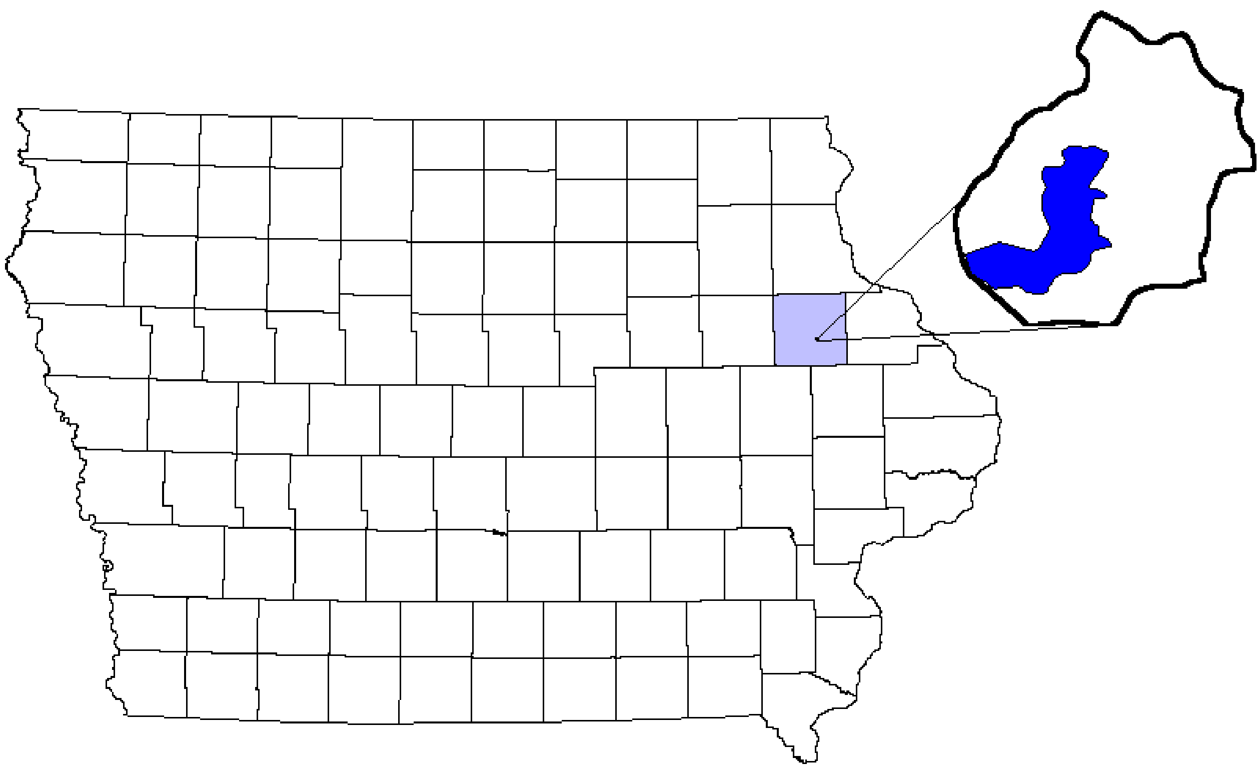
Total Maximum Daily Load
For Nutrients and Organic Enrichment
Silver Lake
Delaware County, Iowa

December 13, 2001

Iowa Department of Natural Resources
Water Resources Section

TMDL for Nutrients and Organic Enrichment
Silver Lake
Delaware County, Iowa

Waterbody Name:	Silver Lake
IDNR Waterbody ID:	IA 01-MAQ-00680-L
Hydrologic Unit Code:	HUC11
Location:	Sec. 16 T88N R4W
Latitude:	42 Deg. 25 Min. N
Longitude:	91 Deg. 19 Min. W
Use Designation Class:	A (primary contact recreation) B(LW) (aquatic life)
Watershed Area:	187acres
Lake Area:	34acres
Major River Basin:	Northeast Iowa River Basin
Receiving Water Body:	Unnamed trib. to Maquoketa River
Pollutant:	Nutrients and Organic Enrichment
Pollutant Sources:	Sheet and rill erosion
Impaired Use:	Aquatic Life (Class B)
1998 303d Priority:	High



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1. Introduction

The Federal Clean Water Act requires the Iowa Department of Natural Resources (DNR) to develop a total maximum daily load (TMDL) for waters that have been identified on the state's 303(d) list as impaired by a pollutant. The purpose of these nutrient and organic enrichment TMDLs for Silver Lake is to calculate the maximum amount of nutrients that the lake can receive and still meet water quality standards, and then develop an allocation of that amount of nutrients to the sources in the watershed.

