Upper Pine Lake

Hardin County, Iowa

Total Maximum Daily Load
For Siltation

December 2002

Iowa Department of Natural Resources
Water Quality Bureau

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Executive Summary

Waterbody Name	Upper Pine Lake
IDNR Waterbody ID	IA 02-IOW-00335-L
Hydrologic Unit Co de:	HUC 07080207
Location:	Sec. 4, T87N, R19W
Latitude:	42 Deg. 22 Min. N
Longitude:	93 Deg. 4 Min. W
Water Quality Standards Designated Uses	Primary Contact Recreation Aquatic Life Support
Watershed Area:	9,680 acres (1991)
Lake Area:	75.2 acres (1991)
Major River Basin:	Iowa-Cedar River Basin
Tributaries:	Pine Creek
Receiving Water Body	Lower Pine Lake
Pollutant	Siltation caused by excess sediment
Pollutant Sources	Stream bed and bank and agricultural non-point erosion
Impaired Use	Aquatic Life Support

The Federal Clean Water Act requires the development of a total maximum daily load (TMDL) for the pollutant(s) that causes a water body to be placed on the State of Iowa impaired waters list [303(d) list]. Upper Pine Lake is on the 1998 list because of an assessment that the lake only partially supports its aquatic life use as a consequence of siltation. The 1998 assessment report reiterates the 1994 and 1996 lake evaluations, the primary cause of impaired water quality is the high rate of siltation.

This document consists of a single TMDL for siltation intended to provide water quality in Upper Pine Lake that fully supports its designated uses. Specifically, sediment delivery reduction has been targeted to address the siltation impairment.

The Upper Pine Lake TMDL includes two phases. Phase 1 will consist of setting a specific target for sedimentation based on the 20 year storage volume available in the lake from the dredging and sedimentation work done in 1997. This work was done after the assessment that listed Upper Pine Lake. Phase 2 will consist of implementing a monitoring plan, evaluating collected data, readjusting target values as needed, and determining if load allocations are sufficient to protect water quality.

Phasing TMDLs is an iterative approach to managing water quality that becomes necessary when the origin, nature and sources of water quality impairments are not well understood. In Phase 1, the waterbody load capacity, existing pollutant load greater than this capacity, and the source load allocations are estimated based on the limited information available. A monitoring plan will determine if prescribed load reductions hit the target and whether or not the target values are sufficient to meet designated uses. Monitoring activities may include routine sampling and analysis, biological assessment, fisheries studies, and watershed and/or waterbody modeling. Section 5.0 includes a description of planned monitoring.

The Upper Pine Lake TMDL for siltation has been prepared in compliance with the current (November 2002) regulations for TMDL development promulgated in 1992 as 40 CFR Part 130.7. These regulations and consequent TMDL development are summarized below:

1. **Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:** Upper Pine Lake, S4, T87N, R19W, 1 mile NE of the City of Eldora, Hardin County.

2. **Identification of the pollutant and applicable water quality standards:** The pollutant causing the water quality impairment is sediment that is rapidly accumulating in critical habitat zones of Upper Pine Lake. Designated uses for Upper Pine Lake are Primary Contact Recreation (Class A) and Aquatic Life (Class B(LW)). Rapid siltation has impaired water quality by reducing lake volume, area, and depth.

3. **Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:** The target of this TMDL is a sediment delivery to the lake that does not exceed the storage capacity of two 1997 control efforts. These are a sediment detention dike with a storage volume of 30,000 cubic yards behind it and a dredged zone downstream of the dike with a storage volume of 40,000 cubic yards. The sediment storage design life is 20 years. The average allowable sediment delivery to the lake is 3,800 tons per year based on the storage volume and design life.

4. **Quantification of the amount or degree by which the current pollutant load in the waterbody, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain water quality standards:**
   The estimated average sediment load to Upper Pine Lake is 9,700 tons per year. The sediment loading capacity is 3,800 tons per year. The difference between the estimated current load and load capacity is 5,900 tons per year. This is the load reduction that must be achieved to protect the aquatic life use.

5. **Identification of pollution source category(s):** Non-point sources of sediment have been identified as the cause of impairment to Upper Pine Lake. The two categories of non-point sources are upland sheet and rill erosion and in-stream and gully erosion. Many watershed erosion control practices have been deployed over the years and watershed modeling indicates that most of the sediment that now gets to the lake is from Pine Creek bed and bank erosion.

6. **Wasteload allocations for pollutants from point sources:** There are no significant sediment point sources in the Upper Pine Lake watershed. Therefore, the wasteload allocation is zero.

7. **Load allocations for pollutants from nonpoint sources:** Load allocations designed to achieve compliance with the TMDL were developed for sediment sources in the watershed. The load allocations are for the two noted non-point source categories. The load allocation for sheet and rill erosion is 1,300 tons per year. The load allocation for gully and stream

bed and bank erosion is 2,500 tons per year. Loads were not allocated for background contributions because sediment originates only from non-point sources.

8. **A margin of safety:** This TMDL margin of safety is implicit because it incorporates the following conservative assumptions:

- The sediment discharged Lower Pine Lake is not included in the load capacity calculation.
- The lowest estimate of sediment reduction from installed practices was used in the load calculation.

There are other aspects of this TMDL that contribute to providing assurance that TMDL water quality objectives will be met. Through the process of phasing, future monitoring and evaluation of use attainment will determine whether or not the siltation impairment still exists. Also, the slow cumulative impact of sedimentation will not cause a sudden severe loss of water quality before monitoring detects it.

9. **Consideration of seasonal variation:** Excessive sedimentation occurs sporadically with big rain events year-round. Therefore, an annual loading period was used to evaluate storage capacity loss. Watershed model parameter inputs also required that seasonal changes (i.e., vegetative cover and practice factors) be accounted for.

10. **Allowance for reasonably foreseeable increases in pollutant loads:** The watershed erosion controls are of a relatively permanent nature and so there is not an allowance for increased sediment load.

11. **Implementation plan:** Although not required by the current regulations, a water quality improvement plan has been included in this siltation TMDL as a guide for involved agencies and stakeholders.

1. Introduction

The Federal Clean Water Act requires the development of a total maximum daily load (TMDL) for the pollutant(s) that causes a water body to be placed on the State of Iowa impaired waters list [303(d) list]. Upper Pine Lake is on the 1998 impaired waters list due to “siltation”. Excess sediment has created a water quality condition only partially supporting the lake’s aquatic life designated use.

The TMDL for Upper Pine Lake determines the maximum sediment load that the lake can receive without causing a water quality impairment and achieve compliance with the requirements of the Iowa Water Quality Standards.

Specifically this siltation TMDL for Upper Pine Lake will:

- Identify the adverse impact that siltation is having on aquatic life use and link this to water quality criteria compliance.
- Identify an acceptable sediment load that assures achievement of the lake’s aquatic life use.
- Estimate the existing sediment load and determine the difference between the existing and acceptable loads.
- Identify sediment sources and estimate a load allocation to each of these sources.
- Provide a brief implementation plan to guide the IDNR, other agencies, and stakeholders in efforts to reduce loads to acceptable levels.

Upper and Lower Pine Lakes are located entirely within Pine Lake State Park in Hardin County two miles northeast of Eldora, Iowa. Pine Lake State Park is state owned and is managed by the IDNR. The 572 acre park and its two lakes provide facilities for boating, fishing, swimming, camping, picnicking, and hiking. There is a swimming beach on Lower Pine Lake but not on Upper Pine Lake. Estimated park usage is 500,000 visits per year.

2. Upper Pine Lake, Description and History

Pine Lake, now called Lower Pine Lake, was formed in 1922 when a dam was constructed just upstream from the confluence of Pine Creek and the Iowa River. Eleven years after it was created, one-third of Pine Lake’s original volume had been lost to sediment. As a consequence, in 1934, a dam was constructed upstream from Pine Lake, creating a second basin to protect Pine Lake. This sediment detention basin has now become a valuable recreational resource in the region and is named Upper Pine Lake.

