Water Quality Improvement Plan for

Upper Pine Lake

Hardin County, Iowa

Total Maximum Daily Load
for Algae

clean water
starts with you.
IOWA DNR WATERSHED IMPROVEMENT

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Watershed Improvement Section
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General Report Summary

What is the purpose of this report?

This report serves multiple purposes. First, it is a resource for increased understanding of watershed and water quality conditions in and around Upper Pine Lake. Second, it satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) for impaired waterbodies. Third, it provides a foundation for locally-driven watershed and water quality improvement efforts. Finally, it may be useful for obtaining financial assistance to implement projects to remove Upper Pine Lake from the federal 303(d) list of impaired waters.

What's wrong with Upper Pine Lake?

Upper Pine Lake is listed as impaired on the 2012 303(d) list for not supporting its primary contact recreation designated use. The impairment is due to elevated levels of algae, which is caused by overly-abundant nutrients, particularly phosphorus, in the lake.

What is causing the problem?

The amount of phosphorus transported to the lake from the surrounding watershed is sufficient to cause excessive growth of algae, which reduces water clarity. Phosphorus is carried to the lake in two primary forms: (1) attached to eroded soil that is transported to the lake by rainfall runoff and stream flow, and (2) dissolved phosphorus in runoff and subsurface flow (e.g., shallow groundwater and tile flow). There are no permitted point sources of phosphorus in the Upper Pine Lake watershed; therefore all phosphorus loads to the lake are attributed to nonpoint sources.

Nonpoint sources are discharged in an indirect and diffuse manner, and often are difficult to locate and quantify. Nonpoint sources of phosphorus in the Upper Pine Lake watershed include sheet and rill erosion from various land uses, runoff and subsurface flows from lands that receive manure or fertilizer application, stream and gully erosion, poorly functioning septic systems, manure deposited by wildlife, and particles carried by dust and wind (i.e., atmospheric deposition). A portion of the phosphorus carried to the lake eventually settles to the lake bottom and accumulates. Under certain conditions, this accumulated phosphorus can become available for algal uptake and growth through an internal recycling process.

What can be done to improve Upper Pine Lake?

To improve the water quality and overall health of Upper Pine Lake, the amount of phosphorus entering the lake must be reduced. A combination of preventative land management, structural mitigation, and in-lake restoration practices are often required to obtain reductions in phosphorus to meet water quality standards. Reducing phosphorus loss from row crops through strategic timing and methods of manure and fertilizer application, increasing use of conservation tillage and cover crops, and implementing or improving existing structural BMPs such as terraces, grass waterways, and constructed wetlands in beneficial locations will significantly reduce phosphorus loads to the lake. Special attention should be given to row crops on steep slopes, where the adoption of cover crops or perennial strips may be especially beneficial. Restoring watershed hydrology to mitigate streambank and gully erosion is challenging to implement, but an effective strategy for reducing sediment and phosphorus transport. Increasing the sediment trapping efficiency of the existing forebay may be the most cost effective structural alternative.

Who is responsible for a cleaner Upper Pine Lake?

Everyone who lives, works, or recreates in the Upper Pine Lake watershed has a role in water quality improvement. Because nonpoint source pollution is unregulated and responsible for the vast majority of sediment and phosphorus entering the lake, voluntary management of land, animals, and the lake itself will be required to achieve measurable improvements to water quality. Many of the practices that protect and improve water quality also benefit soil fertility and structure, the overall health of the agroecosystem, and the value and productivity of the land. Practices that improve water quality and enhance the long-term viability and profitability of agricultural production should appeal to producers, land owners, and lake users alike. Improving water quality in Upper Pine Lake, while also improving the quality of the surrounding land, will require collaborative participation by various stakeholder groups, with land owners playing an especially important role.

Does a TMDL guarantee water quality improvement?

The Iowa Department of Natural Resources (DNR) recognizes that technical guidance and support are critical to achieving the goals outlined in this Water Quality Improvement Plan (WQIP). The TMDL itself is only a document, and without implementation, will not improve water quality. Therefore, a basic implementation plan is included for use by local agencies, watershed managers, and citizens for decision-making support and planning purposes. This implementation plan should be used as a guide or foundation for detailed and comprehensive planning by local stakeholders.

Reducing pollutants from unregulated nonpoint sources requires voluntary implementation of best management practices. Many solutions have benefits to soil health and sustained productivity as well as water quality. However, quantifying the value of those ecosystem services is difficult, and those benefits are not commonly recognized. Consequently, wide-spread adoption of voluntary conservation practices is often difficult to achieve. A coordinated watershed improvement effort for Upper Pine Lake could address some of these barriers by providing financial assistance, technical resources, and information/outreach to landowners to encourage and facilitate adoption of conservation practices.

What are the primary challenges for water quality implementation?

In most Iowa landscapes, implementation requires changes in land management and/or agricultural operations. Management decisions may include changes in the number of acres that are actively tilled and the diversity and rotation of crops produced. These changes present challenges to producers by requiring new equipment (e.g., no-till planters), narrowing planting/harvesting/fertilization windows, and necessitating more active/complex farm management. Additionally, potential short-term losses in yields are more easily recognized and quantified than long-term benefits to soil health and sustained productivity. It is not easy to overcome existing incentives and the momentum of current practices. Promoting a longer-term view with an emphasis on long-term soil fertility, production, agroecosystem health, and reduced input costs will be essential for successful, voluntary implementation by willing conservation partners. In the case of Upper Pine Lake, the large watershed-to-lake ratio of 120:1 presents a formidable challenge for attainment of water quality standards. However, water quality improvement and enhancement of Upper Pine Lake as a recreational resource are certainly attainable goals, and are appropriate and feasible near-term goals for a coordinated watershed improvement effort.

Technical Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Upper Pine Lake, Waterbody ID IA 02-IOW-0335-L_0, located in S4, T87N, R19W, 2 miles E of Eldora in Hardin County
Surface water classification and designated uses:	A1 – Primary contact recreation B(WW-1) – Aquatic life HH – Human health (fish consumption)
Impaired beneficial uses:	A1
TMDL priority level:	High
Identification of the pollutants and applicable water quality standards (WQS):	Class A1, primary contact recreation, is impaired due elevated levels of chlorophyll-a (algae)
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of WQS:	Excess algae are associated with total phosphorus (TP). The allowable average annual TP load = 6,509 lbs/year; the maximum daily TP load = 71 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 WQS:	The existing growing season load of 14,488 lbs/year must be reduced by 7,979 lbs/year to meet the allowable TP load. This is a reduction of 55.1 percent.
Identification of pollution source categories:	There are no regulated point source discharges of phosphorus in the watershed. Nonpoint sources of phosphorus include streambank and gully erosion, fertilizer and manure from row crops, sheet and rill erosion, livestock grazing near streams, wildlife, septic systems, atmospheric deposition, and others.
Wasteload allocations (WLAs) for pollutants from point sources:	There are no allowable point source discharges, but two non-discharging, regulated CAFOs are given WLAs of zero.

Load allocations (LAs) for pollutants from nonpoint sources:	The allowable annual average TP LA is 5,857 lbs/year, and the allowable maximum daily LA is 64 lbs/day.
A margin of safety (MOS):	An explicit 10 percent MOS is incorporated into this TMDL.
Consideration of seasonal variation:	The TMDL is based on annual TP loading. Although daily maximum loads are provided to address legal uncertainties, the average annual loads are critical to in-lake water quality and lake/watershed management decisions.
Reasonable assurance that load and wasteload allocations will be met:	Because there are no regulated point source discharges and the WLA is zero, reasonable assurance is not applicable.
Allowance for reasonably foreseeable increases in pollutant loads:	Because there are no urbanizing areas in the watershed and significant land use change is unlikely, there is no allowance for reasonably foreseeable increases in pollutant loads.
Implementation plan:	An implementation plan is outlined in Section 4 of this Water Quality Improvement Plan. Phosphorus loading and associated impairments must be addressed through a variety of voluntary management strategies and structural practices.

1. Introduction

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

$$\text{TMDL} = \text{LC} = \Sigma\ \text{WLA} + \Sigma\ \text{LA} + \text{MOS}$$

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

One purpose of this Water Quality Improvement Plan (WQIP) for Upper Pine Lake, located in Hardin County in north-central Iowa, is to provide a TMDL for algae, which has decreased water quality in the lake. Another purpose is to provide local stakeholders and watershed managers with a tool to promote awareness and understanding of water quality issues, develop a comprehensive watershed management plan, obtain funding assistance, and implement water quality improvement projects. Over-abundance of phosphorus is largely responsible for excessive algal growth in Upper Pine lake, which impairs primary contact recreation (e.g., swimming, wading) in Upper Pine Lake. The impairment is addressed by development of a TMDL that limits total phosphorus (TP) loads to the lake. Phosphorus reductions should be accompanied by reduced algal growth and increased water clarity.

The plan also includes descriptions of potential solutions to the impairments. This group of solutions is presented as a toolbox of best management practices (BMPs) for improving water quality in Upper Pine Lake, with the ultimate goal of meeting water quality standards and supporting designated uses. These BMPs are outlined in the implementation plan in Section 4.

The Iowa Department of Natural Resources (DNR) recommends a phased approach to watershed management. A phased approach is helpful when the origin, interaction, and quantification of pollutants contributing to water quality problems are complex and difficult to fully understand and predict. Iterative implementation of improvement practices and additional water quality assessment (i.e., monitoring) will help ensure gradual progress towards water quality standards, maximize cost efficiency, and prevent unnecessary or ineffective implementation of costly BMPs. Implementation guidance is provided in Section 4 of this report, and water quality monitoring guidance is provided in Section 5.

This plan will be of limited value unless additional watershed improvement activities and BMPs are implemented. This will require the active engagement of local stakeholders and land owners. Experience has shown that locally-led watershed plans have the highest potential for success. The Watershed Improvement Section of DNR has designed this plan for stakeholder use and is committed to providing ongoing technical support for the improvement of water quality in Upper Pine Lake.

2. Description and History of Upper Pine Lake

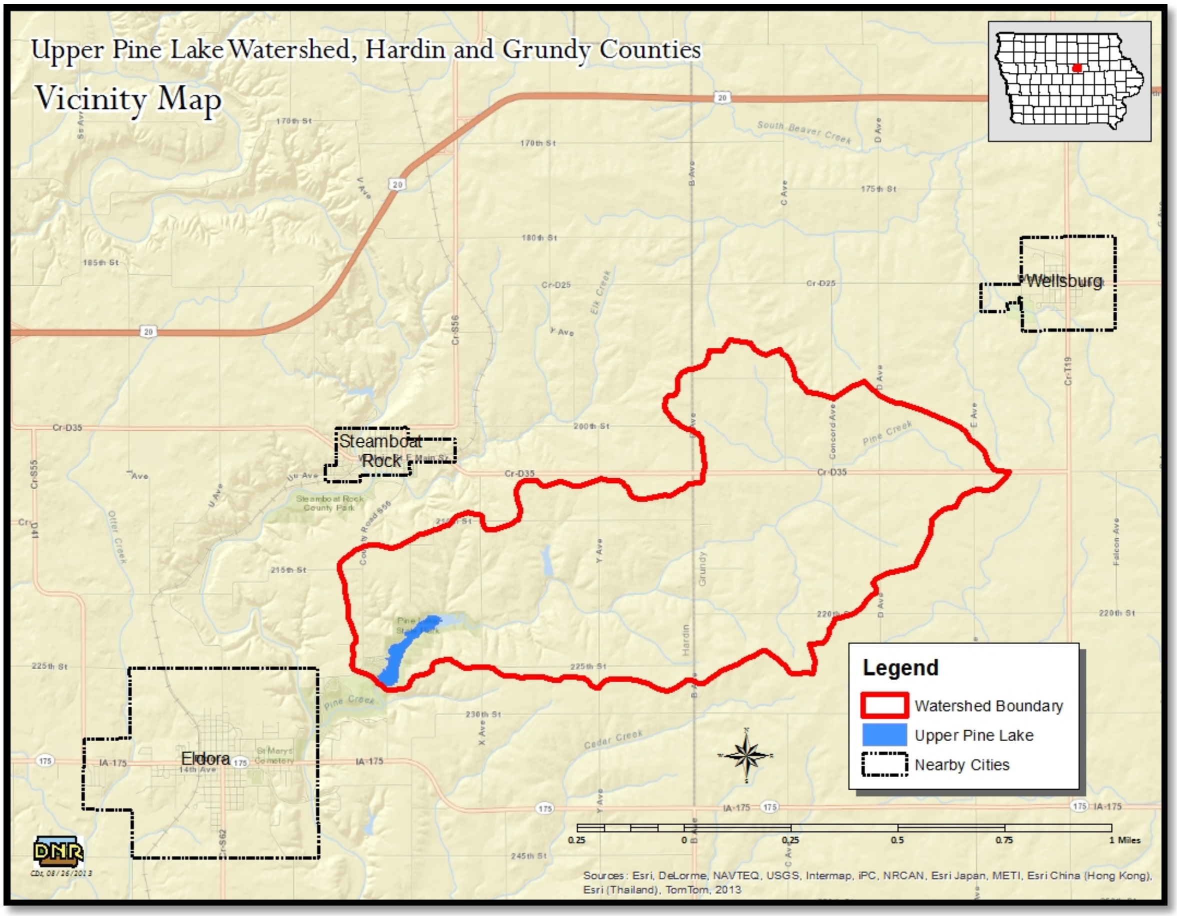
Upper Pine Lake is a man-made impoundment build by the Civilian Conservation Corps in 1935. It is located approximately 2 miles northeast of Eldora, or 15 miles southeast of Iowa Falls, in Hardin County, Iowa (Figure 2-1). The lake lies within Pine Lake State Park, which encompasses 572 acres and is managed by the Iowa DNR. Recreational opportunities include fishing, bird watching, boating, camping, cabin rental, hiking, and swimming. The Center for Agricultural and Rural Development (CARD) at Iowa State University estimates that between 2002 and 2005, Upper Pine Lake averaged over 64,000 visitors per year, whose spending exceeded $4.3 million per year and supported 87 jobs and $1.17 million of labor income in the region (CARD, 2009). The CARD study also suggested that water quality improvements would increase use of the lake, and subsequent economic value of the resource.

Table 2-1 lists some of the general characteristics of Upper Pine Lake and its watershed, as it exists today. Estimation of physical characteristics such as surface area, depth, and volume are based on a bathymetric survey conducted by DNR in 2007.

Table 2-1. Upper Pine Lake watershed and lake characteristics.

DNR Waterbody ID	IA 02-IOW-0335-L_0
12-Digit Hydrologic Unit Code (HUC)	070802070902
12-Digit HUC Name	Pine Creek – Iowa River
Location	Hardin County, S4,T87N,R19W
Latitude	42.38° N (ambient lake monitoring location)
Longitude	93.06° W (ambient lake monitoring location)
Designated Uses	A1 – Primary contact recreation B(WW-1) – Aquatic life HH – Human health (fish consumption)
Tributaries	Unnamed tributaries
Receiving Waterbody	Lower Pine Lake
Lake Surface Area	[1]73.2 acres (includes 13.8 acre wetland)
Length of Shoreline	[1]13,737 feet
Shoreline Development Index	2.17
Maximum Depth	[1]16.2 feet
Mean Depth	[1]7.6 feet
Lake Volume	[1]558 acre-feet
Watershed Area	8,774 acres (includes lake and wetland)
Watershed:Lake Ratio	120:1
Lake Residence Time	[2]12 days

[1] Per 2007 bathymetric survey and subsequent calculations (excludes wetland)
[2] BATHTUB model prediction for average annual conditions (2006-2010)



Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013

Figure 2-1. Vicinity Map.

Water Quality History

Siltation and sediment deposition in Upper Pine Lake has been significant since its construction in 1935. In one sense, this impoundment is capturing sediment thereby protecting Lower Pine Lake from sedimentation. However, the loss of storage in Upper Pine Lake endangers support of its own designated uses. As a result of alarmingly high sedimentation rates, Upper Pine Lake received much study in the 1990s. A Diagnostic Feasibility Study prepared by Iowa State University on behalf of Iowa DNR was completed in 1991. From 1947 to 1961, the volume of Upper Pine Lake decreased from 458 to 304 ac-ft. In 1961 the spillway (and water level) were raised 6 feet to enlarge the lake (thereby reducing the watershed-to-lake ratio) and increase sediment storage capacity. From 1961 to 1990, the lake volume decreased from 763 to 546 ac-ft as a result of continued siltation/sedimentation.

In 1998, the Pine Lake Water Quality project was completed, which utilized a variety of funding sources, including federal nonpoint source pollution funds (Section 319 of the Clean Water Act), federal Clean Lakes program funds (Section 314), Water Quality Incentive Projects (WQIP), and Iowa Publicly Owned Lakes Program (IPOLP) cost-share. Major renovations included removal of 40,000 cubic yards (25 ac-ft) of sediment from Upper Pine Lake and construction of a sediment retention dike in the upper reaches of the reservoir. This dike created the 13.8-acre wetland/forebay that exists today. Additionally, a variety of sediment and erosion control practices were implemented in the watershed including, terraces, grass waterways, sediment basins, and enrollment of cultivated areas into Conservation Reserve Program (CRP) perennial grasses.

In 1998, Upper Pine Lake was included on the state's list of impaired waters for siltation. A TMDL for siltation was written in 2002, which removed Upper Pine Lake from the list of waterbodies requiring a TMDL to be developed until 2008, when the lake became impaired due to excessive levels of algae.

2.1. Upper Pine Lake

Hydrology
The National Weather Service (NWS) Cooperative Program (COOP) station in Eldora, Iowa reports daily maximum and minimum temperature and precipitation. The Iowa State Climatologist provides quality control of these data, which are downloadable from the Iowa Environmental Mesonet (IEM, 2013a). Daily observations between January 1, 2001 and December 31, 2012 were used in climate assessment and model development. Daily potential evapotranspiration (PET) data were obtained for same period from the Iowa Ag Climate Network, also downloadable from the IEM (IEM, 2013b). Table 2-2 reports weather station information.

Table 2-2. Weather station information for Upper Pine Lake.

Data	Temperature/Precipitation	Potential ET
Network	NWS COOP	ISU Ag Climate
Station Name (ID)	Eldora, IA (IA 2573)	Gilbert (A130219)
Latitude	Latitude: 42.39°	42.11°
Longitude	Longitude: -93.10°	-93.58°

Average annual precipitation near Upper Pine Lake was 37.4 inches from 2001-2012. Years 2006 through 2010 were, on average, much wetter than normal, with an annual average rainfall amount of 46.1 inches per year. These wetter than normal years coincide with the years of water quality data used to develop the 2012 Water Quality Assessment and 303(d) list and current impairment status of Upper Pine Lake. Figure 2-2 illustrates the annual precipitation totals, along with lake evaporation (estimated as 70 percent of annual PET). From 2001 to 2012, average annual precipitation exceeded lake evaporation by 3.6 inches (11 percent). However, the range of moisture surplus/deficit varied widely, with a 20.4-inch surplus in 2007, and a 13.2-inch deficit in 2012.

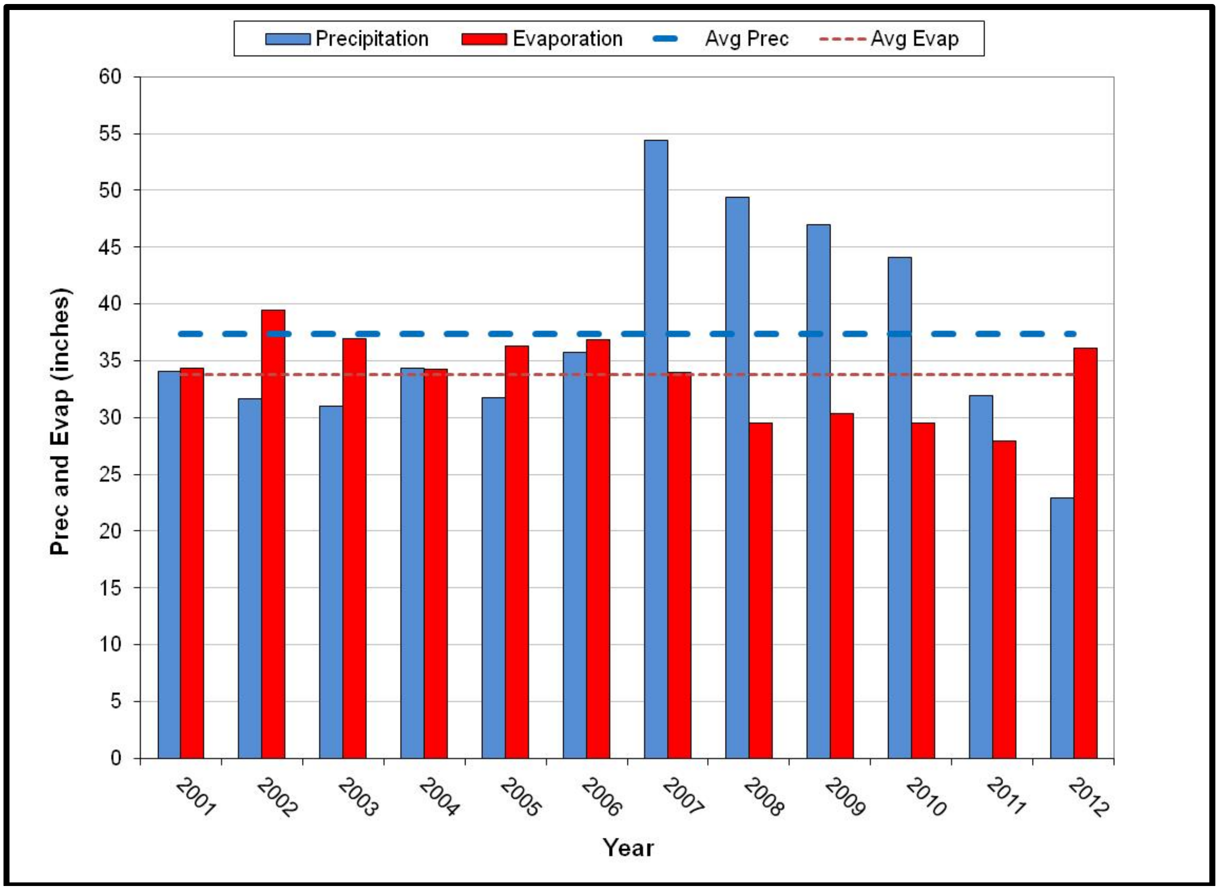


Figure 2-2. Annual precipitation and estimated lake evaporation.

Precipitation is very seasonal in central Iowa, with 72.6 percent of annual rainfall occurring between April and September. Monthly average precipitation (2001-2012) is illustrated in Figure 2-3, along with estimated evapotranspiration (ET) in the watershed. Although precipitation is highest during the growing season, so is ET, and a seasonal moisture deficit often occurs between June and September. Note that watershed ET is typically higher than lake evaporation in the summer months, a result of high temperatures and vegetation transpiring large volumes of moisture from the soil during the peak of the growing season. It is often during this period that harmful algal blooms develop in waterbodies, as water heats up and lake flushing is minimal.

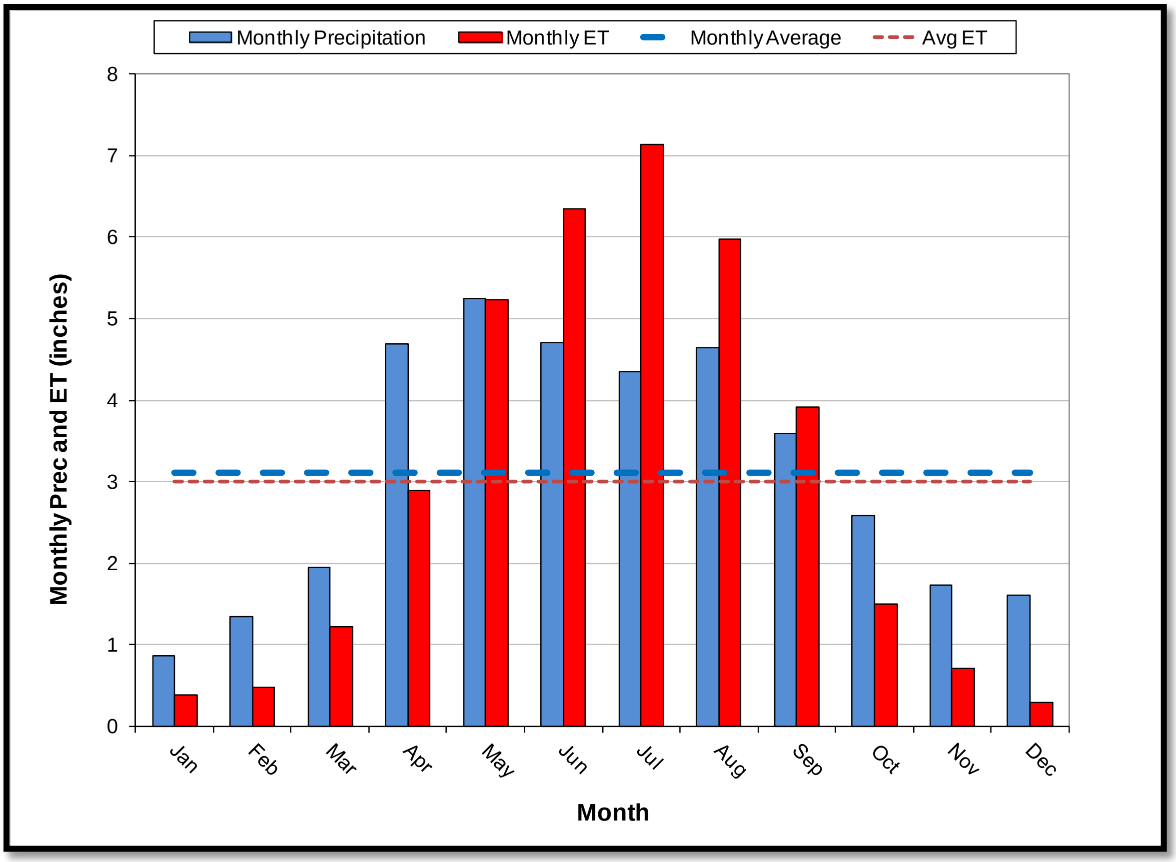


Figure 2-3. Monthly precipitation and estimated ET for the watershed.

An earthen embankment between valley walls was constructed to form the Upper Pine Lake impoundment. Discharge from the lake is controlled by a concrete ogee spillway with a 70-foot wide weir-crest. Overflow from the spillway enters a small channel that flows south approximately 1,000 feet before entering Lower Pine Lake.

Rainfall runoff, direct precipitation, evapotranspiration, shallow groundwater flow, and deep aquifer recharge are all part of the lake's hydrologic system. Due to the extremely large watershed-to-lake ratio of 120:1, the hydraulic residence time of the lake is very short (15 days on average from 2001-2012). Estimated residence time is based on annual precipitation and evaporation data, Spreadsheet Tool for Estimating Pollutant Load (STEPL) estimates of average annual inflow, and a water balance calculated within the BATHTUB model. The BATHTUB water balance calculation includes: inflows (from STEPL), direct precipitation, evaporation calculated from measured PET at Gilbert, Iowa and obtained from the Iowa State University Ag Climate Network on the Iowa Environmental Mesonet (IEM, 2013b), and lake morphometry.

During years of below average precipitation residence time increases, while residence time decreases in wet years. Such a low average residence time suggests that internal loading may not play a significant role in algal blooms, since the flushing rate is very high compared with most Iowa lakes. However, during periods where the water stage falls below the spillway crest (in extreme dry weather), internal loading may be an important process.