Specifically these nutrient and organic enrichment TMDLs for Silver Lake will:

- Identify the adverse impact that nutrients are having on the designated use of the lake and how the excess load of nutrients are violating the water quality standards,
- Identify a target by which the waterbody can be assured to achieve its designated uses,
- Calculate an acceptable nutrient load, including a margin of safety, and allocate to the sources, and
- Present a brief implementation plan to offer guidance to Department staff, DNR partners, and watershed stakeholders in an effort to achieve the goals of the TMDL and restore the lake to its intended use.

Iowa DNR believes that sufficient evidence and information is available to begin the process of restoring Silver Lake. The Department acknowledges, however, that to fully restore Silver Lake additional information will likely be necessary. Therefore, in order to accomplish the goals of this TMDL, a phased approach will be used. By approaching the restoration process in phases, feedback from future assessment can be incorporated into the plan.

Phase I of the nutrient and organic enrichment TMDLs for Silver Lake will address the first target associated with achieving a reduction in the nutrient load associated with the aquatic life impairment. Phase II will evaluate the effect that the nutrient load targets have on the intended results. Included in Phase II will be monitoring for results, reevaluating the extent of the nutrient and organic enrichment impairment, and evaluating if the specific aquatic life impairment originally identified in the TMDL has been remedied. Ultimately, the intent of this TMDL is not to set in stone arbitrary targets, but restore the aquatic life that have been impaired. The phased approach allows DNR to utilize a feedback loop to determine if the initial nutrient load target has been effective.

2. Description of Waterbody and Watershed

Silver Lake is a natural lake located in northeastern Iowa on the southeast edge of Delhi, Iowa. Silver Lake has a surface area of 34 acres, a mean depth of 6 feet, a maximum depth of 15 feet, a storage volume of 219 acre-feet. A dam constructed across the southwest end of this natural lake has raised the water level of Silver Lake higher than the natural high water line.

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.

The Silver Lake watershed has an area of approximately 187 acres and has a watershed to lake ratio of 5.5:1. The landuses and associated areas for the watershed are shown in the table below.

Table 1. Landuse in Silver Lake watershed (2000)

Landuse	Area in Acres	Percent of Total Area
Cropland	129	69
Pasture & Hayland	23	12
Timber	20	11
Other (urban, roads, etc)	15	8
Total	187	100

Topography of the watershed varies from gently to strongly sloping (2-14%). Soils of the watershed are primarily forest-derived 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 phosphorous (UDSA-SCS, 1986)

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

3. Applicable Water Quality Standards

The *Iowa Water Quality Standards* (Iowa, 1996) list the designated uses for Silver Lake as Primary Contact Recreation (Class A) and Aquatic Life (Class B(LW)). Silver Lake also has general uses of secondary contact recreation.

The State of Iowa does not have numeric water quality criteria for nutrients or organic enrichment that apply to Silver Lake. Silver Lake was included on the list of Iowa impaired waters based on the best professional judgment of DNR field staff regarding the water quality. The 1998 Iowa 305(b) report assessed the Class B(LW) uses of Silver Lake as "not supporting" due to excess nutrients and organic enrichment. Excess nutrients are causing algae blooms, which die off and cause oxygen depletions in the lake. These oxygen depletions cause fishkills in the lake due to the organic enrichment from excessive nutrients. The aquatic community has been severely impaired due to both summer and winter oxygen depletion. Dissolved oxygen levels have been improved through the use of a lake aeration system. The excess nutrients are impairing the Class B(LW) designated use by altering the physical and chemical characteristics of the lake so that a balanced community normally associated with lake-like conditions is not maintained (IAC 567-61.3(1)b(7)). Currently the only fish present in Silver Lake are stunted black bullheads. The altering of the physical and chemical characteristics are causing impairments of the following beneficial uses: 1) aquatic habitat; 2) spawning, reproduction and development; and, 3) sport fishing.