2.1. The Lake

Upper and Lower Pine Lakes’ water quality has been of significant regional interest and great effort and resources have been focused on improving it over the last five decades. The siltation problem in Upper Pine Lake has been serious since the dam that created it was built. In a 1991 ISU Diagnostic/Feasibility Study it was estimated that the volume loss to sediment was 7.5 acre-feet per year of a remaining 546 acre-feet. The physical features of Upper Pine Lake in the table below are as described in the 1991 study.

Table 1. Physical Features

Waterbody Name:	Upper Pine Lake
Hydrologic Unit Code:	HUC 07080207
IDNR Waterbody ID	IA 02-IOW-00335-L
Location:	S4, T87N, R19W
Latitude:	42 Deg. 22 Min. N
Longitude:	93 Deg. 4 Min. W
Water Quality Standards Designated Uses	1. Primary Contact Recreation 2. Aquatic Life Support
Tributary	Pine Creek
Receiving Waterbody	Lower Pine Lake
Lake Surface Area	75.2 acres (1991)
Maximum Depth	15.7 feet (1991)
Mean Depth	7.3 feet (1991)
Volume (1991) Volume (1997) post dredging	546 acre-feet (1991) 571 acre feet (1997)
Length of Shoreline	13,600n feet (1991)
Watershed Area	9,680 acres
Watershed/Lake Area Ratio	129

There have been some important changes to the lake since the 1991 ISU study was completed. Among the recommendations from the study were plans to dredge both lakes and to build a dike across the upstream end of Upper Pine Lake to retain sediment. In 1997, both lakes were dredged and a 400-foot long sediment retention dike was constructed across Upper Pine Lake. A total of 40,000 cubic yards of material was dredged from Upper Pine Lake and 140,000 cubic yards was removed from Lower Pine Lake.

Morphometry

Marshes and wetlands have formed in the upper reaches of the two lakes and have become ecologically valuable. The basins themselves are simple. Pine Creek is the main tributary to Upper Pine Lake and Upper Pine Lake is the only significant tributary to Lower Pine Lake. The lakes follow the contours of the original Pine Creek streambed and there are not any other significant tributaries forming branches. The deepest water in both lakes is towards the dam.

Bathymetry for Upper Pine Lake is available for the years 1947, 1961, and 1990. In 1961, the dam was raised 6 feet to an elevation of 999.5 feet. The 1991 ISU Study used the changes in volume between map years to evaluate lake volume loss and estimate average sedimentation rates.

The map below shows the locations of the 1997 dredge cut and sediment dike work. The 1991 ISU Study recommended enlarging the deepest part (15 feet) of the lake at the south end from 4 acres to 10 acres. The actual 1997 dredging work removed material from the shallower north end of the lake creating a zone just downstream from the sediment detention dike that is 12 to 14 feet deep, 1,500 long and 250 feet wide.

Figure 1. 1997 Dredge cut and sediment dike locations, Upper Pine Lake

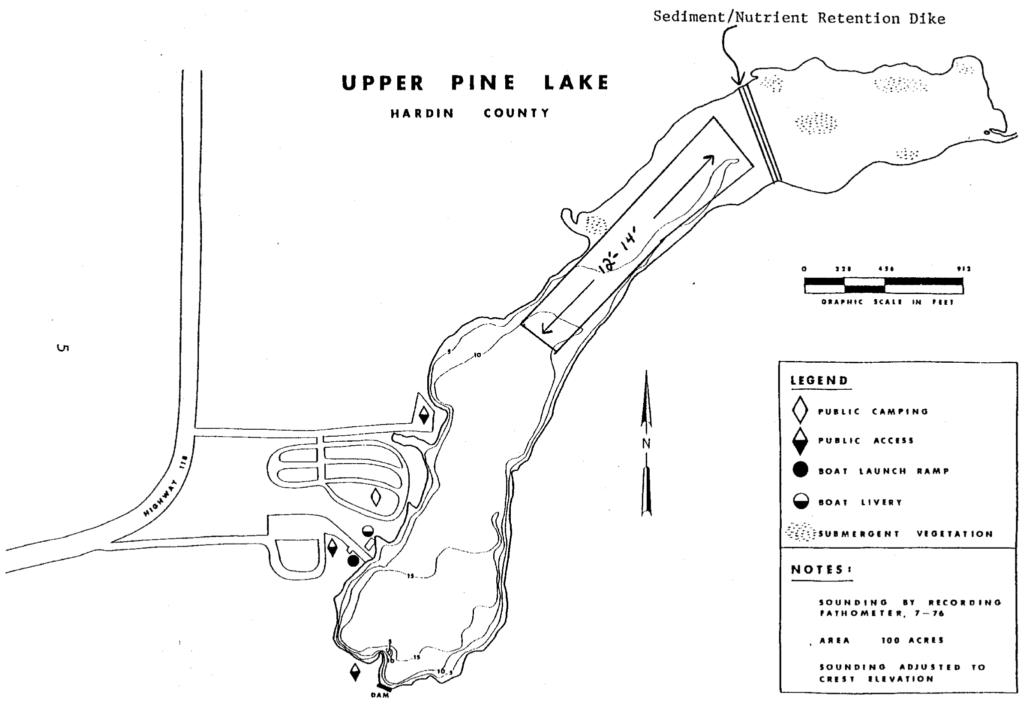


Figure 1. Location of dredge cut and sediment/nutrient retention dike in Upper Pine Lake.

Hydrology

A hydraulic budget for both of the Pine Lakes was prepared for the 1991 ISU Study. This budget used the measured change in lake storage calculated from USGS lake stage records, watershed surface runoff calculations, precipitation and evaporation data from the National Weather Service stations in Eldora and Ames, and outflows over the spillways of the two dams from stage data and stage discharge curves. Groundwater inflow is the only unknown in the system equation. Flows into the lake are from surface runoff, groundwater, and direct precipitation. It was estimated that groundwater accounts for 88% of the inflow into Upper Pine Lake and 91% of the total watershed inflow to both lakes. The ISU Study comments on the groundwater contribution:

> This is …reasonable since … the majority of upland soils are loess over glacial till and the loess infiltration capacity is very high. … the groundwater moves through the loess over impermeable glacial till into the alluvial prism that provides the final route for groundwater into the lake.

This means that much lake inflow does not carry sediment from upland areas of the watershed

2.2. The Watershed

The Upper and Lower Pine Lake watershed area is about 9,680 acres and is in both Hardin and Grundy counties. The watershed-to-lake ratio is 129:1, much higher than the ideal ratio of 20:1 and consequently the acceptable sediment load per acre would need to be low. The watershed is 7 to 8 miles east to west and 2.5 to 3 miles north to south and drains east to west. There are not any urban areas within the watershed and the summerhouses and summer camps associated with Pine Lake State Park have received sewer service within the last few years. The collected wastewater is pumped to the City of Eldora's wastewater treatment plant.

