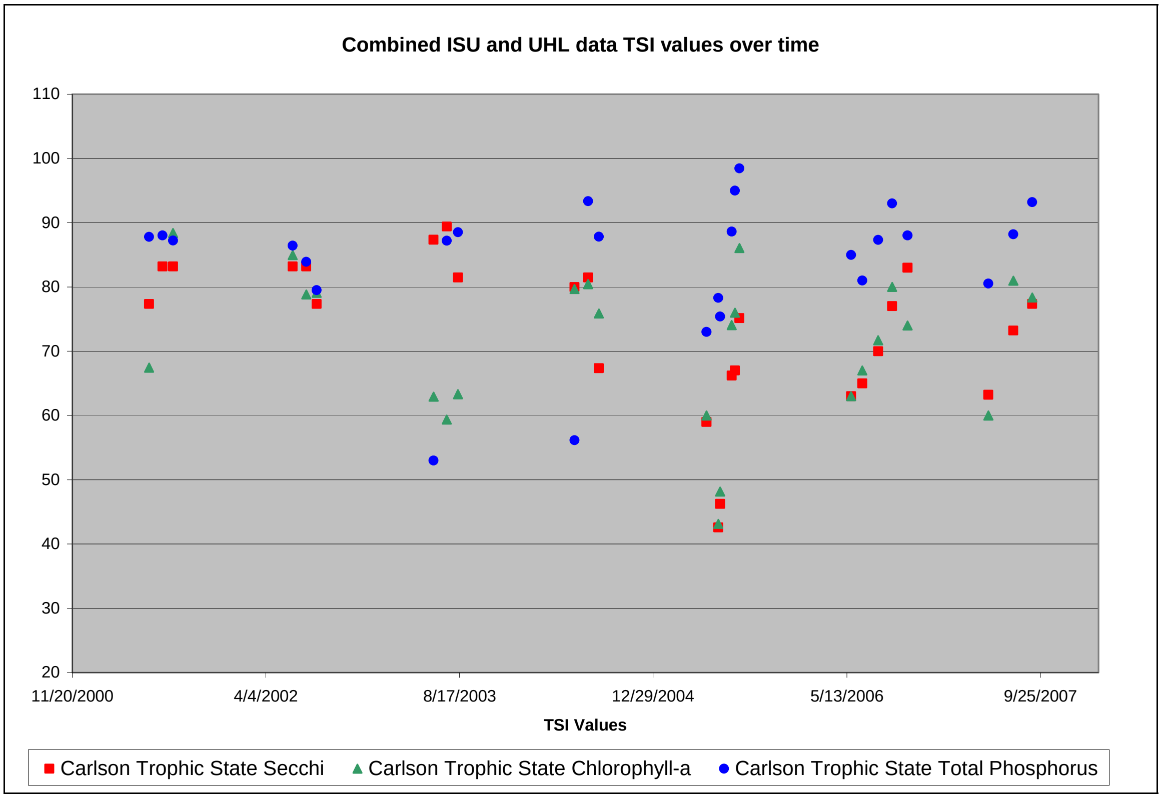


Figure 4. Combined ISU and UHL TSI values over time

3.2. TMDL Target

General description of the pollutant. Phosphorus enters the lake attached to sediment running off from the watershed. The influx of sediment also increases turbidity and decreases water clarity. Due to the enclosed nature of the lake, there is no outlet for the phosphorus, which is then recycled within the lake. The phosphorus causes algal blooms which increase turbidity, decrease water clarity and increase pH via photosynthesis. When algal blooms die and decompose they re-release phosphorus was contained in the biomass, deplete dissolved oxygen levels within the lake and can lead to toxic levels of ammonia. The critical conditions for phosphorus loading and algal growth are just prior to and during the growing season (March-September). During March and April, soil moves more readily with snowmelt and increased precipitation. This transports more sediment with attached phosphorus into the lake. During early spring manure and fertilizer are commonly applied adding additional phosphorus to the soil. During April through late July/early August, algal blooms grow and peak. As the blooms die off additional phosphorus is released into the lake and depending on temperature and pH of the system at the time ammonia may build up to toxic levels

Based on the Iowa 305b assessment protocol that determines if a lake is impaired by algae and turbidity, the targets for this TMDL are a mean TSI value of less than 65 for both chlorophyll and Secchi depth. These values are equivalent to a chlorophyll concentration of 33 ug/l and a Secchi depth of 0.7 meters. Using the Nurnberg, estimates were developed for Silver Lake, yielding a TP target concentration of 96.2 ug/l (see Appendix D for modeling discussion). The existing and target values for concentration and TSI are shown in Table 5.

Table 5. Silver Lake Existing vs. Target TSI Values

Parameter	2001-2007 TSI	Target TSI	2001-2007 Mean	Target	Improvement Needed
Chlorophyll-a	84	<65	112.1 ug/l	<33 ug/l	Decrease 70%
Secchi Depth	70	<65	.5 m	>.7 m	Increase 7%
Total Phosphorus	87	<70	309.4 ug/l	<96.2 ug/l	Decrease 67%

Water body pollutant loading capacity (TMDL). Chlorophyll, Secchi depth, pH and ammonia are all related to the total phosphorus concentration within Silver Lake and the algal blooms resulting from elevated phosphorus levels. As part of a phase II TMDL, the original target phosphorus load reported in the 2001 phosphorus TMDL for Silver Lake will change.