Morphometry

According to the most current bathymetric data (2007), the surface area of Upper Pine Lake is 73.2 acres, including the 13.8 acre wetland formed by the sediment dike that was constructed in 1997. This constructed wetland removes some sediment (and associated phosphorus) from the main tributary that flows into the lake, but its effectiveness would be greatly improved by altering the flow path to prevent short-circuiting. Estimated water volume of the main lake is 558 ac-ft, with a mean depth of 7.6 ft and a maximum depth of 16.2 feet in the southwest corner of the lake. The reservoir, like most man-made stream impoundments, has a very linear shape, with a long and narrow northeast to southwest aspect. The extreme watershed-to-lake ratio (120:1) and historical sedimentation rates suggest that the watershed of Upper Pine Lake has a large impact on water quality of the lake. The significance of sediment (and associated phosphorus) loading from the watershed is further evidenced by the shoreline development index of 2.17, which is extremely high. Values greater than 1.0 suggest the shoreline is highly dissected and indicative of a high degree of watershed influence (Dodds, 2000). High indexes are frequently observed in man-made reservoirs, and it is not surprising that watershed processes are critically important for the chemical/physical/biological processes that take place in Upper Pine Lake.

2.2. The Upper Pine Lake Watershed

The watershed boundary of Upper Pine Lake encompasses of 8,774 acres (including the lake) and is illustrated in Figure 2-4. The watershed-to-lake ratio of 120:1 is extremely high and indicates low potential for successful lake restoration. Significant mitigation of watershed influence would be required, and in-lake techniques would have short effective life spans in the absence of extensive watershed improvements. Overcoming such a large watershed-to-lake ratio would be difficult, costly, and may not result in the reductions necessary to obtain current water quality standards for this impoundment. A prudent watershed management strategy should focus on water quality improvement, problem areas that can be most easily addressed, and implementing alternatives that provide multiple benefits in addition to water quality, such as increased soil health, erosion reduction, and habitat enhancement. Watershed management and implementation strategies are discussed in more detail in Section 4 – Implementation Planning.

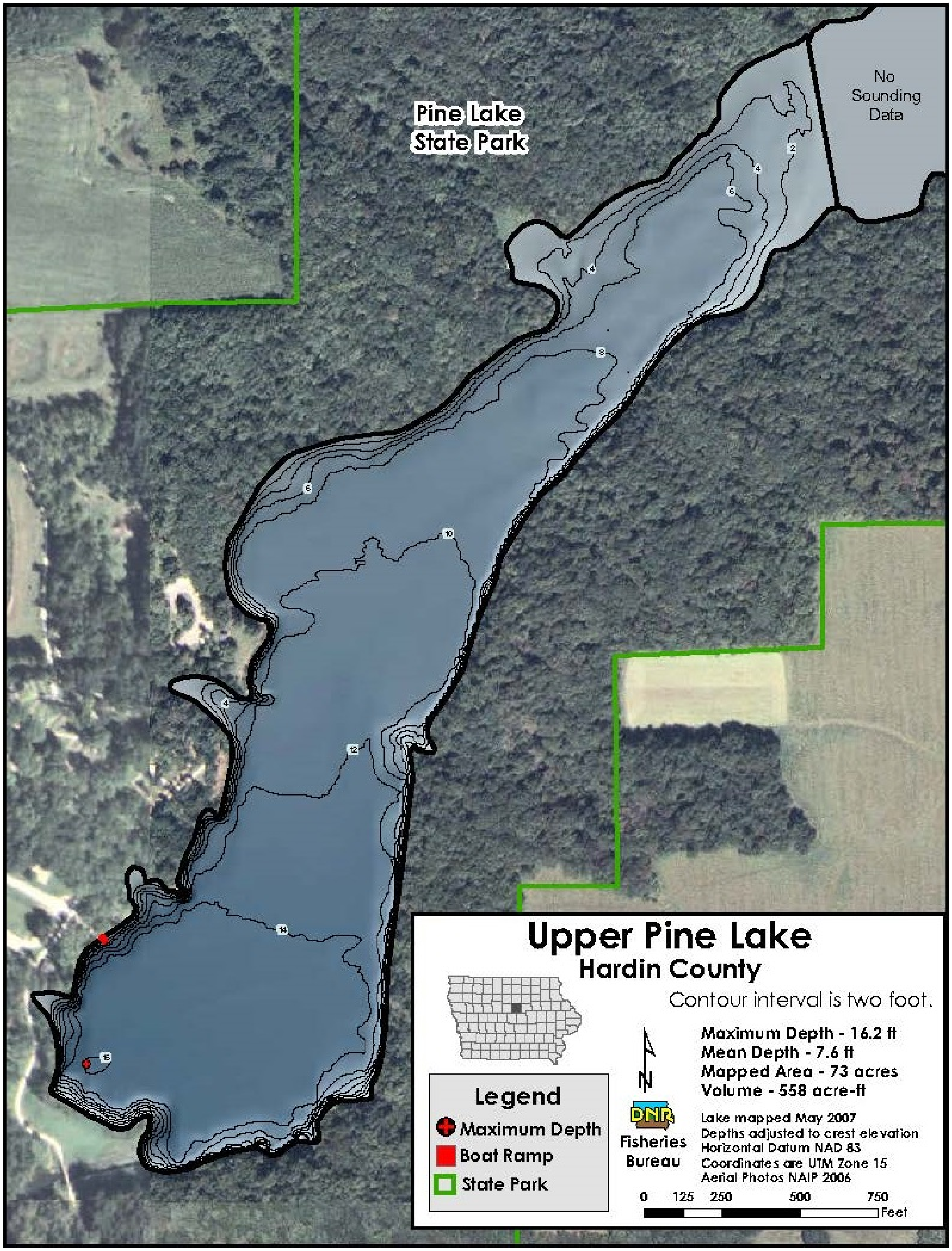


Figure 2-4. Bathymetric map of Upper Pine Lake.

Land Use

A Geographic Information System (GIS) coverage of land use information was developed using the Cropland Data Layer (CDL) for years 2009-2012, which was obtained from the United States Department of Agriculture – National Agricultural Statistics Service (USDA-NASS, 2013). The CDL land cover data is summarized by Common Land Units (CLUs). According to the USDA – Farm Service Agency, CLUs are the smallest units of land that have a permanent, contiguous boundary, common land cover, common owner, and common producer (USDA-FSA, 2013). Cropping decisions can change from year to year and several instances were observed where a single CLU had multiple land covers in the same year. In such cases, CLU boundaries were split to incorporate multiple land cover types. Because land cover pixels are much smaller than CLU field boundaries, many CLUs have one primary land cover, but small isolated pixels with several minor land cover types. In those cases, the major land cover within each CLU boundary was determined using a zonal statistic command within Spatial Analyst. This step served as a land cover "filter" to simplify the data and eliminate small isolated pixels of various land uses within a single field boundary.

Land use was summarized for the entire Upper Pine Lake watershed. Analysis of historical land cover data reveals several interesting trends. While the increase in the area of row crop production between 2002 and 2012 was only 2 percent, there has been a significant (13 percent) increase in corn acres relative to soybeans. This reflects multiple years of corn production before rotating to soybeans, or continuous corn production. This practice has gained popularity in the last decade, primarily due to market changes. Figure 2-5 includes land use maps for both 2002 and 2012. Table 2-3 reports land use area in acres, and Figure 2-6 illustrates the land use composition in pie graph form.

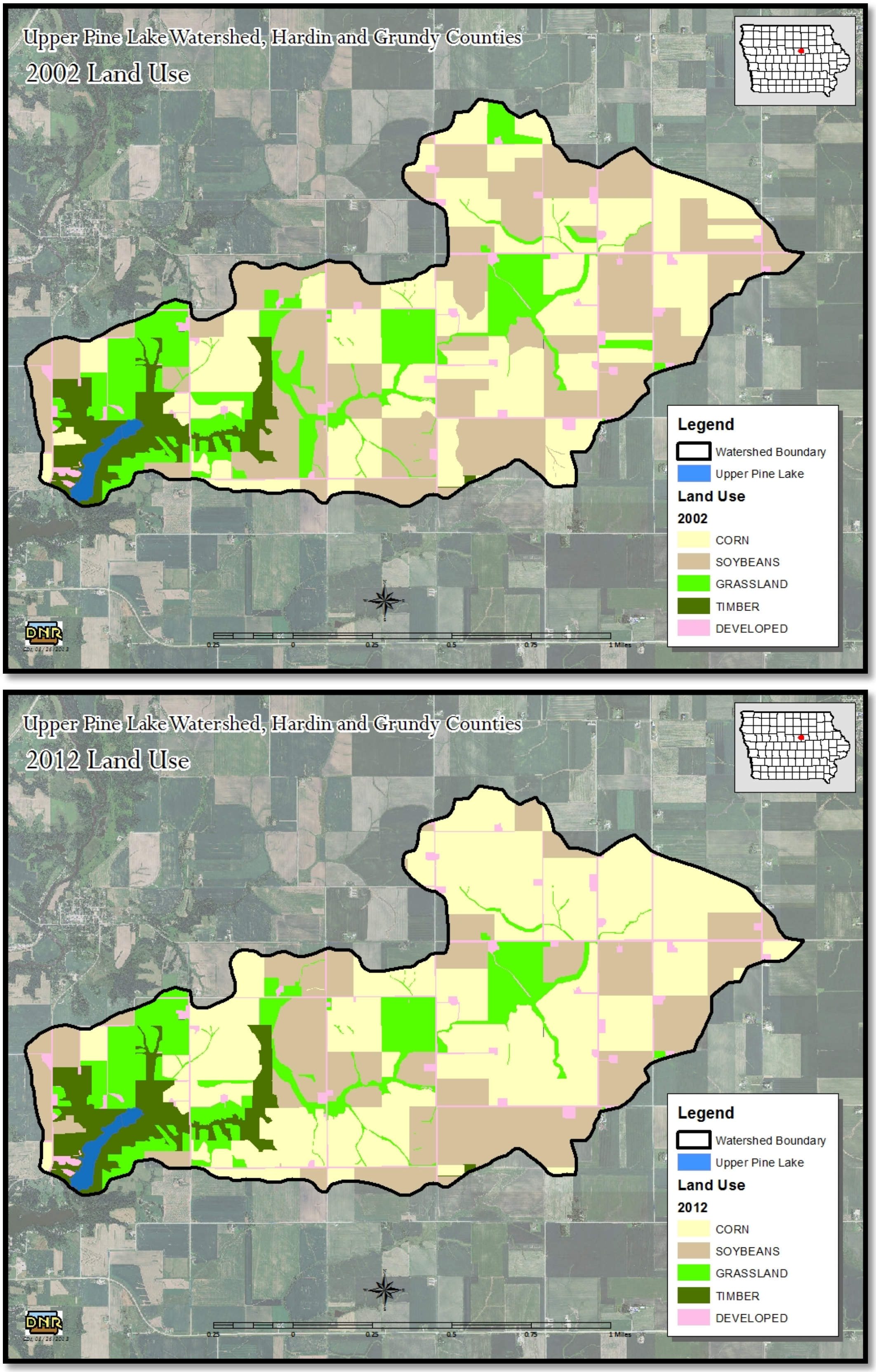
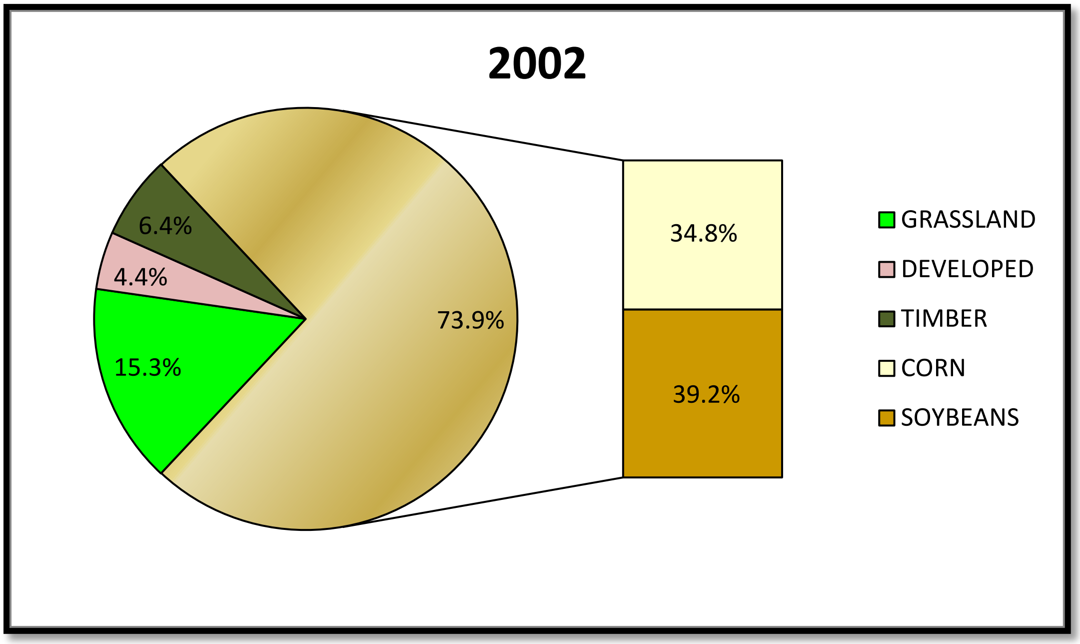


Figure 2-5. Upper Pine Lake watershed land use maps.

Table 2-3. Land use composition of Upper Pine Lake watershed.

Land Use	2002 (acres)	2012 (acres)
Corn	3,025.9	4,176.9
Soybeans	3,406.7	2,445.0
Grassland	1,332.3	1,149.2
Timber	553.3	553.3
[1]Developed	383.2	377.0
Total area excluding lake =	**8,701.4**	**8,701.4**

[1] Includes urban areas, roads, and farmsteads



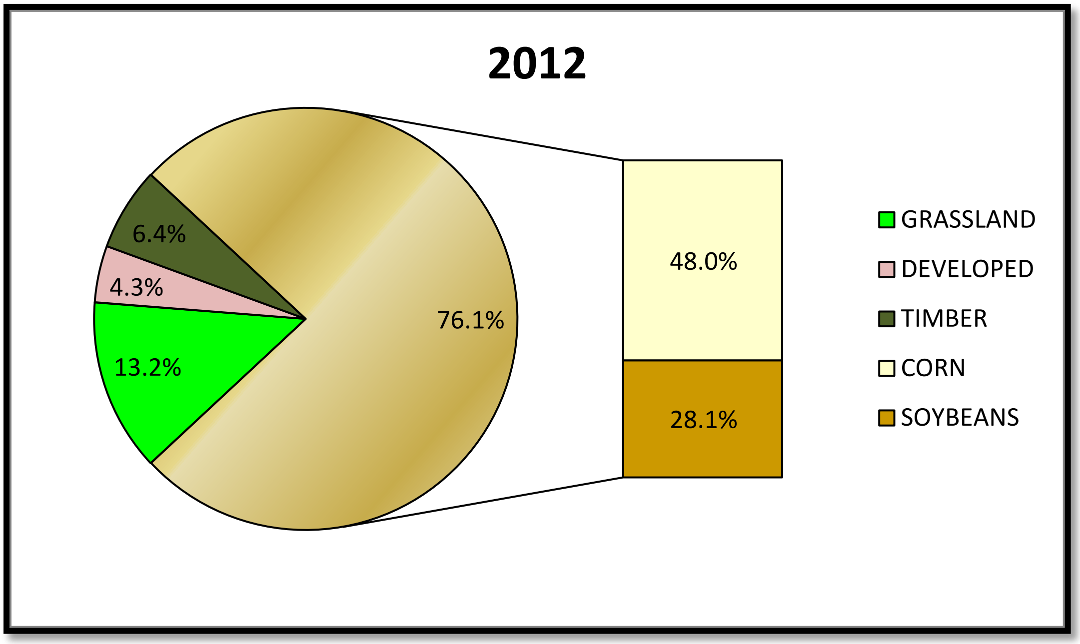


Figure 2-6. Upper Pine Lake watershed land use composition, 2002 and 2012.

Soils, Climate, and Topography

Seven soils series predominate the Upper Pine Lake watershed, as shown in Table 2-4. Of these, Tama, Muscatine, Downs, and Sawmill-Garwin soils comprise 63 percent of the watershed area. Upland areas tend to be well-drained, with poor drainage in the stream corridors of the tributaries. The topography consists of rolling hills with flat upland areas. Slopes steeper than 5 percent are found only near stream valleys, and are concentrated in the west half of the watershed (Figure 2-7). There are few areas with slopes exceeding 9 percent, almost all of them immediately adjacent to the lake or the gullies and small streams surrounding it.

Table 2-4. Predominant soils in the Upper Pine Lake watershed.

Soil Name	Watershed Area (%)	Description of Surface Soil Layer	Typical Slopes (%)
Tama	33.0	Well-drained silty clay loam	2-5
Muscatine	11.2	Somewhat poorly-drained silty clay loam	0-2
Downs	9.5	Well-drained silt loam	2-5
Sawmill-Garwin	9.0	Poorly-drained silty clay loam	0-2
Colo-Ely	5.4	Somewhat poorly-drained silty clay loam	2-5
Garwin	4.5	Poorly-drained silty clay loam	0-2
Colo	4.1	Poorly-drained silty clay loam	0-2
All others	23.3	varies	varies

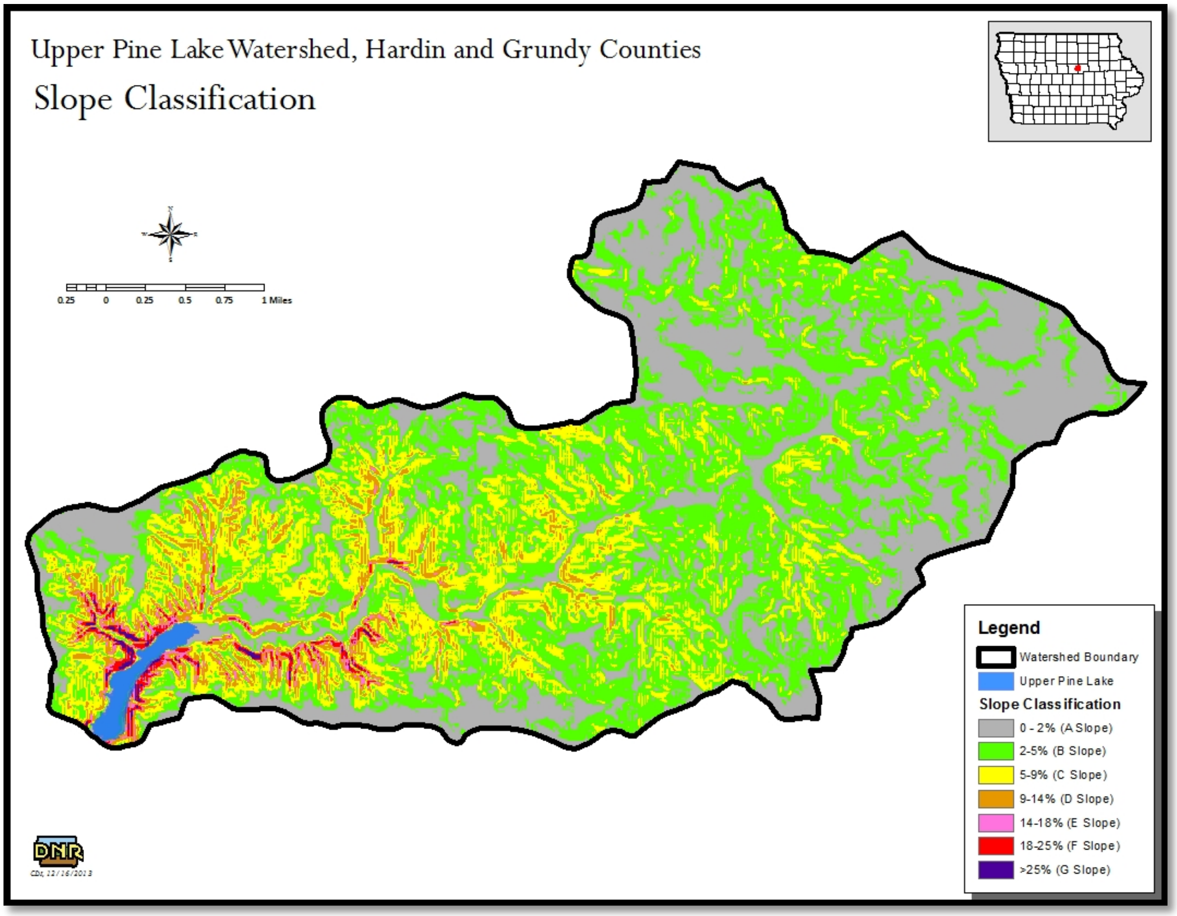


Figure 2-7. Slope classifications in the Upper Pine Lake watershed.

3. TMDL for Algae

A Total Maximum Daily Load (TMDL) is required for Upper Pine Lake by the Federal Clean Water Act. This section of the Water Quality Improvement Plan (WQIP) quantifies the maximum amount of total phosphorus (TP) the lake can assimilate and still fully support primary contact recreation in Upper Pine Lake, which is impaired by algae. This section includes an evaluation of Upper Pine Lake water quality, documents the relationship between algae and TP in Upper Pine Lake, and quantifies the in-lake target and corresponding TMDL.

3.1. Problem Identification

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

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

The 2012 Section 305(b) Water Quality Assessment Report states that primary contact recreation in Upper Pine Lake is assessed (monitored) as “partially supported” due to elevated levels of chlorophyll-a (algae) that cause aesthetically objectionable conditions. The 2012 assessment is included in its entirety in Appendix H, and can be accessed at https://programs.iowadnr.gov/adbnet/assessment.aspx?aid=13839

Applicable Water Quality Standards
The State of Iowa Water Quality Standards (WQS) are published in the Iowa Administrative Code (IAC), Environmental Protection Rule 567, Chapter 61 (http://www.legis.iowa.gov/DOCS/ACO/IAC/LINC/Chapter.567.61.pdf) [Note: This link must be copied and pasted into a web browser]. Although the State of Iowa does not have numeric criteria for sediment, nutrients, or algae (chlorophyll-a), general (narrative) water quality criteria below do apply:

61.3(2) General water quality criteria. The following criteria are applicable to all surface waters including general use and designated use waters, at all places and at all times for the uses described in 61.3(1)“a.”

a. Such waters shall be free from substances attributable to point source wastewater discharges that will settle to form sludge deposits.
b. Such waters shall be free from floating debris, oil, grease, scum and other floating materials attributable to wastewater discharges or agricultural practices in amounts sufficient to create a nuisance.
c. Such waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor or other aesthetically objectionable conditions.

d. Such waters shall be free from substances attributable to wastewater discharges or agricultural practices in concentrations or combinations which are acutely toxic to human, animal, or plant life.

e. Such waters shall be free from substances, attributable to wastewater discharges or agricultural practices, in quantities which would produce undesirable or nuisance aquatic life.

For 303(d) listing purposes, aesthetically objectionable conditions are present in a waterbody when Carlson's Trophic State Index (TSI) for the median growing season chlorophyll-a or Secchi depth exceeds 65 (DNR, 2008). In order to de-list the algae impairment for Upper Pine Lake, the median growing season chlorophyll-a TSI must not exceed 63 in two consecutive listing cycles, per DNR de-listing methodology. A TSI value of 63 corresponds to a chlorophyll-a concentration of 27 micrograms per liter (μg/L).

Problem Statement

Upper Pine Lake is impaired because primary contact recreation is not fully supported due to violations of WQS. High levels of algal production fueled by phosphorus loads to the lake cause the impairment. TP loads must be reduced in order to reduce algae and fully support the lake's designated uses.

Data Sources

Sources of data used in the development of this TMDL include those used in the 2012 305(b) report, several sources of additional water quality data, and non-water quality related data used for model development. Sources include:

- Results of statewide surveys of Iowa lakes sponsored by DNR and conducted by Iowa State University (ISU) from 2001-2012
- Water quality data collected by the State Hygienic Laboratory (SHL) at the University of Iowa from 2005-2008 and 2010-2011 as part of the Ambient Lake Monitoring Program and/or TMDL monitoring
- Precipitation data at Eldora, Iowa, from the NWS COOP program (IEM, 2013a)
- PET data for Gilbert, Iowa, from the ISU Ag Climate Network (IEM, 2013b).
- 10-m Digital Elevation Model (DEM) available from DNR GIS library
- SSURGO soils data maintained by United States Department of Agriculture – Natural Resource Conservation Service (USDA-NRCS)
- 2012 land cover data from USDA-NASS (USDA-NASS, 2013)
- Aerial images (various years) collected and maintained by DNR
- Lake bathymetric data collected in 2007

Interpreting Upper Pine Lake Data

The 2012 305(b) assessment was based on results of the ambient monitoring program conducted from 2006 through 2010 by ISU and SHL, and information from the DNR Fisheries Bureau. Assessment of in-lake water quality in this TMDL utilized SHL and ISU data from 2001-2012. All data was collected at the ambient monitoring location, which is shown in Figure 3-1. Development of the in-lake target, the TMDL, and impairment status are based on data collected at this location, per DNR assessment methodology. In-lake water quality data is reported in Appendix C.

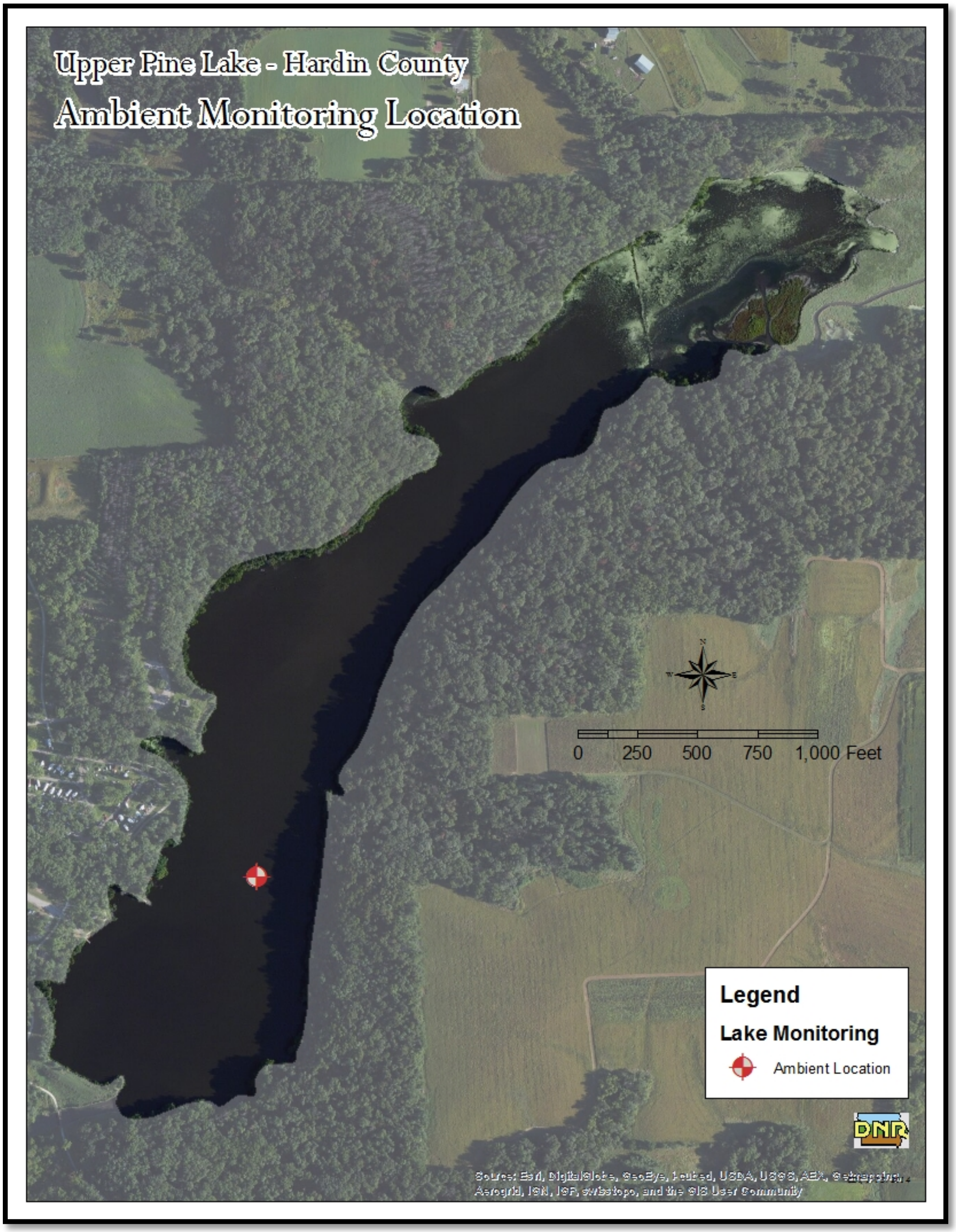


Figure 3-1. Ambient monitoring location for water quality assessment.

