Water Quality Improvement Plan
for

Eldred Sherwood Lake
Hancock County, Iowa

Total Maximum Daily Load
for Algae

clean water
starts with you.
IOWA DNR WATERSHED IMPROVEMENT

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Watershed Improvement Section
2016

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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 Eldred Sherwood 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 Eldred Sherwood Lake from the federal 303(d) list of impaired waters.

What's wrong with Eldred Sherwood Lake?

Eldred Sherwood Lake is listed as impaired on the 2014 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 Eldred Sherwood 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 Eldred Sherwood Lake watershed include sheet and rill erosion from various landuses, runoff and subsurface flows from lands that receive fertilizer application, 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 internal recycling; although internal loading was not found to be a significant source of phosphorus in Eldred Sherwood Lake on a net annual basis.

What can be done to improve Eldred Sherwood Lake?

Reducing phosphorus loss from row crops and implementing or improving existing structural BMPs such as terraces, grass waterways, saturated buffers, and constructed sediment basins 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. Increasing the sediment trapping efficiency of the existing upstream lakes may be the most cost effective structural alternative.

Who is responsible for a cleaner Eldred Sherwood Lake?

Everyone who lives, works, or recreates in the Eldred Sherwood Lake watershed has a role in water quality improvement. Nonpoint source pollution is unregulated and responsible for the vast majority of sediment and phosphorus entering the lake. Therefore, 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 Eldred Sherwood 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. Additionally, those looking to develop sites within the Eldred Sherwood Lake watershed should recognize the impact of improved water quality on property values.

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 Eldred Sherwood Lake and surrounding lakes 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 and fertilization windows, and necessitating more active and 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. However, water quality improvement and enhancement of Eldred Sherwood 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:	Eldred Sherwood Lake, Waterbody ID IA 02-IOW-03830-L_0, located in S21, T94N, R24W, 3 miles NE of Goodell
Surface water classification and designated uses:	A1 – Primary contact recreation B(LW) – Aquatic life HH – Human health (fish consumption)
Impaired beneficial uses:	A1
TMDL priority level:	Priority Group 1
Identification of the pollutants and applicable water quality standards (WQS):	Class A1, primary contact recreation, is impaired due to aesthetically objectionable conditions caused by algae blooms
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 = 929 lbs/year; the maximum daily TP load = 10.2 lbs/day.
Quantification of the amount or degree by which the current pollutant loads in the waterbody, including the pollutants from upstream sources that are being accounted for as background loading, deviate from the pollutant loads needed to attain and maintain WQS:	The existing growing season load of 1,883 lbs/year must be reduced by 954 lbs/year to meet the allowable TP load. This is a reduction of 50.7 percent.
Identification of pollution source categories:	There are no regulated point source discharges of phosphorus in the watershed. Nonpoint sources of phosphorus include fertilizer from row crops, sheet and rill erosion, wildlife, septic systems, atmospheric deposition, and others.
Wasteload allocations (WLAs) for pollutants from point sources:	There are no allowable point source discharges.
Load allocations (LAs) for pollutants from nonpoint sources:	The allowable annual average TP LA is 836 lbs/year, and the allowable maximum daily LA is 9.2 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 for consistency with EPA guidelines, the long-term 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:	Although watershed development may continue in the future, an increase in the pollutant load from landuse change is not expected.
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:

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

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

One purpose of this Water Quality Improvement Plan (WQIP) for Eldred Sherwood Lake, located in Hancock County in northcentral 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, which impairs primary contact recreation (e.g., swimming, wading) in Eldred Sherwood Lake. The impairments are 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 Eldred Sherwood 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 may be able to provide technical support for the improvement of water quality in Eldred Sherwood Lake.

2. Description and History of Eldred Sherwood Lake

The Hancock County Conservation Board was established in January, 1959. The Board manages four parks, 15 wildlife areas, and two wildlife refuges comprising over 1,200 acres in Hancock County. In addition to maintenance and preservation of the natural resources in Hancock County, the Board provides outdoor recreation possibilities and environmental education opportunities.