By using the method given in the EPA document "Options for Expressing Daily Loads in TMDLS" Appendix B "Identifying Daily Expression for Non-daily Concentration-based TMDLs, the maximum daily load is 1.2 lbs/day (see Appendix C for calculation discussion). This method uses a translation period for an annual averaging period of 365 days. This does not mean that waters receiving 1.2 lbs of phosphorus are acceptable everyday, but an acceptable maximum daily concentration once during a 365 day period. This allows for natural variation within the system to occur.

Decision criteria for water quality standards attainment. The decision criteria for water quality standards are based on meeting the TSI values of 65 for chlorophyll-a and Secchi depth and 70 for total phosphorus. They are also based on meeting Iowa Water Quality Standards for pH and ammonia as given in chapter 61 of the Water Quality Standards (available at http://www.iowadnr.com/water/standards/files/chapter61.pdf). For pH, the pH shall not be less than 6.5 nor greater than 9.0. Table 6 below gives the acute ammonia criteria for the lake.

Table 6. Acute Ammonia Water Criterion for listed classes.

Acute Criterion, mg/l as N (or Criterion Maximum Concentration, CMC)		
pH	Class B(WW-1), B(WW-2), B(WW-3) & B(LW)	Class B(CW1) & B(CW2)
6.5	48.8	32.6
6.6	46.8	31.3
6.7	44.6	29.8
6.8	42.0	28.0
6.9	39.1	26.1
7.0	36.1	24.1
7.1	32.8	21.9
7.2	29.5	19.7
7.3	26.2	17.5
7.4	23.0	15.3
7.5	19.9	13.3
7.6	17.0	11.4
7.7	14.4	9.64
7.8	12.1	8.11
7.9	10.1	6.77
8.0	8.40	5.62
8.1	6.95	4.64
8.2	5.72	3.83
8.3	4.71	3.15
8.4	3.88	2.59
8.5	3.20	2.14
8.6	2.65	1.77
8.7	2.20	1.47
8.8	1.84	1.23
8.9	1.56	1.04
9.0	1.32	0.885

3.3. Pollution Source Assessment

Existing load. According to the Nurnberg Oxic Lake model the existing load based on the 2001-2007 mean TP is estimated to be 457 lbs/year. A complete discussion of this model can be found in Appendix D.

Departure from load capacity. The target phosphorus load to achieve the desired TSI for chlorophyll-a and Secchi depth is 154 lbs/year. The current load is 457 lbs/year. The difference is 304 lbs/year requiring a 67 percent reduction.

Identification of pollutant sources. The total phosphorus load within Silver Lake is comprised of an external and internal load. The external load consists of phosphorus attached to sediment and dissolved phosphorus entering the waterbody via tributaries or runoff. The internal load consists of phosphorus that is trapped in the lake and recycled between sediments and the water column via in-lake processes. Separating how much of the total load is external verses internal is very difficult for a system like Silver Lake for several reasons. First, the lake has no direct tributaries coming in or out of the lake therefore the only incoming water is from overland flow and direct precipitation. Water escapes the lake by a possible seepage at the dam and from the lake to the groundwater, both of which are difficult to quantify. A geophysical study of the lake in 2001 indicated some possible water loss to the groundwater under the deepest part of the lake. However, review of the data collected during the study indicated several discrepancies in data collection. A similar study should be conducted before making the assumption that there is seepage from the lake to groundwater. Until better evidence is collected, the conservative approach would be to assume there is no loss of lake water or phosphorus via the bottom of the lake.

In an attempt to estimate a range of the internal load of Silver Lake, a mass balance approach using RUSLE values and the Nurnberg model were used. This model was not used for the estimation of the load because not all parameters are in range which introduces additional error. However, the equation for the Nurnberg model does take internal loading into account. Both methods are explained in appendix D. The two methods combined give a range of 21-25 percent internal loading. This maybe higher still but would require additional data to verify the actual range.

Even with a range of 21-25 percent of the phosphorus recycling within the lake itself, the problem must be addressed by stopping incoming sediment from the surrounding watershed and removing phosphorus attached to sediment within the lake. Even if all the phosphorus coming into the lake was stopped this still leaves a significant amount of within the lake. Therefore, restoration efforts must focus on in-lake as well as land management restoration efforts.

Allowance for increases in pollutant loads. There are no allowances for increases in pollutant loads for this watershed.

3.4. Pollutant Allocation

The TMDL is based on a target concentration of 96.2 ug/l resulting in a target load of 154 lbs P/year.

Wasteload allocation. There are no permitted discharges in Silver Lake, therefore, the WLA is set to zero.

Load allocation. One-hundred percent of the load is allocated to non-point sources, therefore the LA is set at 138.6 lbs/year.

Margin of safety. An explicit margin of safety of 10% was employed resulting in an MOS of 15.4 lbs/year.