Carlson's Trophic State Index (TSI) was used to evaluate the relationships between TP, algae (chlorophyll-a), and transparency (Secchi depth) in Upper Pine Lake. If the TSI values for the three parameters are the same, the relationships between the three are strong. If the TP TSI values are higher than chlorophyll TSI, it suggests there are limitations to algal growth besides phosphorus. Figure 3-2 illustrates each of the individual TSI values throughout the analysis period. TSI values that exceed the 303(d) listing threshold of 65 (for Secchi depth and chlorophyll-a) are in the red-shaded box on the top half of Figure 3-2. Data incorporated into the 2012 305(b) report is in the gray-shaded box (2006-2010) in Figure 3-2.

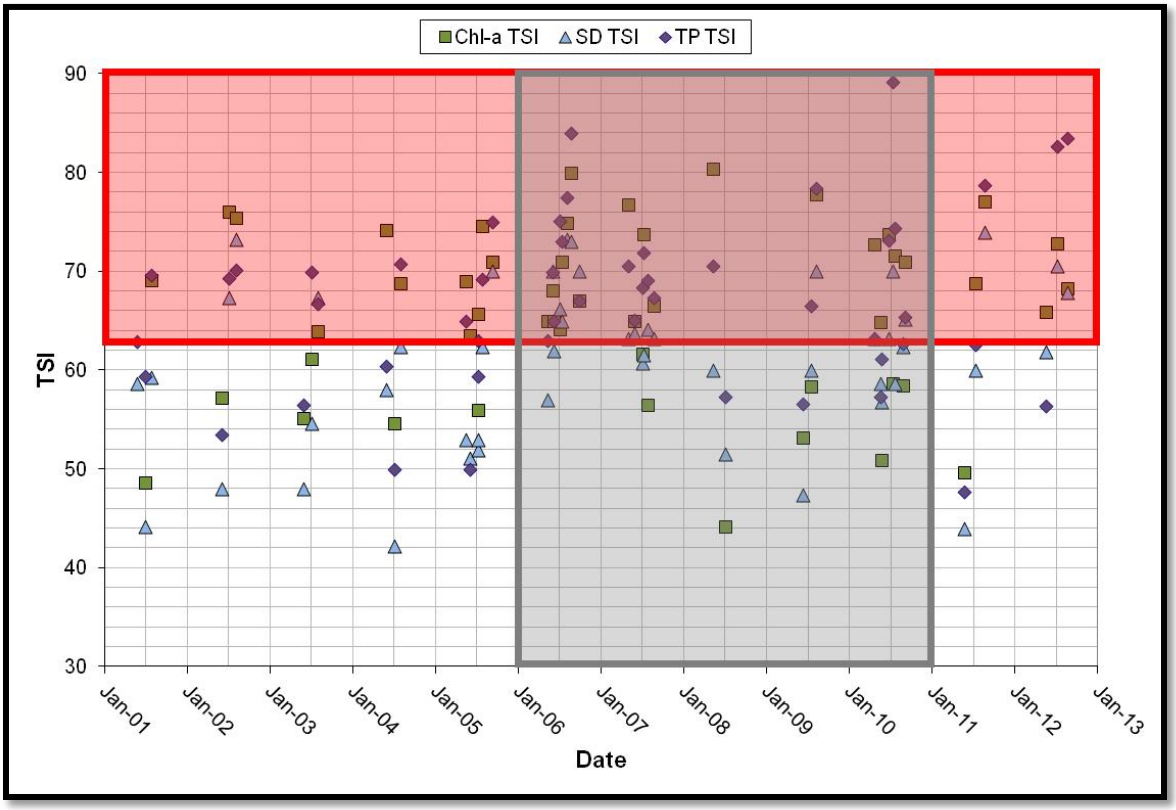


Figure 3-2. Growing season TSI values for individual samples (2001-2012).

Averaging the growing season TSI values for each year (2001-2012) results in overall TSI values of 58 for Secchi depth, 69 for chlorophyll-a, and 70 for phosphorus. The water clarity trend is negative, with increasing TSI values for Secchi depth, chlorophyll-a, and TP (Figure 3-3). However, it appears that Secchi and chlorophyll-a TSI values have leveled off since 2006. Averaging growing season TSI values from data used in the 2012 Water Quality Assessment (2006-2010) results in TSI values of 62 for Secchi depth, 70 for chlorophyll-a, and 71 for TP. Note the strong correlation between chlorophyll-a and TP TSI values, which provides some evidence of the importance of phosphorus for algal growth. However, when the TP TSI exceeds the chlorophyll-a TSI, as it typically has since 2009, other factors besides phosphorus may limit algal growth.

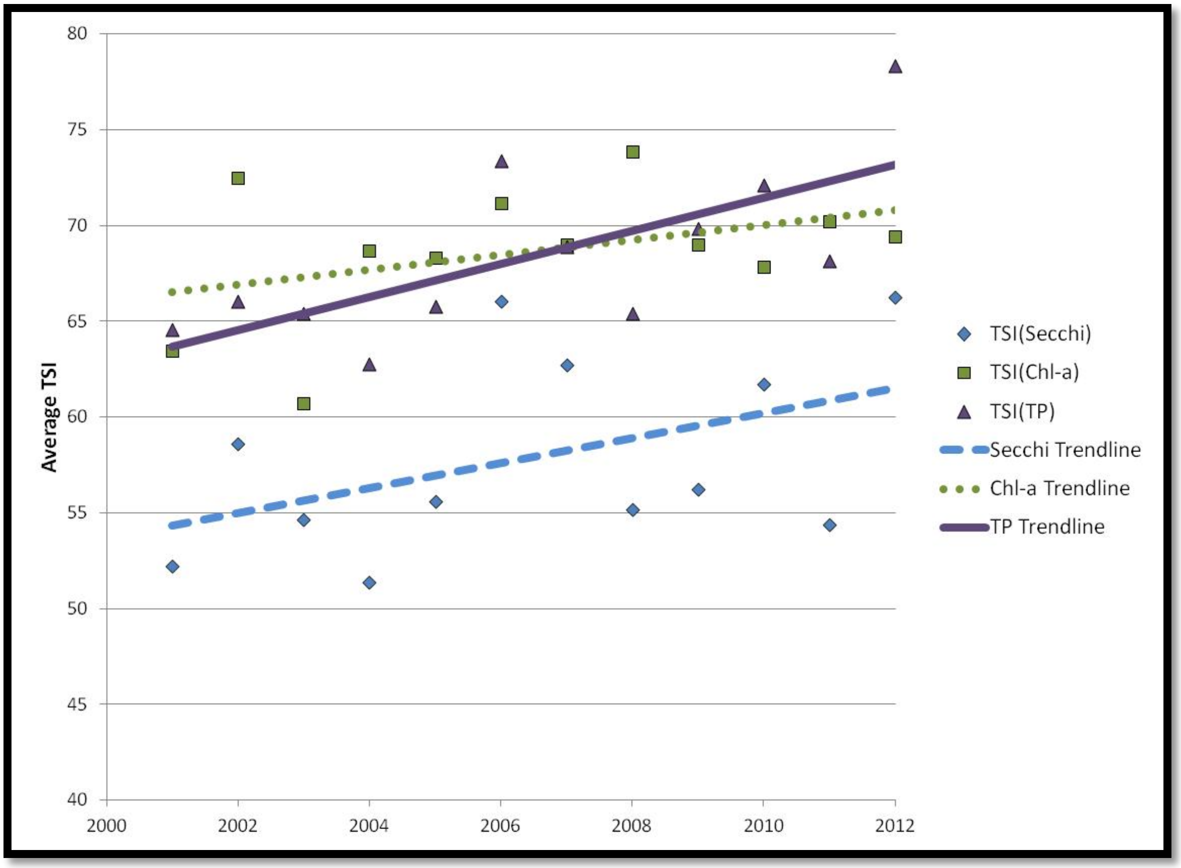


Figure 3-3. Growing season mean TSI values (2001-2011).

Figures 3-4 and 3-5 can be utilized to interpret differences (deviations) between Carlson's TSI values for TP, Secchi depth, and chlorophyll-a. Each quadrant of the chart indicates the potential factors that may limit algal growth in a lake. A detailed description of this approach is available in *A Coordinator's Guide to Volunteer Lake Monitoring Methods* (Carlson and Simpson, 1996). If the deviation between the chlorophyll-a TSI and TP TSI is less than zero (Chl TSI < TP TSI), the data point will fall below the X-axis.

Chlorophyll-a and TP TSI deviations are nearly evenly split between positive and negative deviations, with a slight majority (28 of 50 samples) lying below the x-axis in Figure 3-4. The central tendency of deviations forms an elliptical pattern just below and to the right of the dashed 1:1 line. These metrics are indicative of low non-algal turbidity levels and algal limitation that is caused by both TP limitation, and zooplankton grazing (or other non-nutrient related limitation), depending on conditions at the time the water quality sample was collected.

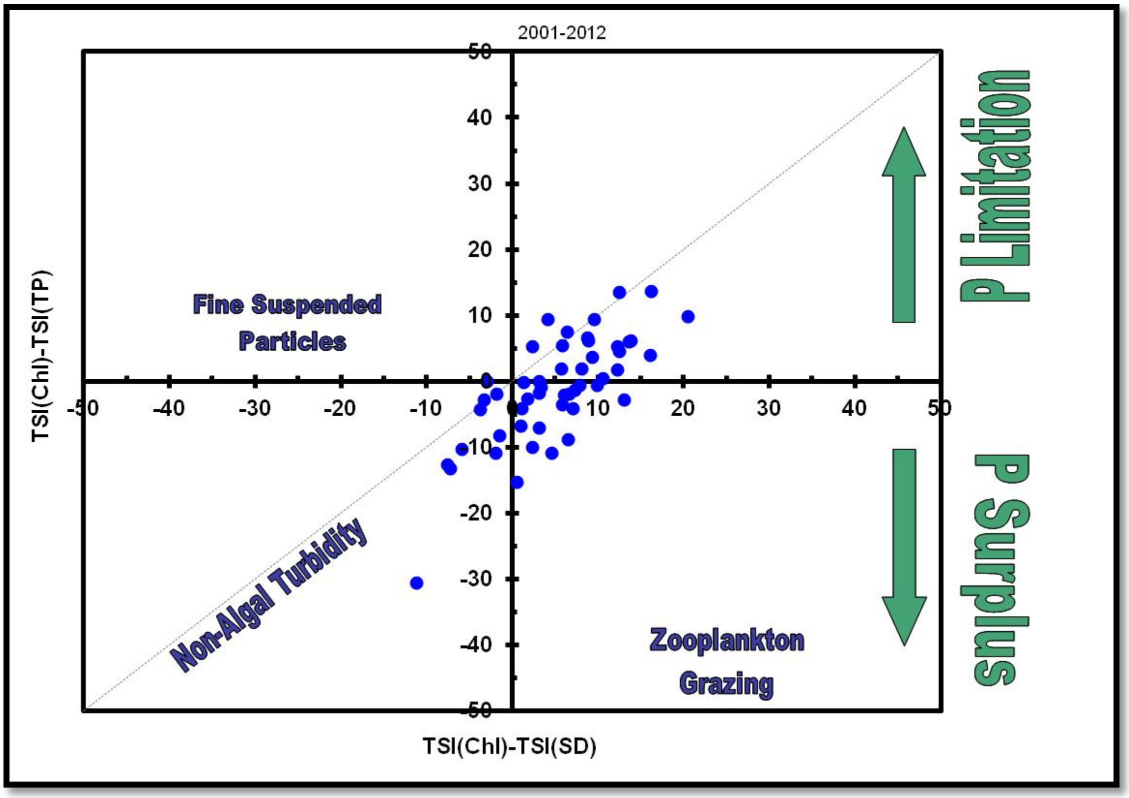


Figure 3-4. Phosphorus TSI deviations (2001-2012 grab samples).

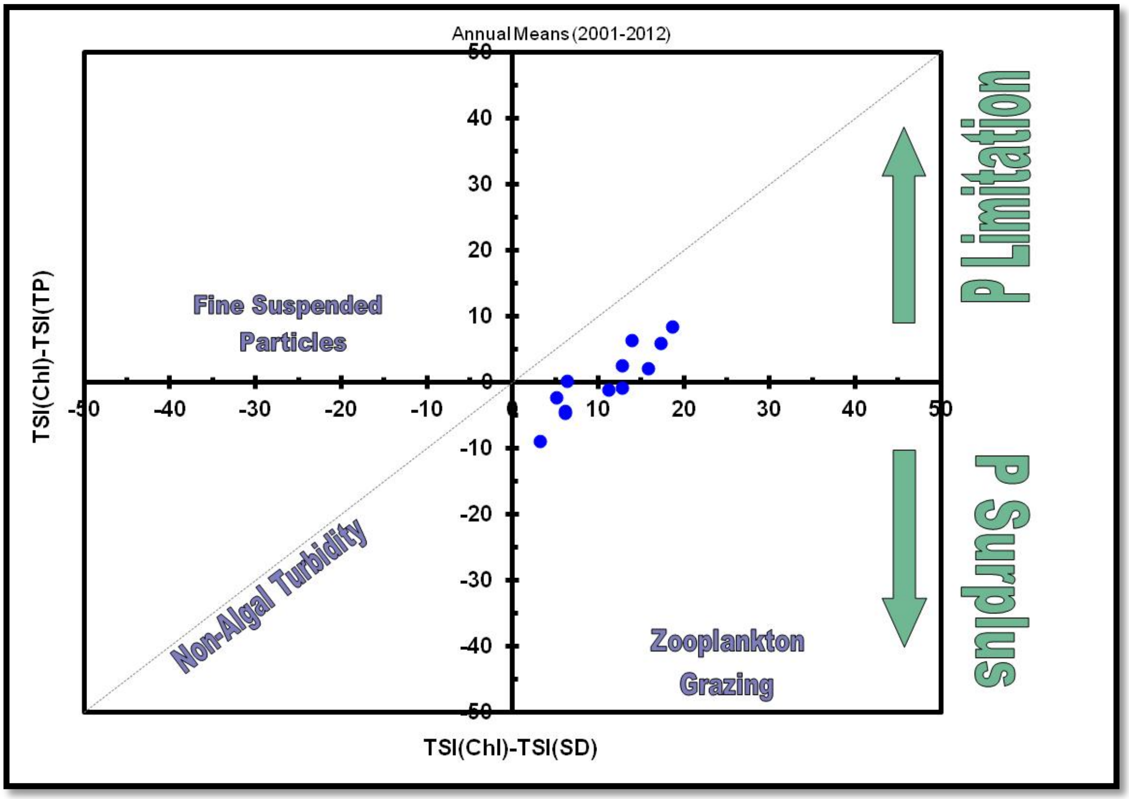


Figure 3-5. Phosphorus TSI deviations (2001-2012 annual averages).

Neither Secchi depth, chlorophyll-a, or TP annual average TSI values show any correlation to annual or growing season precipitation (Figure 3-6). This analysis reveals that high chlorophyll-a and TP levels are observed in both wet and dry years, and that both conditions must be considered when developing the TMDL.

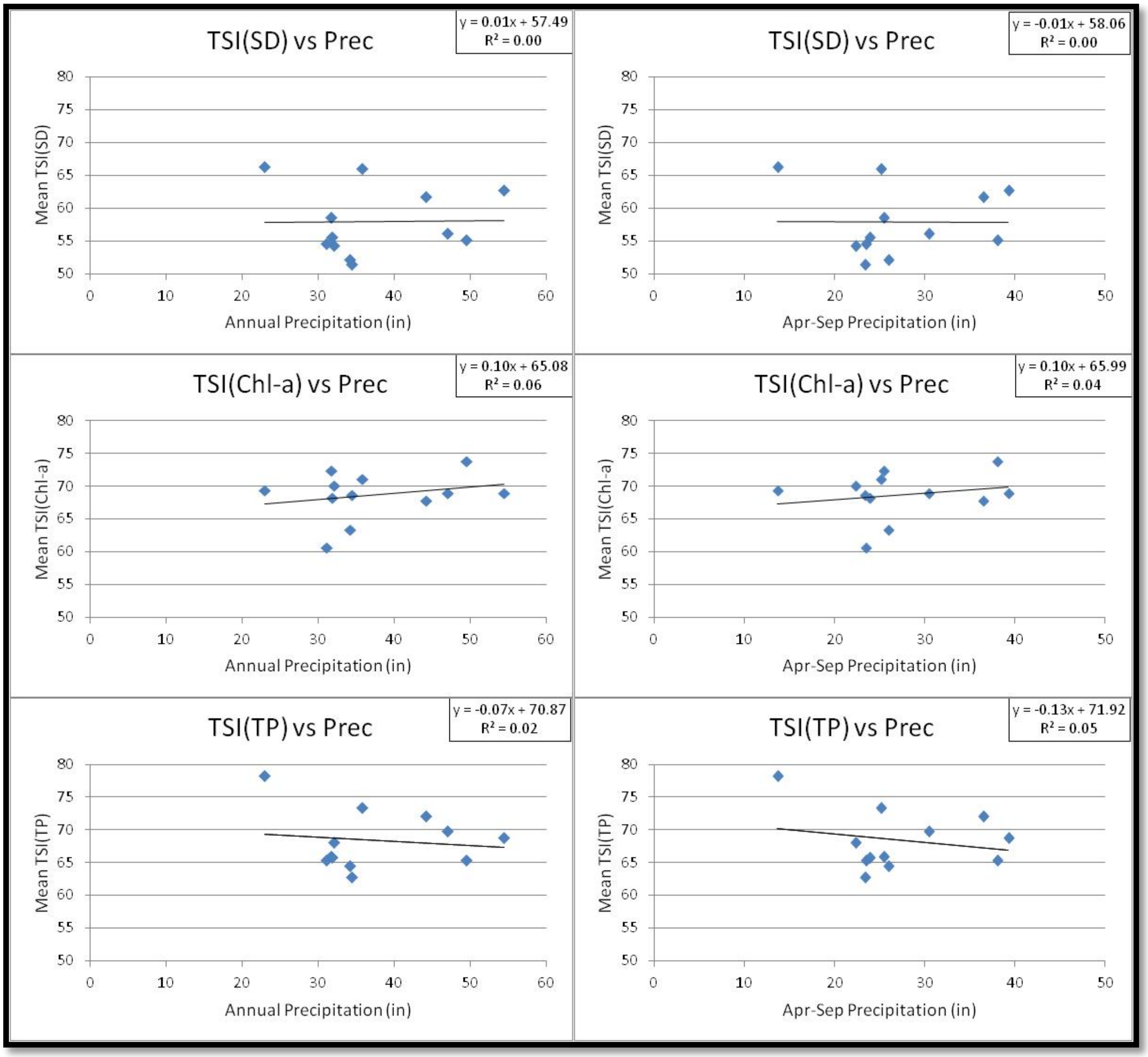


Figure 3-6. TSI values plotted against annual and growing season precipitation.

3.2. TMDL Target

General description of the pollutant

The 2012 305(b) assessment attributes poor water quality in Upper Pine Lake to excess algae, and the data interpretation described in Section 3.1 indicates phosphorus load reduction will best address the impairment. It will be important to continue to assess TSI values for chlorophyll-a as phosphorus reduction practices are implemented. If phosphorus reductions are not accompanied by reductions in algal blooms, then reductions of nitrogen may prove necessary to reduce algae to an acceptable level.

However, phosphorus should be reduced first, as it is the primary limiting nutrient in algal growth. Additionally, reductions in nitrogen that result in nitrogen limitation favor growth of harmful cyanobacteria, which have the ability to fix nitrogen from the atmosphere. These bacteria, often referred to as blue-green algae, can emit cyanotoxins to the water, which can harm humans, pets, and wildlife if ingested.

Table 3-1 reports the simulated chlorophyll-a, TP, and Secchi depth at the ambient monitoring location for both existing and target conditions. In-lake water quality was simulated using the BATHTUB model, which is described in more detail in Appendix E. The chlorophyll-a TSI target of 63 complies with the narrative "free from aesthetically objectionable conditions" criterion and will result in delisting Upper Pine Lake if attained in two consecutive 303(d) listing cycles. Note that TP and Secchi depth values in Table 3-1 are not TMDL targets. Rather, they represent in-lake water quality resulting from TP load reductions required to obtain the chlorophyll-a target.

Table 3-1. Existing and target water quality (ambient monitoring location).

Parameter	2006-2010 Mean	[1]TMDL Target
Secchi Depth	0.9 m	1.7 m
TSI (Secchi Depth)	62	52
Chlorophyll-a	54 μg/L	27 μg/L
TSI (Chlorophyll-a)	70	63
TP	105 μg/L	65 μg/L
TSI (TP)	71	64

[1] Target is chlorophyll-a TSI of 63 or less, TP and Secchi depth values are coincidental.

Selection of environmental conditions

The critical period for poor water clarity is the growing season (April through September). However, long-term phosphorus loads lead to buildup of phosphorus in the reservoir and can contribute to algal growth regardless of when phosphorus first enters the lake. Therefore, both existing and allowable TP loads to Upper Pine Lake are expressed as annual averages. Phosphorus loads are also expressed as daily maximums to comply with EPA guidance.

Waterbody pollutant loading capacity (TMDL)

This TMDL establishes a chlorophyll-a TSI target of 63 using analysis of existing water quality data and Carlson's trophic state index methodology. The allowable TP loading capacity was developed by performing water quality simulations using the BATHTUB model. BATHTUB is a steady-state water quality model that performs empirical eutrophication simulations in lakes and reservoirs (Walker, 1999). The BATHTUB model was calibrated to water quality data collected by ISU and SHL from 2006 through 2010, consistent with the assessment period for the 2012 305(b) report. The BATHTUB model is driven by weather, lake morphometry (i.e., size and shape), watershed hydrology, and sediment and nutrient loads predicted by the STEPL model. STEPL utilizes simple equations to predict sediment and nutrient loads from various land use and animal sources, and includes a tool that estimates potential sediment and nutrient reductions resulting from implementation of Best Management Practices (BMPs).

STEPL input included local soil, land cover, and climate data. A detailed discussion of the parameterization and calibration of the STEPL and BATHTUB models is provided in Appendices D through F.

The annual TP loading capacity was obtained by adjusting the TP loads in the calibrated BATHTUB model until the target chlorophyll-a TSI of no greater than 63 was attained for the lake segment in which ambient monitoring data is collected. The load response curve from the BATHTUB model output is illustrated in Figure 3-7. The annual loading capacity of Upper Pine Lake is set at 2,953 kg/yr (6,509 lbs/yr).

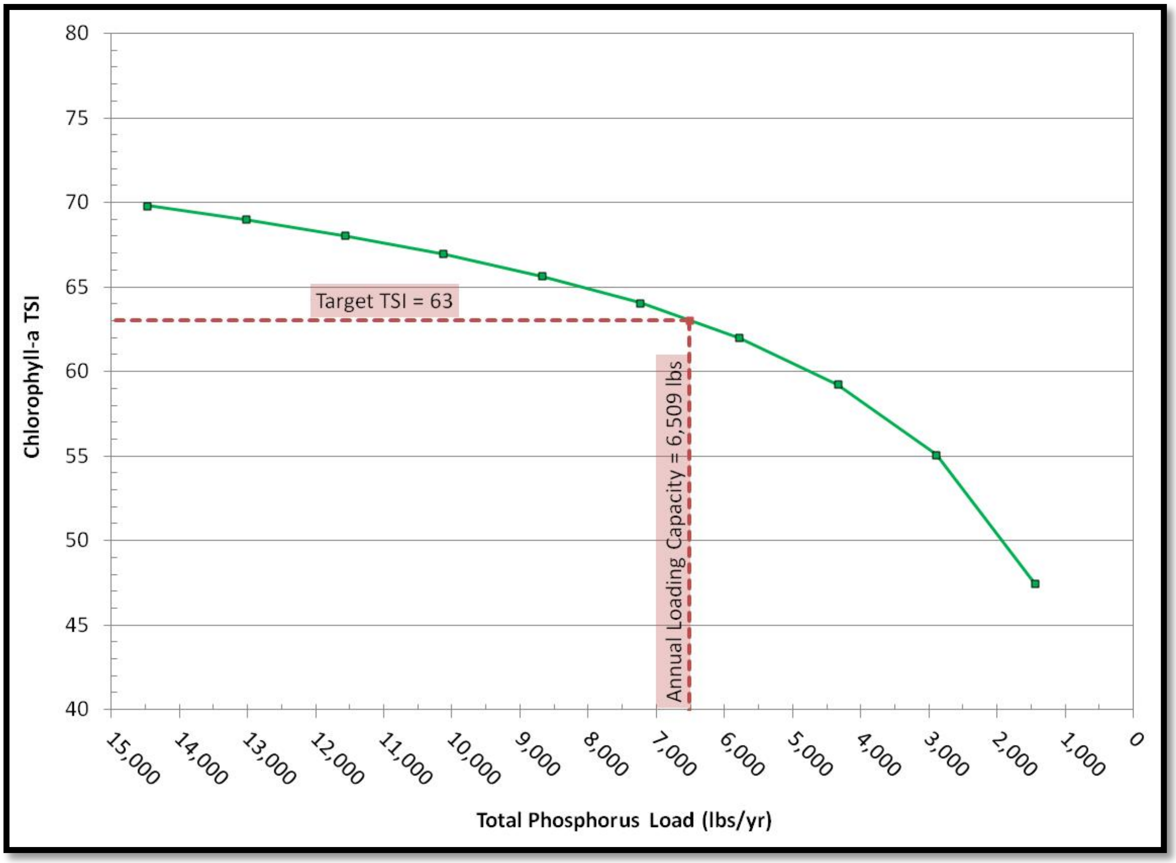


Figure 3-7. Simulated load response between chlorophyll-a TSI and TP load.

In November of 2006, The U.S. Environmental Protection Agency (EPA) issued a memorandum entitled *Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. circuit in Friends of the Earth, Inc. v. EPA, et al., No. 05-5015, (April 25, 2006) and Implications for NPDES Permits.* In the context of the memorandum, EPA

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

As recommended by EPA, the loading capacity of Upper Pine Lake for TP is expressed as a daily maximum load, in addition to the annual loading capacity of 6,509 lbs/year. The annual average load is applicable to the assessment of in-lake water quality and water quality improvement actions, while the daily maximum load satisfies EPA's recommendation for expressing the loading capacity as a daily load.