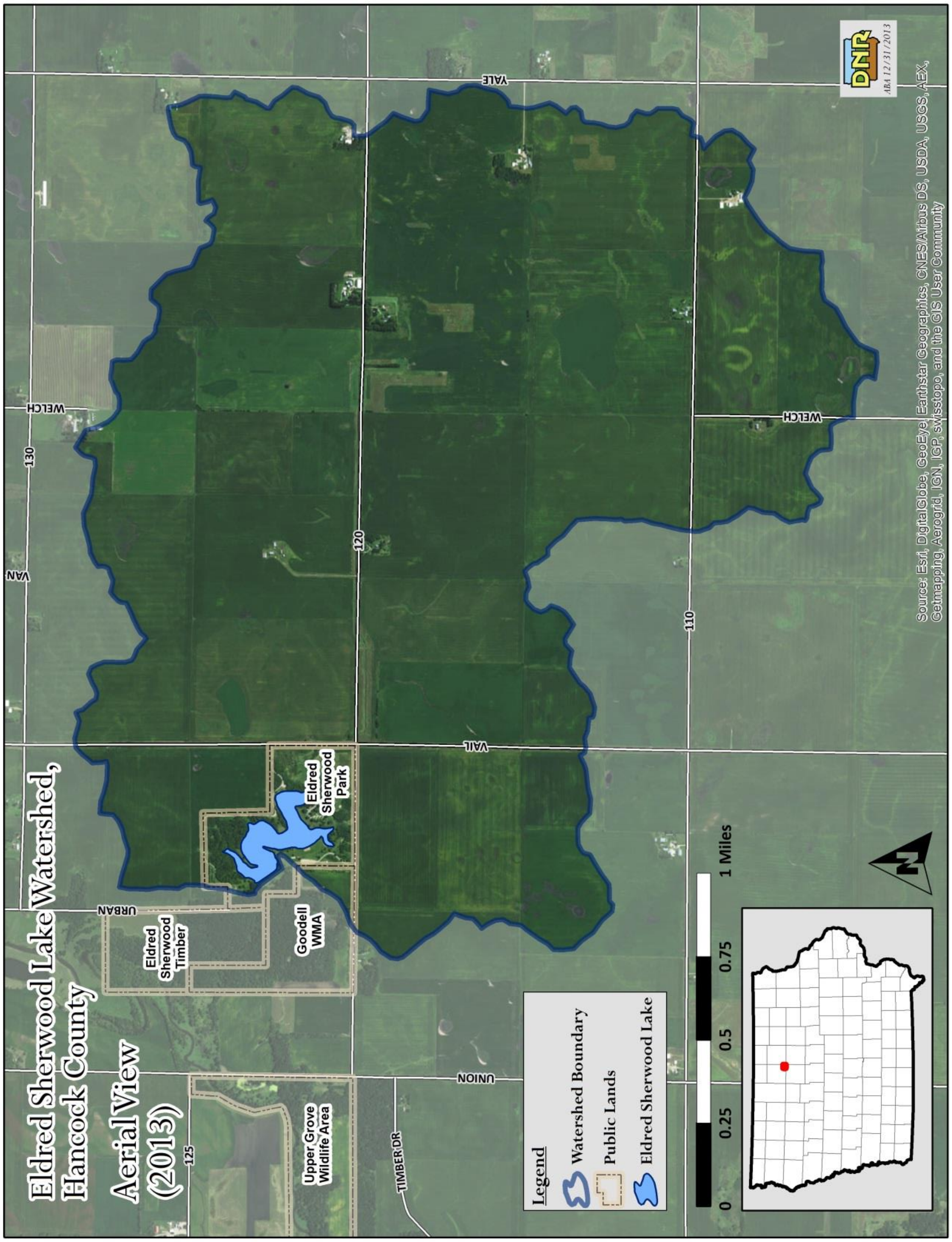
The Hancock County Conservation Board acquired 100 acres of property in 1965 near the existing Eldred Sherwood Recreation Area. Plans for a park and campground were created in 1966-67. The manmade lake, park, and campground completed construction by 1969 and opened to the public in 1970. Other public grounds near Eldred Sherwood Lake include the Upper Grove Wildlife Area, Eldred Sherwood Timber, and the Goodell Watershed Management Authority.

Table 2-1 lists some of the general characteristics of Eldred Sherwood Lake and its watershed. Figure 2-1 shows the vicinity map for the lake system and its watershed. Estimation of physical characteristics such as surface area, depth, and volume are based on a bathymetric survey conducted by DNR in 2015.

Table 2-1. Eldred Sherwood Lake watershed and lake characteristics

DNR Waterbody ID	ID Code: IA 02-IOW-03830-L_0
12-Digit Hydrologic Unit Code (HUC)	070802070205
12-Digit HUC Name	East Branch Iowa River
Location	Hancock County, S21, T94N, R24W
Latitude	42.94° N (ambient lake monitoring location)
Longitude	93.56° W (ambient lake monitoring location)
Designated Uses	A1 – Primary contact recreation B(WW-1) – Aquatic life HH – Human health (fish consumption)
Tributaries	Unnamed drainage ditch
Receiving Waterbody	East Branch Iowa River
Lake Surface Area	[1]22.0 acres
Length of Shoreline	[1]8,542 feet
Shoreline Development Index	2.46
Maximum Depth	[1]21.4 feet
Mean Depth	[1]7.9 feet
Lake Volume	[1]176 acre-feet
Watershed Area	2624 acres (includes lake)
Watershed:Lake Ratio	119:1
Lake Residence Time	[2]42 days

[1] Per May 2015 bathymetric survey and subsequent calculations
[2] BATHTUB model prediction for average annual conditions (2008-2012)



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 2-1. Vicinity Map

Water Quality History
Limited water quality history exists for Eldred Sherwood Lake. An Erosion and Sediment Worksheet provided by Natural Resource Conservation Service (NRCS) was conducted to determine sheet and rill erosion, and sediment delivery to the lake. This is explained further in the modeling appendices D and E of this document.

Eldred Sherwood Lake has been part of the statewide survey of Iowa Lakes conducted from 2000-2012 by Iowa State University (ISU). A statewide ambient lake monitoring program conducted in 2005 – 2008 and 2010 by State Hygienic Laboratory (SHL) also provided data on the water quality of Eldred Sherwood Lake. These results are listed in Appendix C – Water Quality Data.

2.1. Eldred Sherwood Lake

Hydrology
Work began on a development plan for Eldred Sherwood Park in 1967. The plan detailed construction designs for the dam and spillway on the western shore to create approximately 22 acres of lake area. The topography created an irregular shape that is consistent with other manmade lakes in the state. Two drainage swales in the southwestern corner and two on the eastern side of the park convey surface water from the upland watershed area.

The National Weather Service (NWS) Cooperative Program (COOP) station in Kanawha, 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, 2016a). Daily observations between January 1, 2001 and December 31, 2014 were used in climate assessment and model development. Daily potential evapotranspiration (PET) data were obtained for 2001-2013 from the Iowa Ag Climate Network, also downloadable from the IEM (IEM, 2016b). Table 2-2 reports weather station information.

Table 2-2. Weather station information for Eldred Sherwood Lake

Data	Temperature/Precipitation	Potential ET
Network	NWS COOP	ISU Ag Climate
Station Name (ID)	NCCD, IA (IAC002)	Kanawha (A134309)
Latitude	Latitude: 43.05°	42.94°
Longitude	Longitude: -93.49°	-93.79°

Average annual precipitation near Eldred Sherwood Lake was 32.6 inches from 2001-2014. Years 2007 through 2010 were, on average, much wetter than normal, with an annual average rainfall amount of 38.5 inches per year. These wetter than normal years coincide with several of the years of water quality data used to develop the 2014 Water Quality Assessment and 303(d) list and current impairment status of Eldred Sherwood Lake. Conversely, years 2011-2012 were much drier than normal, with an annual average rainfall of 21.7 inches per year. Section 3.1 includes an assessment of potential relationships between precipitation and in-lake water quality. Figure 2-2 illustrates the annual precipitation totals, along with lake evaporation (estimated as 70 percent of annual PET). From 2001 to 2013, average annual precipitation nearly equaled lake evaporation; with values of 32.2 inches and 32.8 inches, respectively. However, the range of moisture surplus and deficit varied widely, with an 11.5-inch surplus in 2008, and an 18.1-inch deficit in 2012.