4. Water Quality Conditions

Water quality studies have been completed on Silver Lake by Iowa State University for the Clean Lakes Classification Study (Bachmann et al., 1980, Bachmann et al. 1994) and Iowa Lakes Survey 2000 (Downing and Ramstack, 2000), and also by the University of Northern Iowa (UNI, 2000). In addition, two special studies were conducted in 2001 by the DNR. One of these studies was a subsurface exploration of Silver Lake to determine the interaction of the lake with groundwater (DNR, 2001). The second study, Results of Sediment Cores Taken From Silver Lake, Delaware County, Iowa, examined the diatom composition of the sediments to determine what historic water quality may have been compared to the current condition (Garrison, 2001).

Table 2. Data collected in 1979 by Iowa State University (Bachmann, et al., 1980).

Date Collected	7/3/79	7/31/79	9/10/79
Secchi (meters)	1.8	1.7	2.8
Total Phosphorus as P (µg/L)	159	191	226
Total Phosphorous as PO4 (µg/L)	485	586	691
Total K Nitrogen (mg/L)	-	-	1.1
Chlorophyll-a (ug/L) corr.	3	27	4.6
Suspended Solids* (mg/L)`	3.3	4	2.7

Table 3. Data collected in 1990 by Iowa State University (Bachmann, et al., 1994).

Date Collected	5/20/90	6/20/90	7/19/90
Secchi (meters)	0.5	1.5	0.5
Total Phosphorus as P (µg/L)	428	702	687
Total Nitrogen (mg/L)	2.9	4.2	2.7
Chlorophyll-a (µg/L)	117	17.6	329.9
Suspended Solids* (mg/L)`	62.6	4.9	20.9

Table 4. Data collected in 2000 by Iowa State University (Downing, et al., 2001).

Date Collected	7/6/00	8/1/00	9/12/00
Secchi (meters)	0.1	0.2	0.1
Total Phosphorus as P (µg/L)	643	413	529
Total Nitrogen (mg/L)	2.16	1.81	2.63
Chlorophyll-a (µg/L)	359	5	286
Suspended Solids (mg/L)`	114.3	31.3	89.0

The Clean Lakes Classification Studies completed in 1979 and 1990 show that total phosphorous levels in Silver Lake doubled in the 1980's. The levels have remained constant since 1990. Suspended solids and chlorophyll–a values also increased substantially from 1979 to 1990. These levels have also remained very high since 1990. Secchi disk depth has been reflective of the water quality in Silver Lake. The highest Secchi depths were in 1979 when total phosphorous, suspended solids, and chlorophyll-a values were at their lowest. As the values for these parameters has increased, the Secchi depth has decreased to just a few inches.

The Summer Lakes Study conducted by the University of Northern Iowa (1998-present) 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 µg/L. Total phosphorous values are not available from the 1999 study, but total dissolved phosphorous ranged from 50 to 225 µg/L. Dissolved phosphorous is a part of the total phosphorous 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. Therefore, the concentrations seen in Silver Lake are exceedingly high and would normally suggest anaerobic conditions (UNI, 2000). The IDNR has installed a lake aeration system that operates year round to prevent oxygen depletion and subsequent fishkills.

Silver Lake does not appear to be phosphorous limited; there is enough phosphorous in the lake to support exceedingly high levels of biomass. This would be true even if all inputs of phosphorous were ceased today. Phosphorous has no chemical mechanism by which it can be vented from the lake. Instead it is continually recycling between the sediments and the biomass. Nitrogen appears to be the limiting factor in Silver Lake. TN:TP ratios in Silver Lake range from 3.4:1 to 6.7:1. EPA Nutrient Criteria guidance states that low TN:TP (<7:1) ratios are indicative of nitrogen limitation (EPA, 2000). In addition, these low ratios are typically the result of very high total phosphorous loads, rather than a shortage of nitrogen (EPA, 2000).

Results from the Subsurface Exploration of Silver Lake (DNR, 2001) show that 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 enters Silver Lake from overland runoff, and to a lesser extent precipitation. This generalized flow of water from the lake can cause potential problems with dredging activities in the lake because of the risk of disrupting the soil strata that may be acting as a seal and reducing the flow of water from the lake. In addition, groundwater monitoring near the dam indicates the presence of a probable leak in or near the dam.