3.5. TMDL Summary

The following equation represents the phase I total maximum daily load (TMDL) and its components for Silver Lake Delaware:

TMDL = Load Allocation (non-point sources and background) + Wasteload Allocation (point sources) + Margin of Safety (either explicit or implicit)

Expressed annually:

Total Phosphorus $\text{TMDL}_{\text{annual}}$ = LA (138.6 lbs/year) + WLA (0.0 lbs/year) + MOS (15.4 lbs/year) = 154 lbs/year

Expressed as daily:

Total Phosphorus $\text{TMDL}_{\text{daily concentration}}$ = LA (1.1 lbs/day) + WLA (0.0 ug/l /day) + MOS (0.1 lbs/day) = 1.2 lbs/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 TMDL. Therefore, this plan is included for use by local professionals, watershed managers, and citizens for decision-making support and planning purposes. The best management practices (BMPs) listed below represent a comprehensive list of tools that may help achieve water quality goals if applied in an appropriate manner; however, it is up to land managers, citizens, and local conservation technicians to determine exactly how best to implement them.

4.1 General Approach and Reasonable Timeline

Initiative and action by local landowners and citizens are crucial to improving the overall health of any watershed but this is especially true of the Silver Lake watershed in which most of the land is privately owned. Watershed work and improvements to the lake should proceed in conjunction with a comprehensive monitoring system that will adequately characterize daily, seasonal, and annual pollutant loadings in the lake as improvements to the watershed are made.

4.2. Best Management Practices (BMPs)

All the water quality problems within Silver Lake stem from the excess of phosphorus within the lake. The main delivery mechanism is phosphorus attached to sediment entering the lake as storm water runoff. Therefore, to decrease the phosphorus delivered to the lake, it is necessary to reduce the sediment delivered to the lake. Since most of the land surrounding Silver Lake is used for row crop farming, the largest reductions in sediment delivery could be made on these lands. These reductions can come from conservation practices that reduce bare ground cover and slow sediment loss and delivery. This includes using buffer strips, terraces, contour farming, water and sediment control structures, sediment basis and grassed waterways. A full explanation of such processes, proposed BMPs specific to this watershed and modeled outcomes from implementing such practices can be found in Appendix E of this document.

After the installation of watershed BMPs, dredging of the lake to remove the excess phosphorus trapped within lake sediment should occur. Significant changes to water quality will not occur unless the source of phosphorus being recycled within the lake is also reduced. In 2001 Team Services was contracted to do a subsurface exploration of Silver Lake to assess the feasibility of dredging the lake. They concluded that dredging the deepest part of the lake on the southwest side could possibly break the seal between the lake and underlying groundwater. This could potentially lead to significant de-watering of the lake. This would lead to a further decrease in water quality. However, after reviewing the coring data from the study, possible discrepancies in the data were found and revisiting this study is advisable before any dredging begins.

5. Future Monitoring

Water quality monitoring is a critical element in assessing the historic and current status of water resources. Furthermore, monitoring is necessary to track the effectiveness of water quality improvements made in the watershed and to document the status of the waterbody in terms of achieving total maximum daily loads.

5.1. Monitoring Plan to Track TMDL Effectiveness

Currently, Silver Lake water quality is monitored three times a year during the critical period of May to September. These water samples are used to track annual water quality trends and conditions. This sampling effort is completed by the University Hygenic Lab (UHL) of the University of Iowa as part of a statewide lake sampling program. Effects of the implementation of BMPs and any future lake dredging will be evaluated through data collected via this sampling program.

5.2. Idealized Plan for Future Watershed Projects

The purpose of this section is to outline what an appropriate monitoring plan would look like for the Silver Lake Watershed if there were no logistical or financial restraints (Table 7).

Table 7. Idealized monitoring plan for Silver Lake Delaware.

Component	Sample Frequency	Parameters/Details
1. Water chemistry sampling	Bi-weekly from March to November	All common parameters listed in Appendix A of the Iowa Water Monitoring Plan 2000 (http://wqm.igsb.uiowa.edu/publications/plan2000.htm)
2. Plant and Fish Inventory	Annually	Monitoring should be done to track improvement in aquatic plant and fish varieties and evaluate DO tolerance of species.
3. Continuous dissolved oxygen	Continuously (6-minute intervals) from June to October	Dissolved oxygen autosampler deployment according to UHL protocols

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. Public Meetings

Initial notice of the TMDL development was given to the public on March 25, 2008 at a public meeting in the town of Delhi. This initial meeting was attended by 24 landowners, stakeholders, city officials, school district officials and DNR staff members.

A final public meeting was held on October 8th, 2008 in Delhi, Iowa. The meeting was attended by DNR staff, a Soil Conservation District member and 3 private land owners from within the watershed.

6.2. Written Comments

No written comments were received during the comment period.

7. References

Bachmann, R.W., T.A. Hoyman, L.K. Hatch, and B.P. Hutchins. 1994. A classification of Iowa's lakes for restoration. Department of Animal Ecology, Iowa State University, Ames, Iowa. 517 p.

Bachmann, R.W., M.R. Johnson, M.V. Moore, and T.A. Noonan. 1980. Clean lakes classification study of Iowa's lakes for restoration. Iowa Cooperative Fisheries Research Unit and Department of Animal Ecology, Iowa State University, Ames, Iowa. 715 p.

DNR. 2001. Subsurface Exploration of Silver Lake, Delaware County. TEAM Services Report No. 1-714. August 22, 2001.

EPA. 2000. Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs. USEPA, Office of Water, Washington, D.C. April 2000.

Herring, Joe DNR 2006. Silver Lake (Delaware) TMDL: Revisited. Internal DNR Document.