The maximum daily load was estimated from the growing season average load using a statistical approach that is outlined in more detail in Appendix G. This approach uses a log-normal distribution to calculate the daily maximum from the long-term (e.g., seasonal) average load. The methodology for this approach is taken directly from a follow-up guidance document entitled *Options for Expressing Daily Loads in TMDLs* (EPA, 2007), and was issued shortly after the November 2006 memorandum cited previously. This methodology can also be found in EPA's 1991 *Technical Support Document for Water Quality Based Toxics Control*. Using the approach, the annual loading capacity of 6,509 lbs/yr is equivalent to an average daily load of 18 pounds per day (lbs/day) and a maximum daily load of 71 lbs/day.

Decision criteria for WQS attainment
The narrative criteria in the water quality standards require that Upper Pine Lake be free from "aesthetically objectionable conditions." The metric for WQS attainment for de-listing the impairment is a chlorophyll-a TSI of 63 or less in two consecutive 303(d) listing cycles. This TSI target corresponds to a chlorophyll-a concentration of no greater than 27 μg/L.

Compliance point for WQS attainment
The TSI target for listing and delisting of Upper Pine Lake is measured at the ambient monitoring location shown in Figure 3-1. For modeling purposes, the lake was divided into multiple segments (see Figure E-2 of Appendix E). To maintain consistency with other Clean Water Act programs implemented by the Iowa DNR, the TMDL target is based on water quality of Segment A, which best represents the ambient monitoring location in Upper Pine Lake.

3.3. Pollution Source Assessment

Existing load
Average annual simulations of hydrology and pollutant loading were developed using the STEPL model (Version 4.1). STEPL was developed by Tetra Tech, for the US EPA Office of Water, and has been utilized extensively in the United States for TMDL development and watershed planning. Model description and parameterization are described in detail in Appendix D.

Using STEPL and BATHTUB to simulate annual average conditions between 2006 and 2010, the annual TP load to Upper Pine Lake was estimated to be 14,488 lbs/yr. This load assumes that the existing wetland forebay in the northeast corner of the lake removes 15 percent of the phosphorus entering from the watershed. The simulation period (for existing conditions) is the same as the assessment period (for the 2012 Integrated Report).

This period was relatively wet, with only one year (2006) of the five-year span having below average precipitation. Because these conditions are reflected in the water quality assessment, this period was determined to be most appropriate for development of the numeric TMDL.

Departure from load capacity
The TP loading capacity for Upper Pine Lake is 6,509 lbs/yr and 71 lbs/day (maximum daily load). To meet the target loads, an overall reduction of 55.1 percent of the TP load is required. The implementation plan included in Section 4 describes potential BMPs, potential TP reductions, and considerations for targeted selection and location of BMPs.

Identification of pollutant sources
The existing TP load to Upper Pine Lake is entirely from nonpoint sources of pollution. Table 3-2 reports estimated annual average TP loads to the lake from all known sources, based on the STEPL simulation of average annual conditions from 2006-2010. The predominant sources of phosphorus to Upper Pine Lake include erosion from land in row crop production, as well as runoff containing manure and fertilizer. Row crops comprise 76 percent of the land area of the watershed (Figure 2-6), and 87 percent of the phosphorus load to the lake (Figure 3-8). Relatively minor sources include developed areas such as roads, farmsteads, and Pine Lake State Park (4.2 percent), erosion and runoff from pasture (5.1 percent), and streambank erosion (1.5 percent). There are no dog runs or equestrian trails in the state park; hence any nonpoint source contributions are represented by the land use inputs in the STEPL model.

All showers and flush toilets in Pine Lake State Park are connected to the wastewater treatment system of the City of Eldora, which discharges outside the watershed. Pit latrine toilets are pumped as needed and delivered to a wastewater treatment plant. There are two hog confinements within the Upper Pine Lake watershed. None of the facilities are allowed to discharge; however, liquid swine manure is applied in the watershed. This potential source of phosphorus is simulated in STEPL by inputting the number of swine present and the resulting manure application in each subwatershed. There is also one small, unregulated open feedlot in which up to 300 beef cattle are raised. Runoff from this feedlot is not directly hydrologically connected to any streams or tile drains in the watershed, therefore it is not simulated as a feedlot in STEPL. Potential impacts from collection and land application of beef manure from this feedlot are simulated in the same fashion as swine manure from the confinements described previously. As a result, TP loads from swine and beef manure application are reflected in the TP loads from row crops.

Internal recycling of phosphorus in the lake was not explicitly simulated or calculated, because predicted phosphorus loads to the lake from the watershed were large enough to fully account for observed water quality in the lake. The BATHTUB model empirically and indirectly accounts for low to moderate levels of internal loading without the addition of an internal loading input to the model. In lakes with substantial internal loading issues, inclusion of additional internal load inputs is sometimes necessary, but that was not the case for Upper Pine Lake. The extremely high flushing rate, which stems from the large watershed-to-lake ratio of 120-to-1, likely contributes to the low significance of internal loading in Upper Pine Lake. However, internal recycling of phosphorus may be important in extremely dry conditions, typically late in the growing season, when the water level falls below the spillway crest, creating a stagnant pool in the reservoir. Water level measurements using a pressure transducer were taken continuously from March to October of 2010, a wet year, and no instances of zero-discharge were observed. Reduction of internal lake loads is still thought to be a valid water quality improvement alternative, but watershed loads are more critical to long-term water quality in the lake.

Allowance for increases in pollutant loads

There is no allowance for increased phosphorus loading included as part of this TMDL. A majority of the watershed is in agricultural row crop production, and is likely to remain in cropland in the future. Pine Lake State Park, which is adjacent to the lake, is unlikely to undergo significant land use changes. There are no incorporated unsewered communities in the watershed, therefore it is unlikely that a future WLA would be needed for a new point source discharge.

Table 3-2. Average annual TP loads from each source (2006-2010).

Source	Descriptions and Assumptions	[1]TP Load (lb/yr)	Percent (%)
Row Crops	Corn and soybeans	12,556	86.7
Pasture	Includes grazed and ungrazed grassland	741	5.1
Developed	Urban areas, roads, and farmsteads	606	4.2
Streambank	Stream bank and ephemeral gullies	216	1.5
Timber/Forest	Ungrazed timber, including shrub/scrub	155	1.1
Septic Systems	Private on-site wastewater systems	148	1.0
Geese	Geese, primarily at the lake	50	0.3
Atmospheric	Deposition from wind, rain, etc.	16	0.1
Total		14,488	**100.0**

[1] Predicted TP loads to lake after 15 percent in the wetland forebay.

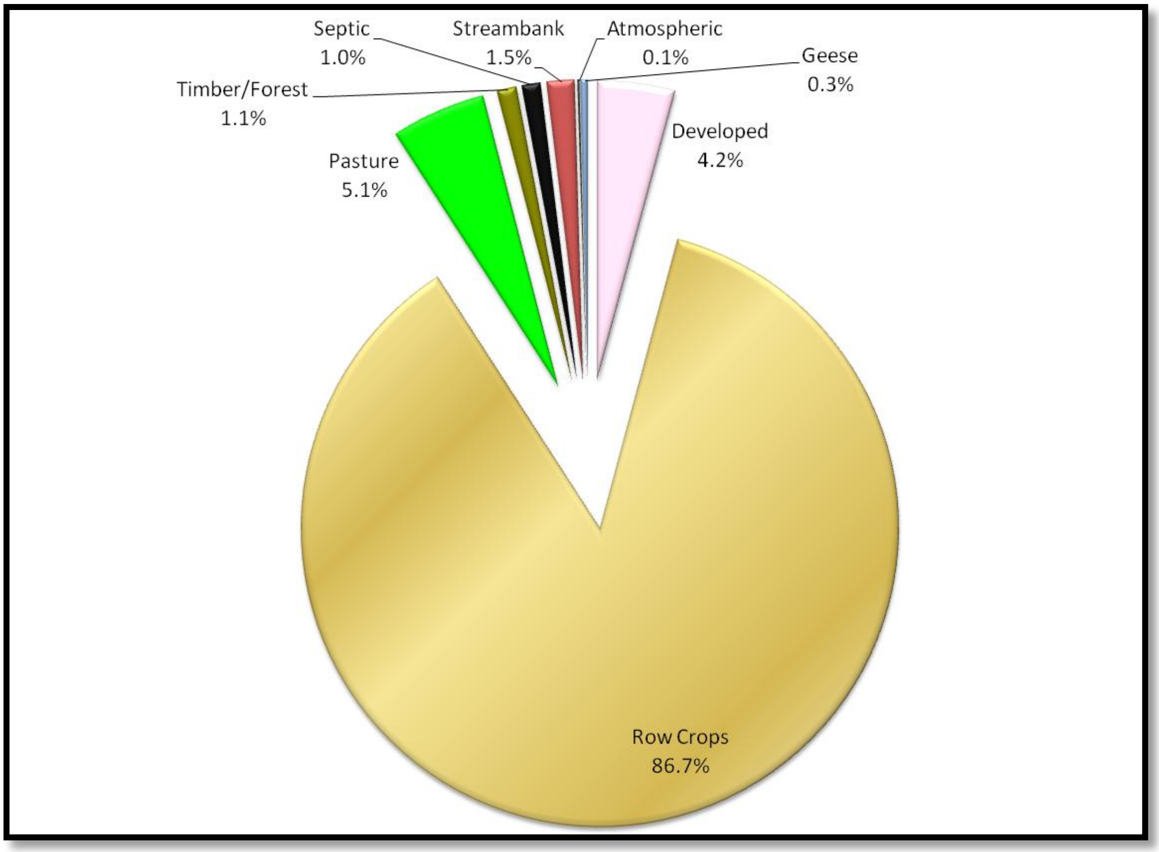


Figure 3-8. Relative TP loads by source.

3.4. Pollutant Allocation

Wasteload allocation

There are no permitted point source dischargers of phosphorus in the Upper Pine Lake watershed. Two of the hog confinements are considered regulated concentrated animal feeding operations (CAFOs) and are given numeric WLAs of zero.

Table 3-3. Existing point source load and TMDL WLA.

Point Source	Facility ID	Existing Load (lb/year)	WLA (lb/year)
CAFO (swine)	310713181	0	0
CAFO (swine)	310716188	0	0

Load allocation

Nonpoint sources of phosphorus to Upper Pine Lake include erosion and loss of manure and fertilizer from land in row crop production, erosion and manure from pasture and other grasslands, stream and gully erosion, erosion from timber/wooded areas, transport from developed areas (roads, residences, etc.), wildlife defecation, and atmospheric deposition (from dust and rain). Septic systems, which are not regulated or permitted under the Clean Water Act, but can fail or drain illegally to ditches, also contribute phosphorus to the lake. Changes in agricultural land management, implementation of structural best management practices (BMPs), repair or replacement of failing septic systems, and in-lake restoration techniques can reduce phosphorus loads and improve water quality in Upper Pine Lake. Based on the inventory of sources, management and structural practices targeting land in row crop production offer the largest potential reductions in TP loads.

Table 3-4 shows an example load allocation scenario for the Upper Pine Lake watershed that meets the overall TMDL phosphorus target. The LA is 5,858 lbs/year, with a maximum daily LA of 64 lbs/day. The daily maximum LA was obtained by subtracting the daily WLA and daily MOS from the statistically-derived TMDL (as described in Section 3.2 and Appendix G). The specific reductions shown in Table 3-4 are not required, but provide one of many possible combinations of reductions that would achieve water quality goals.

Table 3-4. Example load allocation scheme to meet target TP load.

TP Source	Existing Load (lb/year)	LA (lb/year)	NPS Reduction (%)
Row Crops	12,556	4,772	62
Pasture	741	333	55
Developed	606	454	25
Streambank/Gully	216	108	50
Timber/Forest	155	116	25
Septic Systems	148	9	94
Geese	50	50	0
Atmospheric	16	16	0
Total	**14,488**	**5,858**	**59.6%**

Margin of safety

To account for uncertainties in data and modeling, a margin of safety (MOS) is a required component of all TMDLs. An explicit MOS of 10 percent (651 lbs/year, 7 lbs/day) was utilized in the development of this TMDL.

Reasonable Assurance

Under current EPA guidance, when a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur, the TMDL should provide reasonable assurance that nonpoint source control measures will achieve expected load reductions. Because there are no permitted or regulated point source discharges contributing phosphorus to Upper Pine Lake and the WLA is zero, demonstration of reasonable assurance is not applicable to this TMDL.

3.5. TMDL Summary

The following general equation represents the total maximum daily load (TMDL) calculation and its components:

TMDL = LC = Σ WLA + Σ LA + MOS

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

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

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

TMDL = LC = Σ WLA (0 lbs-TP/year) + Σ LA (5,858 lbs-TP/year)
+ MOS (651 lbs-TP/year) = **6,509 lbs-TP/year**

Expressed as the maximum daily load:

TMDL = LC = Σ WLA (0 lbs-TP/day) + Σ LA (64 lbs-TP/day)
+ MOS (7 lbs-TP/day) = **71 lbs-TP/day**

4. Implementation Planning

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources (DNR) recognizes that technical guidance and support are critical to achieving the goals outlined in this Water Quality Improvement Plan (WQIP). Therefore, this implementation plan is included for use by local agencies, watershed managers, and citizens for decision-making support and planning purposes. The best management practices (BMPs) discussed are potential tools that will help achieve water quality goals if appropriately utilized. It is possible that only a portion of BMPs included in this plan will be feasible for implementation in the Upper Pine Lake watershed. Additionally, there may be potential BMPs not discussed in this implementation plan that should be considered. This implementation plan should be used as a guide or foundation for detailed and comprehensive planning by local stakeholders.

Collaboration and action by residents, landowners, lake users, and local agencies will be essential to improve water quality in Upper Pine Lake and support its designated uses. Locally-led efforts have proven to be the most successful in obtaining real and significant water quality improvements. Improved water quality results in economic and recreational benefits for people that live, work, and recreate in the watershed. Therefore, each group has a stake in promoting awareness and educating others about water quality, working together to adopt a comprehensive watershed improvement plan, and applying BMPs and land management changes in the watershed.

4.1. Previous Watershed Planning and Implementation

There is a long history of watershed and lake improvement efforts for Upper (and Lower) Pine Lake. In 1970, the State Conservation Commission (which is now Iowa DNR) requested that the Hardin and Grundy County Soil Conservation Districts collaborate to develop an inventory and watershed plan for the lakes. The resulting inventory focused on sheet and rill erosion as well as stream and gully erosion. Erosion control practices in the form of 160 miles of grass backslope terrace and 16 sediment basins were proposed for implementation, at a project cost of over $940,000 (in 1970 dollars). It appears that this plan was partially implemented, but a relatively small number of these structures were actually built following the 1970 plan.

In 1991, the Iowa DNR developed a diagnostic feasibility (DF) study for Upper and Lower Pine Lakes. The effort was funded by the Friends of Pine Lake, a marine fuel tax, and the federal Clean Lakes Program (Section 314 of the Clean Water Act). The DF study, like the 1970 plan, emphasized terrace construction and sediment basins to reduce transport of sheet and rill erosion to the lakes. Additional recommendations included a large sediment trap near the inlet of Upper Pine Lake, targeted in-lake dredging, and installation of aeration systems in the lake to prevent both winter and summer fish kills.

Following the DF study, the Pine Creek Water Quality Project was initiated in 1993 and concluded in 1998. The bulk of funds were provided by the Clean Lakes Program, the federal Nonpoint Source Program (Section 319), and the Iowa Publicly Owned Lake

Program (IPOLP). Clean Lakes Program dollars were used to dredge approximately 40,000 cubic yards of sediment from the bottom of the lake and to construct a sediment dike across the upper end of the lake, which forms the shallow wetland forebay still present today. Watershed practices implemented with Section 319 and IPOLP cost-share dollars included:

- Over 60,000 feet of grassed waterways
- Over 17,000 feet of terraces
- Four sediment basins
- Eight grade stabilization structures

Additionally, Water Quality Incentive Program (WQIP) funds were used to implement the following practices by agricultural producers in the watershed.

- Nutrient and pest management
- Increased record keeping
- No-till
- Contour farming
- Critical area seeding
- Field borders
- Livestock exclusion (from streams)
- Wildlife habitat improvement

In total, approximately one million dollars was spent from 1993-1998 in an effort to reduce erosion and sediment and nutrient transport to Upper and Lower Pine Lakes. Modeling indicated that implementation would reduce sediment loads to the lake by 65 percent, but monitoring data has never documented such reductions. Water quality did improve for several years (based on TSI values for TP, chlorophyll-a, and Secchi depth) after implementation, but data collected from 2000 to 2002 indicated that algae levels exceeded those observed from 1992-1993. The 2008 Water Quality Assessment, based on 2005 and 2006 data, resulted in an algae impairment and placed Upper Pine Lake on the state’s 303(d) list of impaired waters. Subsequent assessments have indicated the algae impairment persists.

4.2. Future Planning and Implementation

General Approach

Future watershed management and BMP implementation efforts in the Upper Pine Lake watershed should utilize a phased approach. Given the large watershed-to-lake ratio and the morphology of this reservoir, attainment of existing water quality standards may not be attainable in this impoundment. Water quality improvement and enhancement of Upper Pine Lake as a recreational resource are certainly attainable goals. Efforts should be targeted to maximize benefits and minimize costs. Emphasis should be placed on non-structural water quality practices that increase infiltration (thereby reducing runoff and erosion), keep the soil covered with vegetation, and minimize direct inputs by livestock or other sources. Construction or improvement of the existing, sediment/nutrient forebay may be one structural practice worthy of investigation. Projects with multiple benefits (e.g., wildlife habitat, soil conservation, and water quality) may do more to protect and preserve the use of Upper Pine Lake for future generations than those focused solely on water quality. Additional funding avenues besides Section 319 funds may help facilitate multiple-objective projects.

Timeline
Planning and implementation of future improvement efforts may take several years, depending on stakeholder interest, availability of funds, landowner participation, and time needed for design and construction of any structural BMPs. Realization and documentation of significant water quality benefits may take 5-10 years or longer, depending on weather patterns, amount of water quality data collected, and the successful selection, location, design, construction, and maintenance of BMPs. Given the relatively minor water quality response to previous implementation efforts in this watershed, sustained improvement may be a more appropriate goal than impairment delisting.

Tracking milestones and progress
A monitoring plan, based on the one outlined in Section 5 of this WQIP, would address several of the elements required for a nine-element plan approved by EPA for the use of 319 funds. Establishment of specific short, intermediate, and long-term water quality goals and milestones would also be needed to acquire 319 funding. A path to full attainment of water quality standards and designated uses must be included, but efforts should first focus on documenting water quality improvement resulting from BMPs and elimination of any phosphorus “hot spots” that may exist.

4.3. Best Management Practices

No stand-alone BMP will be able to sufficiently reduce phosphorus loads to Upper Pine Lake. Rather, a comprehensive package of BMPs will be required to reduce sediment and phosphorus transport to the lake, which causes elevated algal growth and impairment of designated uses in Upper Pine Lake. The majority of phosphorus that enters the lake is from erosion and nutrient losses from lands in corn and soybean production. However, losses from developed areas, septic systems, streambank erosion, and even grass and timber areas occur. Each of these sources has distinct phosphorus transport pathways and processes, therefore, each requires a different set of BMPs and strategies.

Other sources, although relatively small on an annualized basis, can have important localized and seasonal effects on water quality. It is important that all sources are considered to reduce phosphorus loads in the most comprehensive manner possible. Experience has shown that watershed projects that involve widespread “ownership” of potential solutions have the best chance of success. At the same time, resources to address the various sources of phosphorus should be allocated in a manner that is reflective of the importance to the impairment: algal blooms caused primarily by excess phosphorus loads to the lake. Potential BMPs are grouped into three types: land management (prevention), structural (mitigation), and in-lake alternatives (remediation).

Land Management (Prevention Strategies)

Many agricultural BMPs are designed to reduce erosion and nutrient loss from the landscape. These BMPs provide the highest level of soil conservation and soil health benefits, because they prevent erosion and nutrient loss from occurring. Land management alternatives implemented in row crop areas should include conservation practices such as cross-slope farming, no-till and strip-till farming, diversified crop rotation methods, utilization of in-field buffers, and cover crops. Incorporation of applied manure and fertilizer into the soil by knife injection equipment reduces phosphorus levels, as well as nitrogen and bacteria levels, in runoff from application areas. Strategic timing of manure and fertilizer application and avoiding over-application may have even greater benefits to water quality. Application of manure on frozen ground should be avoided, as should application when heavy rainfall is forecasted.

The Upper Pine Lake watershed has only a few small grazed pastures, but they are primarily adjacent to tributary streams. Though not suspected to be a large source of phosphorus, even a few acres of pasture with direct access to the stream could impact water quality in the lake. Well-managed pastures can have very little negative impact on water quality, since the ground is covered with vegetation year-round. Stable and diverse pasture forages hold soil in place, filter runoff, and uptake nutrients for growth. Exclusion of livestock from streams and riparian areas can provide additional water quality benefits. Rotational grazing systems can improve water quality in adjacent waterbodies compared with continuously grazed systems. More research is needed, but there is evidence that forage diversity, degree of vegetation coverage/residue, and regrowth rates are higher in rotationally-grazed pastures (Dinnes, 2004). These characteristics increase erosion protection, filter runoff, and provide increased nutrient uptake compared with continually grazed grasses and forages. Table 4-1 summarizes land management BMPs and associated phosphorus reduction estimates.

Structural BMPs (Mitigation Strategies)

Although they do not address the underlying generation of sediment or nutrients, structural BMPs such as sediment control basins, terraces, grass waterways, riparian buffers, and wetlands can play a valuable role in reduction of sediment and nutrient transport to Upper Pine Lake. These BMPs attempt to mitigate the impacts of soil erosion and nutrient loss by intercepting them before they reach a stream or lake. Structural BMPs should be targeted to "priority areas" to increase their cost effectiveness and maximize pollutant reductions. Landowner willingness and the physical features of potential sites must also be considered when targeting structural practices. These practices may offer additional benefits not directly related to water quality improvement. These secondary benefits are important to emphasize to increase landowner and public interest and adoption. Potential structural BMPs are listed in Table 4-2, which includes secondary benefits and potential TP reductions.

Table 4-1. Potential land management BMPs (prevention strategies).

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

[1] Adopted from Dinnes (2004) with professional judgment. Actual reduction percentages may vary widely across sites and runoff events.
[2] Note: Tillage incorporation can increase TP in runoff in some cases.

Landowner buy-in, ease of construction, and difficulty implementing preventative land management measures all contribute to the popularity of sediment control structures as a sediment and phosphorus mitigation strategy. This is a proven practice, if properly located, designed, constructed, and maintained. However, if not properly designed and constructed, sediment control basins may trap substantially less sediment and phosphorus than widely-used rules-of-thumb that are often assumed when quantifying reductions in the context of a watershed management plan. There are at least three general criteria that should be considered when designing sediment control basins. First, the area of the basin should be appropriate relative to the size of the drainage area. Effective sediment control basins require a minimum size of at least one percent of the total drainage area to the basin. Second, drawdown times (i.e., the time it takes for runoff from a storm event to drain from the basin) should be no less than 24 hours, and preferably 40 hours. Shorter drawdown periods do not adequately settle fine sediments, which carry a large portion of attached phosphorus. Third, sediment basins should be shaped such that the length to width ratio is maximized to prevent short-circuiting across the shortest flow-path through the basin. A minimum length to width ratio of 3:1 is commonly cited in the literature.

To obtain reductions in TP load necessary to meet water quality targets, land management strategies and structural BMPs should be implemented to obtain the largest and most cost-effective water quality benefit. Targeting efforts should consider areas with the highest potential phosphorus loads to the lake. Factors affecting phosphorus contribution include: land cover, steep slopes; proximity to waterbodies; tillage practices, grazing practices (including cattle stream access) and method, timing, and amount of manure and commercial fertilizer application.

Table 4-2. Potential structural BMPs (mitigation strategies).

BMP or Activity	Secondary Benefits	[1] Potential TP Reduction
Terraces	Soil conservation, prevent in-field gullies, prevent wash-outs	50%
Grass Waterways	Prevent in-field gullies, prevent washouts, some ecological services	50%
[2]Sediment Control Structures	Some ecological services, gully prevention	Varies
[3]Wetlands	Ecological services, potential flood mitigation, aesthetic value	15%
[4]Sediment Forebay	Ecological services, aesthetic value	55%
Riparian Buffers	Ecological services, aesthetic value, alternative agriculture	45%

[1] Adopted from Dinnes (2004) with professional judgment. Actual reduction percentages may vary widely across sites and runoff events.
[2] Not discussed in Dinnes (2004). Phosphorus removal in sediment basins varies widely and is dependent upon the size of the structure relative to the drainage area, the length:width ratio, and drawdown time of a specified rainfall/runoff event.
[3] Note: TP reductions in wetlands vary greatly depending on site-specific conditions, such as those listed for sediment control structures. Generally, removal of phosphorus is lower in wetlands than in sediment control structures. Wetland can sometimes be sources, rather than sinks, of phosphorus
[4] Average of removal efficiencies from EPA Wet Pond Fact Sheet (http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=68)

The Spreadsheet Tool for Estimating Pollutant Load (STEPL) model was used in TMDL development to predict phosphorus loads to Upper Pine Lake. Figure 4-1 shows the annual phosphorus export from each subbasin in the Upper Pine Lake watershed STEPL model. Figure 4-2 is a phosphorus export map that indicates relative contributions of each subwatershed. Red-shaded bars and subwatersheds indicate the highest phosphorus export and green shading indicating the lowest export rates. The figures reveal that more phosphorus is exported from Subbasin 2 annually than from other Subbasins, with Subbasin 1 having the lowest TP export. Figure 4-3 shows TP losses for each subbasin after adjusting for drainage area. On a per-area basis, Subbasin 1 has the lowest TP yield, with losses from Subbasin 2, 3, and 4 being nearly equivalent.

Subbasin-level information indicates that construction of a large, in-stream sediment trapping structure would have the largest effect near the outlet of Subbasin 2. Alternatively, this analysis shows that improving the sediment-trapping efficiency of the existing forebay created by the sediment/nutrient dike may be an efficient way to decrease TP loads to the lake with less capital costs.