The results of sediment cores taken from Silver Lake (Garrison, 2001) show that there is 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 the lake was in a clear-water macrophyte phase. Phosphorus levels were dramatically lower than at the top of the core, which represents current conditions. Lower phosphorous levels are indicated by the dominant diatoms being those associated with vegetation as well as planktonic diatoms which indicate lower phosphorous levels. The presence of other fossils other than diatoms support the hypothesis of lower phosphorous levels. These include sponge spicules and chrysophyte cysts. It is difficult to estimate the phosphorus concentrations during the time period represented at the bottom of the core, but the phosphorous levels likely were less than 100 µg/L (see list of references in Appendix II). Unlike the bottom of the core, at the top of the cores, 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 phosphorous levels. These taxa are *C*. cf. *tholiformis*, S*. hantzschi*i, and *S. minutulus*.

Silver Lake has had a history of periodic winterkills caused by dissolved oxygen depletion since at least the early 1960's due to a combination of factors - very high levels of nutrients in the lake which 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 1970's were infrequent enough that bass, bluegill and channel catfish populations could be developed providing fair to good fishing for a few years between winterkills.

However, 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 to switch to trying to establish northern pike as the primary sport fish because they grow to a catchable size faster and are more tolerant of low levels of dissolved oxygen than are bass and bluegill. Northern pike were stocked from 1987 until 1995, but these stockings resulted in only brief periods of good fishing.

It became evident in the mid-1990's that in spite of continuous aeration, the lake was experiencing winter and summerkills every year, preventing the development of any type of viable sport fishery. The only sportfish species present in the lake from then to the present is black bullhead, a species that is extremely tolerant of oxygen depletions. Without any predator fish species in the lake, the bullhead population has become so numerous that most are only 6 to 7 inches long and their body condition is very poor. Annual fishing activity on Silver Lake is almost zero.

5. Desired Target

The listing of Silver Lake is based on narrative criteria. There are no numeric criteria for nutrients or organic enrichment applicable to Silver Lake or its sources in Chapter 61 of the *Iowa Water Quality Standards* (Iowa, 1996). The Environmental Protection Agency is requiring all states to adopt or show significant progress towards adopting nutrient criteria by 2004. This will include water quality standards for nitrogen, phosphorous, and chlorophyll-a. Since numeric criteria for these parameters do not currently exist, appropriate targets need to be determined. The target needs to address both the nutrient load to the lake as well as a measurement of the aquatic life within the lake. This is a phased TMDL and each phase will incorporate a separate target. The Phase I target is for nutrient delivery to the lake, and the Phase II target will address the fishery of the lake.

The Phase I target for this TMDL is to reduce the in lake phosphorous concentration of Silver Lake. A recent study of the past and present diatom populations of Silver Lake indicate that the phosphorous levels in Silver Lake were historically much closer to a level of 100 µg/L. This data shows that the "historic" phosphorous levels in Silver Lake were much lower than current levels. Therefore, the first desired target is to achieve an in-lake total phosphorous level of 100 µg/L. Chlorophyll-a is an expression of algae in the water column and by reducing the available phosphorous in the water column, a reduction in chlorophyll-a should also occur. The reduction in algae blooms and chlorophyll-a levels will result in less severe die-offs and associated oxygen depletion in the lake. The frequency of dissolved oxygen related fishkills will be greatly reduced. In addition, as reductions in phosphorous loading to Silver Lake are made, it is expected that reductions in the nitrogen loading to the lake will also occur. This is a reasonable first estimate to accomplish a reduction in nutrients and resultant organic enrichment and to restore aquatic life.

The Phase II target will be achieved when the fishery of Silver Lake is determined to be fully supporting the Class B aquatic life uses. This assessment will be in accordance with the Statewide Biological Sampling Plan protocol (Larscheid, 2001). This protocol is currently being used to develop benchmarks for the fishery of Iowa's lakes. The results from the Silver Lake assessment will be compared with the benchmarks being developed. These assessments will include age, growth, size structure, body condition, relative abundance, and species.

Silver Lake will not be considered restored until the Phase II target is achieved. If the aquatic life target is achieved prior to the nutrient delivery target, then the level of best management practices may be maintained at a level at or above those in place at the time of the assessment. If however, after a reasonable time following the completion of the nutrient delivery practices the aquatic life has not been restored, then further study and practices may be necessary.