Garrison, Paul. 2001. Results of Sediment Cores Taken from Silver Lake, Delaware County, Iowa. Wisconsin Department of Natural Resources, Monona, WI.

Downing, John A., and Joy M. Ramstack. 2001. Iowa Lakes Survey – Summer 2000 Data. Iowa Sate University, Department of Animal Ecology. January 2001.

Iowa. 1996. *Iowa Administrative Code 567, Chapter 61, Iowa Water Quality Standards.*

Larscheid, Joe. Statewide Biological Sampling Plan, July 2001.

Lee, K., T.M. Isenhart, R.C. Schultz, and S.K. Mickelson. 2000. Multispecies riparian buffer trap sediment and nutrients during rainfall simulations. J. Environ. Qual. 12:336-340.

Mickelson, Steven K, James L. Baker, and Imran Syed Ahmed. 2001. Presentation entitled "Conservation Buffers". Proceedings of the 2001 Agriculture and the Environment Conference. March 5-7, 2001, Scheman Building, Iowa State University, Ames, Iowa.

UNI. 2000. University of Northern Iowa Summer Lakes Study 1999-2000: Interim Report to the Roy J. Carver Charitable Trust, Iowa Space Grant Consortium.

USDA-SCS. 1986. United States Department of Agriculture, Soil Conservation Service. March 1986. Soil Survey of Delaware County, Iowa.

Diatom Trophic Status References

Bennion, H. 1994. A diatom-phosphorus transfer function for shallow, eutrophic ponds in southeast England. Hydrobiol. 275/276: 391-410.

Bennion, H. 1995. Surface-sediment diatom assemblages in shallow, artificial, enriched ponds, and implication for reconstructing trophic status. Diat. Res. 10:1-19.

Bradbury, J.P. 1975. Diatom stratigraphy and human settlement in Minnesota. Geol. Soc. America Spec. Paper. 171:1-74.

Charles, D.F., Smol, J.P.,and Engstrom, D.R., 1994. Paleolimnological approaches to biological monitoring. In: Biological Monitoring of Aquatic Systems, Loeb, S. and Spacie, D. (eds.)p. 233-293. Ann Arbor, MI: Lewis Press.

Dixit, S.S., & J.P. Smol, 1994. Diatoms as indicators in the Environmental Monitoring and Assessment Program – Surface Waters (EMAP-SW). Envir. Monit. Assess. 31:275-306.

Dixit, S.S., J.P. Smol, D.F. Charles, R.M. Hughes, S.G. Paulsen, & G.B. Collins. 1999. Assessing water quality changes in the lakes of the northeastern United States using sediment diatoms. Can. J. Fish. Aquat. Sci. 56: 131-152.

Garrison, P.J. and R.E. Wakeman. 2000. Use of paleolimnology to document the effect of lake shoreland development on water quality. J. Paleolimnol. 24:369-393.

Hall, R.I. and J.P. Smol. 1999. Diatoms as indicators of lake eutrophication. In: E.F. Stormer & J.P. Smol (eds). The Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press. 128-168.

Reavie, E.D. and J.P. Smol. 1997. Diatom-based model to infer past littoral habitat characteristics in the St. Lawrence River. J. Great Lakes Res. 23:339-348.

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 water bodies (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 water bodies 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 water body 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 water bodies 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 water bodies. 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 water body 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 water bodies. 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 water body 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 water body 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 water body 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 water body. (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 water bodies.
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 water bodies are judged when determining the health and quality of our aquatic ecosystems. These standards vary depending on the type of water body (lakes vs. rivers) and the assigned uses (general use vs. designated uses) of the water body that is being dealt with. This appendix is intended to provide information about how Iowa's water bodies 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 water body.

General Use Segments

A general use segment water body 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 water body, 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 water bodies 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 water body 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 water bodies.

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

Designated use classes are determined based on a Use Attainability Analysis, or UAA. This is a procedure in which the water body is thoroughly scrutinized, using existing knowledge, historical documents, and visual evidence of existing uses, in order to determine what its designated use(s) should be. This can be a challenging endeavor, and as such conservative judgment is applied to ensure that any potential uses of a water body are allowed for. Changes to a water body's designated uses may only occur based on a new UAA, which depending on resources and personnel, can be quite time consuming.

It is relevant to note that on March 22, 2006, a revised edition of Iowa's water quality standards became effective which significantly changed the use designations of the state's surface waters. Essentially, the changes that were made consisted of implementing a "top down" approach to use designations, meaning that all water bodies should receive the highest degree of protection applicable until a UAA could be performed to ensure that a particular water body did not warrant elevated protection. For more information about Iowa's water quality standards and UAAs, contact the Iowa DNR's Water Quality Bureau.

Appendix C --- Calculating a Daily Expression for Phosphorus

As a result of the D.C. Circuit Court of Appeals decision in Friends of the Earth, Inc. v. EPA et al., No 05-5015 (D.C. Cir. 2006), EPA recommended all future TMDLs and associated load allocations and waste load allocations be expressed in terms of a daily time increment. Generally, TMDL analytical approaches that result in longer (non-daily) averaging periods may continue to be used to demonstrate consistency with applicable water quality criteria. However, all final TMDL submissions should include an adequate expression of daily loads in addition to any longer-term loading expression that may be developed as a result of the TMDL analysis (USEPA 2006a). In response to this ruling the EPA drafted a document "Options for Expressing Daily Loads in TMDLs" providing technical support and methods acceptable to EPA for calculating daily loads in given situations.