Table 2, Watershed Characteristics

Upper Pine Lake Watershed Area	9,680 acres (1991)
Average Annual Precipitation	33 inches
Precipitation Highest Monthly Average	5.5 inches, June
Significant Sediment Point Sources	None
Stream Length, Pine Creek (doesn't include lakes)	6.9 miles

Topography and Soils:
The upland terrain is gently rolling and leads to steeper slopes near Pine Creek. Closer to the lakes the land is moderately to strongly sloping. About 78% of the watershed is underlain by loess, 18% by alluvium, and 4% by sandstone, glacial till or sand. The soils that have developed over these fall within the Group B hydrologic soil group. Group B soils have a moderate infiltration rate when thoroughly wet. They consist mainly of moderately deep or deep and moderately well drained to well-drained soils that have a moderately fine to moderately coarse texture and a moderate rate of water transmission

Land Use

Table 3. Landuse in the Upper Pine Lake Watershed for 2000

Landuse	Area in Acres	Percent of Total Area
Cropland	6,872	80
Forest	444	4
Pasture & Hay	1212	13
Urban	136	2
Other (roads, water, etc)	3	1
Total	8,667	100

Figure 2 Upper Pine Lake and its watershed

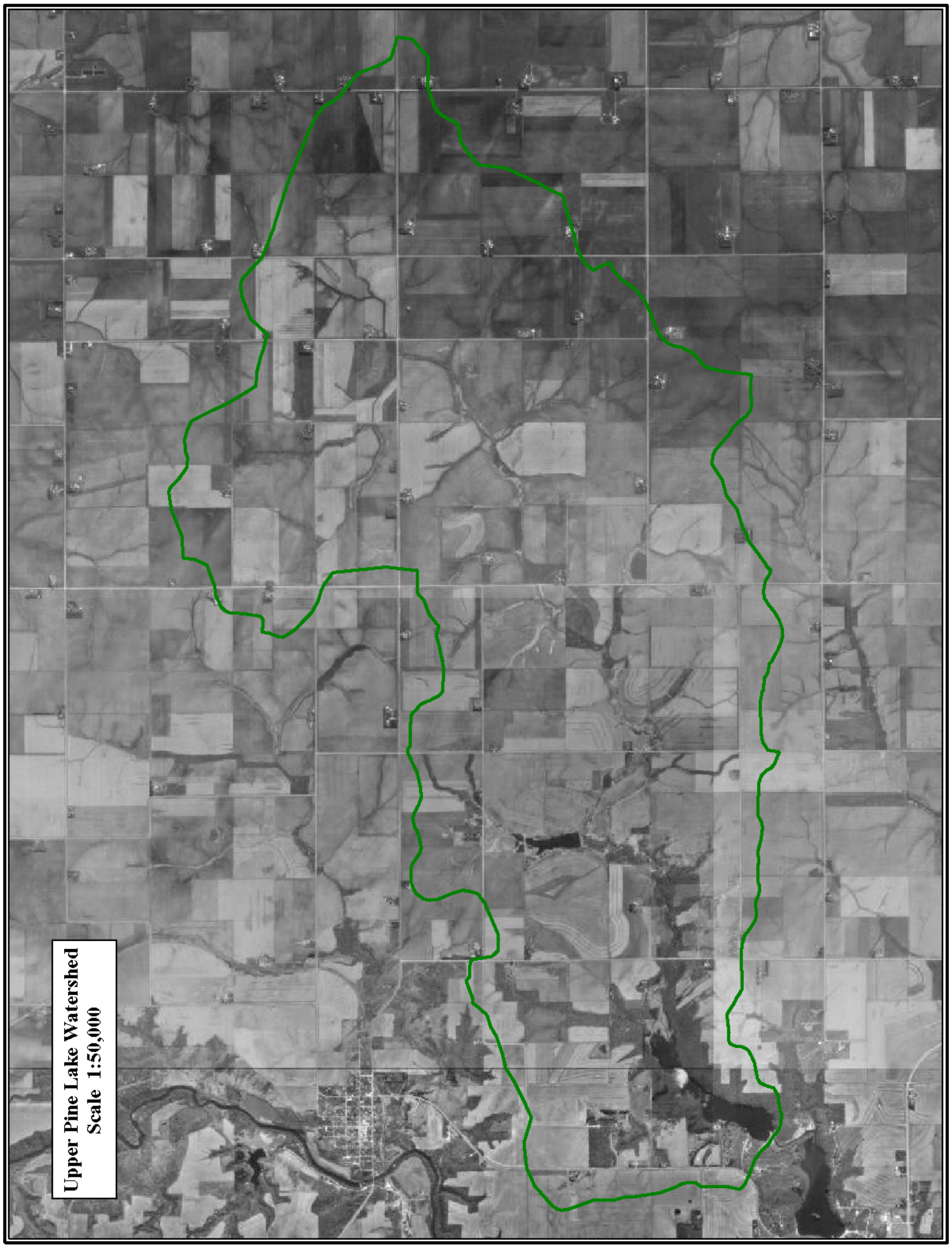
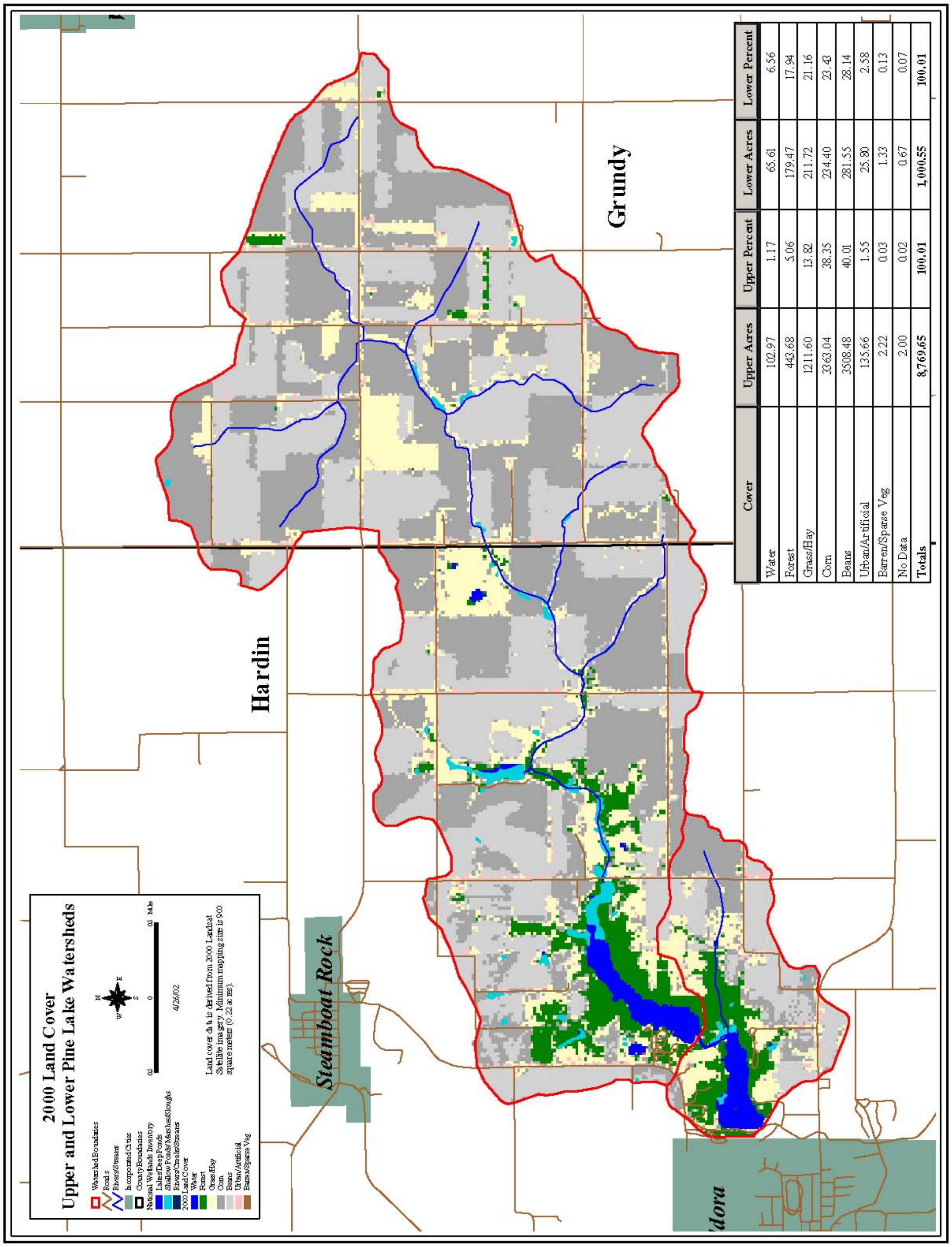


Figure 3 Upper Pine Lake Landuse



Cover	Upper Acres	Upper Percent	Lower Acres	Lower Percent
Water	102.97	1.17	65.61	6.56
Forest	443.68	5.06	179.47	17.94
Grass/Hay	1211.60	13.82	211.72	21.16
Corn	3363.04	38.35	234.40	23.43
Beans	3508.48	40.01	281.55	28.14
Urban/Artificial	135.66	1.55	25.80	2.58
Barren/Sparse Veg	2.22	0.03	1.33	0.13
No Data	2.00	0.02	0.67	0.07
Totals	**8,769.65**	**100.01**	**1,000.55**	**100.01**

2.3. History and Background

The following table is a chronology of Upper Pine Lake watershed activities.