6. Loading Capacity

The results of sediment cores taken from Silver Lake (Garrison, 2001) show that there is a dramatic change in the water quality of Silver Lake during the time span of the sediment cores. During the time period represented by the bottom of the core (30-50 years ago), the lake level was lower and the lake was in a clear-water macrophyte phase. Phosphorus levels were dramatically lower than at the top of the core. It is difficult to estimate the phosphorus concentrations during the time period represented at the bottom of the core, but based on the diatom community, the phosphorous levels likely were less than 100 µg/L. The dominant diatom community at the top of the core is composed of species that are indicative of very high phosphorous levels. Current phosphorous levels in Silver Lake average around 500-600 µg/L.

To achieve an in-lake phosphorous level of 100 μg/L, the lake can receive 60 pounds of phosphorous per year.

7. Pollutant Sources

Observations of the watershed indicate that possible pollutant sources include urban runoff, sheet and rill erosion from cropland, animal feeding operations, and nutrient management on surrounding cropland.

Water quality in Silver Lake is influenced only by nonpoint sources. There are no point source discharges in the watershed. Field investigations to determine landuses, conservation practices, livestock operations, and gully erosion were made in 1999 by the University of Northern Iowa (UNI, 2000) and the local NRCS office.

In the summer of 1999, the UNI Summer Lakes Study (UNI, 2000) obtained nutrient applications in the Silver Lake watershed. These application rates change from year to year based on the cropping rotation. In 1999, the northern farmland (approximately 90 acres) had fertilizer applied at a rate of about 19 pounds of nitrogen, 49 pounds of phosphorous, and 70 pounds of potassium per acre.

The farmland east of the lake (approximately 69 acres) had fertilizer applied at a rate of 4 pounds of nitrogen, 3 pounds of phosphorous, and 12 pounds of potassium per acre. This is supplemented by an addition of 114 pounds of nitrogen per acre as anhydrous ammonia.

In addition to the fertilizer application, liquid hog manure is applied to some of the cropland in the watershed at the rate of 3,000 to 4,000 gallons/acre. Assuming 1000 gallons of farrow-finish hog manure contains 44 pounds of nitrogen and 32 pounds of phosphorous (ISU Pm-1599), this would contribute an additional 132 to 176 pounds of nitrogen and 96 to 128 pounds of phosphorous per acre. This level of application results in an excess of phosphorous and nitrogen applied to cropland in the Silver Lake watershed. Much of this excess enters the lake through surface runoff.

Other possible sources of nutrients to the lake include septic systems and urban storm water. The City of Delhi is in close proximity to the west bank of Silver Lake. The city has a sewer system, and there are very few septic systems in the watershed, but if they are improperly maintained, they could be supplying nutrients to the lake also. Any fertilizers used in the urban portion of the watershed have the potential of entering the lake.

Silver Lake currently contains an excess of nutrients (phosphorous and nitrogen) in the water column, sediments, and in biomass. Phosphorous is continually recycled through a lake system and has no effective way of being removed. This "internal" nutrient loading is due to the accumulation of nutrients from years of loading from the watershed.

8. Pollutant Allocation

8.1 Point Sources: There are no point discharges within the Silver Lake watershed. Therefore, the Wasteload Allocation established under this TMDL is zero.

8.2 Non-Point Sources: The non-point source discharges are originating from sheet and rill erosion and overland runoff. The watershed of Silver Lake is comprised primarily of cropland (69%) and pasture / hayland (12%). Much of the nutrient loading to Silver Lake results from the over application of fertilizer and manure to cropland in the watershed. This over application results in high levels of nitrogen and phosphorous in Silver Lake. The Load Allocation set by this TMDL is 60 pounds of phosphorous delivered to Silver Lake each year.

8.3 Margin of Safety

The margin of safety for this TMDL is implicit. The dual endpoints for this TMDL assures that that the aquatic life uses will be restored regardless of the accuracy of the nutrient delivery endpoint. Failure to achieve water quality standards will result in review of the TMDL, allocations, and/or sediment management approaches and probable revision.

9. Seasonal Variation

This TMDL accounts for seasonal variation by recognizing that (1) nutrient loading varies substantially by season and between years, and (2) nutrient impacts are felt over multi-year timeframes. Nutrient loading and transport are predictable only over long timeframes. Moreover, in contrast to pollutants which cause short-term beneficial use impacts and are thus sensitive to seasonal variation and critical conditions, the nutrient impacts in this watershed occur over much longer time scales. For these reasons, the longer time frames (pounds per year) used in this TMDL are appropriate.