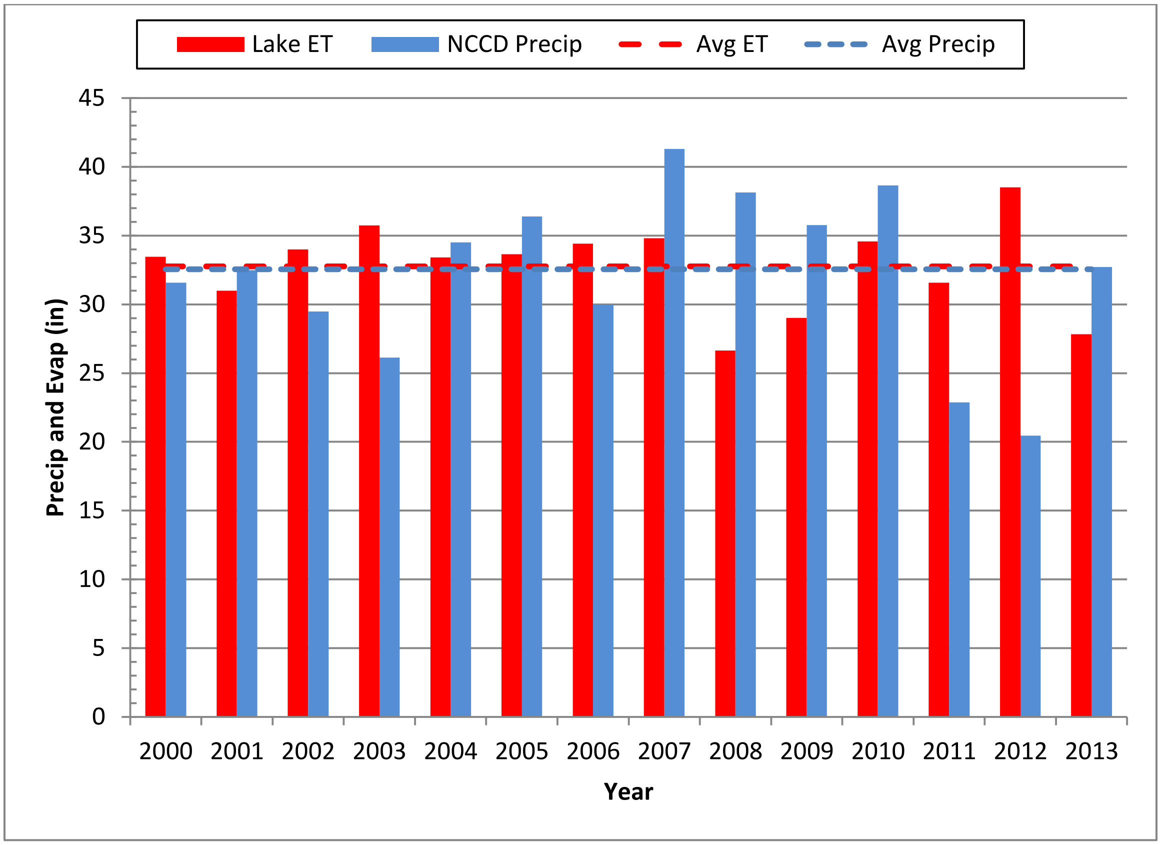


Figure 2-2. Annual precipitation and estimated lake evaporation

Precipitation varies greatly by season in central Iowa, with 75 percent of annual rainfall occurring between April and September. Monthly average precipitation (2001-2014) is illustrated in Figure 2-3, along with estimated evapotranspiration (ET) in the watershed based on vegetation cover. 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. In addition, watershed evaporation far exceeds precipitation during the summer months, which can create water budget deficits in the watershed. It is often during this period that harmful algal blooms develop in waterbodies, as water heats up and lake flushing is minimal. The watershed to lake ratio (118:1) indicates that rainfall events producing runoff and subsurface tile flow will impact lake water levels much more dramatically than a lake with a relatively smaller watershed.