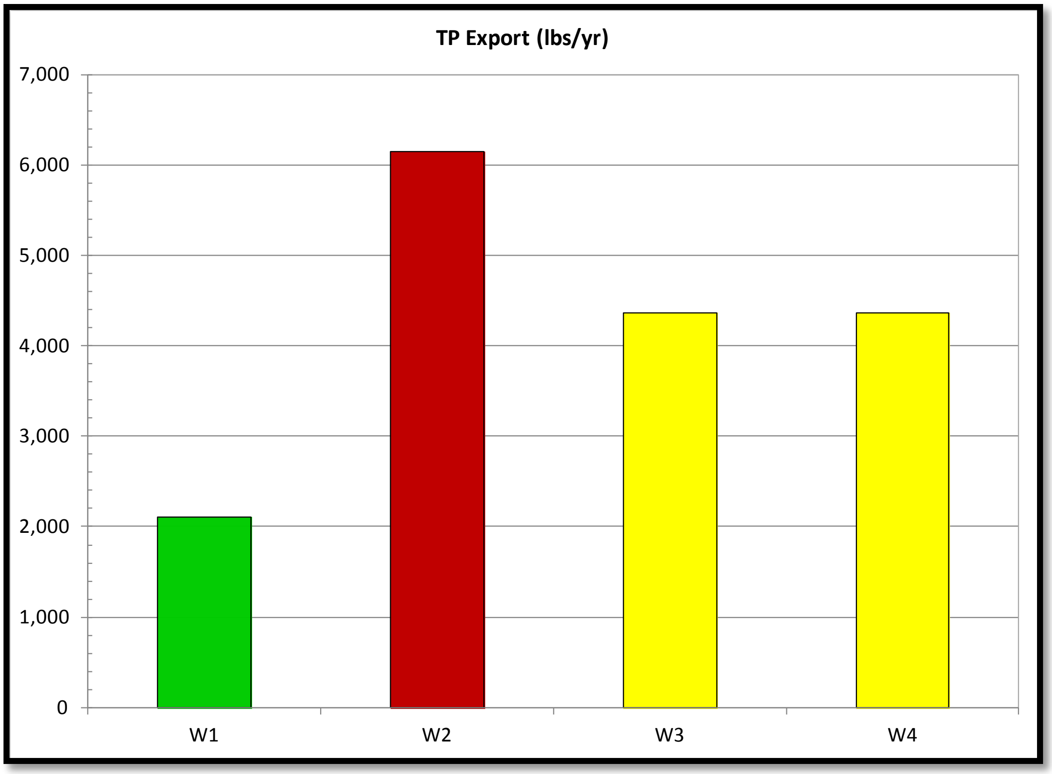
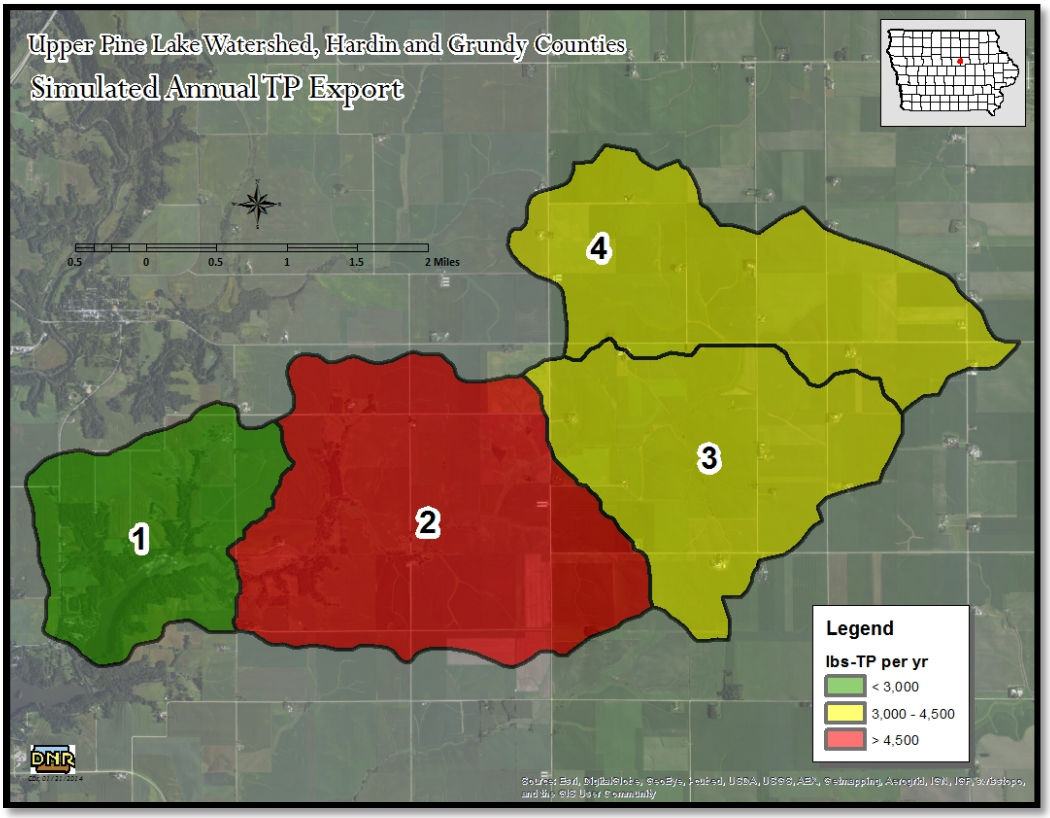


Figure 4-1. Predicted TP export from each STEPL subwatershed.



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 4-2. Subwatershed TP export map.

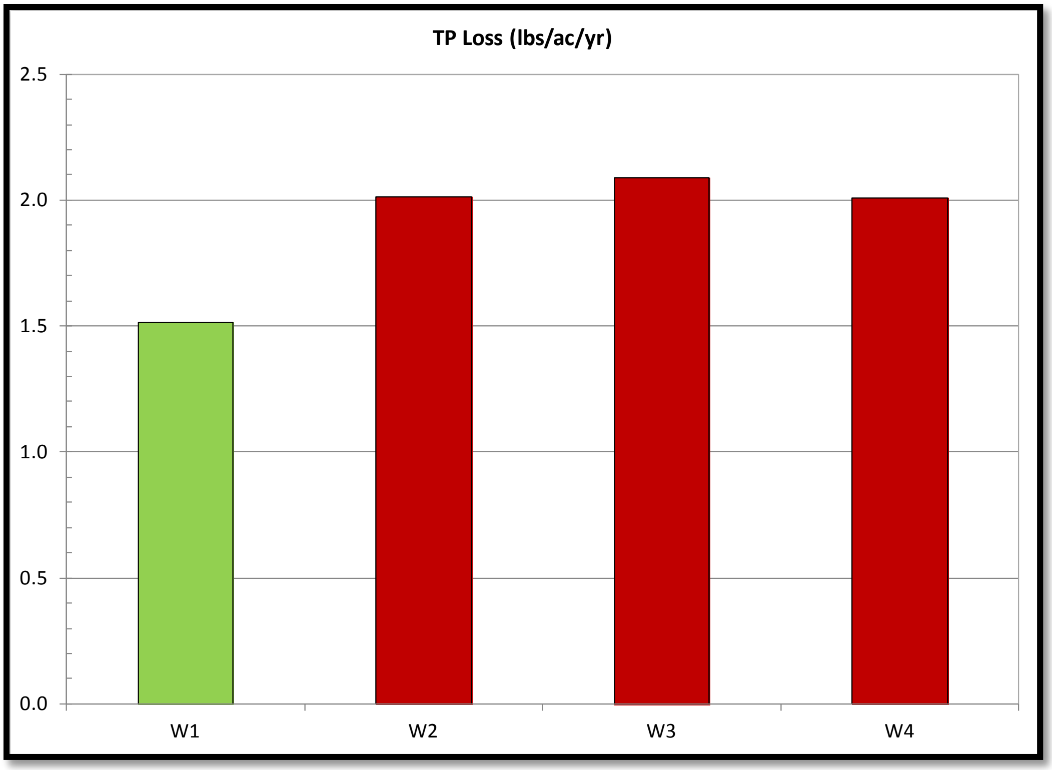
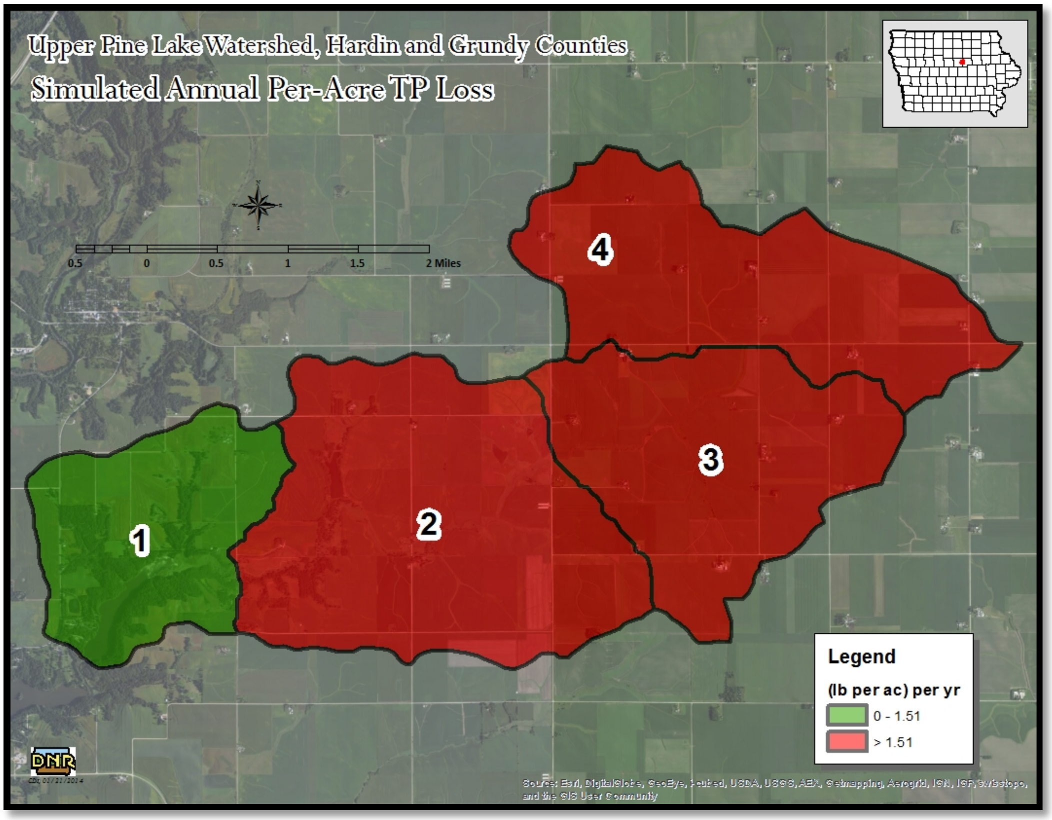


Figure 4-3. Predicted per-acre TP loss for each STEPL subwatershed.



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 4-4. Subwatershed per-acre TP loss map.

Figure 4-5, which illustrates the intersection of highly erodible land (HEL), row crops (corn and soybeans), and estimated manure application areas, may be more useful than subbasin-level analysis for watershed planning. Phosphorus "hot spots" are most likely found where these three features overlap, since erosion rates are higher in HEL, and land that receives regular manure application is often high in soil phosphorus.

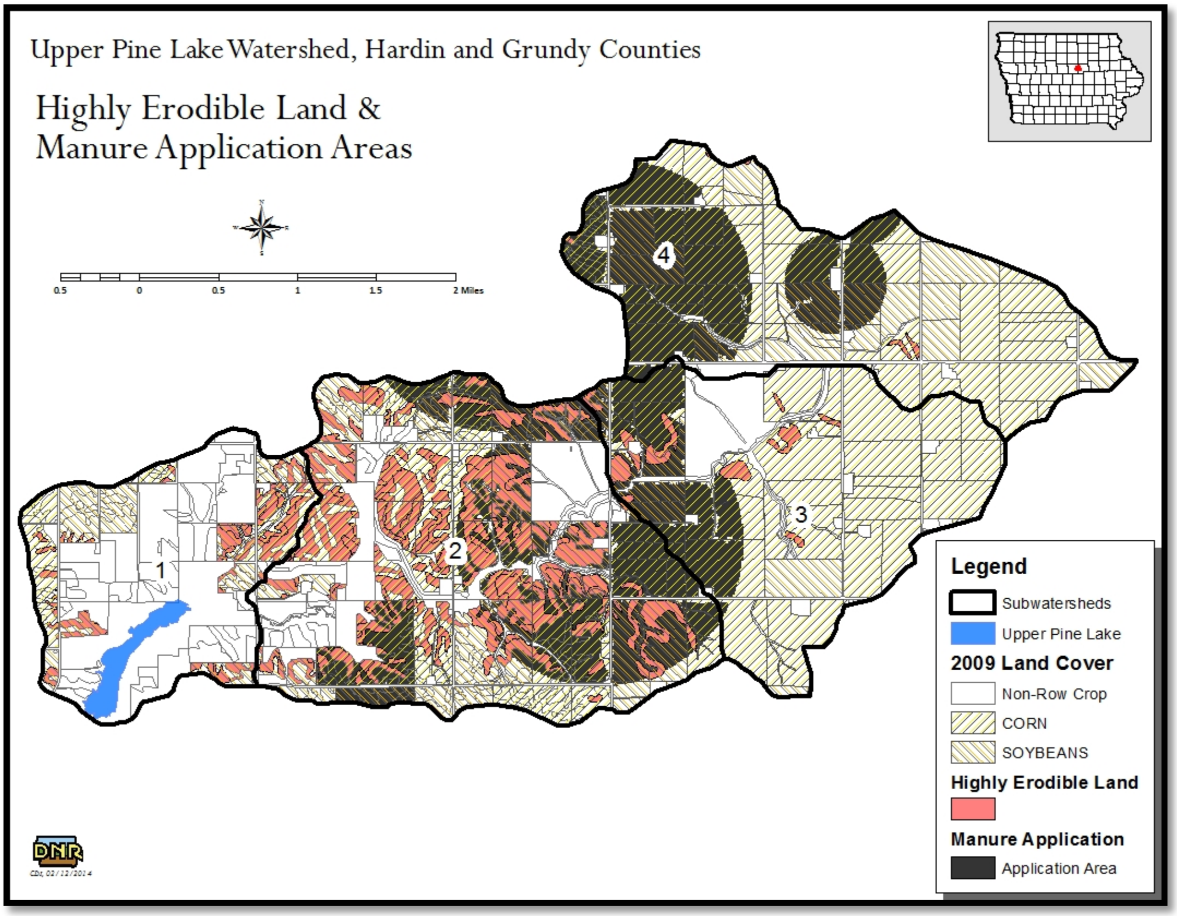


Figure 4-5. Map of highly erodible land and manure application areas.

The existing sediment load to the lake predicted using STEPL is 6,273 tons/year. This includes sheet and rill erosion as well as streambank erosion, and reflects the sediment delivery ratio for each subwatershed. The per-acre delivered sediment load is 0.7 tons/acre. Approximately 2.7 pounds of total phosphorus per ton of sediment is delivered to the lake; however, this number includes dissolved phosphorus as well as attached forms. Some BMPs are designed to prevent or eliminate erosion, but may not address dissolved phosphorus. BMPs should be targeted in a way that ensures that the removal mechanism of the BMP is appropriate to the form of phosphorus (dissolved vs. attached to sediment) and transport pathway (runoff vs. subsurface flow vs. direct deposition, etc.).

More detailed information should be collected in order to target specific BMPs to specific areas (e.g., fields or pastures) within a subwatershed. This level of detailed targeting is best accomplished by local officials working collaboratively with local stakeholders and land owners.

In-Lake BMPs (Remediation Strategies)

Phosphorus recycled between the bottom sediment and water column of the lake is, at times, an important contributor of bioavailable phosphorus to lakes. The average annual contribution of TP to the system from internal loading appears to be relatively small in Upper Pine Lake. The reservoir has a very large watershed-to-lake ratio, so external inputs typically dwarf internal recycling. However, internal loading may influence in-lake water under certain conditions despite its relatively insignificant average annual phosphorus contribution. Internal loads may exacerbate algal blooms in late summer periods, especially if lake outflow ceases and water temperatures exceed normal levels. It is important to understand that external phosphorus loads from wet weather supply the build-up of phosphorus in the bottom sediments. Estimates of external loads from the Upper Pine Lake watershed are of large enough magnitude to fully explain observed in-lake chlorophyll-a levels. Even in lakes with high suspected internal loads, uncertainty regarding the magnitude of internal loads is one of the biggest challenges to TMDL development and lake restoration. Because of these factors, reductions from watershed sources of TP should be given implementation priority. If and when monitoring shows that the external watershed load has been adequately reduced, then additional in-lake measures may be warranted.

Brief descriptions of potential in-lake restoration methods are included in Table 4-3. Phosphorus reduction percentages of each alternative will vary and depend on a number of site-specific factors. It is virtually impossible to determine how much of the internal load is due to each of the contributing factors, and equally difficult to predict phosphorus reductions associated with individual improvement strategies. In-lake measures should be a part of a comprehensive watershed management plan that includes watershed practices in order to enhance, prolong, and protect the effectiveness of in-lake investments.

Table 4-3. Potential in-lake BMPs for water quality improvement.

In-Lake BMPs	Comments
Fisheries management	Low to moderate reductions in internal phosphorus load may be attained via fisheries improvement, though the annual average internal load in Upper Pine Lake appears to be relatively small. The reduction of in-lake phosphorus as a result of this practice is uncertain, but the overall health of the aquatic ecosystem may be improved, which typically improves overall water quality as well.
Targeted dredging and sediment forebay improvement	Targeted dredging in shallow inlet areas would create pockets of deep-water habitat for predatory fish that would help control rough fish populations. Strategic dredging would also increase the sediment capacity of the inlet areas, thereby reducing sediment and phosphorus loads to the larger, open water area of the lake. Sediment and phosphorus capture in the inlet forebay at the NE corner of the reservoir could be enhanced by constructing submerged berms and/or jetties to create additional sediment deposition areas and increased residence time of the forebay.
Shoreline stabilization	Helps establish and sustain vegetation, which provides local erosion protection and competes with algae for nutrients. Impacts of individual projects may be small, but cumulative effects of widespread stabilization projects can help improve water quality. The entire shoreline of Upper Pine Lake is publicly owned, making this alternative possible in all areas of the lake. However, this alternative is costly, and water quality benefits alone may not fully justify the investment.

5. Future Monitoring

Water quality monitoring is critical for assessing the current status of water resources as well as historical and future trends. Furthermore, monitoring is necessary to track the effectiveness of best management practice (BMP) implementation and to document attainment of total maximum daily loads (TMDLs) and progress towards water quality standards (WQS).

Future monitoring in the Upper Pine Lake watershed can be agency-led, volunteer-based, or both. The Iowa Department of Natural Resources (DNR) Watershed Monitoring and Assessment Section administers a water quality monitoring program, called IOWATER, that provides training to interested volunteers. More information can be found at the program web site:
http://www.iowadnr.gov/Environment/WaterQuality/WaterMonitoring/IOWATER.aspx

Volunteer-based monitoring efforts should include an approved water quality monitoring plan, called a Quality Assurance Project Plan (QAPP), in accordance with Iowa Administrative Code (IAC) 567-61.10(455B) through 567-61.13(455B). The IAC can be viewed
here: http://search.legis.state.ia.us/NXT/gateway.dll/ar/iac/5670___environmental%20protection%20commission%20__5b567__5d/0610___chapter%2061%20water%20quality%20standards/_c_5670_0610.xml?f=templates$fn=default.htm.

Failure to prepare an approved QAPP will prevent data collected from being used to evaluate waterbody in the 305(b) Integrated Report – the biannual assessment of water quality in the state, and the 303(d) list – the list that identifies impaired waterbodies.

5.1. Routine Monitoring for Water Quality Assessment

Data collection in Upper Pine Lake to assess water quality trends and compliance with water quality standards (WQS) will include monitoring conducted as part of the DNR Ambient Lake Monitoring Program. This is the same source of data used to develop the TMDL. The Ambient Lake Monitoring Program was initiated in 2000 in order to better assess the water quality of Iowa lakes. Currently, 138 of Iowa's lakes are being sampled as part of this program, including Upper Pine Lake. Typically, one location near the deepest part of the lake is sampled, and many chemical, physical, and biological parameters are measured.

Sampling parameters are reported in Table 5-1. At least three sampling events are scheduled every summer, typically between Memorial Day and Labor Day. While the ambient monitoring program can be used to identify trends in overall, in-lake water quality, it does not lend itself to calculation of watershed loads, identification of individual pollutant sources, or the evaluation of BMP implementation.

Table 5-1. Ambient Lake Monitoring Program water quality parameters.

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

5.2. Expanded Monitoring for Detailed Analysis

If the goal of monitoring is to evaluate spatial and temporal trends and differences in water quality resulting from implementation of BMPs, a more intensive monitoring program will be needed. Table 5-2 outlines potential locations, type of monitoring, parameters collected, and the purpose of each type of data collected as part of an expanded monitoring effort. It is unlikely that available funding will allow collection of all data included in Table 5-2, but the information should be used to help stakeholders identify and prioritize data needs.

Table 5-2. Expanded monitoring plan.

[1]Location	Type	Parameters	Purpose
In-Lake	Monthly or semi-monthly grab samples	Ambient program parameters (Table 5-1)	Detect in-lake WQ trends.
	Continuous data loggers	Temperature, DO, pH, and chl-a	Assist model calibration; evaluate diffusion/dispersion.
Tributary	Runoff events with automated samplers	Flow, sediment, P, and N	Model calibration and pollutant load calculations.
	Monthly or semi-monthly grab samples	Flow, sediment, P, and N	Detect changes in baseflow concentrations and track trends over time.
	[2]Depth-integrated sediment sampling	[2]Depth-integrated sediment sampling	Reveals sediment and phosphorus transport characteristics and correlations between TSS and actual sediment. May be necessary for accurate sediment and TP load calculation
Edge of Field	Runoff events with automated samplers	Flow, sediment, P, and N	Calculate pollutant loads and improvement after BMP implementation; especially useful in a paired field/catchment study.

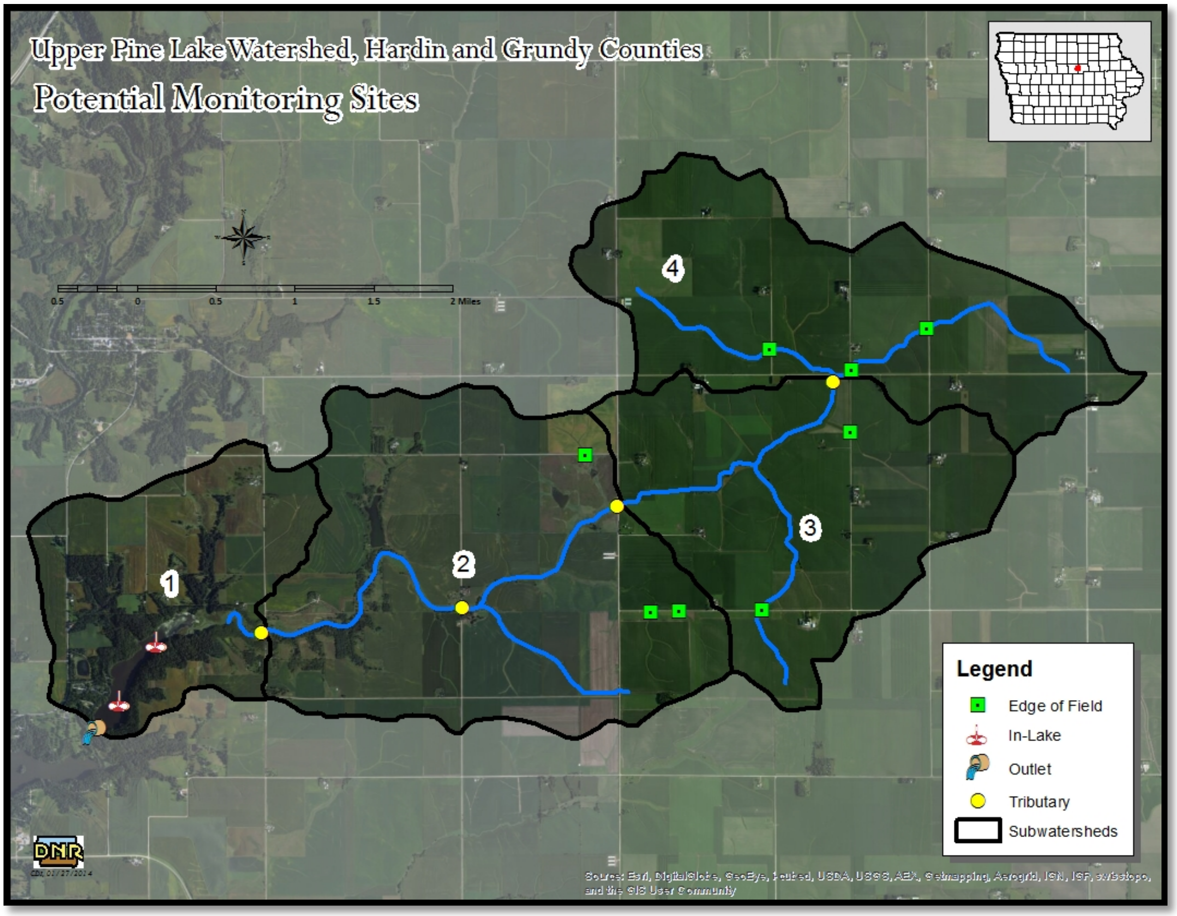


Figure 5-1. Potential monitoring locations.

This expanded monitoring information would improve statistical analysis for evaluating changes and/or trends in water quality over time. Additionally, more detailed data could be used to improve/develop watershed and water quality models for simulation of implementation scenarios and prediction of water quality response. Monitoring parameters and locations should be continually evaluated. Adjustment of parameters and/or locations should be based on BMP placement, newly discovered or suspected pollution sources, and other dynamic factors. The DNR Watershed Improvement Section can provide technical support to locally led efforts in collecting further water quality and flow monitoring data in the Upper Pine Lake watershed.

6. Public Participation

Public involvement is important in the Total Maximum Daily Load (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 Upper Pine Lake.

6.1. Public Meeting

March 6 2014
A public meeting to present the results of the TMDL study, obtain stakeholder input, and discuss next steps for community-based watershed planning was held in the City Council Chambers at the Eldora City Hall from 6:00 to 7:30 pm on Thursday, March 6, 2014. Attendees included DNR State Park officials, the City Manager (Eldora), landowners and tenant farmers within the watershed, environmental advocates, and private citizens that enjoy recreational activities in and around the lake. Approximately 20 individuals were in attendance.

6.2. Written Comments

The public comment period began April 20th and ended March 24th, 2014. One public comment was received during the public comment period, and it is included in Appendix I of this document, along with an official response from DNR.

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8. Appendices

Appendix A --- Glossary of Terms, Abbreviations, and Acronyms

303(d) list:	Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface waterbodies (creeks, rivers, wetlands, and lakes) that do not support their general and/or designated uses. Also called the state's "Impaired Waters List."
305(b) assessment:	Refers to section 305(b) of the Federal Clean Water Act, it is a comprehensive assessment of the state's public waterbodies' ability to support their general and designated uses. Those bodies of water which are found to be not supporting or only 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 lot, yard, corral, building, or other area in which animals are confined and fed and maintained for 45 days or more in any 12-month period, and all structures used for the storage of manure from animals in the operation. Open feedlots and confinement feeding operations are considered to be separate animal feeding operations.
AU:	Animal Unit. A unit of measure used to compare manure production between animal types or varying sizes of the same animal. For example, one 1,000 pound steer constitutes one AU, while one mature hog weighing 200 pounds constitutes 0.4 AU.
Benthic:	Associated with or located at the bottom (in this context, "bottom" refers to the bottom of streams, lakes, or wetlands). Usually refers to algae or other aquatic organisms that reside at the bottom of a wetland, lake, or stream (see periphyton).
Benthic macroinvertebrates:	Animals larger than 0.5 mm that do not have backbones. These animals live on rocks, logs, sediment, debris and aquatic plants during some period in their life. They include crayfish, mussels, snails, aquatic worms, and the immature forms of aquatic insects such as stonefly and mayfly nymphs.