Establishing a total maximum daily load for Silver Lake poses a unique challenge in that there are no tributaries directly feeding into the lake and all the water coming into the lake is either from overland flow or precipitation. Therefore, there is no existing flow data available for modeling this lake. The Options for Expressing Daily Loads in TMDLs document presents a similar case study in which a statistical approach is considered to be 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 document also provides table C-1 to aid in calculation of the MDL.

Table C-1 Multipliers used to convert an LTA to 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

For Silver Lake, a long term load of 154 (LA+MOS) lbs per year is needed to reach the desired TSI(TP) of 70 and lead to reductions in algal blooms, high pH readings and occasional ammonia violations. The CV (coefficient of variation) is the ratio of the standard deviation to the mean of the data set and results in a value of .3804. The z statistic of probability of occurrence used for this TMDL is based on an averaging period of 365 days resulting in a z-score of 2.778. The resulting σ^2 value is .1351. This yields a final LTA multiplier of 2.59 and results in a MDL of 1.1 lbs/day.

Appendix D --- Modeling

D.1 Calculating Total P Loading

A number of different empirical models that predict annual phosphorus load based on measured in-lake phosphorus concentrations were evaluated. In addition, watershed phosphorus delivery using both export coefficients and an annual loading function model as outlined in Reckhow's EUTROMOD User's Manual was calculated. This resulted in a TP load of 330 lbs/yr. The results from both approaches were compared to select the best-fit empirical model (Figure D-1).

Lake	Silver Lake	TSI (TP)
Growing Season Mean Total Phosphorus (ug/L)	309	87
Lake Model	Average Annual Phosphorus Load (lbs)	All Parameters In Range
EUTROMOD	425132	NO
Canfield-Bachmann Natural Lake	1109	YES
Canfield-Bachmann Artificial Lake	3868	YES
Walker Reservoir	2076	NO
Reckhow Natural Lake	1200	NO
Reckhow Anoxic Lake	223	YES
Reckhow Oxic Lake (z/Tw < 50 m/year)	456	NO
Reckhow Oxic Lake (z/Tw > 50 m/year)	NA	NA
Vollenweider 1982 Combined OECD	716	YES
Vollenweider 1982 Shallow Lake and Reservoir	742	YES
Nurnberg 1984 Oxic Lake - Target External	382	NO
External	382	Calibration Factor
Internal	75	
Simple First Order	516	1
First Order Settling	372	1
Walker Second Order	8545	NO

Figure D-1 Lake response model ran for existing condition of 309 ug/l and resulting Nurnberg external internal loading.

The Nurnberg, Reckhow Anoxic Lake and The First Order Sampling models resulted in values closest to the Loading Function and export estimates The Nurnberg model is an annual model that should ideally be used in combination with annual average in-lake phosphorus measurements. However, for a polymictic lake the annual average phosphorus concentration can be approximated by the epilimnetic growing season concentration. The available in-lake phosphorus monitoring data for Silver Lake corresponds with the growing season.

The high phosphorus and inorganic suspended solids levels at Silver Lake indicate the likelihood of a significant internal loading. The existing load predicted by the Nurnberg Model also indicates a significant internal load. Therefore, use of the Loading Function estimate with the Nurnberg Oxic Lake Model was selected as the basis for determining the existing load. The Nurnberg Model was also used to determine load targets as a function of the relative contribution from internal and external sources.

The equation for the Nurnberg Oxic Lake Model is:

$$P = \frac{L_{ext}}{q_s}(1 - R) + \frac{L_{\text{int}}}{q_s}$$

Where:
P = lake concentration
L_{ext} = External load
L_{int} = Internal load
q_s = overland flow

$$R = \frac{15}{18 + q_s}$$

Performing a basic mass balance would be the first step to quantify how much of the TP within Silver Lake is from external sources verses internal recycling. The spreadsheet model offers a RUSLE equation as well. However, the RUSLE ran via GIS interface used to produce the value of 543 tons of soil lost per year uses updated land coverages and better digital elevation maps and therefore yields more accuracy. However, export coefficients for land use remain the same as what is documented in Reckhow et al. 1980 EPA 440/5-80-011.

Using the RUSLE values of 543 t/y soil loss, 1.3 pounds of phosphorus per ton of soil and a delivery ratio of 21 percent yields 145 pounds of phosphorus entering the lake per year:

543 tons soil/year x 1.3 lbs P per ton soil x 0.21 lake delivery ratio = 145 lbs P/ year delivered in-lake.

This equation does not take into account dissolved phosphorus entering the lake. The volume of the lake is approximately 219 acre-feet or 2.7 E+8 liters. The addition of 145 lbs of phosphorus to this volume with no internal loading would yield a concentration of 243 ug/l. The average lake concentration is 309 ug/l which is a difference of 66 ug/l. This would indicate a internal load of approximately 21 percent.

Estimating external loading verses internal loading is one of the hardest steps in modeling a watershed such as Silver Lake that has no direct tributaries entering the lake and instead is supplied completely by overland flow. To further complicate estimating this relationship, there is no mechanism for phosphorus removal from the lake either. Therefore, internal recycling within the lake will continue until sediment is removed from the bottom of the lake in an attempt to remove phosphorus.