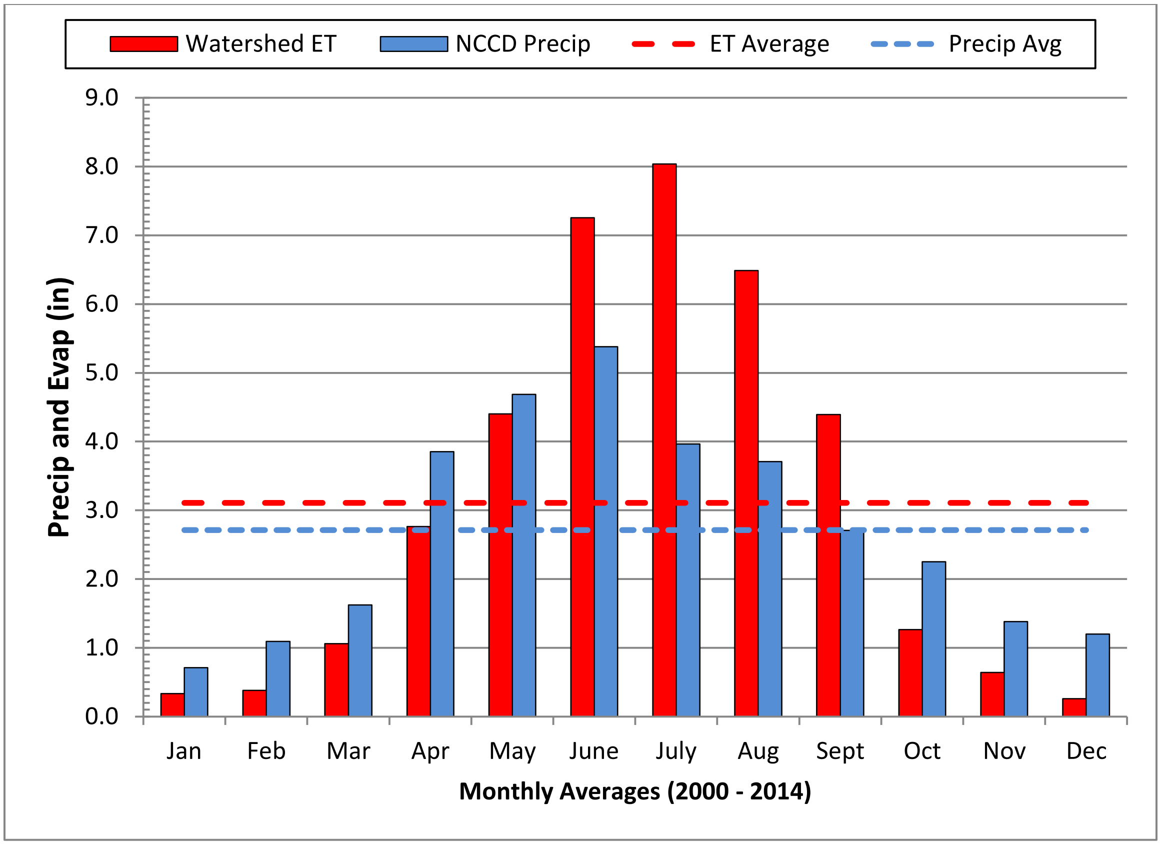


Figure 2-3. Monthly precipitation and estimated ET for the watershed

Rainfall runoff, direct precipitation, evapotranspiration, tile drainage, shallow groundwater flow, and deep aquifer recharge are all part of the lake's hydrologic system. 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 Kanawha, 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. In wet years, the opposite is true as residence time decreases. Such a low average residence time (42 days for average conditions) suggests that internal loading may not play a significant role in algal blooms, since the flushing rate is 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 (2015), the surface area of Eldred Sherwood Lake is 22.0 acres. Estimated water volume of the main lake is 176 acre-feet (ac-ft), with a mean depth of 7.9 ft and a maximum depth of 21.4 ft in the northwest arm of the lake. The reservoir, like most man-made stream impoundments, has an irregular shape, with two main inlet arms, one south and one east of the main body. Evidence of sedimentation in the lake's upper reaches suggests that the watershed of Eldred Sherwood Lake has a large impact on water quality. The significance of sediment (and associated phosphorus) loading from the watershed is further evidenced by the shoreline development index of 2.45, which is high. Values greater than 1.0 suggest the shoreline is highly dissected and indicative of a high degree of watershed influence (Dodds, 2000). High values are frequently observed in man-made reservoirs, and it is not surprising that watershed processes are critically important for the chemical, physical, and biological processes that take place in Eldred Sherwood Lake. Lake morphometry and bathymetry data are shown in Figure 2-4.

2.2. The Eldred Sherwood Lake Watershed

The watershed boundary of Eldred Sherwood Lake encompasses 2,624 acres (including the lake) and is illustrated in Figure 2-1. The watershed-to-lake ratio of 118:1 is significantly above the 20:1 ratio identified as an indicator of lakes with good potential for restoration. Substantial mitigation of watershed influence will be required for water quality improvement, and in-lake techniques will fail unless accompanied by extensive watershed improvements. 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.