Table 4. Upper Pine Lake Chronology

Year	Event
1922	Pine Lake created
1934	Dam built above Pine Lake to create Upper Pine Lake
1947	Hydrographic Survey of Upper Pine Lake
1961	Hydrographic Survey, lake drained, dam elevation raised 6 feet
1989-1990	Sept'89-Jun'90 Samples collected for Diagnostic/Feasibility Study
1990	Hydrographic Surveys of Upper and Lower Pine Lakes Summer sampling for Classification of Iowa's Lakes for Restoration Study
1991	May'91 ISU Study, Diagnostic/Feasibility Report
1993-1998	Pine Lake Water Quality Project (3 yr study extended to 5 yr)
1997	DNR dredging at Upper and Lower Pine, sediment detention dike in Upper Pine
2000-2004	Summer sampling Iowa Lakes Survey
2005	Iowa Lakes Survey Report

There have been four recent projects or studies that have significant value for understanding the problems and potential solutions for Upper Pine Lake water quality.

1991 Upper and Lower Pine Lakes Restoration Diagnostic/Feasibility Study
The May 1991 Upper and Lower Pine Lakes Restoration Diagnostic/Feasibility Study (ISU Study) was a thorough review of the lake's past and existing condition. The study describes the origin of the sediment problem, quantifies it, and recommends steps to remedy it.

The Pine Creek Water Quality Project, 1993 to 1998
In 1993, the Hardin and Grundy County Soil and Water Conservation Districts began the Pine Creek Water Quality Project. The project implemented conservation practices as well as nutrient and pest management strategies. These included:

- 60,888 feet of grassed waterways;
- 17,190 ft of terraces;
- 4 sediment and water control basins;
- Numerous structures protecting 831 acres of drainage;
- Critical area seeding;
- Stream bank stabilization.

The project ended in 1998. Project staff used the Agricultural Non Point Source watershed model (AGNPS) to estimate the impact of erosion management and control on sediment delivery from watershed uplands. Implemented erosion control practices reduced sediment delivery an estimated 66%. These practices included 10,200 feet of 99-foot wide filter strips along Pine Creek

Clean Lakes Program, Phase II Project, Final Report
The Phase 2 Final Report details the work done to the Pine Lakes. In 1997, both lakes were dredged. Forty thousand cubic yards were removed from Upper Pine Lake and 140,000 cubic yards were removed from Lower Pine. In addition, a 400-foot dike was constructed at the upper end of Upper Pine Lake to retain sediment and sediment adsorbed nutrients. In-lake and tributary monitoring collected data for water quality evaluations.

The Iowa State University Lake Study
The Iowa State University Lake Study began in 2000 and is scheduled to run five years. This study by the university Limnology Laboratory approximates a sampling scheme used by Roger Bachman in earlier Iowa lake studies. Samples are collected three times during the early, middle and late summer. Among the variables measured are secchi disk depth, phosphorous series, nitrogen series, TSS, and VSS. Data from 2000, 2001 and 2002 have been used to evaluate the lake's trophic state.

3. TMDL for Siltation

3.1 Problem Identification

Upper Pine Lake was put on the 1998 impaired water list for siltation. As noted previously, bathymetry shows that siltation has caused a significant loss of lake volume, depth and surface area. The Upper Pine Lake sediment problem is inevitable without erosion reduction and sediment storage practices because;

- the watershed to lake area ratio of 129 is much greater than the ideal of 20,
- the lake's original purpose was to intercept sediment to protect Pine Lake,
- the watershed soils are erosive.

Rapid sediment deposition impairs normal aquatic life in many ways:

- The reduction of volume and depth is especially negative in shallow areas that are critical for feeding and reproduction of aquatic life. Some of the most critical areas are in the upstream areas of tributary arms where most sediment settles as stream velocities rapidly decrease.
- Shallower lakes are more susceptible to summer algal blooms and winter fish kills. There is a smaller and smaller volume of water under the winter ice that can provide dissolved oxygen.
- Shallow water selects for rough fish such as bullheads and carp. Experience with temporarily drained Iowa lakes is that populations of these species explode as shallower water predominates. These species also overgraze on macrophytes and stir up bottom sediments causing turbidity and recycling of deleterious nutrients.

Impaired Beneficial Uses and Applicable Water Quality Standards
The Iowa Water Quality Standards list the designated uses for Upper Pine Lake as:

- Class "A". Primary Contact Recreation. Waters in which recreational or other uses may result in prolonged and direct contact with the water with the risk of ingesting water such as swimming, water skiing, and canoeing.

- Class "B (LW)". Aquatic Life. Water in which a significant and viable aquatic community is maintained year round. Class B waters are to be protected for wildlife, fish, aquatic and semi-aquatic life, and secondary contact uses.

Iowa does not have numeric standards for siltation or sedimentation. The "partially supported" assessment for aquatic life uses was made by IDNR staff based on information collected in the late 1980's and early 1990's for the 1991 ISU Diagnostic/Feasibilty Study and follow up monitoring and evaluation.

The following assessments are from relevant 305(b) Reports:

- 1994 Report based primarily on data from the 1991 ISU Study. Fishable uses (aquatic life) were assessed as partially supported due to high sedimentation rate estimates (7.4 cm/year), and short life expectancy (29 years), estimated summer fish kill occurrence of 1 in 10 years. Swimmable uses (primary contact recreation) not assessed.
- 1996 Report based on 1994 assessment. Partial support of aquatic life uses. Swimmable uses (primary contact recreation) not assessed.
- 1998 Report based on 1996 assessment. There was concurrence of IDNR Fisheries staff with the 1996 evaluation that Upper Pine Lake had continued partial support for aquatic life uses in 1998.

As can be seen, the 1994 evaluation of partially supporting aquatic life use carried over into the 1996 and 1998 assessments causing the lake to be placed on the 1998 impaired waters list. The siltation impairment is the consequence of sediment accumulation leading to a loss of volume and depth, particularly in the shallow areas where Pine Creek flows into the lake. The loss of volume and depth has created conditions that are incompatible with an aquatic community "normally associated with lake-like conditions". Accumulated sediment impinges on critical habitat zones.

Data Sources

There are four sources of lake data that have been incorporated into this TMDL. The data was collected at different times in the life of the various watershed and waterbody improvement projects. These projects and studies are described in the watershed history section. The data sources are:

- May 1991 ISU Diagnostic/Feasibility Study.
- Final Report for the Pine Creek Water Quality Project, 1993-1998
- Clean Lakes Program Phase II Project Final Report, May, 1998
- ISU Iowa Lake Study, 2000 to 2005

Some of the original data from these sources can be found in Appendix B.

Interpreting Upper Pine Lake Water Quality Data

The data that speaks most directly to the sedimentation impairment is the bathymetric mapping that was done in 1947, 1961, and 1990. For the 1991 ISU Diagnostic/Feasibility Study, the data from the 1947 and 1961 maps was digitized and lake volumes for all three maps were calculated. The decrease in lake volume between maps tells how much volume was lost and an average annual sedimentation rate can be estimated. The following table summarizes Upper Pine Lake sediment accumulation between 1947 and 1990.