Base flow:	Sustained flow of a stream in the absence of direct runoff. It can include natural and human-induced stream flows. Natural base flow is sustained largely by groundwater discharges.
Biological impairment:	A stream segment is classified as biologically impaired if one or more of the following occurs, the FIBI and or BMIBI scores fall below biological reference conditions, a fish kill has occurred on the segment, or the segment has seen a > 50% reduction in mussel species.
Biological reference condition:	Biological reference sites represent the least disturbed (i.e. most natural) streams in the ecoregion. The biological data from these sites are used to derive least impacted BMIBI and FIBI scores for each ecoregion. These scores are used to develop Biological Impairment Criteria (BIC) scores for each ecoregion. The BIC is used to determine the impairment status for other stream segments within an ecoregion.
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:	Concentrated Animal Feeding Operation. A federal term defined as any animal feeding operation (AFO) with more than 1,000 animal units confined on site, or an AFO of any size that discharges pollutants (e.g. manure, wastewater) into any ditch, stream, or other water conveyance system, whether man-made or natural.
CBOD5:	5-day Carbonaceous Biochemical Oxygen Demand. Measures the amount of oxygen used by microorganisms to oxidize hydrocarbons in a sample of water at a temperature of 20°C and over an elapsed period of five days in the dark.
CFU:	A Colony Forming Unit is a cell or cluster of cells capable of multiplying to form a colony of cells. Used as a unit of bacteria concentration when a traditional membrane filter method of

	analysis is used. Though not necessarily equivalent to most probably number (MPN), the two terms are often used interchangeably.
Confinement feeding operation:	An animal feeding operation (AFO) in which animals are confined to areas which are totally roofed.
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. To be considered "credible," data must be collected and analyzed using methods and protocols outlined in an approved Quality Assurance Project Plan (QAPP).
Cyanobacteria (blue-green algae):	Members of the phytoplankton community that are not true algae but are capable of photosynthesis. Some species produce toxic substances that can be harmful to humans and pets.
Designated use(s):	Refer to the type of economic, social, or ecological activities that a specific waterbody is intended to support. See Appendix B for a description of all general and designated uses.
DNR:	Iowa Department of Natural Resources.
Ecoregion:	Areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources based on geology, vegetation, climate, soils, land use, wildlife, and hydrology.
EPA (or USEPA):	United States Environmental Protection Agency.
Ephemeral gully erosion:	Ephemeral gullies occur where runoff from adjacent slopes forms concentrated flow in drainage ways. Ephemerals are void of vegetation and occur in the same location every year. They are crossable with farm equipment and are often partially filled in by tillage.
FIBI:	Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.
FSA:	Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.
General use(s):	Refer to narrative water quality criteria that all public waterbodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated

uses.

Geometric Mean (GM):	A statistic that is a type of mean or average (different from arithmetic mean or average) that measures central tendency of data. It is often used to summarize highly skewed data or data with extreme values such as wastewater discharges and bacteria concentrations in surface waters. In Iowa's water quality standards and assessment procedures, the geometric mean criterion for *E. coli* is measured using at least five samples collected over a 30-day period.
GIS:	Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.
Groundwater:	Subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.
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.
IDALS:	Iowa Department of Agriculture and Land Stewardship
Integrated report:	Refers to a comprehensive document that combines the 305(b) assessment with the 303(d) list, as well as narratives and discussion of overall water quality trends in the state's public waterbodies. The Iowa Department of Natural Resources submits an integrated report to the EPA biennially in even numbered years.
LA:	Load Allocation. The portion of the loading capacity attributed to (1) the existing or future nonpoint sources of pollution and (2) natural background sources. Wherever possible, nonpoint source loads and natural loads should be distinguished. (The total pollutant load is the sum of the wasteload and load allocations.)
LiDAR:	Light Detection and Ranging. Remote sensing technology that uses laser scanning to collect height or elevation data for the earth's surface.

Load:	The total amount of pollutants entering a waterbody from one or multiple sources, measured as a rate, as in weight per unit time or per unit area.
Macrophyte:	An aquatic plant that is large enough to be seen with the naked eye and grows either in or near water. It can be floating, completely submerged (underwater), or partially submerged.
MOS:	Margin of Safety. A required component of the TMDL that accounts for the uncertainty in the response of the water quality of a waterbody to pollutant loads.
MPN:	Most Probable Number. Used as a unit of bacteria concentration when a more rapid method of analysis (such as Colisure or Colilert) is utilized. Though not necessarily equivalent to colony forming units (CFU), the two terms are often used interchangeably.
MS4:	Municipal Separate Storm Sewer System. A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) owned and operated by a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to state law) having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under state law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act (CWA) that discharges to waters of the United States.
Nonpoint source pollution:	Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related either to land or water use including failing septic tanks, improper animal-keeping practices, forestry practices, and urban and rural runoff.
NPDES:	National Pollution Discharge Elimination System. The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under Section 307, 402, 318, and 405 of the Clean Water Act. Facilities subjected to

	NPDES permitting regulations include operations such as municipal wastewater treatment plants and industrial waste treatment facilities, as well as some MS4s.
NRCS:	Natural Resources Conservation Service (United States Department of Agriculture). Federal agency that provides technical assistance for the conservation and enhancement of natural resources.
Open feedlot:	An unroofed or partially roofed animal feeding operation (AFO) in which no crop, vegetation, or forage growth or residue cover is maintained during the period that animals are confined in the operation.
Periphyton:	Algae that are attached to substrates (rocks, sediment, wood, and other living organisms). Are often located at the bottom of a wetland, lake, or stream.
Phytoplankton:	Collective term for all photosynthetic organisms suspended in the water column. Includes many types of algae and cyanobacteria.
Point source pollution:	Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources are generally regulated by a federal NPDES permit.
Pollutant:	As defined in Clean Water Act section 502(6), a pollutant means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.
Pollution:	The man-made or man-induced alteration of the chemical, physical, biological, and/or radiological integrity of water.
PPB:	Parts per Billion. A measure of concentration that is the same as micrograms per liter (µg/L).
PPM:	Parts per Million. A measure of concentration that is the same as milligrams per liter (mg/L).
RASCAL:	Rapid Assessment of Stream Conditions Along Length. RASCAL is a global positioning system (GPS) based assessment procedure designed to provide continuous stream and riparian condition data at a watershed scale.

Riparian:	Refers to areas near the banks of natural courses of water. Features of riparian areas include specific physical, chemical, and biological characteristics that differ from upland (dry) sites. Usually refers to the area near a bank of a stream or river.
RUSLE:	Revised Universal Soil Loss Equation. An empirical model for estimating long term, average annual soil losses due to sheet and rill erosion.
Scientific notation:	See explanation on page 107.
Secchi disk:	A device used to measure transparency in waterbodies. The greater the Secchi depth (typically 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 that is delivered to the waterbody of concern.
Seston:	All particulate matter (organic and inorganic) suspended in the water column.
SHL:	State Hygienic Laboratory (University of Iowa). Provides physical, biological, and chemical sampling for water quality purposes in support of beach monitoring, ambient monitoring, biological reference monitoring, and impaired water assessments.
Sheet & rill erosion:	Sheet and rill erosion is the detachment and removal of soil from the land surface by raindrop impact, and/or overland runoff. It occurs on slopes with overland flow and where runoff is not concentrated.
Single-Sample Maximum (SSM):	A water quality standard criterion used to quantify *E. coli* levels. The single-sample maximum is the maximum allowable concentration measured at a specific point in time in a waterbody.
SI:	Stressor Identification. A process by which the specific cause(s) of a biological impairment to a waterbody can be determined from cause-and-effect relationships.
Storm flow (or stormwater):	The discharge (flow) from surface runoff generated by a precipitation event. *Stormwater* generally refers to runoff that is routed through some artificial channel or structure, often in urban

areas.

STP:	Sewage Treatment Plant. General term for a facility that treats municipal sewage prior to discharge to a waterbody according to the conditions of an NPDES permit.
SWCD:	Soil and Water Conservation District. Agency that provides local assistance for soil conservation and water quality project implementation, with support from the Iowa Department of Agriculture and Land Stewardship.
TDS:	Total Dissolved Solids: The quantitative measure of matter (organic and inorganic material) dissolved, rather than suspended, in the water column. TDS is analyzed in a laboratory and quantifies the material passing through a filter and dried at 180 degrees Celsius.
TMDL:	Total Maximum Daily Load. As required by the Federal Clean Water Act, a comprehensive analysis and quantification of the maximum amount of a particular pollutant that a waterbody can tolerate while still meeting its general and designated uses. A TMDL is mathematically defined as the sum of all individual wasteload allocations (WLAs), load allocations (LAs), and a margin of safety (MOS).
Trophic state:	The level of ecosystem productivity, typically measured in terms of algal biomass.
TSI (or Carlson's TSI):	Trophic State Index. A standardized scoring system developed by Carlson (1977) that places trophic state on an exponential scale of Secchi depth, chlorophyll, and total phosphorus. TSI ranges between 0 and 100, with 10 scale units representing a doubling of algal biomass.
TSS:	Total Suspended Solids. The quantitative measure of matter (organic and inorganic material) suspended, rather than dissolved, in the water column. TSS is analyzed in a laboratory and quantifies the material retained by a filter and dried at 103 to 105 degrees Celsius.
Turbidity:	A term used to indicate water transparency (or lack thereof). Turbidity is the degree to which light is scattered or absorbed by a fluid. In practical terms, highly turbid waters have a high degree of cloudiness or murkiness caused by suspended particles.

UAA:	Use Attainability Analysis. A protocol used to determine which (if any) designated uses apply to a particular waterbody. (See Appendix B for a description of all general and designated uses.)
USDA:	United States Department of Agriculture
USGS:	United States Geologic Survey (United States Department of the Interior). Federal agency responsible for implementation and maintenance of discharge (flow) gauging stations on the nation's waterbodies.
Watershed:	The land area that drains water (usually surface water) to a particular waterbody or outlet.
WLA:	Wasteload Allocation. The portion of a receiving waterbody's loading capacity that is allocated to one of its existing or future point sources of pollution (e.g., permitted waste treatment facilities).
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.
WWTF:	Wastewater Treatment Facility. General term for a facility that treats municipal, industrial, or agricultural wastewater for discharge to public waters according to the conditions of the facility's NPDES permit. Used interchangeably with wastewater treatment plant (WWTP).
Zooplankton:	Collective term for all animal plankton suspended in the water column which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

Scientific Notation

Scientific notation is the way that scientists easily handle very large numbers or very small numbers. For example, instead of writing 45,000,000,000 we write 4.5E+10. So, how does this work?

We can think of 4.5E+10 as the product of two numbers: 4.5 (the digit term) and E+10 (the exponential term).

Here are some examples of scientific notation.

10,000 = 1E+4	24,327 = 2.4327E+4
1,000 = 1E+3	7,354 = 7.354E+3
100 = 1E+2	482 = 4.82E+2
1/100 = 0.01 = 1E-2	0.053 = 5.3E-2
1/1,000 = 0.001 = 1E-3	0.0078 = 7.8E-3
1/10,000 = 0.0001 = 1E-4	0.00044 = 4.4E-4

As you can see, the exponent is the number of places the decimal point must be shifted to give the number in long form. A **positive** exponent shows that the decimal point is shifted that number of places to the right. A **negative** exponent shows that the decimal point is shifted that number of places to the left.

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

Introduction

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

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

General Use Segments

A general use segment waterbody is one that 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 that consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use waterbody, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

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

Designated Use Segments

Designated use segments are waterbodies that maintain flow throughout the year, or at least hold pools of water that 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 thirteen different designated use classes (Table B-1) that may apply, and a waterbody may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

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

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

Designated use classes are determined based on a Use Attainability Analysis, or UAA. This is a procedure in which the waterbody 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 waterbody are allowed for. Changes to a waterbody'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 waterbodies should receive the highest degree of protection applicable until a UAA could be performed to ensure that a particular waterbody 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 --- Water Quality Data

The following is a summary of the sampling data from the Iowa State University (ISU) Iowa Lakes Information System and University of Iowa State Hygienic Laboratory (SHL) monitoring efforts.

C.1. Individual Sample Results

Table C-1. ISU and SHL water quality sampling data ([1]ambient location).

Source	DATE	Secchi (m)	Chl-a (µg/L)	TP (µg/L)	Ortho-P (µg/L)	TN (mg/L)	ISS (mg/L)	TSS (mg/L)
ISU	6/4/2001	1.1		58.6	*	15.4	6.30	9.60
ISU	7/9/2001	3.0	6.3	46.2	*	12.4	1.10	2.50
ISU	8/6/2001	1.0	50.6	93.4	*	6.5	*	6.43
ISU	6/10/2002	2.3	15.1	30.7	2.0	7.7	5.67	10.67
ISU	7/15/2002	0.6	102.3	91.7	0.5	5.0	2.20	8.40
ISU	8/12/2002	0.4	96.7	97.1	1.7	1.6	5.45	21.82
ISU	6/9/2003	2.3	12.2	37.6	1.7	12.8	6.00	10.00
ISU	7/15/2003	1.5	22.4	95.4	1.9	10.4	5.80	11.80
ISU	8/11/2003	0.6	30.0	76.8	1.4	7.9	3.50	15.00
ISU	6/7/2004	1.1	84.8	49.6	0.5	2.2	8.00	15.40
ISU	7/12/2004	3.5	11.5	24.0	0.5	9.0	*	*
ISU	8/9/2004	0.9	49.3	101.2	4.0	5.8	0.50	5.23
UHL	5/25/2005	1.6	51.0	70.0	10.0	12.1	9.00	14.00
ISU	6/13/2005	1.9	28.7	24.1	0.5	10.4	4.60	7.80
ISU	7/18/2005	1.8	35.7	46.1	*	11.0	1.86	6.43
UHL	7/19/2005	1.6	14.0	60.0	10.0	10.8	2.00	6.00
ISU	8/8/2005	0.9	88.2	90.8	*	5.8	1.33	10.67
UHL	9/20/2005	0.5	63.0	140.0	20.0	1.5	4.00	11.00
UHL	5/22/2006	1.2	35.0	60.0	10.0	10.2	4.00	9.00
ISU	6/12/2006	0.5	45.7	96.1	1.3	7.3	10.40	18.60
UHL	6/20/2006	0.9	35.0	70.0	10.0	5.9	2.00	6.00
ISU	7/17/2006	0.6	30.6	136.6	*	3.5	3.00	9.67
UHL	7/25/2006	0.7	59.0	120.0	10.0	2.6	4.00	12.00
ISU	8/15/2006	0.4	91.1	161.9	1.1	2.7	6.50	18.50
UHL	9/5/2006	0.4	160.0	250.0	10.0	2.7	7.00	28.00
UHL	10/9/2006	0.5	43.0	80.0	20.0	9.4	5.00	12.00
UHL	5/16/2007	0.8	110.0	100.0	20.0	13.3	3.00	11.00
ISU	6/12/2007	0.8	33.2	68.4	2.5	13.2	4.00	10.80
ISU	7/17/2007	0.9	23.7	85.9	2.5	10.0	2.00	9.00
UHL	7/19/2007	0.9	81.0	110.0	10.0	9.9	2.00	10.00
ISU	8/8/2007	0.8	14.0	90.1	20.9	6.3	6.80	11.00
UHL	9/6/2007	0.8	39.0	80.0	10.0	8.2	4.00	8.00
UHL	5/22/2008	1.0	160.0	100.0	10.0	9.8	8.00	19.00
UHL	7/16/2008	1.8	4.0	40.0	10.0	8.5	2.00	6.00

Continued on next page

Source	DATE	Secchi (m)	Chl-a (µg/L)	TP (µg/L)	Ortho-P (µg/L)	TN (mg/L)	ISS (mg/L)	TSS (mg/L)
ISU	6/25/2009	2.4	10.0	38.0	4.5	9.2	2.00	2.50
ISU	7/30/2009	1.0	17.0	75.6	4.5	6.1	2.00	7.70
ISU	8/20/2009	0.5	123.0	172.0	4.5	2.7	6.70	18.30
UHL	5/5/2010	0.8	73.0	60.0	10.0	7.8	8.00	16.00
UHL	6/1/2010	1.1	33.0	40.0	10.0	9.2	3.00	8.00
ISULL	6/7/2010	1.3	7.9	52.1	4.0	2.8	2.00	5.30
UHL	7/6/2010	0.8	81.0	120.0	10.0	8.3	4.00	14.00
ISULL	7/26/2010	0.5	17.5	362.8	196.1	6.2	2.00	2.50
UHL	8/3/2010	1.1	65.0	130.0	30.0	7.7	3.00	9.00
ISULL	9/10/2010	0.9	17.2	57.8	4.0	7.7	2.00	8.70
UHL	9/17/2010	0.7	61.0	70.0	10.0	4.8	2.00	9.00
ISU	6/6/2011	3.1	6.9	20.4	5.5	9.6	2.50	3.00
ISU	7/25/2011	1.0	49.2	57.4	5.5	5.4	2.50	11.80
ISU	9/6/2011	0.4	113.8	175.9	5.5	2.4	2.50	18.28
ISU	6/4/2012	0.9	36.4	37.4	5.0	5.3	5.39	9.80
ISU	7/23/2012	0.5	73.9	231.7	79.0	1.3	10.00	22.00
ISU	9/5/2012	0.6	46.6	245.1	73.0	1.2	2.00	14.33

[1] Ambient monitoring location = STORET ID 22420002
* Missing data

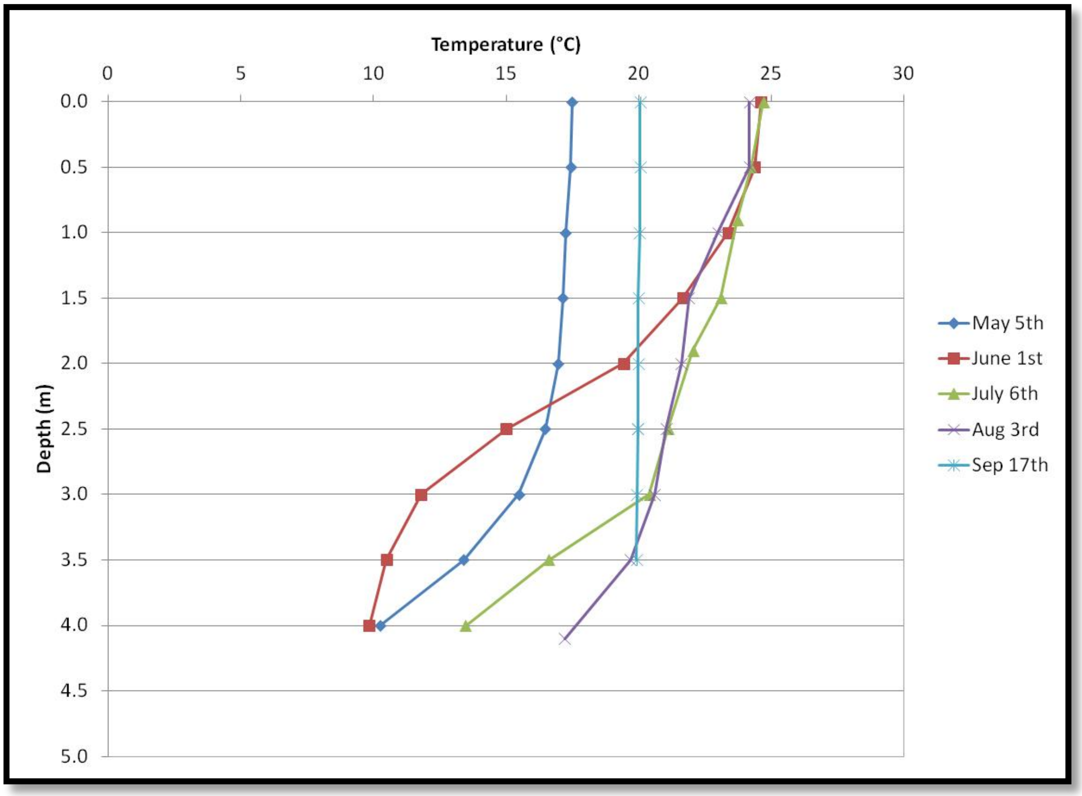
C.2. Annual Mean Data

Table C-2. Precipitation and annual mean TSI values ([1]ambient location).

Date	Annual Precipitation (in)	Apr-Sep Precipitation (in)	Secchi TSI	Chl-a TSI	TP TSI
2001	34.1	25.9	52	63	65
2002	31.7	25.4	59	72	66
2003	31.0	23.5	55	61	65
2004	34.3	23.3	51	69	63
2005	31.8	23.8	56	68	66
2006	35.7	25.1	66	71	73
2007	54.4	39.3	63	69	69
2008	49.4	38.0	55	74	65
2009	47.0	30.4	56	69	70
2010	44.1	36.4	62	68	72
2011	32.0	22.3	54	70	68
2012	22.9	13.7	66	69	78

[1] Ambient monitoring location = STORET 22420002

C.3. Lake Profile Data



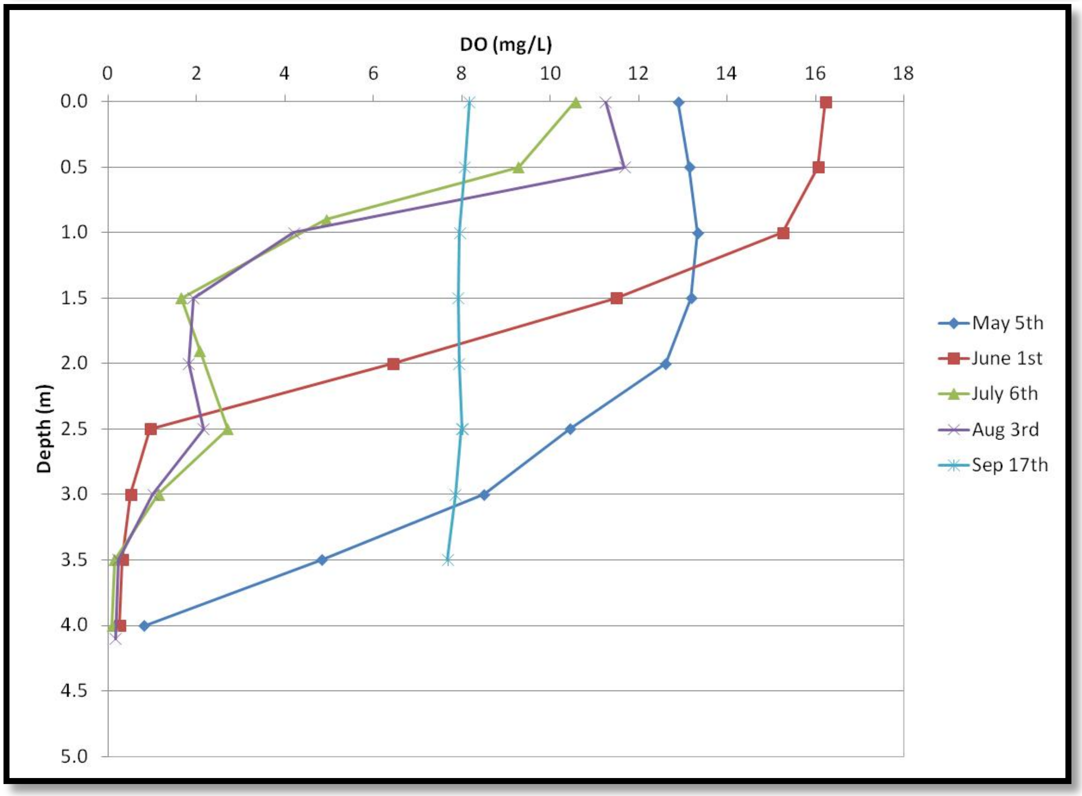


Figure C-1. Temperature and DO profiles (2010).

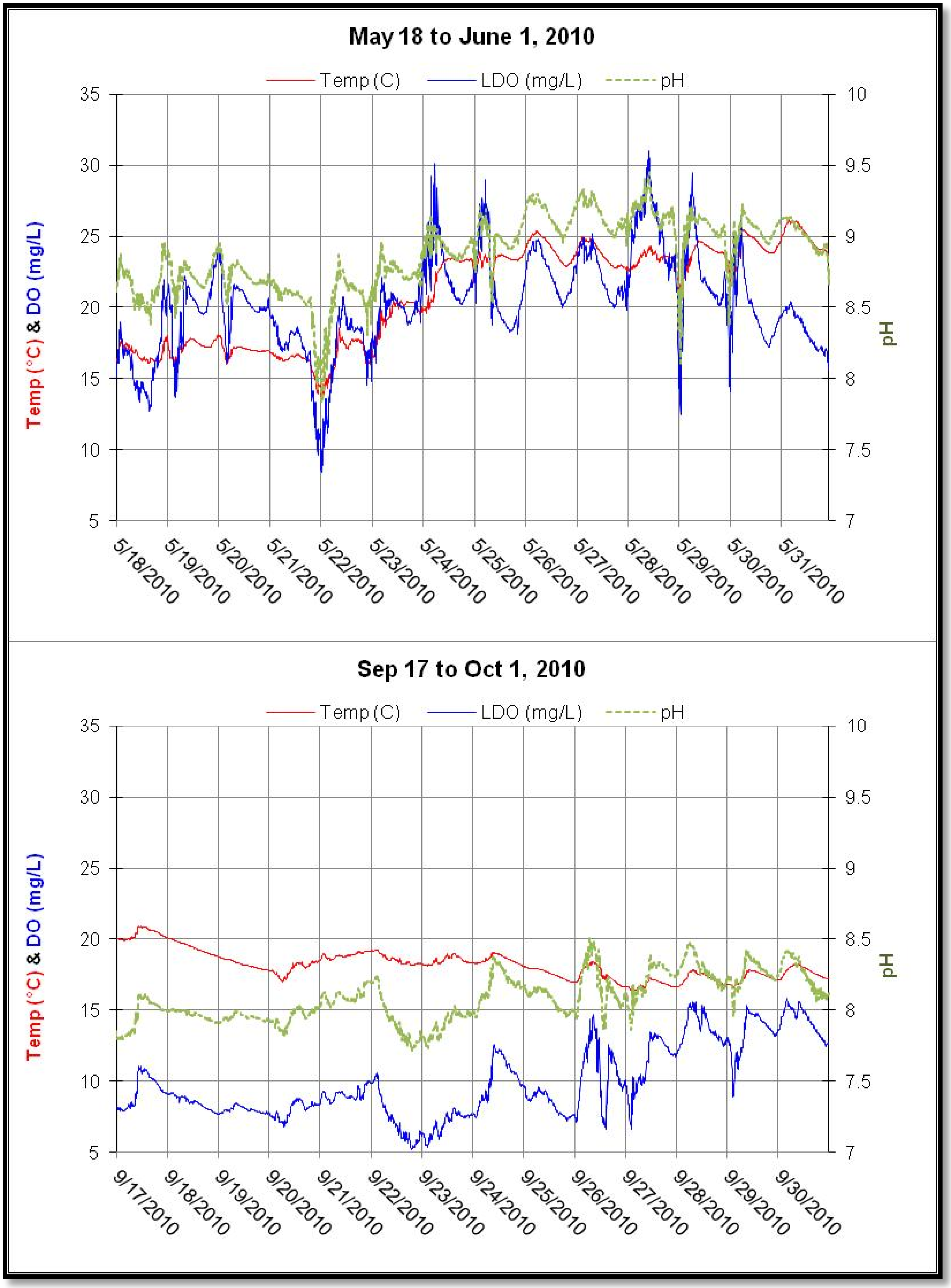


Figure C-2. Continuous temperature, DO, and pH data from 2010 deployments.

Appendix D --- Watershed Model Development

Watershed and in-lake modeling were used in conjunction with analysis of observed water quality data to develop the Total Maximum Daily Load (TMDL) for the algae impairment to Upper Pine Lake in Hardin County, Iowa. This TMDL targets an allowable phosphorus load that will satisfy the algae impairment (see Section 3 of this document for details). Reduction of phosphorus is expected to reduce algal blooms, which decrease water clarity and impair recreational use of the lake. The Spreadsheet Tool for Estimating Pollutant Load (STEPL), version 4.1, was utilized to simulate watershed hydrology and pollutant loading. In-lake water quality simulations were performed using BATHTUB 6.1, an empirical lake and reservoir eutrophication model. The integrated watershed and in-lake modeling approach allows the holistic analysis of hydrology and water quality in Upper Pine Lake and its watershed. This section of the Water Quality Improvement Plan (WQIP) discusses the modeling approach and development of the STEPL watershed and BATHTUB lake models.