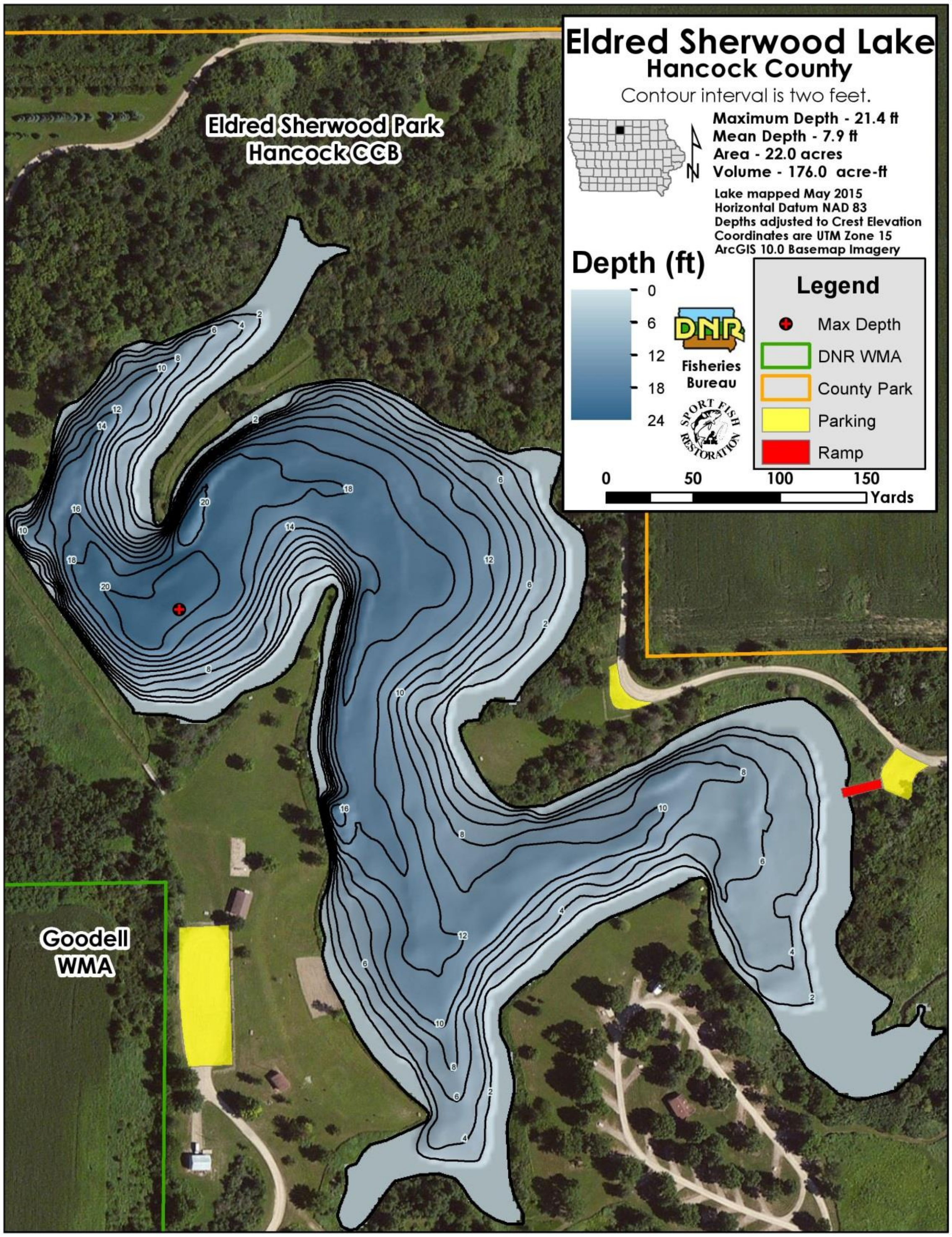


Figure 2-4. Bathymetric map of Eldred Sherwood Lake

Landuse

A Geographic Information System (GIS) coverage of landuse information was developed using the Cropland Data Layer (CDL) for years 2012 and 2014, which was obtained from the United States Department of Agriculture – National Agricultural Statistics Service (USDA-NASS, 2016). 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, 2012). 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. In addition to landuse, tillage and management information was collected by local watershed personnel via 2016 windshield survey of the watershed. Due to agricultural management operations in the watershed, areas with multiple land covers consisting of soybean and corn ground have been aggregated together under a “Row Crop” land cover. Landuse utilized in model development is shown in Figure 2-5.

Analysis of historical aerial photography and data prior to park construction reveals several trends. The original estimated landuse percentages from 1967 were 71 percent cropland, 16 percent pasture, 10 percent forest, and 2 percent other. The majority of the watershed is currently in a corn / soybean rotation, or continuous corn landuse, with no pasture remaining. Table 2-3 shows that row crops currently make up 90.9 percent of the watershed. Examination of the crop ground also shows the majority of soil is tile drained, which increases productivity of corn and soybeans, reduces erosion, and affects nutrient fate and transport. A small section of crop ground utilizes an expanded corn / soybean / meadow rotation where the field is left as hay for several years to recharge subsurface nutrients. The timber and grassland (0.9 and 2.8 percent, respectively) surrounds Eldred Sherwood Lake within the recreation area. Both active and inactive farmstead areas currently take up a total of 1.5 percent of watershed area.