Within the spreadsheet model the only mechanism to estimate internal load is the Nurnberg 1984 Lake model. To use the Nurnberg equation to estimate the internal load, enter the lake concentration (309 ug/l) and run the existing lake conditions in the Lake Response Models worksheet. With an external load of 382, the internal load is 75 lb/yr (Figure D-4). Within this context however, a pound of internal TP load in the Nurnberg equation is not the same as a pound of external load. The effect of a pound of internal load is driven by the outlet hydraulic retention time in the Hydrology worksheet. To figure out what the ratio of an internal pound is to an external pound, put zero into the internal load cell (B18) and hit enter. The value that is now in cell B17 is the load if it were all from external watershed sources (Figure D-2). The ratio is calculated like this: (682-382)/75 = 4 lbs/external to 1 lb internal load or 25% internal recycling.

Between the generic mass balance approach and the Nurnberg model a range of 21-25 percent internal loading is produced. Within a small enclosed lake such as Silver Lake with the very high concentrations that have been recorded, it is possible this amount is much higher but without additional data and monitoring (i.e. lake sediments and surrounding soil P tests) this range represents the best estimate available at this time. It also indicates that even if all external sources of P were eliminated, a significant internal load would still exist, requiring in-lake restoration efforts.

The target load of 154 was based on attaining an in-lake concentration of 96.2 ug/l. This concentration was based on attaining a TSI of 70 (Figure D-3). The value of 154 includes the internal (23 lbs) and external (121 lbs) loads for a total P load.

Lake	Silver Lake	TSI (TP)
Growing Season Mean Total Phosphorus (ug/L)	309	87
Lake Model	Average Annual Phosphorus Load (lbs)	All Parameters In Range
EUTROMOD	425132	NO
Canfield-Bachmann Natural Lake	1109	YES
Canfield-Bachmann Artificial Lake	3868	YES
Walker Reservoir	2076	NO
Reckhow Natural Lake	1200	NO
Reckhow Anoxic Lake	223	YES
Reckhow Oxic Lake (z/Tw < 50 m/year)	456	NO
Reckhow Oxic Lake (z/Tw > 50 m/year)	NA	NA
Vollenweider 1982 Combined OECD	716	YES
Vollenweider 1982 Shallow Lake and Reservoir	742	YES
Nurnberg 1984 Oxic Lake - Target External	382	NO
External	682	Calibration Factor
Internal	0	
Simple First Order	516	1
First Order Settling	372	1
Walker Second Order	8545	NO

Figure D-2. The value in cell B17 of the Nurnberg model is the load if it were all from external watershed sources.

Target TSI	70
Growing Season Mean Total Phosphorus (ug/L)	96.21
Lake Model	Average Annual Phosphorus Load (lbs)
EUTROMOD	871
Canfield-Bachmann Natural Lake	180
Canfield-Bachmann Artificial Lake	316
Walker Reservoir	254
Reckhow Natural Lake	373
Reckhow Anoxic Lake	69
Reckhow Oxic Lake (z/Tw < 50 m/year)	142
Reckhow Oxic Lake (z/Tw > 50 m/year)	NA
Vollenweider 1982 Combined OECD	172
Vollenweider 1982 Shallow Lake and Reservoir	197
Nurnberg 1984 Oxic Lake - Target External	121
External	121
Internal	23

Figure D-3. Results of target Modeling.

Appendix E --- Using RUSLE to Predict Changes in Soil Loss with Future BMPs

The Universal Soil Loss Equation (USLE) was developed by the USDA based on data collected beginning in the 1930's and originally published in 1965. With additional research and data, the Revised Universal Soil Loss Equation was published in 1997 by the U.S. Department of Agriculture. The current equation is:

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

While factors such as rainfall and hillslope are fixed, other factors such as cover management and support practice can be changed to reflect different land uses. For Silver Lake Delaware County, an initial RUSLE model to represent current conditions was developed. This model was made using current GIS land-use coverages and information gained through personal communications with NRCS personnel working in the Silver Lake watershed.

E-1. Methods

Sheet and rill erosion: ArcView GIS is used to calculate soil loss for sheet and rill erosion, using the NRCS Revised Universal Soil Loss Equation (RUSLE). RUSLE C and P factors are gathered by means of field level watershed assessments. RUSLE K and LS factors are derived from statewide digital soils data and Digital Elevation Models (DEMs). Precipitation information (RUSLE R factor) exists in a county based dataset. Inputs to the equation vary based on soil type, land use, and slope; so the output is at a sub-field scale. Output units are tons/acre/year.

Sediment delivery is then calculated, using ArcView, based on the "Erosion and Sediment Delivery" method developed by the state geologist for Iowa NRCS (Natural Resources Conservation Service Field Office Technical Guide, Section 1, Erosion Prediction: IA-198 "Erosion and Sediment Delivery", Schneider, March 27, 1998). This method uses sediment delivery ratios (SDRs), which have been derived from numerous sediment surveys and vary based on the landform regions and drainage areas of the watersheds in Iowa. Multiplying the sheet and rill erosion rate with the SDR value and the acreage yields a sediment delivery value in tons/year.