D.1. Modeling Approach

Data from a 12-year period of record, 2001-2012, were analyzed and used to develop watershed and lake models for the simulation and prediction of phosphorus loads and in-lake response. Models representing a variety of conditions (e.g., wet, dry) and various years were developed. This process was instructive in understanding watershed and in-lake processes, and in the validation of model inputs and calibration. However, only data from 2006-2010 were utilized in the final calibrated model for development of the numeric TMDL. This simulation period is identical to the water quality assessment period upon which the 2012 Integrated Report and 303(d) list were generated. As such, it best reflects the conditions of the algae impairment.

D.2. STEPL Model Description

STEPL is a watershed-scale hydrology and water quality model developed for the U.S. Environmental Protection Agency (EPA) by Tetra Tech, Incorporated. STEPL is a long-term average annual model used to assess the impacts of land use and best management practices on hydrology and pollutant loads. STEPL is capable of simulating a variety of pollutants, including sediment, nutrients (nitrogen and phosphorus), and 5-day biochemical oxygen demand (BOD5). Required input data is minimal if the use of county-wide soils and coarse precipitation information is acceptable to the user. If available, the user can modify soil and precipitation inputs with higher resolution and local soil and precipitation data. Precipitation inputs include average annual rainfall and rainfall correction factors that describe the intensity (i.e., runoff producing) characteristics of long-term precipitation. Characteristics that affect STEPL estimates of hydrology and pollutant loading include land cover types, population of agricultural livestock, wildlife populations, population served by septic systems, and urban land uses. STEPL also quantifies the impacts of manure application and best management practices (BMPs). Almost all STEPL inputs can be customized if site-specific data is available and more detail is desired.

The watershed was divided into 4 subbasins to help quantify the relative pollutant loads stemming from different areas of the watershed and to assist with targeting potential BMP locations. Hydrology and pollutant loadings are summarized for each subbasin and also aggregated as watershed totals.

D.3. Meteorological Input

Precipitation Data
The STEPL model includes a pre-defined set of weather stations from which the user may obtain precipitation-related model inputs. Unfortunately, none of the NWS COOP stations within a reasonable distance of Upper Pine Lake are included in the STEPL model. Therefore, rainfall data from the NWS COOP station at Eldora, Iowa, was used for modeling purposes. Weather station information and rainfall data were reported in Section 2.1 (see Table 2.2 and Figures 2.2 and 2.3)

Average annual precipitation from 2006-2010 was 46.1 inches/year, well above the 12-year (2001-2012) annual average of 37.4 inches. In 2008, 49.4 inches of rainfall fell at the Eldora station, compared with only 35.7 inches in 2006. The preceding years (2001-2005) were far drier, with an annual average of only 32.6 in/yr.

The STEPL precipitation correlation and rain day correction factors were calculated outside of STEPL and entered directly in the STEPL "Input" worksheet to override the default rainfall data. Precipitation data from the modeling period of 2006-2010 were utilized in parameterization. The rain day correction factor of 0.612 was calculated by dividing the number of days that it rained at least 5mm by the number of days with at least 1 mm of rainfall. This ratio is intended to estimate the number of days that could potentially generate surface runoff. Precipitation inputs are reported in Table D-1, as entered in the "Input" worksheet of the 2006-2010 Upper Pine Lake STEPL model.

Table D-1. STEPL rainfall inputs (2006-2010 average annual data).

Rain correction factors			
[1]0.899	[2]0.612		
[3]Annual Rainfall	**[4]Rain Days**	**[5]Avg. Rain/Event**	**Input Notes/Descriptions**
46.1	90	0.752	[1]The percent of rainfall that exceeds 5 mm per event
			[2]The percent of rain events that generate runoff
			[3]Annual average precipitation from 2006-2010 (in)
			[4]Average days of precipitation per year (days)
			[5]Average precipitation per event (in)

D.4. Watershed Characteristics

Topography
The Upper Pine Lake watershed was delineated into 4 subbasins using ArcGIS (version 10.1) and a 10-meter resolution digital elevation model (DEM) developed by the Iowa Department of Natural Resources (DNR). Figure D-1 illustrates the watershed and subbasin boundaries.

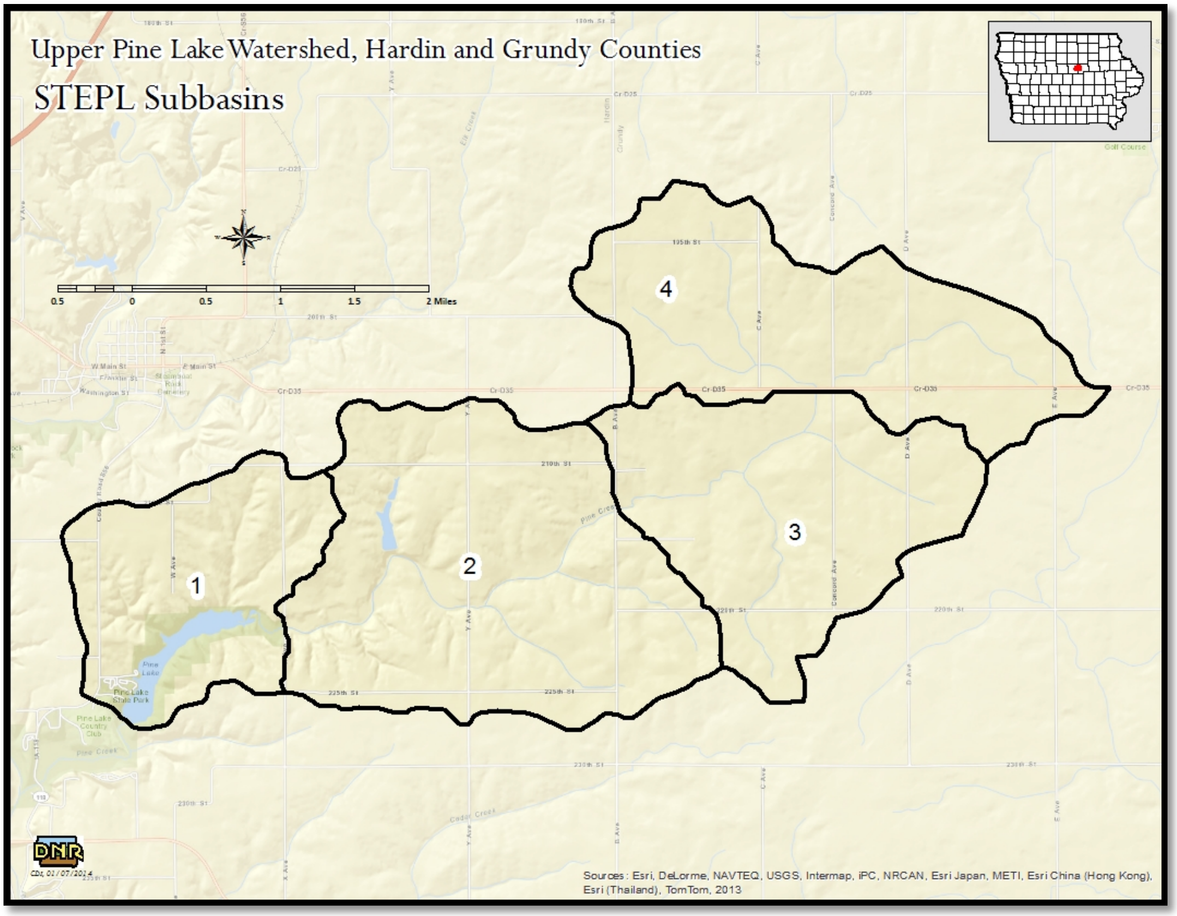


Figure D-1. STEPL subbasin map.

Land Use
A Geographic Information System (GIS) coverage of land use information was developed using the Cropland Data Layer (CDL) for years 2009-2012, which was obtained from the United States Department of Agriculture – National Agricultural Statistics Service (USDA-NASS, 2013). The CDL land cover data is summarized by Common Land Units (CLUs). According to the USDA – Farm Service Agency, CLUs are the smallest units of land that have a permanent, contiguous boundary, common land cover, common owner, and common producer (USDA-FSA, 2013). Cropping decisions can change from year to year and several instances were observed where a single CLU contained multiple land cover types in the same year. In such cases, CLU boundaries were split to incorporate all major land covers into the STEPL model. Because land cover pixels are much smaller than CLU field boundaries, many CLUs have one primary land cover, but small isolated pixels with several minor land cover types. In those cases, the dominant land cover within each CLU boundary was determined using a zonal statistic command within Spatial Analyst. This step served as a land cover "filter" to simplify the data and eliminate small isolated pixels of various land uses within a single field boundary.

STEPL land cover classifications are reported in Table D-2, with land use distribution previously illustrated in the map (Figure 2-5) and pie-chart (Figure 2-6) in Section 2.2.

Table D-2. STEPL land use inputs.

Watershed	[1]Urban	Cropland	[2]Pastureland	Forest	User Defined	Feedlots
W1	72.36	485.42	430.28	400.89	0	0
W2	64.59	2373	449.87	161.84	0	0
W3	85.01	1774.1	231.23	0.07	0	0
W4	116.36	2008.65	47.76	0	0	0
TOTALS						

[1]Urban includes all developed areas, including roads and farmsteads
[2]Pastureland includes pasture and ungrazed grassland.

Each land cover type was assigned a specific USLE C-factor and P-factor (Table D-3), based on regional estimates developed by DNR and Soil and Water Conservation district personnel for watershed assessments performed in the same ecoregion. C- and P-factors were assigned to each CLU using best available data. P-factors for row crop fields ranged from 0.4 to 1, with values of 1 representing no existing erosion practices. C-factors vary widely, from 0.0 for paved roads to 0.26 for row crops with extensive tillage and little plant residue. All USLE parameters were area-weighted and summarized for each subwatershed before input to the STEPL model.

Table D-3. C- and P-factors for each land cover and practice (BMP).

Land Cover Description	C-Factor	Practice	P-Factor
Corn-Soybeans; Conventional-Till	0.260	Terraces	0.6
Corn-Soybeans; Mulch-Till	0.125	Contour Farming	0.7
Corn-Soybeans; No-Till Beans, Mulch-Till Corn	0.080	Contour Buffers	0.7
Corn-Soybeans; No-Till Beans and Corn	0.050	Field Buffers	0.8
Grassland and Pasture	0.008	Ponds/Basins	0.4
Farmstead	0.020		
Timber	0.013		
Road	0.000		

Soils

Soils are discussed in detail in Section 2.2. The hydrologic soil group (HSG) and the USLE K-factor are the critical soil parameters in the STEPL model. Watershed soils are predominantly HSG type B soils, with some D soils near the riparian corridors. HSG values were area-weighted for each subbasin and used to modify curve numbers (CNs) in STEPL. USLE K-factors are also specific to each soil type, and were area-weighted in the same fashion as C- and P-factors and entered into the “Input” worksheet in the STEPL model.

Slopes

Slopes are described in more detail in Section 2.2. USLE land slope (LS) factors were obtained from the SSURGO data and were assigned at the field-scale, then area-weighted to develop land-use specific LS factors for each STEPL subwatershed. Resulting LS-factors in entered into the "Input" worksheet in the STEPL model vary between 0.33 and 1.59.

Curve Numbers

The STEPL model includes default curve numbers (CNs) selected automatically based on HSG and land use. CNs in the Upper Pine Lake STEPL model were manually adjusted by area-weighting HSG values so that differences in soil types are better reflected in CN values. Table D-4 lists the resulting CNs for each land use and subwatershed in the STEPL model.

Table D-4. STEPL curve numbers.

Subwatershed	[1]Urban	Cropland	[2]Pastureland	Forest/Timber
W1	89	78	69	70
W2	90	80	71	70
W3	90	81	72	70
W4	91	82	73	70

[1] Urban includes all developed areas, including roads and farmsteads
[2] Pastureland includes pasture and ungrazed grassland.

Sediment Delivery Ratio

The sediment load to the lake is smaller than total sheet and rill erosion because some of the eroded material is deposited in depressions, ditches, or streams before it reaches the watershed outlet (i.e., the lake). The sediment delivery ratio (SDR) is the portion of sheet and rill erosion that is transported to the watershed outlet. STEPL calculates the SDR for each subbasin using a simple empirical formula based on drainage area (i.e., subbasin area). The resulting SDR values range from 0.21 (Subbasin 2) to 0.25 (Subbasins 1).

D.5. Animals

Agricultural Animals and Manure Application

The STEPL model utilizes livestock population data and the duration (in months) that manure is applied to account for nutrient loading from livestock manure application. There are an estimated 9,960 swine from which liquid swine manure is applied to row crops in the Upper Line Lake watershed. Livestock confinements are not allowed to discharge manure, therefore the WLA is zero. However, liquid swine manure from a portion of these animals is applied to row crops in the watershed. Application areas were determined based on the number of swine in each facility, and the number of acres needed for agronomic application rates. Manure application is expected to occur over the course of 4 weeks (1 month total) in the spring and fall. However, as an annual average loading model, STEPL does not separate application times.

Livestock Grazing

There are no significant cattle grazing operations in the Upper Pine Lake watershed. Most of the grassland is ungrazed, with the few exceptions being small, isolated areas adjacent to the stream corridor. Erosion and nutrient loss from all grasslands are associated with the pasture landuse in the STEPL model, which likely results in an over-estimate of TP loads from this source. Erosion from pasture (and other grassland that may be in poor condition) carries sediment-bound phosphorus, which is accounted for by using a sediment nutrient enrichment ratio. The STEPL default enrichment ratio is 2.0, but this was changed to 1.3 based on enrichment ratio guidance per the Iowa Phosphorus Index http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_007643.pdf). STEPL simulates nutrient loss in pasture and grassland runoff by assuming a phosphorus concentration of 0.3 mg/L in the runoff. Similarly, a phosphorus concentration of 0.06 was used to simulate phosphorus loads from shallow groundwater in grazed areas.

Open Feedlots

Feedlot operators are not required to report open feedlot information to DNR for feedlots with less than 1,000 animal units (AUs), and these facilities are considered unregulated. Open feedlots with 1,000 AUs or more must develop and submit a Nutrient Management Plan to the Iowa DNR. There is one known unregulated open feedlot with a capacity of up to 300 head of beef cattle. As an unregulated source, this facility is not covered by the WLA, but manure from this feedlot is applied to row crops in the STEPL model. The facility is not explicitly simulated as a feedlot in STEPL per model guidelines because it is not hydrologically connected to any watercourse that drains to Upper Pine Lake. No other active feedlots are documented in the DNR Animal Feeding Operations Database, nor were any observed during several field visits.

Wildlife

The estimated deer population in the Upper Pine Lake watershed is based on the Red Rock Wildlife Management Unit estimate and the deer harvest rate from Hardin County (DNR Deer Biologist, December 2, 2013, personal communication). The estimated county-wide average deer density is approximately 5 deer per square mile, but an average of 15 deer per square mile was entered in the “Animals” worksheet of the STEPL model for Upper Pine Lake watershed to account for increased density of deer around the lake. Population densities of 5,000 raccoons and 5,000 beavers per square mile were used to account for other wildlife (e.g., furbearers, upland birds, etc.) for which data is lacking.

Phosphorus contributions from waterfowl in and near the lake by Canada geese were explicitly calculated rather than simulated by STEPL. An estimate of goose population and subsequent phosphorus contributions at Upper Pine Lake were provided by DNR waterfowl biologists (Guy Zenner, DNR, November 3, 2012, personal communication). On an annual average basis, there are 280 geese residing at the lake; however, populations vary throughout the year due to migratory patterns and nesting seasons. Peak populations are observed between November and March. The mean defecation rate was assumed to be 28 droppings per day per goose, with higher rates during the day than at night. The assumed TP content of geese droppings was 1.8 percent. The amount of time geese spend on water was also considered, with hours spent on water also varying seasonally. Resulting TP loads from geese were 59 lbs/yr, which was included in the total load entered into the BATHTUB model.

D.6. Septic Systems

A GIS coverage of rural population in areas with private onsite wastewater treatment systems (e.g., septic systems) is available from DNR. Using the rural population in each subbasin and the assumption that each septic system serves 2.43 people (national average per STEPL default), the number of septic systems in each subbasin was calculated. Using this approach, the total number of septic systems for the entire watershed was estimated to be 50. Based on the rural population and typical rates of septic system compliance in rural Iowa, 25 percent of systems were assumed to function improperly. This information is included in the "Inputs" worksheet of the STEPL model for Upper Pine Lake. Even with this assumption, which is likely an over estimate, phosphorus contributions from septic systems are projected to be just 1.0 percent of the total load to the lake (Table 3-2, Figure 3-8)

D.7. References

U.S. Department of Agriculture – Farm Service Agency (USDA-FSA). 2013. http://www.fsa.usda.gov/Internet/FSA_File/clu_2007_infosheetpdf.pdf. Accessed August 2013.

U.S. Department of Agriculture – National Agricultural Statistical Summary (USDA-NASS). 2013. http://nassgeodata.gmu.edu/CropScape/. Accessed August 2013.

Appendix E --- Water Quality Model Development

Two models were used to develop the Total Maximum Daily Load (TMDL) for Upper Pine Lake. Watershed hydrology and pollutant loading was simulated using the Spreadsheet Tool for Estimating Pollutant Load (STEPL), version 4.1. STEPL model development was described in detail in Appendix D.

In-lake water quality simulations were performed using BATHTUB 6.14, an empirical lake and reservoir eutrophication model. The BATHTUB model developed for Upper Pine Lake does not simulate dynamic conditions associated with storm events or individual growing seasons. Rather, the model predicts average water quality in the assessment period for the 2012 Integrated Report (2006-2010). This appendix discusses development of the BATHTUB model. The integrated watershed and in-lake modeling approach allows the holistic analysis of hydrology and water quality in Upper Pine Lake and its watershed.

E.1. BATHTUB Model Description

BATHTUB is a steady-state water quality model developed by the U.S. Army Corps of Engineers that performs empirical eutrophication simulations in lakes and reservoirs (Walker, 1999). Eutrophication-related parameters are expressed in terms of total phosphorus (TP), total nitrogen (TN), chlorophyll a (chl-a), and transparency. The model can distinguish between organic and inorganic forms of phosphorus and nitrogen, and simulates hypolimnetic oxygen depletion rates. Water quality predictions are based on empirical models that have been calibrated and tested for lake and reservoir applications (Walker, 1985). Control pathways for nutrient levels and water quality response are illustrated in Figure E-1.

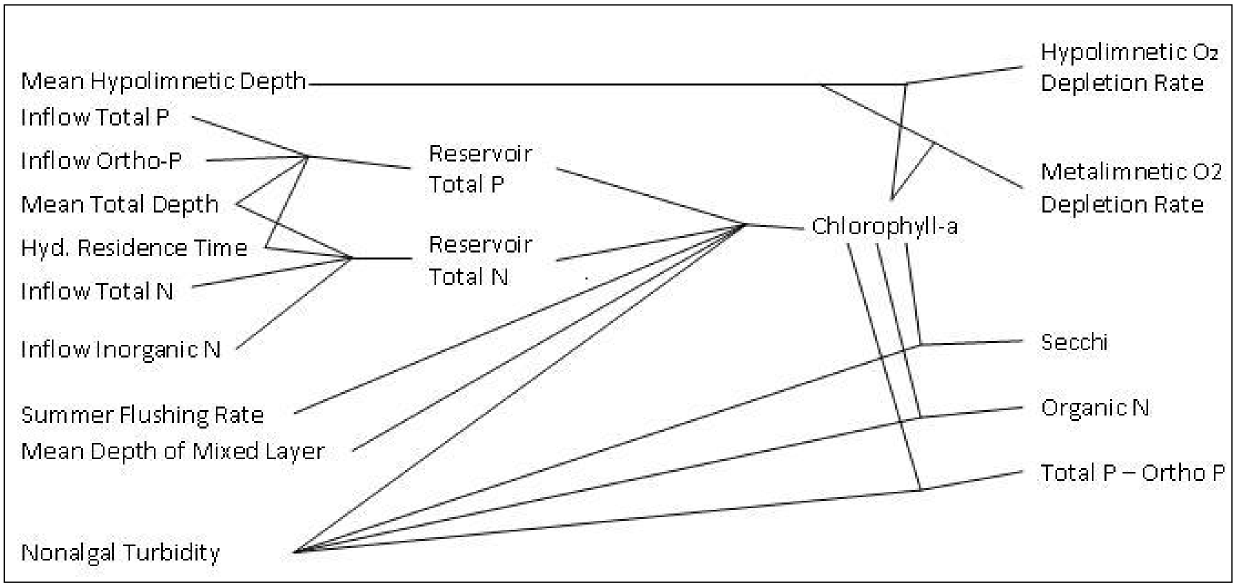


Figure E-1. Eutrophication control pathways in BATHTUB (Walker, 1999).

E.2. Model Parameterization

BATHTUB includes several data input menus/modules to describe lake characteristics, simulation equations, and external (i.e., watershed) inputs. Data menus utilized to develop the BATHTUB model for Upper Pine Lake include: model selections, global variables, segment data, and tributary data. The model selections menu allows the user to specify which modeling equations (i.e., empirical relationships) are used in the simulation of in-lake nitrogen, phosphorus, chlorophyll-a, transparency, and other parameters. The global variables menu describes parameters consistent throughout the lake such as precipitation, evaporation, and atmospheric deposition. The segment data menu is used to describe lake morphometry, observed water quality, calibration factors, and internal loads in each segment of the lake/reservoir. The tributary data menu specifies nutrient loads to each segment using mean flow and concentration in the averaging period. The following sub-sections describe the development of the Upper Pine Lake BATHTUB model and report input parameters for each menu.

Model Selections

BATHTUB includes several models/empirical relationships for simulating in-lake nutrients and eutrophication response. For TP, TN, chlorophyll-a, and transparency, Models 1 and 2 are the most general formulations, based upon model testing results (Walker, 1999). Alternative models are provided in BATHTUB to allow use of other eutrophication models, evaluate sensitivity of each model, and facilitate water quality simulation in light of data constraints.

Table E-1 reports the models selected for each parameter used to simulate eutrophication response in Upper Pine Lake. Preference was given to Models 1 and 2 during evaluation of model performance and calibration of the Upper Pine Lake model, but final selection of model type was based on applicability to lake characteristics, availability of data, and agreement between predicted and observed data. The Canfield & Bachman (Reservoirs) model was utilized to predict in-lake phosphorus levels because it provided the best agreement with observed data, and because Little River Lake is a reservoir and representative of aquatic systems for which this model was developed. The Jones & Bachman model was used for simulation of chlorophyll-a for the same reasons. Model performance is discussed in more detail in Appendix F.

Table E-1. Model selections for Upper Pine Lake.

Parameter	Model No.	Model Description
Total Phosphorus	04	Canfield & Bachman (reservoirs)
Total Nitrogen	*00	not computed
Chlorophyll-a	05	Jones & Bachman
Transparency	*01	vs. chlorophyll-a & turbidity
Longitudinal Dispersion	*01	Fischer-numeric
Phosphorus Calibration	*01	decay rates
Nitrogen Calibration	*01	decay rates
Availability Factors	*00	ignore

* Asterisks indicate BATHTUB defaults

Global Variables

Global input data for Upper Pine Lake are reported in Table E-2. Global variables are independent of watershed hydrology or lake morphometry, but affect the water balance and nutrient cycling of the lake. The first global input is the averaging period. Both seasonal and annual averaging periods are appropriate, depending on site-specific conditions. An annual averaging period was utilized to quantify existing loads and in-lake water quality, and to develop TMDL targets for Upper Pine Lake.

Table E-2. Global variables data for 2006-2010 simulation period.

Parameter	Observed Data	BATHTUB Input
Averaging Period	Annual	1.0 year
Precipitation	46.1 in	1.17 m
Evaporation	32.0 in	0.81 m
[1]Increase in Storage	0	0
[2]Atmospheric Loads:		
TP	0.3 kg/ha-yr	30 mg/m^2-yr
TN	7.7 kg/ha-yr	770.3 mg/m^2-yr

[1] Change in lake volume from beginning to end of simulation period.
[2] From Anderson and Downing, 2006.

Precipitation was summarized for the 5-year period of 2006-2010 from the National Weather Service Cooperative weather station at Eldora, Iowa (IEM, 2013a). Potential evapotranspiration data for the same period was obtained from the Gilbert, Iowa weather station via the ISU Ag Climate database (IEM, 2013b). Net change in reservoir storage was assumed to be zero. These data were summarized and converted to BATHTUB units (meters) and entered in the global data menu. Atmospheric deposition rates were obtained from a regional study (Anderson and Downing, 2006). Nutrient deposition rates are assumed constant from year to year.

Segment Data

Lake morphometry, observed water quality, calibration factors, and internal loads are all included in the segment data menu of the BATHTUB model. Separate inputs can be made for each segment of the lake or reservoir system that the user wishes to simulate. In lakes with simple morphometry and one primary tributary, simulation of the entire lake as one segment is often acceptable. If evaluation of individual segments of the lake (or inflowing tributaries) is desirable, the lake can be split into multiple segments. Each segment may have a distinct tributary.

The Upper Pine Lake BATHTUB model includes 3 lake segments to facilitate simulation of diffusion and dispersion that likely occur as water traverses this long, narrow reservoir. All three segments lie in STEPL Subbasin 1 (Figure D-1). Segment A is the deep water area in which water quality data is regularly collected through DNR's Ambient Monitoring Program. Because the ambient monitoring location is used for listing and delisting purposes, the TMDL target applies only to this segment of Upper Pine Lake. Segment B is the middle segment, and Segment C is the upper end, which receives inflows from the 14-acre wetland forebay located northeast of the lake (Figure E-2).

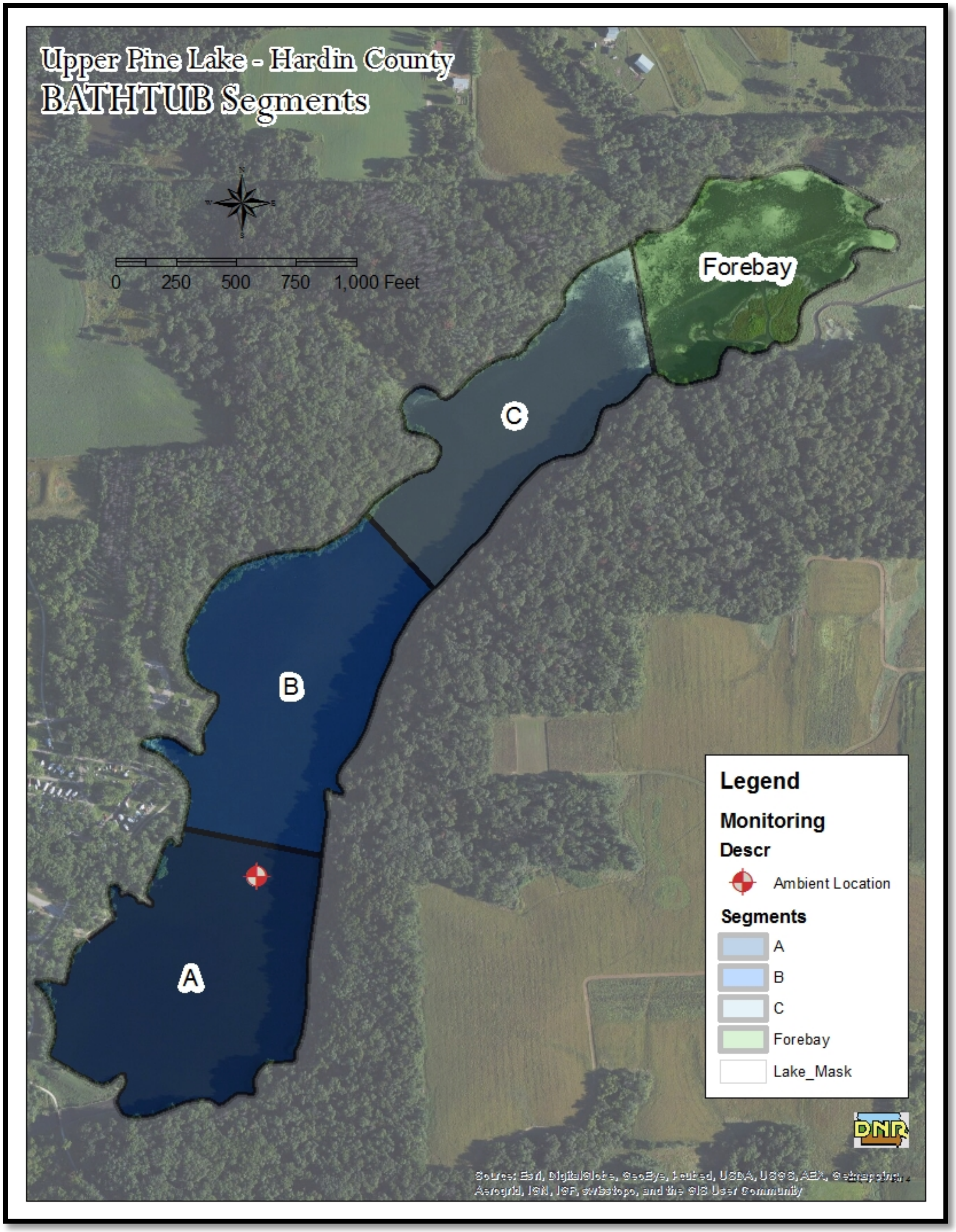


Figure E-2. Lake segmentation in BATHTUB model.