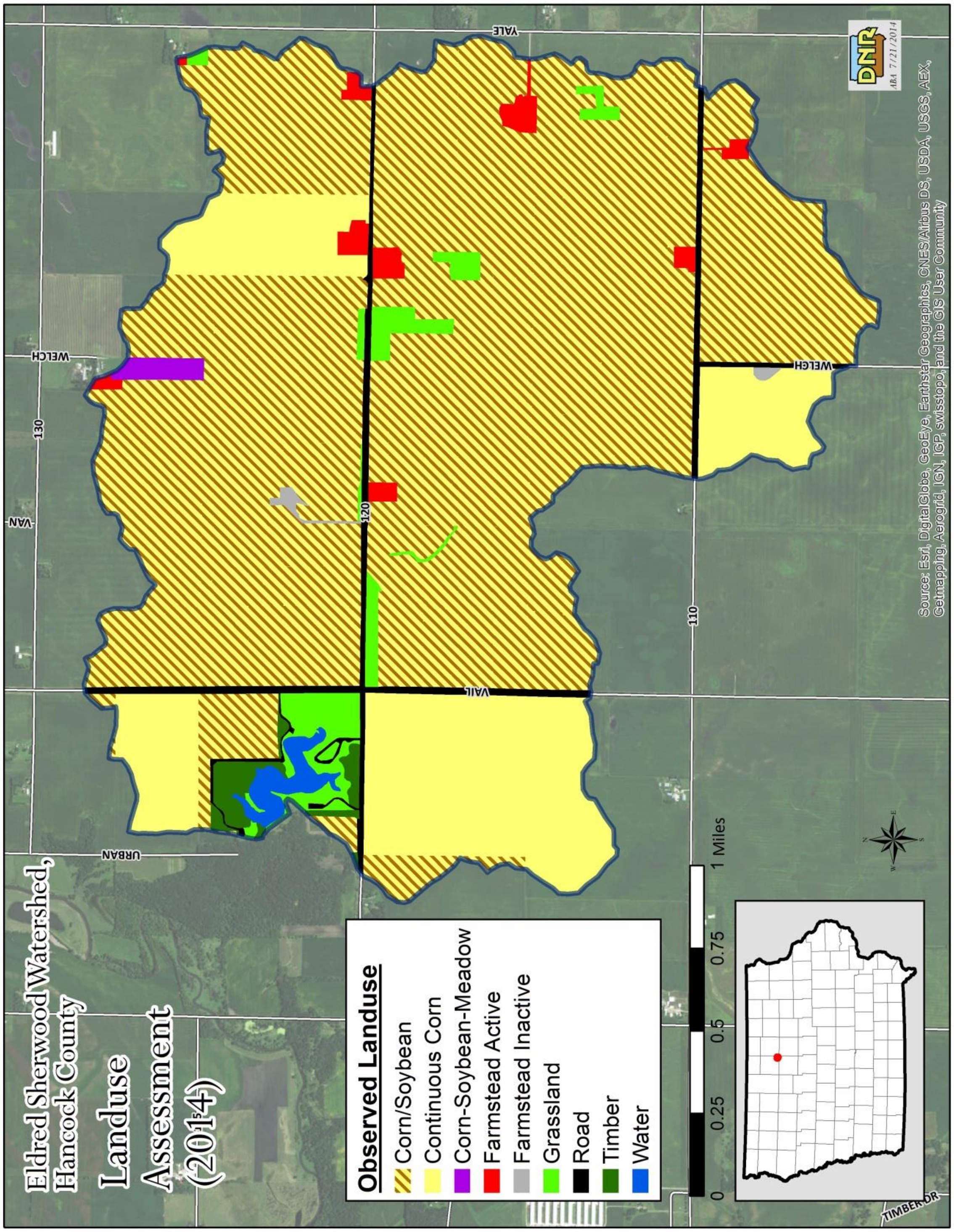


Figure 2-5. Eldred Sherwood Lake watershed landuse map

Table 2-3. Landuse composition of Eldred Sherwood Lake watershed

Landuse	Area (acres)	Percent (%)
Corn / Soybean Rotation	1935.0	73.8
Continuous Corn	447.7	17.1
Corn / Soybean / Meadow Rotation	11.1	0.4
Timber	24.9	0.9
Grassland	74.4	2.8
Road	70.5	2.7
Farmstead Active	33.2	1.3
Farmstead Inactive	5.4	0.2
[1]Water	22.0	0.8
Total area =	**2624.2**	**100.0**

[1] Eldred Sherwood Lake surface area

Soils, Climate, and Topography

The Eldred Sherwood Lake watershed is in the northern region of the Des Moines Lobe. Four soils series dominate the Eldred Sherwood Lake watershed, as shown in Figure 2-6 and Table 2-4. Of these, the Clarion / Nicollet / Webster soil association comprise 63.6 percent of the watershed. These soils are characterized by nearly level or gently undulating slopes; however, near larger streams, many soils are gently rolling to hilly and a few can be steep (USDA-NRCS, 1979). This association is well to poorly drained and closed depressions or "potholes" are a common feature. Table 2-4 and Figure 2-6 are both organized by landscape position, with upland soils like Clarion appearing before lower position soils like Canisteo or Okoboji. Most of these lower formations have been drained for use in agriculture. Several smaller soil classes associated with prairie potholes are listed as well. All other minor classes are listed as "Other."

Table 2-4. Predominant soils of the Eldred Sherwood Lake watershed

Soil Name	Area (ac)	Area (%)	Description of Surface Soil Layer	Typical Slopes (%)
Clarion	722.9	27.5	Moderately well drained soils on uplands, glacial till; slightly to moderately eroded	0-9
Nicollet	598.9	22.8	Somewhat poorly drained loamy glacial till; slightly eroded	0-5
Webster	348.1	13.3	Poorly drained soils formed in till or alluvium; slightly eroded	0-3
Canisteo	417.8	15.9	Poorly and very poorly drained loamy till	0-5
Okoboji	160.0	6.1	Poorly drained soils formed in till or alluvium; slightly eroded	0-1
Harps	121.1	4.6	Very poorly drained alluvium or lacustrine sediment; form depressions	0-3
Blue Earth	22.5	0.9	Very poorly drained lacustrine sediment; indicate depressions	0-1
Crippin	22.5	0.9	Somewhat poorly drained loamy glacial till; slightly eroded	0-3
Lester	30.8	1.2	Well drained loamy till; slightly to moderately eroded	5-18
Spillville	55.6	2.1	Moderately well to somewhat poorly drained alluvium;	0-5
Vinje	29.5	1.1	Well drained to moderately well drained glacial lacustrine sediment; slightly eroded	2-14
Others	72.2	2.8	Varies	Varies
Water	22.0	0.8	---	---
Total	2624.2	100.0	Varies	Varies