It is expected that the majority of nutrient delivery to Silver Lake occurs during the snow melt runoff period in late winter / early spring, and after periods of high rainfall in the spring and early summer.

10. Monitoring

Bathymetric mapping of Silver Lake will be completed by 2002. This mapping will show the original lake bottom and the depth of sediment that has been deposited in the lake. Additional water quality monitoring will be completed at Silver Lake as part of the Iowa Lakes Survey 2000 by Iowa State University and as part of the Summer Lakes Study by the University of Northern Iowa (UNI). Silver Lake will be monitored three times per year from 2000-2004 as part of the Iowa Lakes Survey, and the monitoring plan for the UNI study will be developed in cooperation between the IDNR and UNI in early 2002. The DNR Fisheries Bureau will conduct an assessment of the fishery of Silver Lake after nutrient reductions in the lake are made and a fishery is able to sustain in the lake. This assessment will be in accordance with the Statewide Biological Sampling Plan protocol (Larscheid, 2001). At the completion of this assessment, the data will be evaluated to determine the listing status of Silver Lake.

11. Implementation

The Iowa Department of Natural Resources recognizes that an implementation plan is not a required component of a Total Maximum Daily Load. However, the IDNR offers the following implementation strategy to DNR staff, partners, and watershed stakeholders as a guide to improving water quality at Silver Lake.

To achieve reductions in nutrient delivery to Silver Lake, several best management practices are needed. These include nutrient management and permanent vegetation. Constructed wetlands within the watershed would also trap and assimilate both nitrogen and phosphorous before they could reach the lake.

Nutrient management in the watershed is needed to reduce nitrogen and phosphorous inputs to Silver Lake. Much of the excess nutrients delivered to the lake originate from the over application of manure to cropland in the watershed. If the watershed is to continue being used for production agriculture, soil tests should be completed to determine appropriate amounts of fertilizer and/or manure to be applied. For nitrogen management, the late-spring soil nitrate test will help determine needed fertilizer application. In addition, nitrogen credit should be given for manure application and previous legume crops. Producers in the watershed should be encouraged and assisted in determining the risk of phosphorous movement from their fields by use of the P-Index developed by Iowa State University, the National Soil Tilth Lab, and NRCS, and adopted by NRCS in Technical Notice #25.

Excess nutrients may cause violations of narrative water quality standards (Iowa, 1996). If over application of manure is documented as continuing to degrade the water quality of Silver Lake appropriate legal action will be considered by the IDNR.

The idling of land in the watershed would reduce the inputs of sediment with attached nutrients and also soluble nutrients to the lake. Properly placed conservation buffers have the effect of capturing phosphorous laden sediment and reducing total phosphorous from runoff by 70-90% (Mickelson et al., 2001). Total nitrogen may be reduced by 50-80% by buffers (Lee, et al., 2000).

Silver Lake does not appear to be phosphorous limited; there is enough phosphorous in the lake to support exceedingly high levels of biomass. This would be true even if all inputs of phosphorous were ceased today. Phosphorous has no chemical mechanism by which it can be vented from the lake. Instead it is continually cycling between the sediments and the biomass. Reductions in available phosphorous in Silver Lake may not be achieved without removing the phosphorous laden sediments from the lake. In-lake restoration of Silver Lake is part of Phase II of this TMDL. This could include construction of fish habitat, jetty construction for access, and dredging of accumulated sediments from the lake bottom. Resources should not be spent on in-lake restoration until proper management practices are in place in the watershed. These management practices should protect the lake from further excessive loading of sediment and nutrients.

12. Public Participation

A public meeting was held in Des Moines and Delhi regarding the Silver Lake TMDL on January 27 and February 1, 2001. A second public meeting was held on October 29, 2001 in Delhi to present the Final Draft TMDL to the public. Any comments received will be reviewed and given consideration and, where appropriate, incorporated into the TMDL.

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14. Appendix I: Diatom Trophic Status References

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15. Appendix II: Calculations

To determine phosphorous load from the watershed to Silver Lake to achieve the desired endpoint of 100 µg/L. Volume of Silver Lake is approximately 219 acre-feet.

219 ac-ft = 270,162,605 L
100 µg/L = 0.100 mg/L

$$270{,}162{,}605 \text{ L} * \frac{0.100 \text{ mg}}{\text{L}} = 27{,}016{,}261 \text{ mg} = 59.56 \text{ lbs. / year}$$

Silver Lake and watershed.