Table 5, Estimated Sedimentation (from 1991 ISU diagnostic study)

Bathymetry year	Lake volume, acre-feet	Cumulative sedimentation, acre-feet	Average sedimentation rate, acre-feet
1947	457.6	1947 to 1961 = 153.2	1947 to 1961 = 10.9
1961, dam elev. = 993.5 ft	304.4		
1961, dam elev. = 999.5 ft	763.3	1961 to 1990 = 217.8 **Total**, 1947 to 1990 = 371.0	1961 to 1990 = 7.5
1990	545.5		

Mapping data from 1935 when the lake was created is no longer available so that volume loss in the lake's first 12 years is not known. The volume loss, or inversely, the sediment gain, between 1947 and 1961 was 153 acre-feet, about a 33% volume loss over 14 years. The lake volume was increased from 304 to 763 acre-feet in 1961 when the dam was raised six feet. Between 1961 and 1990 the volume loss was 217 acre-feet, 28% of the original volume after the dam was raised. The average annual sedimentation rate between 1947 and 1961 was 10.9 acre-feet per year and between 1961 and 1990 was 7.5 acre-feet per year, a significant decrease.

Water Quality Conditions:
The siltation of Upper Pine Lake and the subsequent shallower water directly contributes to detrimental eutrophication. Eutrophic condition is evaluated using Carlson's Trophic State Index (TSI), which provides a framework for water quality data interpretation. Calculation of the TSI and the equations that generate the total phosphorous (TP), chlorophyll a (chlor a), and secchi depth (SD) index values are found in Appendix B. The calculated TSI's for these variables locate the lake in the trophic state continuum from oligotrophic to hyper-eutrophic. A lake is becoming more than just eutrophic at TSI's of 60 to 70. A TSI over 70 indicates a hypereutrophic condition.

In Table 6 the TSI equations have been applied to the available data collected for the 2000 ISU Iowa Lakes Study previously described. These TSI values depict the Upper Pine Lake water quality condition as firmly in the eutrophic range of the trophic state continuum. The variability in the calculated TSI values indicates that phosphorous may not always be the controlling factor for the lake's trophic state.

Table 6. The TSI values calculated using the ISU Lake Study data are:

	2000 data	2001 data	2002 data
TSI (chlor a)	59	63	72
TSI (SD)	65	52	59
TSI (TP)	84	65	66

In 2001 IDNR Fisheries Bureau staff had this to say about Upper Pine Lake. *The upper end of the lake is weed choked and shallow and losing volume. The resulting turbidity and loss of habitat are impacting reproduction of bass and blue gill. The size distribution for these species is skewed with poor recruitment for younger ages. Most of the eroded sediment appears to originate from stream bed and bank erosion*.

Potential Pollution Sources
Point Sources: No significant sediment point sources exist in the Upper Pine watershed.
Non-point Sources**:** There are two important potential non-point sediment sources in the Upper Pine Lake watershed. They are:

- streambank and gully erosion and
- upland sheet and rill erosion in farmed fields.

Other less significant sources are construction and development activities, grasslands, and forest.

Natural Background Conditions
Natural background contributions of sediment were not separated from the total non-point source load.

3.2 TMDL Endpoint

The water quality target for this siltation TMDL is the volume of sediment that can be contained behind the sediment detention dike and the dredged area downstream of the dike.

Criteria for Assessing Water Quality Standards Attainment
Numeric Water Quality Standards Criteria**:** There is not a numeric water quality criterion for siltation, i.e. loss of volume, area, or depth.

Quantification of Water Quality Standards Criteria**:** Siltation is a loss of lake volume, area, and depth that can be measured. For Upper Pine Lake the loss of volume since the lake was created in 1935 is unknown because original hypsometry is no longer available. However, the volume loss from 1947 to 1990 is known. Total sediment accumulation during these 43 years was 371 acre-feet. The lake volume in 1990 was 546 acre-feet.

For Upper Pine Lake the allowable sedimentation rate is that which is sustainable within the 20-year design life of the 1997 in-lake remediation work.

Selection of Environmental Conditions
The “critical condition” for which this sediment TMDL applies is the entire year. An annual loading period was used to define Upper Pine Lake’s sediment loading capacity. Sediment loads are actually the result of periodic precipitation events and the non-point source controls are targeted at times when high loading occurs.

Waterbody Pollutant Loading Capacity
The load capacity for this siltation TMDL is the amount of deposited sediment Upper Pine Lake can receive annually and not use up the sediment storage behind the sediment detention dike and the volume dredged in 1997. For the purposes of this TMDL, the delivered watershed sediment load is set the same as the deposited sediment load. This assumption leads to a conservative target in that any sediment leaving the lake is a margin of safety. The dredged storage volume downstream of the sediment detention dike is 40,000 cubic yards. The storage volume behind the sediment detention dike is 30,000 cubic yards. The total 70,000 cubic yard storage volume spread over the 20-year design life of the 1997 work results in an annual storage of 3,500 cubic yards.

The allowable sediment delivery to Upper Pine Lake is **3,800 tons per year** at an estimated dry weight of 80 pounds per cubic foot of volume.

3.3. Pollution Source Assessment

Upper Pine Lake sediment sources fall into two categories. The first is upland sheet and rill erosion estimated using watershed erosion models. These models are also used to estimate impacts of implemented erosion control practices. The second category is gully and stream bed and bank erosion that are estimated for this TMDL by subtracting the upland erosion estimates from the measured 30-year average annual sedimentation rate in Upper Pine Lake.

Three estimates of upland sediment delivery before and after erosion control practices are available. These are:

- IDNR estimates based on RUSLE equations, TR-55 hydrology, and IDNR GIS coverages (see Appendix A)
- Pine Creek estimates based on AGNPS modeling and assumptions about erosion control effectiveness
- Phase II Project Report estimates using unexplained methods, probably AGNPS modeling.

The average annual volume loss of 7.5 acre-feet per year has been used to derive a total average annual sediment delivery of 11,500 tons per year. This measured value is the starting point for source evaluation. Table 7 shows evaluated values for the three estimates.

Table 7. Sediment Delivery Estimates

	IDNR estimates, 2002 RUSLE modeling	**Pine Creek Project estimate, 1998**	**Phase II Project, Report estimate, 1998**
Before practices, total sediment delivery	11,500 tons/yr	11,500 tons/yr	11,500 tons/yr
Before practices, upland sediment delivery	7,000 tons/yr	6,560 tons/yr	7,900 tons/yr
In-stream erosion	4,500 tons/yr	4,940 tons/yr	3,600 tons/yr
After practices, upland sediment delivery	5,200 tons/yr	2,200 tons/yr	2,800 tons/yr
After practices total sediment delivery (current)	9,700 tons/yr	7,140 tons/yr	6,400 tons/yr

The largest difference between the three estimates is the reduction in sediment delivery. Both 1998 estimates of sediment reduction due to installed erosion control practices are about twice as high as the 2002 IDNR estimate. The 2002 IDNR estimate will be used to calculate existing loads because it provides a margin of safety needed due to procedural uncertainty.

Existing Sediment Load
The estimated existing Upper Pine Lake average annual sediment load is 9,700 tons per year. Pine Creek delivers most of this. The rest is direct drainage to the lake, much of which comes from 900 acres north and west of the lake. The land directly adjacent to the lake is woodland. Sediment discharged over the dam into Lower Pine Lake is not included in the siltation mass balance.

Departure from Sediment Load Capacity
The targeted total sediment loading capacity for Upper Pine Lake is 3,800 tons per year. Estimated existing load to the lake is 9,700 tons per year. This is 5,900 tons per year over the sediment load capacity.

Identification of Sediment Sources
There are no significant point source sediment discharges in the Upper Pine Lake watershed. Non-point source identification and sediment quantification were established with data and modeling done for previous watershed projects and through the application of an IDNR developed model based on the Revised USLE using NRCS TR-55 hydrology and GIS data input in 2002.

Watershed Non-point Sources of Sediment. Two categories of sediment sources have been identified in the Upper Pine Lake watershed. These are upland sheet and rill erosion and gully and stream bed and bank erosion.