Phosphorus load reductions are calculated by multiplying the sediment load reduction (tons/year) by 1.3 lbs phosphorus per ton of sediment. The average soil P value for the state is based on methodology from the "Potash and Phosphate Institute (PPI) Soil Test Levels in North America" bulletin that was published in 2001. Currently, phosphorus load reductions only account for sediment-attached phosphorus and not dissolved phosphorus. Total Phosphorus export coefficients (Table E-1) were taken from "Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients" (Reckhow et al. 1980 EPA 440/5-80-011).

EPA TP Export Coefficients (lbs/acre/year)	
Alfalfa	0.678
Corn	0.312
Dairy	0.723
Feedlot	199.849
Forest	0.184
Grazing	0.723
Milo	0.678
Mixed Ag	0.241
Pasture	0.571
Soybeans	2.320
Wheat	0.678
Commercial	0.981
Industrial	0.981
Mixed Urban	0.981
Residential	0.981

Table E-1. Export Coefficients for RUSLE TP in lbs/acre/year

Figure E-1 is a depiction of soil loss within the watershed with current land management practices. The model was then changed for different possible soil conservation scenarios to anticipate what the effects of these changes would be. Placement of each BMP was based on suitability of the land. Therefore, some BMPs such as contour farming cover small percentages of the Silver Lake Watershed where slope is suitable for such a practice whereas practices such as no-till farming cover larger areas. Since different land conditions (i.e. slope, soil type, etc.) dictate what BMPs can be installed, a combination of practices suited to different land types is ideal. By examining possible BMPs and their effects on the watershed, stakeholders, landowners and watershed improvement group members can begin planning a strategy for improving Silver Lake's water quality (Figures E-2 to E-5).

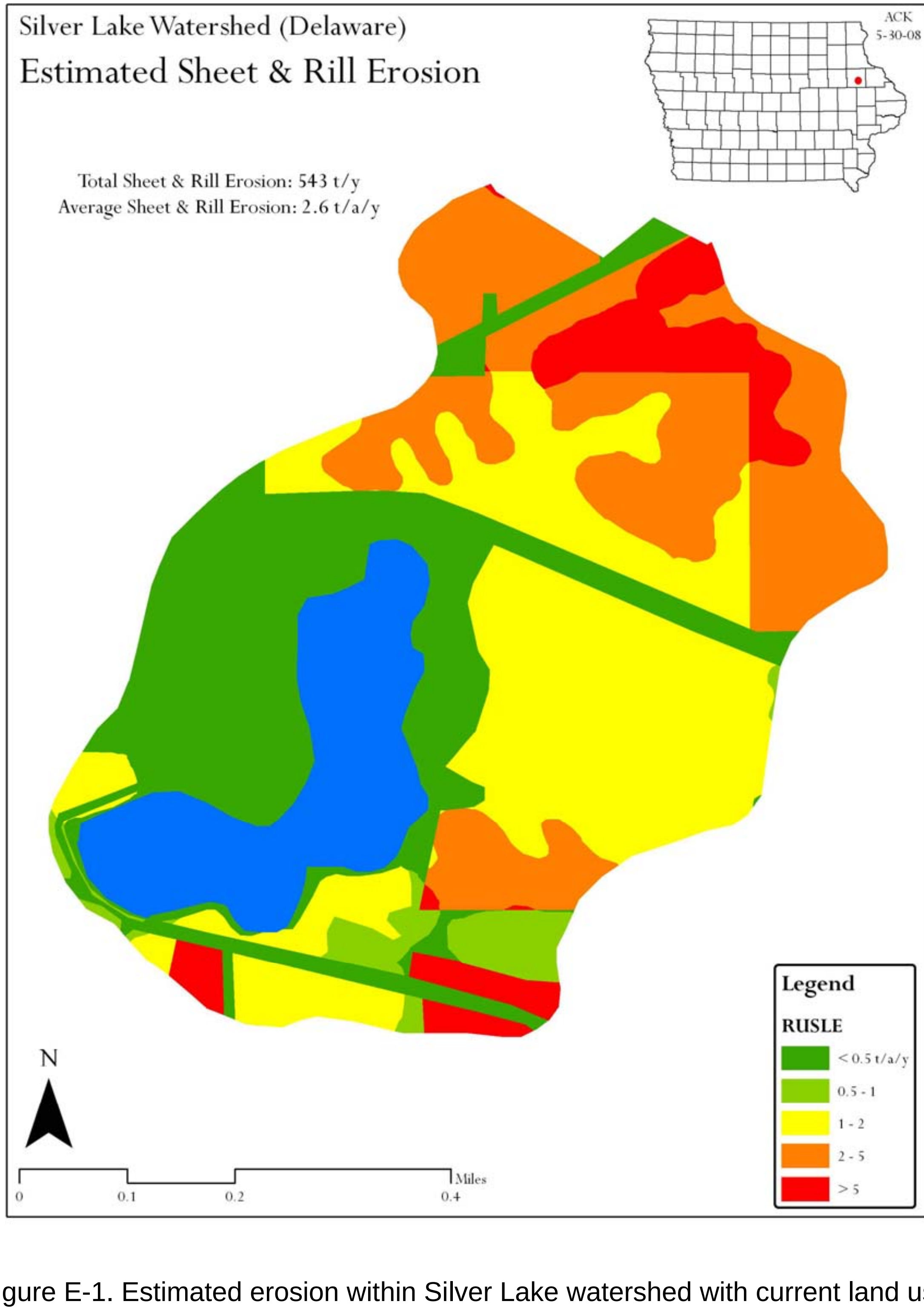


Figure E-1. Estimated erosion within Silver Lake watershed with current land use and conservation practices

Figure E-2. Estimated erosion within Silver Lake watershed with contour farming practices adopted.