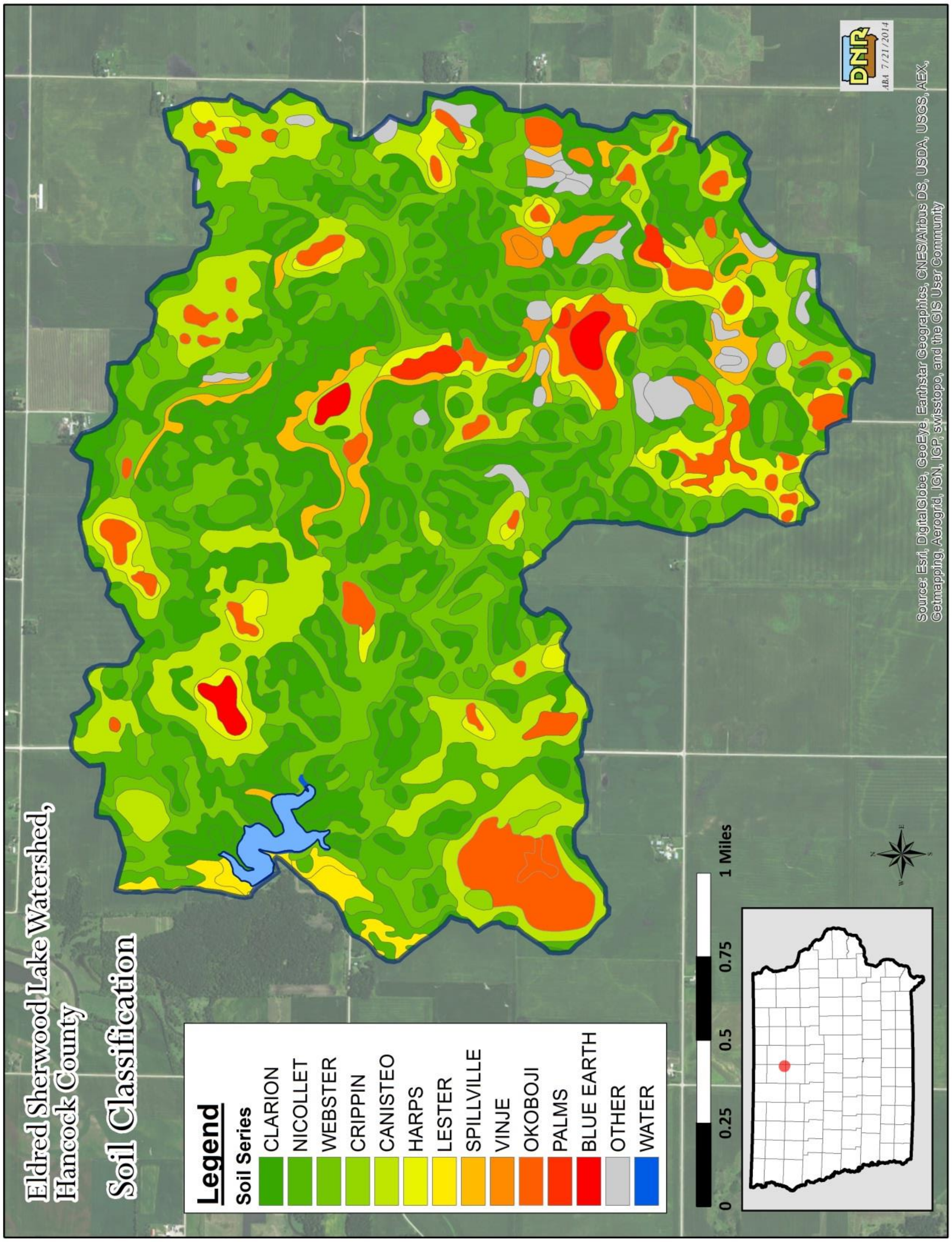


Figure 2-6. Eldred Sherwood Lake soil classification map

The topography consists of gently rolling and abundant moraines from previous glaciation of the region. The most prominent landform patterns are the end moraines created at the furthest extent of the glaciation, and the shallow pothole wetlands created by uneven melting as the glaciers receded. These landforms make up the typical landscape of the Des Moines lobe. Slopes are therefore mostly gently sloping, to sloping, but there are areas of strongly sloping to moderately steep slopes where the topography transitions from upland regions to these pothole formations. Depending on the size of the pothole, there can be considerable flat areas within the pothole that indicate substantial sediment deposition over time. Flat to gently sloping (0 – 5 percent slope) regions make up 80.1 percent of the watershed. Table 2-5 shows the percentage breakdown of slope classifications throughout the watershed, and Figure 2-7 illustrates the distribution of the slopes within the Eldred Sherwood Lake watershed.

Prairie pothole formations within the Eldred Sherwood Lake watershed are shown in Figure 2.8. These potholes account for greater than 1,100 acre-feet (ac-ft) of storage, an order of magnitude larger than storage in Eldred Sherwood Lake. This can affect the watershed by storing surface runoff in the depressions, which decreases sediment delivery and increases subsurface flows (i.e. tile and groundwater) to the lake.

Table 2-5. Slope classifications of the Eldred Sherwood Lake watershed

Slope Class (%)	Area (%)	Description of Slope Class
0 – 2 (Class A)	31.0	Flat to very gently sloping
2 – 5 (Class B)	49.1	Gently sloping
5 – 9 (Class C)	14.2	Sloping
9 – 14 (Class D)	3.8	Strongly sloping
14 – 25 (Class E, F)	1.0	Moderately steep
> 25 (Class G)	0.9	Steep to very steep
Total	100.0	---