Linkage of Sources to Endpoint
The average annual sediment load of 9,700 tons to Upper Pine Lake originates entirely from non-point sources. The annual non-point source sediment contribution of 9,700 tons/yr needs to be reduced by 5,900 tons/yr to reach the 3,800 tons/yr endpoint.

3.4 Pollutant Allocation

Waste Load Allocation
There are no significant sediment point source contributors in the Upper Pine Lake watershed. Therefore, the sediment Waste Load Allocation (WLA) is zero tons per year.

Load Allocations
The Load Allocation (LA) for this siltation TMDL is 3,800 tons per year of and is distributed among the identified non-point sources as follows. In the absence of detailed source information, the load has been divided between the two source categories as follows:

- Stream bed and bank and gully erosion = 1,300 tons per year
- Upland sheet and rill erosion = 2,500 tons per year

The higher allocation has been given to upland sheet and rill erosion because there have been numerous efforts to control this type of erosion over the last four decades. The most effective upland controls have already been implemented. Few stream erosion control measures have been implemented.

Margin of Safety
The implicit margin of safety for this TMDL is the result of three factors:

- Use of the lowest estimate of reduced sediment delivery due to upland control practices. The two 1998 project estimates of delivery reduction were twice that of the 2002 IDNR estimate.
- Sediment discharged from the lake over the downstream weir is not included in the sediment load allocation.

3.5 Sediment TMDL Summary

The equation for total maximum daily load shows the lake sediment load capacity.

WLA (zero tons/year)+LA (3,800 tons/year)+MOS (Implicit)=
Load Capacity (3,800 tons/year)

4. Implementation Plan

This TMDL implementation plan provides guidance for agencies and stakeholders working to improve Upper Pine Lake water quality. The emphasis is on non-point source reduction activities that target sediment. These include:

Gully and stream bed and bank erosion: IDNR Fisheries and the NRCS have identified bed and bank erosion as the significant sediment source now that so many upland erosion controls have been initiated. Many significant stream and gully sediment contributions were identified in the 1998 Pine Creek Project Final Report and some stream bank restoration work was done. Additional problem locations should be identified. Restoration activities should be targeted at areas that are the largest contributors of sediment from eroding stream banks. Suggested controls are:

- Install check dams on smaller tributaries to reduce peak flows during runoff events.
- Install stream bank protection using vegetation and graded rock.
- Stabilize stream banks by shaping and removing overhangs.

Overland sheet and rill erosion: Erosion control activities, including the maintenance of installed structures, need to continue in the watershed. The watershed should be periodically evaluated and erosion control activities focused on identified large contributors of lake sediment. Emphasis should be on row crop fields close to the lake or stream and having steeper slopes without effective management practices in place. Suggested controls are:

- Management practices that will increase crop residue such as no-till farming,
- Construct terraces and grassed waterways.
- Install buffer strips along stream corridors.
- Construct grade stabilization structures to reduce head cutting and gully expansion.

<u>Sediment Reduction Goal</u>: In addition to remediation of the water quality impairment in Upper Pine Lake, the sediment reductions identified in this TMDL are necessary to protect the public investment in the Pine Lakes and Pine Lake State Park. If future evaluations of the lake condition indicate that the sediment delivery goal is inadequate to prevent siltation impairment, the TMDL will be revised and new sediment allocations will be made.

5. Monitoring and Evaluation Plan

Monitoring of Upper Pine Lake will be conducted to assess the rate of siltation and compare it to the average annual sedimentation rate that corresponds to the calculated sediment load capacity. The monitoring and evaluation plan for Upper Pine Lake consists of the following:

1. The most important information for evaluation is direct measurement of siltation volume using bathymetry to calculate current values and compare them with the 1990 volume estimate. This new mapping should be done in the next three years. In 2005 it will have been 15 years since the 1990 lake bottom maps were made and the siltation rate estimated. This is long enough to obtain a reasonable average annual sedimentation rate.
2. A biological assessment should be made to determine the current state of aquatic life uses.
3. Additional watershed modeling should be performed to assess the effectiveness of installed best management practices.
4. Pine Creek should be evaluated for erosion potential and a direct estimate made of stream bed and bank sediment contributions to the lake.

6. Public Participation

Public meetings regarding the procedure and timetable for developing the Upper Pine Lake TMDL were held on January 14, 2002, in Des Moines, Iowa; and on February 4, 2002 in Eldora, Iowa. The public notice period was from November 15, 2002 through December 3, 2002. This draft TMDL was available to the public on the IDNR Internet site and copies of the draft TMDL were electronically distributed to stakeholders.

Public comment was received by email from one person regarding both Upper and Lower Pine Lakes. The comment suggested that tributary and lake shore erosion be addressed. This TMDL incorporated these comments as appropriate.

Commentators: Carl A. Carlson, 22587 V Avenue, Eldora, Iowa

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Appendix A: Model and Model inputs

The Revised Universal Soil Loss Equation (RUSLE) is an erosion model designed to predict the longtime annual average soil loss (A) carried by runoff from specific field slopes in specified cropping and management systems. The equation used by RUSLE is:

A=(R)x(K)x(L)x(S)x(C)x(P)

- A= computed spatial average soil loss and temporal average soil loss per unit of area expressed in the same units as K, tons/acre/year.
- R= rainfall-runoff erosivity factor. The rainfall erosion index plus a factor for any significant runoff from snowmelt.
- K= soil erodibility factor. The soil loss rate per erosion index unit for a specified soil as measured on a standard plot.
- L= slope length factor. The ratio of soil loss from the field slope gradient to soil loss from standard plot length under identical conditions
- S= slope steepness factor. The ratio of soil loss from the field slope gradient to soil loss from a 9% slope under identical conditions.
- C= cover management factor. The ratio of soil loss from an area with specified cover and management to soil loss from an identical area in tilled continuous fallow.
- P= support practice factor. The ratio of soil loss with a support practice like contouring, strip-cropping, or terracing to soil loss with straight row farming up and down the slope.

Data from IDNR soil, landuse and other GIS coverages have been used as input to the RUSLE equation. The IDNR RUSLE erosion model uses a grid of 30 by 30 meter cells to estimate gross soil loss that includes all erosion in the watershed. Sediment yield is the quantity of gross erosion that is delivered to a specific location such as a water body.

This model has been applied to the Pine Creek watershed to generate estimates of sheet and rill erosion but it does not determine sediment yield. In a watershed, sediment yield includes erosion from slopes, channels, and mass wasting, minus the sediment that is deposited after it is eroded but before it reaches Upper Pine Lake. The sediment delivery ratio is the sediment yield divided by the gross erosion and is a simple method of estimating delivery to the waterbody. The RUSLE model was run on the watershed before and after the Pine Creek Project management practices were implemented. The sediment estimates from these runs were 64,000 tons/year without and 48,000 tons/year with the practices implemented. The average annual sediment delivery to the lake between 1961 and 1990 was a volume of 7.5 acre-feet per year. At 70 pounds/cf this volume is 11,500 tons of sediment on a dry mass basis. The measured sediment delivery ratio is 18% (11,500/64,000) before management practices.