Figure E-3. Estimated erosion within Silver Lake watershed with no-till farming practices adopted

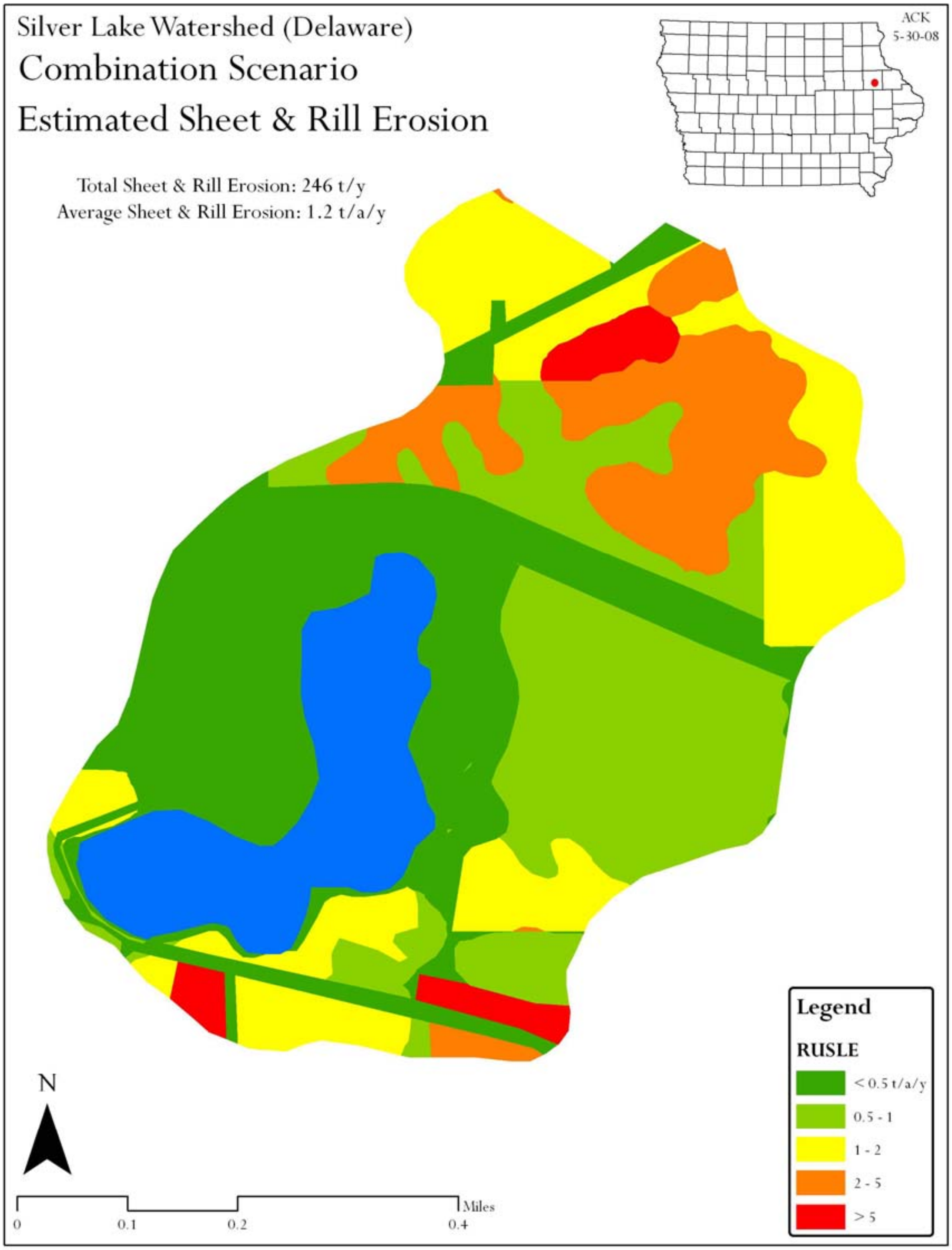


Figure E-4. Estimated erosion within Silver Lake watershed with a combination of contour and no-till farming practices adopted.

E-2. Results

Table E-1 summarizes the different scenarios from the RUSLE models. While a combination of contour and no-farming yield the largest reduction in sediment loss, the largest single practice loss is attributed to no-till farming. The no-till practice carries the additional benefit of reducing the amount of commercial fertilizers needed, because as the remaining residue decomposes it releases nutrient back into the soil. However, if cost or time restraints allow only one BMP to be used within the watershed, no-till farming would yield the largest single practice improvement to soil loss.

Table E-2. Simulated effects of different land management scenarios within Silver Lake Watershed.

Management Practice	Estimated Annual Sheet and Rill Erosion (tons/year)	Estimated Sediment Delivery (tons/year)	Reduction from current conditions
No BMPs (current conditions)	543	114	N/A
Contour Farming	466	98	14%
No-Till Farming	296	62	45%
Combination Contour and No-Till Farming	246	52	55%

Appendix F --- Public Comments

No public comments were received during the comment period.