The wetland is separated from the lake by a sediment retention berm, therefore there is very little mixing and diffusion between the wetland and the main lake. For this reason, the wetland forebay was not simulated in BATHTUB. Instead, the wetland was assumed to remove 15 percent of the TP load from the watershed, which is at the low end of potential treatment for wet ponds, as summarized in an EPA Fact Sheet on BMPs (http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=68). The forebay is not expected to perform as well as a wet retention pond for several reasons. First, the forebay is relatively shallow and already full of sediment. Second, it is not a true wet pond designed primarily for sediment removal. Rather, it was once part of the lake that was retrofitted to behave like a wetland. Finally, water and associated pollutants appear to short-circuit the wetland, thereby reducing the residence time and removal efficiency. Dredging the forebay and constructing berms and/or jetties to force inflows to traverse more of the wetland would increase the effective area of the forebay and could increase TP removal to as high as 50-60 percent or more.

Segment morphometry was calculated for each segment in the model. Bathymetric survey data and ESRI GIS software was used to estimate segment surface area, mean depth, and segment length. Temperature and dissolved oxygen (DO) profiles were used to estimate the mixed layer and hypolimnetic depth at the ambient monitoring location in Segment A. All other segments were determined to be unstratified due to their shallowness in relation to the temperature and DO profiles collected from Segment A. These profiles are plotted in Appendix C, along with other water quality data analyzed and/or used in model development.

Mean water quality parameters observed for the assessment period (2006-2010) are reported in Table E-3. These data were compared to output in Segment A of the BATHTUB lake model to evaluate model performance and calibrate the BATHUB and STEPL models for each scenario. Data for model calibration was available only in Segment A. The TMDL and future water quality assessment and listing will be based solely on data from Segment A.

Table E-3. Ambient (Segment A) water quality (2006-2010 annual means).

Parameter	Measured Data	[1]BATHTUB Input
Total Phosphorus	105 ug/L	105 ppb
Total Nitrogen	7.4 mg/L	Not computed
Chlorophyll-a	54 ug/L	54 ppb
Secchi Depth	0.9 m	0.9 m

[1] Measured or monitored data converted to units required by BATHTUB
ppb = parts per billion = micrograms per liter (ug/L)

Tributary Data

The empirical eutrophication relationships in the BATHTUB model are influenced by the global and segment parameters previously described, but are heavily driven by flow and nutrient loads from the contributing drainage area (watershed). Flow and nutrient loads can be input to the BATHTUB model in a number of ways. Flow and nutrient loads used in the development of the Upper Pine Lake BATHTUB model utilize watershed hydrology and nutrient loads predicted using the STEPL model described in Appendix D. Output from STEPL includes annual average flow and nutrient loads.

Tributary data were obtained from the STEPL model, converted to units consistent with BATHTUB, and entered in the tributary data menu. Table E-4 lists the STEPL subbasins that drain to the tributary and also illustrates the connectivity of BATHTUB segments.

Table E-4. Flow and transport linkages in STEPL and BATHTUB.

STEPL Subbasin	BATHTUB Tributary	BATHTUB Segment
1 2 3 4	1	C
		B
		A (ambient location)

E.3. References

Anderson, K., and J. Downing. 2006. Dry and wet atmospheric deposition of nitrogen, phosphorus, and silicon in an agricultural region. Water, Air, and Soil Pollution, 176:351-374.

Iowa Environmental Mesonet (IEM). 2013a. Iowa State University Department of Agronomy. Iowa Ag Climate Network. Download available at http://mesonet.agron.iastate.edu/request/coop/fe.phtml
Accessed in August 2013.

Iowa Environmental Mesonet (IEM). 2013b. Iowa State University Department of Agronomy. Iowa Ag Climate Network. Download available at http://mesonet.agron.iastate.edu/agclimate/hist/dailyRequest.php.
Accessed in August 2013.

Walker, W. 1985. Empirical methods for predicting eutrophication in impoundments; Report 4, Phase III: Applications manual, “Technical Report E-81-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Walker, W. 1996 (Updated 1999). Simplified Procedures for Eutrophication Assessment and Prediction: User Manual. US Army Corps of Engineers Waterways Experiment Station. Instruction Report W-96-2.

Appendix F --- Model Performance and Calibration

The Upper Pine Lake watershed and water quality models were calibrated by comparing simulated and observed local and regional data. The primary source of calibration data is the ambient lake monitoring data collected by Iowa State University (ISU) and the University of Iowa State Hygienic Laboratory (SHL) between 2001 and 2012. Literature values and results from regional studies regarding sediment and phosphorus exports in similar watersheds were also utilized to evaluate model performance. Calibration was an iterative process that involved running both the watershed model (STEPL) and in-lake model (BATHTUB), and refining model parameters to (1) produce simulated values that were within reasonable ranges according to similar studies, and (2) provide good agreement with observed water quality in Upper Pine Lake.

F.1. STEPL Performance and Calibration

The STEPL model is a long-term average annual simulation model, and is incapable of simulating storm events or short-term fluctuations in hydrology and nutrient loads. There is no long-term monitoring data for tributaries in the Upper Pine Lake watershed, therefore model calibration relied heavily upon sediment and phosphorus exports reported in similar watersheds in the region. Table F-1 reports estimated sheet and rill erosion rates found in several Iowa watersheds that lie within the Southern Iowa Drift Plain ecoregion, which is characterized by irregular plains with open, low hills and moderate loess soils overlaying loamy and clay glacial till.

Table F-1. Sheet and rill erosion in Southern Iowa Drift Plain watersheds.

Watershed	County	Area (acres)	Proximity (miles)	Erosion (tons/ac/yr)
Diamond Lake	Poweshiek	2,767	25	2.9
Fox River	Appanoose	119,067	45	3.1
Lake Hawthorne	Mahaska	3,289	15	5.3
Badger Creek Lake	Madison	11.397	80	3.9-4.5
Lake Miami	Monroe	3,595	30	2.2
Miller Creek	Monroe	19,930	15	2.3
[1]Upper Pine Lake	**Hardin/Grundy**	**[2]8,701**	**--**	**[3]3.0**

[1] Annual sheet/rill erosion estimated for this TMDL using STEPL (2006-2010).
[2] Area per updated delineation (excludes area of lake)
[3] Erosion estimate ignores existing BMPs, consistent with other watersheds in table.

The Upper Pine Lake STEPL model predicts sheet and rill erosion rates that are consistent with those predicted by DNR for other watersheds in the ecoregion. The 2006-2010 simulated annual average sheet and rill erosion rate was 3.0 tons/acre, compared with average estimated rates between 2.2 and 5.3 tons/acre/year estimated in other watersheds. Note that erosion rates in Table F-1 reflect sheet and rill erosion, not sediment delivered to the lake.

Table F-2 compares the annual average TP export simulated by the Upper Pine Lake STEPL model with study results in other watersheds in the Southern Iowa Drift Plain ecoregion. These rates include gully and streambank erosion. TP export in the Upper Pine Lake watershed is within the range of rates observed in literature or simulated in previous TMDLs in the region. Because the STEPL model predicted sediment and phosphorus loads similar in magnitude to estimates developed for other local and regional watersheds, DNR has determined the STEPL model to be adequate for estimation of phosphorus loads to Upper Pine Lake for development of TMDLs and implementation planning.

Table F-2. Comparison of TP exports in tile-drained watersheds.

Watershed/Location	Source	TP Export (lb/ac)
[1]Old Mans Creek near Iowa City, IA	USGS, 2001	4.0
[1]Skunk River at August, IA	USGS, 2001	2.4
[2]Lake Geode, Henry Co.	DNR (Previous TMDL)	1.4
[2]Badger Creek Lake	DNR (Previous TMDL)	2.2
Upper Pine Lake	**2014 TMDL model**	**2.0**

[1] Average annual TP export, 1996-1998, (USGS, 2001)

[2] Annual average TP export per previous DNR TMDL modeling studies

F.2. BATHTUB Model Performance

Performance of the BATHTUB model was assessed by comparing predicted water quality with observed data collected in Upper Pine Lake. Simulation of TP concentration and chlorophyll-a (algae) was critical for TMDL development, and were the focus of calibration efforts. Secchi depth predictions were also calibrated because transparency is frequently correlated with algal growth and is also used to determine impairment status. Nitrogen constituents are less important because Upper Pine Lake is not nitrogen limited.

Calibration

Table F-3 reports observed and predicted annual average TP, chlorophyll-a, and Secchi depths in the open water area (Segment A) of Upper Pine Lake, along with the dispersion coefficient and calibration coefficients for each parameter of interest. More comprehensive observed data is reported in Appendix C. Predicted water quality is based on BATHTUB simulations, and the calibration coefficients were iteratively adjusted in order to obtain the best possible agreement between observed and predicted water quality, while minimizing changes in the default coefficients. The calibration period was 2006-2010, the period on which the 2012 Water Quality Assessment was based.

Calibration coefficients listed alongside the simulated values in Table F-3 were entered in the “Model Coefficients” menu of the BATHTUB model, and apply to all segments of the lake. Coefficients are within the recommended range according to the BATHTUB user guidance (Walker, 1999); however, the TP coefficient of 2.00 is the maximum. A long-term “validation” model was used to test the calibration coefficients against long-term data. This is not a true validation because it includes the same years as the calibration period. However, it indicates that the model, as calibrated, would do a reasonably good job of simulating long-term chlorophyll-a levels, which are the basis of the algae impairment.

Table F-3. Observed and simulated water quality with calibration factors.

Parameter	[1]Observed	[2]Predicted	Calibration Coefficient
Assessment period and TMDL conditions (2006-2010)			
Dispersion coefficient	--	--	0.44
Total Phosphorus (ug/L)	105	105	2.00
Chlorophyll-a (ug/L)	54	54	0.76
Secchi depth (m)	0.9	0.9	1.30
Long-term "validation" period (2001-2012)			
Dispersion coefficient	--	--	0.44
Total Phosphorus (ug/L)	101	90	2.00
Chlorophyll-a (ug/L)	52	51	0.76
Secchi depth (m)	0.9	1.2	1.30

[1] Average concentration observed at ambient monitoring location
[2] Average annual concentration predicted in Segment A of BATHTUB lake model

F.3. References

U.S. Geological Survey (USGS), 2001. Water Quality Assessment of the Eastern Iowa Basins – Nitrogen, Phosphorus, Suspended Sediment, and Organic Carbon in Surface

Walker, W. 1996 (Updated 1999). Simplified Procedures for Eutrophication Assessment and Prediction: User Manual. US Army Corps of Engineers Waterways Experiment Station. Instruction Report W-96-2.

Appendix G --- Expressing Average Loads as Daily Maximums

In November of 2006, The U.S. Environmental Protection Agency (EPA) issued a memorandum entitled *Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. circuit in Friends of the Earth, Inc. v. EPA, et al., No. 05-5015, (April 25, 2006) and Implications for NPDES Permits.* In the context of the memorandum, EPA

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

Per the EPA requirements, the loading capacity of Upper Pine Lake for TP is expressed as both a maximum annual average and a daily maximum load. The annual average load is more applicable to the assessment of in-lake water quality and water quality improvement actions, whereas the daily maximum load expression satisfies the legal uncertainty addressed in the EPA memorandum. The allowable annual average was derived using the BATHTUB model described in Appendix E, and is 6,509 lbs/year.

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

The *Options for Expressing Daily Loads in TMDLs* document presents a similar case study in which a statistical approach is considered the best option for identifying a maximum daily load (MDL) 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:

$$MDL = LTA \times e^{[z\sigma - 0.5\sigma^2]}$$

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 allowable annual average of 6,509 lbs/year is equivalent to a long-term average (LTA) daily of 18 lbs/day. The LTA is the allowable annual load divided by the 365-day averaging period. The average annual allowable load must be converted to a MDL. The 365-day averaging period equates to a recurrence interval of 99.7 percent and corresponding z statistic of 2.778, as reported in Table G-1. The coefficient of variation

(CV) is the ratio of the standard deviation to the mean. However, there is insufficient data to calculate a CV as it relates to TP loads to the lake, because the models are based on annual averages over several years. In cases where data necessary for calculating a CV is lacking, EPA recommends using a CV of 0.6 (EPA, 1991). The resulting σ^2 value is 0.31. This yields a TMDL of 71 lbs/day. The TMDL calculation is summarized in Table G-2. An explicit MOS of 10 percent (9 lbs) was applied, resulting in a daily LA of 64 lbs/day to the daily equation daily TMDL equations. The resulting TMDL, expressed as a daily maximum, is:

TMDL = LC = Σ WLA (0 lbs-TP/day) + Σ LA (64 lbs-TP/day)
+ MOS (7 lbs-TP/day) = **71 lbs-TP/day**

Table G-1. Multipliers used to convert a LTA to an MDL.

Averaging Period (days)	Recurrence Interval	Z-score	Coefficient of Variation								
			0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
30	96.8%	1.849	1.41	1.89	2.39	2.87	3.30	3.67	3.99	4.26	4.48
60	98.4%	2.135	1.50	2.11	2.80	3.50	4.18	4.81	5.37	5.87	6.32
90	98.9%	2.291	1.54	2.24	3.05	3.91	4.76	5.57	6.32	7.00	7.62
120	99.2%	2.397	1.58	2.34	3.24	4.21	5.20	6.16	7.05	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	12.1	13.7

Table G-2. Summary of LTA to MDL calculation for the TMDL.

Parameter	Value	Description
LTA	17.8 lbs/day	Annual TMDL (8,393 lbs) divided by 365 days
Z Statistic	2.778	Based on 180-day averaging period
CV	0.6	Used CV from annual GWLF TP loads
σ^2	0.31	$\ln(CV^2 + 1)$
MDL	**71 lbs/day**	**TMDL expressed as daily load**

Appendix H --- 2012 305(b) Water Quality Assessment

Segment Summary

Waterbody ID Code: IA 02-IOW-0335-L_0
Location: Hardin County, S4,T87N,R19W, 0.5 mi E of Eldora.
Waterbody Type: Lake
Segment Size: 69 Acres
This is a Significant Publically Owned Lake

Segment Classes:
Class A1
Class B(WW-1)
Class HH

Assessment Comments

Assessment is based on: (1) results of the statewide survey of Iowa lakes conducted from 2006 through 2010 by Iowa State University (ISU), (2) results of the statewide ambient lake monitoring program conducted from 2006 through 2008 by University Hygienic Laboratory (UHL), (3) information from the IDNR Fisheries Bureau, and (4) results of fish kill investigations in May 2005 and April 2009.

Assessment Summary and Beneficial Use Support

- Overall Use Support – Partial
- Aquatic Life Support – Partial
- Fish Consumption - Not assessed
- Primary Contact Recreation - Partial
- Assessment Type: Monitored
- Integrated Report Category: 5a
- Trend: Stable
- Trophic Level: Eutrophic

Basis for Assessment and Comments

SUMMARY: The Class A1 (primary contact recreation) uses are assessed (monitored) as “partially supported” due to elevated levels of chlorophyll a (algae) that cause aesthetically objectionable conditions. The Class B(WW-1) aquatic life uses are assessed (evaluated) as “partially supported” due to fish kills that occurred in May 2005 and April 2009. Nutrient loading to the water column and siltation also remain water quality concerns at this lake. Fish consumption uses remain “not assessed” due to the lack of fish contaminant monitoring at this lake. Sources of data for this assessment include: (1) results of the statewide survey of Iowa lakes conducted from 2006 through 2010 by Iowa State University (ISU), (2) results of the statewide ambient lake monitoring program conducted from 2006 through 2008 by University Hygienic Laboratory (UHL), (3) information from the IDNR Fisheries Bureau, and (4) results of fish kill investigations in May 2005 and April 2009.

Note: A TMDL for siltation at Upper Pine Lake was prepared by IDNR and approved by EPA; thus, this lake was placed into IR Category 4a (TMDL approved). Because not all impairments at this lake are addressed by the TMDL, this waterbody was moved from IR Category 4a to Category 5a (impaired; TMDL required).

EXPLANATION: Results from the ISU and UHL lake surveys suggest that the Class A1 (primary contact recreation) uses at Upper Pine Lake are “partially supported” due to elevated chlorophyll a (algae) levels. Using the median values from these surveys from 2006 through 2010 (approximately 22 samples), Carlson’s (1977) trophic state indices for Secchi depth, chlorophyll a, and total phosphorus were 63, 65, and 69 respectively for Upper Pine Lake. According to Carlson (1977) the Secchi depth, chlorophyll a, and total phosphorus values all place Upper Pine Lake in between the eutrophic and hypereutrophic categories. These values suggest high levels of chlorophyll a and suspended algae in the water, moderately poor water transparency, and high levels of phosphorus in the water column.

The level of inorganic suspended solids is moderate at Upper Pine Lake and suggests that non-algal turbidity may occasionally cause water quality problems, but does not suggest impairment at this lake. The median inorganic suspended solids concentration at Upper Pine Lake was 3.5 mg/L, which was the 63rd lowest of the 134 monitored lakes.

Data from the 2006-2010 ISU and UHL surveys suggest a moderate population of cyanobacteria exists at Upper Pine Lake. These data show that cyanobacteria comprised 81% of the phytoplankton wet mass at this lake. The median cyanobacteria wet mass (21.8 mg/L) was the 61st highest of the 134 lakes sampled.

The Class B(WW-1) (aquatic life) uses are assessed (evaluated) as “partially supported” due to a fish kills that occurred in May of 2005 and April of 2009. The 2005 kill was attributed to natural causes (spawning stress). The kill affected bluegill and crappie; no estimates were made of the number of dead fish. The kill was believed due to fluctuating water temperatures that contributed to spawning stress. The 2009 kill was also attributed to natural causes (fluctuating water temperatures). The 2009 kill affected approximately 2500 fish; mostly bluegill and crappie. No estimate of the value of these fish was made. According to IDNR’s assessment/listing methodology, the occurrence of a single pollutant-caused fish kill, or a fish kill of unknown origin, on a waterbody or waterbody reach during the most recent assessment period (2008-2011) indicates a severe stress to the aquatic community and suggests that the aquatic life uses should be assessed as “impaired.” If a cause of the kill was not identified during the IDNR investigation, or if the kill was attributed to non-pollutant causes (e.g., winterkill), the assessment type will be considered “evaluated.” Such assessments, although suitable for Section 305(b) reporting, lack the degree of confidence to support addition to the state Section 303(d) list of impaired waters (IR Category 5). Waterbodies affected by such fish kills will be placed in IR subcategories 2b or 3b and will be added to the state list of waters in need of further investigation.

Information from the IDNR Fisheries Bureau suggests that nuisance algae blooms are a concern at this lake. Data from the ISU and UHL lake surveys, however, suggest Upper Pine Lake has relatively good chemical water quality. Data from these surveys show that during 2006-2010 there was one violation of the Class B(WW-1) criterion for ammonia in 21 samples. Based on IDNR’s assessment methodology, a single violation of the ammonia criterion does not suggest impairment of the Class B(WW-1) uses. There were no violations of the Class B(WW-1) criterion for dissolved oxygen in 22 samples and no violations of the pH criterion in 22 samples. These results suggest that the Class B(WW-1) uses are "fully supported."

Fish consumption uses remain "not assessed" due to the lack of fish contaminant monitoring in this lake.

Monitoring and Methods

Assessment Key Dates

5/25/2005 Fishkill
5/22/2006 Fixed Monitoring Start Date
4/27/2009 Fishkill
9/10/2010 Fixed Monitoring End Date

Methods

- Surveys of fish and game biologists/other professionals
- Non-fixed-station monitoring (conventional during key seasons and flows)
- Primary producer surveys (phytoplankton/periphyton/macrophyton)

Appendix I --- Public Comments

Public Comment:

From: Alice Draper [mailto:alicefarms@heartofiowa.net]
Sent: Saturday, March 01, 2014 11:57 AM
To: Berckes, Jeff [DNR]
Subject: water quality meeting for Upper Pine Lake

Question for the March 6, 2014 meeting in Eldora, IA:

What about the proven method of wood chip filtration for nitrates and experimental use of bio char (incinerated plant matter) for phophorus in studies by Cornell Univ., Ithaca, NY ending in summer 2014?

Could this be incorporated in the present structure of the , wetland,basin and spillway areas? Is it expensive but wouldn't it be worth the cost to preserve our income from recreation – fishing,boating, etc.

Alice Draper
641-939-7038
alicefarms@heartofiowa.net
32668 232 St.
Eldora, IA 50627

Iowa DNR Response (See official letter on next page)

Fields of Opportunities

STATE OF IOWA

TERRY E. BRANSTAD, GOVERNOR
KIM REYNOLDS, LT. GOVERNOR

DEPARTMENT OF NATURAL RESOURCES
CHUCK GIPP, DIRECTOR

March 25, 2014

Alice Draper
32668 232 St.
Eldora, IA 50627

Dear Ms. Draper:

Thank you for your comment on the Upper Pine Lake Water Quality Improvement Plan for algae. Your comment related to wood chip and biochar filtration.

Wood chip bioreactors are proven systems for nitrate reduction from subsurface tile drainage at the field scale (Jaynes et al., 2007 and Schipper et al, 2010). The long-term viability of these systems appears promising, and is still under evaluation (Moorman et al., 2010 and Robertson, 2008). However, application of wood chip bioreactors is limited to field-scale subsurface tile drainage, and they do not significantly reduce phosphorus, which is the primary pollutant of concern with respect to the algae impairment in Upper Pine Lake. For those two reasons, wood chip bioreactors were not included in the list of best management practices (BMPs) for phosphorus reduction in Chapter 4 of the Water Quality Improvement Plan. However, wood chip bioreactors may be a valid practice in the context of a holistic watershed management plan.

Amending agricultural soils with biochar is a potential agronomic practice that is in the early stages of evaluation. Biochar amendments appear to increase the ability of a soil to retain both moisture and nutrients, including phosphorus (Laird et al., 2010). This could reduce leaching of dissolved phosphorus, but would not reduce transport of phosphorus that is attached to eroded soil particles. Widespread adoption of this practice would likely have both soil and water quality benefits, but at this time, this practice is considered to be experimental and not included in the description of BMPs for phosphorus reduction in Chapter 4 of the Water Quality Improvement Plan. However, soil amendments with biochar, if proven viable from an agronomic standpoint, may be a valid component of a holistic watershed management plan.

Biochar “filtration” of Pine Creek is likely not feasible, due to very large volumes and high velocity of water present during phosphorus-carrying runoff conditions. Biochar filters treat smaller volumes of water flowing at slow velocity, and those conditions are not present in Pine Creek when phosphorus loads are high and reduction is needed the most. Implementation of an experimental biochar filter to treat a small, isolated inflow of phosphorus to Upper Pine Lake may be a worthwhile research endeavor, but experimental measures are outside the scope of practices included in Chapter 4 of the Water Quality Improvement Plan.

Thank you again for taking the time to comment. If you would like to investigate these ideas further, we have included the full reference list for your review below.

Sincerely,

Charles Ikenberry, P.E.

REFERENCES:

Jaynes, D.B., T.C. Kaspar, T.B. Moorman, and T.B. Parkin. 2008. In situ bioreactors and deep drain-pipe installation to reduce nitrate losses in artificially drained fields. Journal of Environmental Quality. 37: 429-436.

Laird, D.A., P. Fleming, D.D. Davis, R. Horton, B. Wang, and D.L. Karlen. 2010. Impact of biochar amendments on the quality of a typical Midwestern agricultural soil. Geoderma. 158(3-4): 443-449.

Moorman, T.B., T.B. Parkin, T.C. Kaspar, and D.B. Jaynes. 2010. Denitrification activity, wood loss, and N_2O emissions over 9 years from a wood chip reactor. Ecological Engineering. 36(11): 1567-1574.

Robertson, W.D. 2008. Nitrate removal rates in woodchip media of varying age. Ecological Engineering. 36(11): 1587-1587.

Schipper, L.A., W.D. Robertson, A.J. Gold, D.B. Jaynes, and S.C. Cameron. 2010. Denitrifying bioreactors – An approach for reducing nitrate loads to receiving waters. Ecological Engineering. 36(11): 1532-1543.

Appendix J --- DNR Project Files and Locations

This appendix is primarily for future reference by DNR staff that may wish to access the original spreadsheets, models, maps, figures, and other files utilized in the development of the TMDL.

Directory\folder path	File name	Description
W:\...\Data\Raw\	Various files	All raw data received from others
W:\...\Data\Reduced\	UP_Ambient_Reduced.xls	Summary of in-lake WQ data
	Profiles_2010.xls	Lake profile data from 2010
	SondeLoggers	Temp, DO, pH deployment data
W:\...\Data\Reduced\Climate	UPL_Climate_Reduced_1MM.xls	Summary of precipitation and PET data
W:\...\Documents\Draft_TMDL	Draft TMDL reports	Includes review comments
W:\...\Documents\Final_TMDL	Final report	
W:\...\Documents\References	Various .pdf and .doc files	References cited in the WQIP and/or utilized to develop model input parameters
W:\...\GIS\GIS_Data	Various shapefiles (.shp) and raster files (.grd)	Used to develop models and maps
W:\...\GIS\Projects	ArcGIS project files	Used to develop models and maps
W:\...\Maps, Figures, Images\Maps	Various .pdf and .jpg files	Maps/figures used in the WQIP document
W:\...\Modeling	Allocations_Final.xls	Used to develop phosphorus source inventory and potential load allocation scenario
	TMDL_Equation_Calcs.xls	Used to develop the TMDL equation (LA, WLA, and MOS)
	TMDL_Target_BATHTUB	Load response curve calcs
W:\...\Modeling\STEPL	STEPL_ 2006-2010.xls	Used to simulated/predict existing watershed loads
	STEPL_ 2001-2012.xls	
	Various .xls files	Used to develop/calculate STEPL model inputs
W:\...\Modeling\BATHTUB\InputFiles	BATHTUB _2006-2010.xls	Calculated/converted STEPL outputs to BATHTUB inputs for existing conditions
	BATHTUB _2001-2012.xls	
	Various .btb files	BATHTUB input files for various scenarios