Figure 4. RUSLE modeling results <u>without</u> 1998 Pine Creek Project management practices

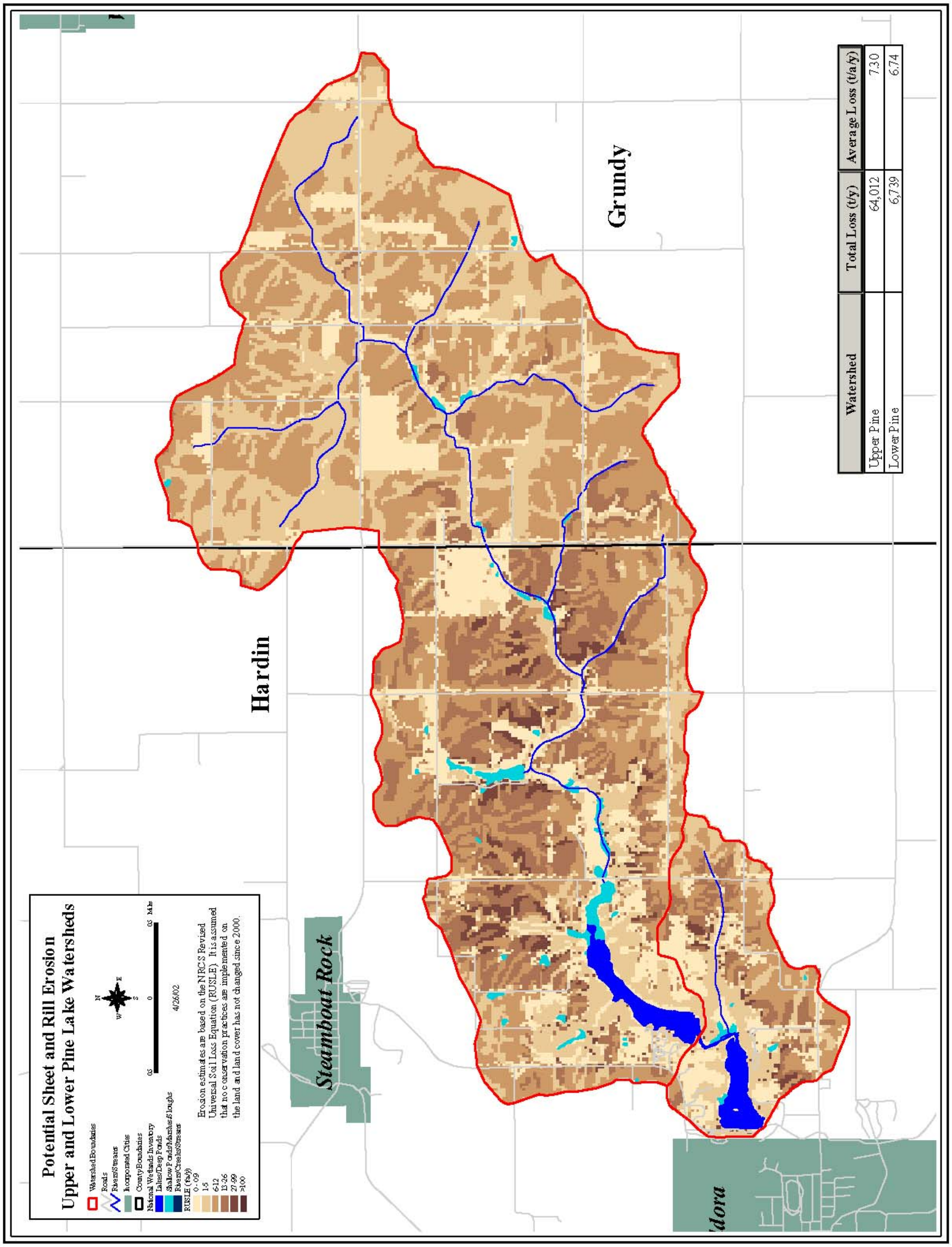
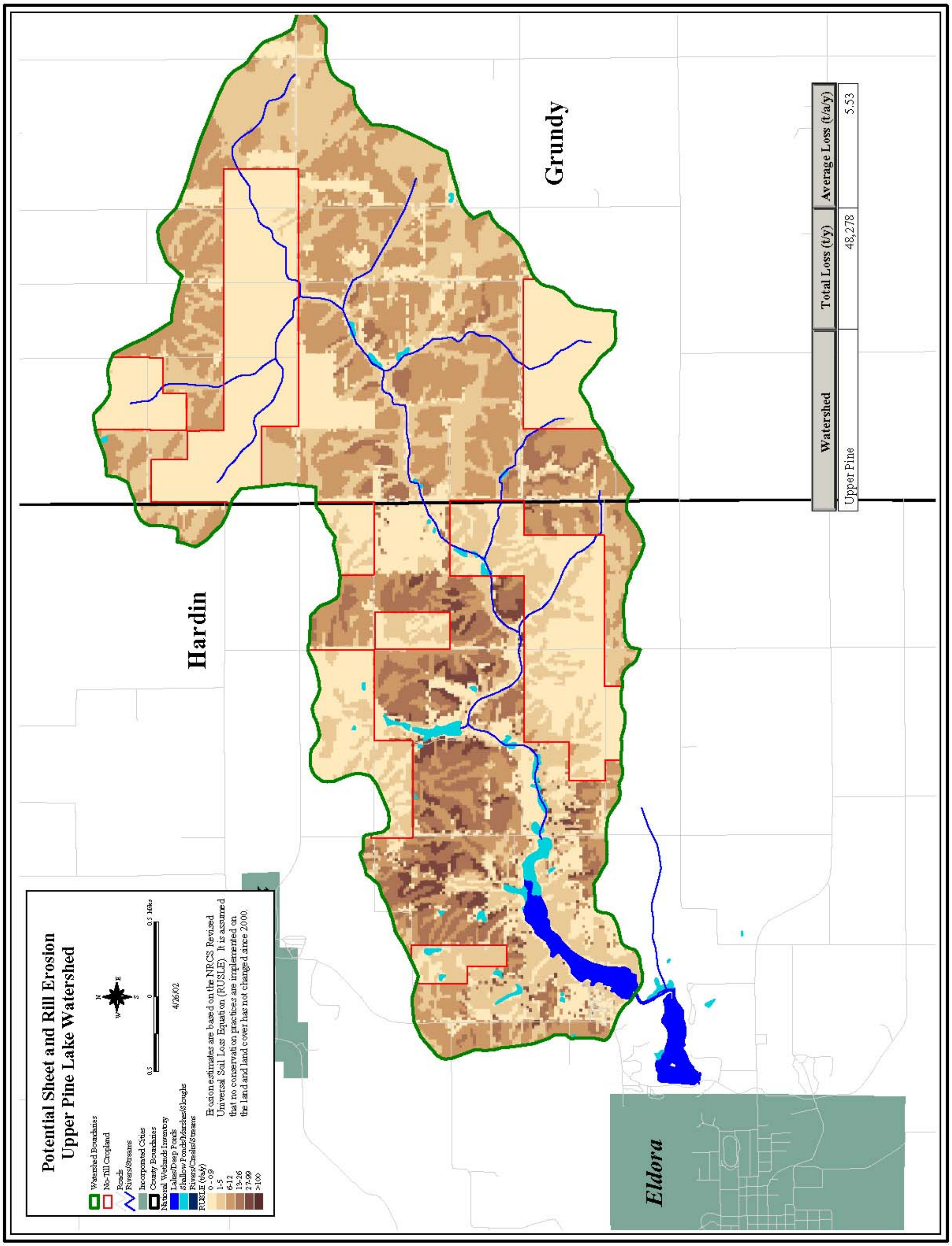


Figure 5. RUSLE modeling results <u>with</u> 1998 Pine Creek Project management practices.



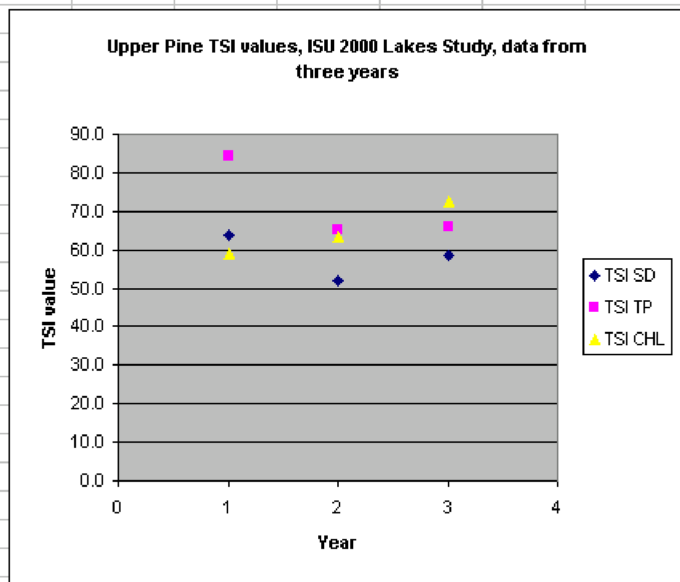
Appendix B: Data from Earlier Evaluations

Upper Pine Lake - data used to develop TSI evaluation of nutrient condition
Data from three different studies:
1. Phase 1, 1991 Diagnostic/Feasibility Study
2. Phase 2, 1998 Project Final Report
3. **ISU 2000 Iowa Lakes Study**

Data from summer 2000

date	SD	TP	Chlor a	TN
07/10/2000	0.2	610	39	5.97
07/31/2000	1.4	94	10	9.44
08/28/2000	0.7	85	4	5.56
average	**0.8**	**263.0**	**17.7**	**7.0**
stddev	**0.6**	**300.5**	**18.7**	**2.1**
TSI 0.5m	**63.8**	**84.5**	**58.8**	**82.5**

	TSI SD	TSI TP	TSI CHL
Data from summer 2000	**63.8**	**84.5**	**58.8**
Data from summer 2001	**52.1**	**65.0**	**63.5**
Data from summer 2002	**58.6**	**66.0**	**72.4**



Data from summer 2001

date	SD	TP	Chlor a	TN
06/04/2001	1.1	61		15.43
07/09/2001	3.0	49	6	12.4
08/06/2001	1.1	94	51	6.47
average	**1.7**	**68.0**	**28.5**	**11.4**
stddev	**1.1**	**23.3**	**31.8**	**4.6**
TSI 0.5m	**52.1**	**65.0**	**63.5**	**89.6**

Data from summer 2002

date	SD	TP	Chlor a	TN
all 3	1.1	73	71	na
average	**1.1**	**73.0**	**71.0**	**#DIV/0!**
stddev	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
TSI 0.5m	**58.6**	**66.0**	**72.4**	**#DIV/0!**

	SD	TP	Chl
	0.2	610	39
	1.4	94	10
	0.7	85	4
	1.1	61	
	3.0	49	6
	1.1	94	51
	1.1	73	71
average	**1.2**	**152.3**	**30.2**
stddev	**0.9**	**202.5**	**27.8**
TSI 0.5m	**57.0**	**76.6**	**64.0**

Carlson's TSI Equations:

TSI (SD) = 60 – 14.41 (ln SD)
TSI CHL) = 9.81 (ln CHL) + 30.6
TSI (TP) = 14.42 (ln TP) + 4.15

Upper Pine Lake - data used to develop TSI evaluation of nutrient condition
Data from three different studies:

1. Phase 1, 1991 Diagnostic/Feasibility Study
2. Phase 2, 1998 Project Final Report
3. ISU 2000 Iowa Lakes Study

Phase 1, 1991 Project Final Report Data, TSI development data
Top Layer, 0.5 m

date	SD	TP	Chlor a	TN
09/18/1989	1.1	144	86.4	1.44
10/02/1989	0.9	102	85.7	1.79
10/25/1989	3.5	72	9.63	1.57
12/20/1989	2.1	82	28.6	1.18
01/20/1990	4.0	50	1.58	1.62
02/24/1990	2.0	89	23.3	2.15
03/31/1990	0.6	171	7.33	9.48
04/27/1990	3.3	91	4.13	6.51
05/11/1990	0.8	59	1.65	9.29
05/30/1990	1.2	135	6.11	17.73
06/12/1990	1.0	46	13.1	20.17
06/26/1990	0.3	228	9.58	17.61
07/10/1990	1.65	45	2.8	20.54
07/24/1990	1.5	36	3.05	18.27
08/07/1990	0.4	97	6.5	14.18
08/22/1990	0.6	165	3.25	10.5

TSI summer values

date	SD	TP	Chlor a	TN
06/12/1990	1.0	46	13.1	20.17
06/26/1990	0.3	228	9.58	17.61
07/10/1990	1.65	45	2.8	20.54
07/24/1990	1.5	36	3.05	18.27
08/07/1990	0.4	97	6.5	14.18
08/22/1990	0.6	165	3.25	10.5
average	**0.9**	**102.8**	**6.4**	**16.9**
stddev	**0.6**	**78.2**	**4.2**	**3.9**
TSI 0.5m	**61.4**	**71.0**	**48.8**	**95.2**

Phase 1, 1991 Project Final Report Data, TSI development data
Middle Layer, 1.5 m

date	SD	TP	Chlor a	TN
09/18/1989	1.1	131	65.4	1.4
10/02/1989	0.9	140	73.3	1.7
10/25/1989	3.5	72	8.2	1.8
12/20/1989	2.1	70	11.8	1.2
01/20/1990	4.0	63	1.6	1.6
02/24/1990	2.0	131	86.0	2.0
03/31/1990	0.6	155	1.3	9.5
04/27/1990	3.3	137	2.2	7.2
05/11/1990	0.8	75	1.6	9.6
05/30/1990	1.2	100	10.4	19.3
06/12/1990	1.0	31	13.0	19.8
06/26/1990	0.3	309	8.8	14.0
07/10/1990	1.7	47	3.6	20.6
07/24/1990	1.5	36	6.5	18.4
08/07/1990	0.4	88	5.8	15.8
08/22/1990	0.6	125	3.3	9.9

TSI summer values

date	SD	TP	Chlor a	TN
06/12/1990	1.0	31	13.0	19.8
06/26/1990	0.3	309	8.8	14.0
07/10/1990	1.7	47	3.6	20.6
07/24/1990	1.5	36	6.5	18.4
08/07/1990	0.4	88	5.8	15.8
08/22/1990	0.6	125	3.3	9.9
average	**0.9**	**106.0**	**6.8**	**16.4**
stddev	**0.6**	**105.7**	**3.6**	**4.0**
TSI 0.5m	**61.4**	**71.4**	**49.4**	**94.8**

Upper Pine Lake - data used to develop TSI evaluation of nutrient condition
Data from three different studies:

1. Phase 1, 1991 Diagnostic/Feasibility Study
2. Phase 2, 1998 Project Final Report
3. ISU 2000 Iowa Lakes Study

TSI development data from Phase 2, 1998 Project Final Report Data
Top Layer, 0.5 m

date	SD	TP	Chlor a	TN
05/06/1992	1.6	31	10.44	8.42
05/28/1992	4.5	17	2.4	10.16
06/04/1992	4.3	17	6.89	6.34
06/26/1992	1.4	24	23.7	9.92
07/10/1992	0.8	52	39.25	5.81
07/23/1992	0.9	95	65.71	7.71
08/12/1992	0.5	87	62.45	8
08/25/1992	0.6	59	4.86	7.21
09/17/1992	0.6	47	45.18	4.73
09/29/1992	0.8	83	48.22	4.74
10/20/1992	0.8	53	17.39	4.19
11/04/1992	1.2	88	10.75	4.68
12/02/1992				
01/21/1993	2.8	30	8.53	11.58
02/24/1993	2.1	25	5.47	10.6
03/18/1993	0.3	495	30.87	8.37
04/22/1993	0.6	149	1.79	8.88

TSI summer values

date	SD	TP	Chlor a	TN
06/04/1992	4.3	17	6.89	6.34
06/26/1992	1.4	24	23.7	9.92
07/10/1992	0.8	52	39.25	5.81
07/23/1992	0.9	95	65.71	7.71
08/12/1992	0.5	87	62.45	8
08/25/1992	0.6	59	4.86	7.21
average	**1.4**	**55.7**	**33.8**	**7.5**
stddev	**1.4**	**31.8**	**26.6**	**1.4**
TSI 0.5m	**55.0**	**62.1**	**65.1**	**83.5**