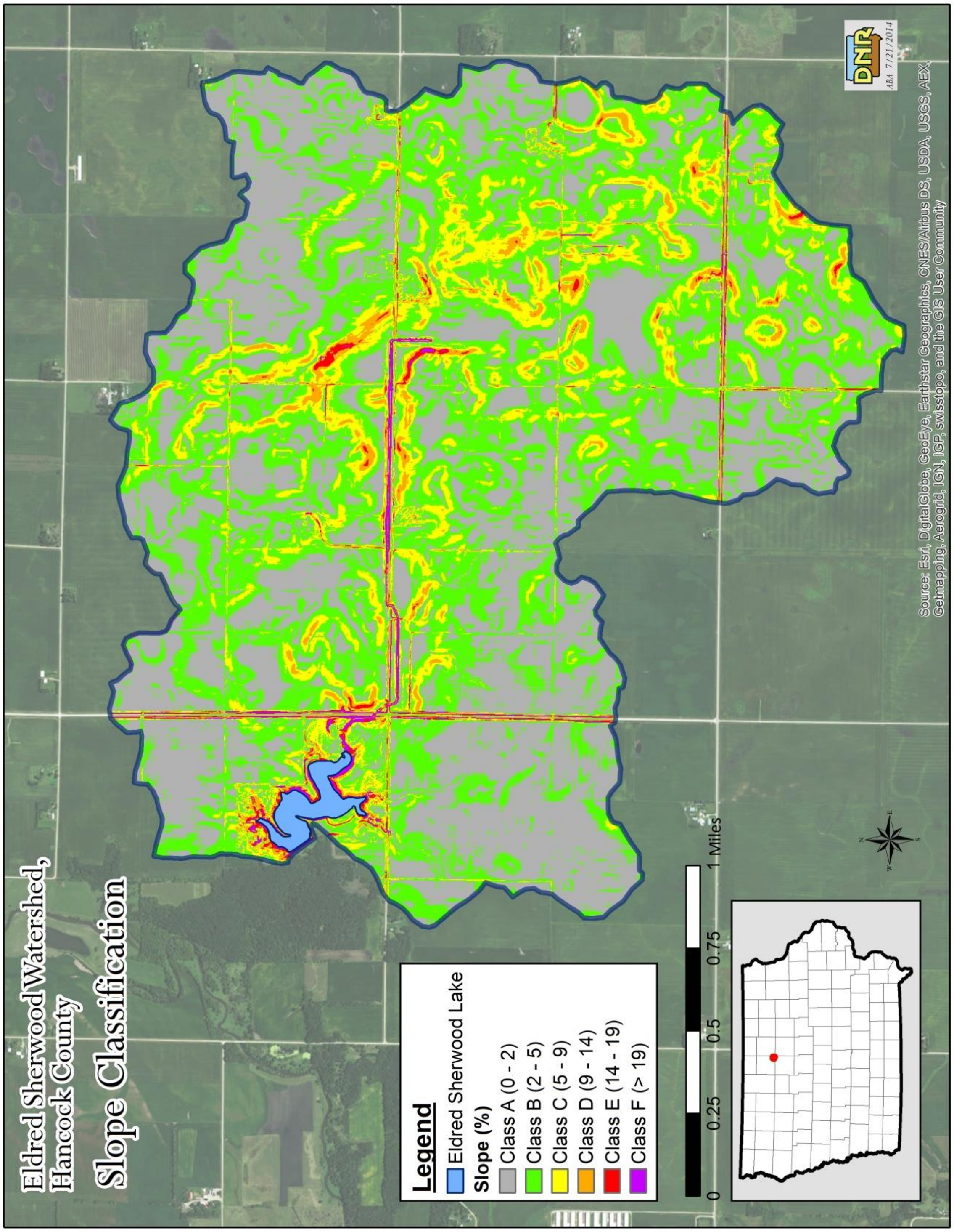


Figure 2-7. Slope classifications in the Eldred Sherwood Lake watershed

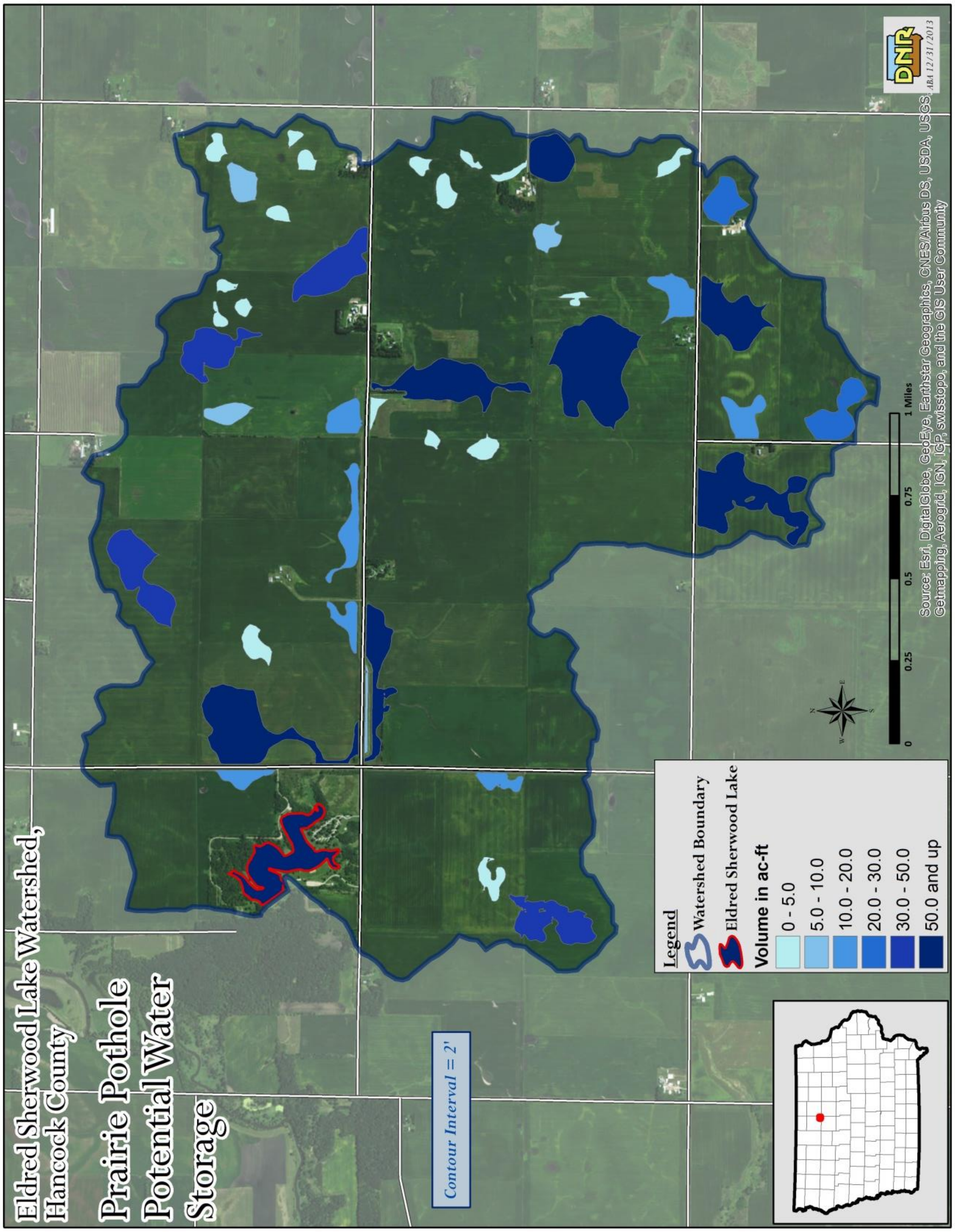


Figure 2-8. Prairie pothole storage in the Eldred Sherwood Lake watershed

3. TMDL for Algae

A Total Maximum Daily Load (TMDL) is required for Eldred Sherwood Lake by the Federal Clean Water Act (CWA). 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 Eldred Sherwood Lake, which is impaired by algae. This section includes an evaluation of Eldred Sherwood Lake water quality, documents the relationship between algae and TP in Eldred Sherwood Lake, and quantifies the in-lake target and corresponding TMDL.

3.1. Problem Identification

Eldred Sherwood 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 2014 Section 305(b) Water Quality Assessment Report states that primary contact recreation in Eldred Sherwood Lake is assessed (monitored) as only "partially supported" due to elevated levels of chlorophyll-a (algae) that cause aesthetically objectionable conditions. A partially supported designated use is considered impaired under CWA. The 2014 assessment is included in its entirety in Appendix H, and can be accessed at https://programs.iowadnr.gov/adbnet/assessment.aspx?aid=16171

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 exceeds 65 (DNR, 2008). In order to de-list the algae impairment for Eldred Sherwood Lake, the median growing season chlorophyll-a TSI must not exceed 63 in two consecutive listing cycles, per DNR de-listing methodology.

Problem Statement
Eldred Sherwood 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. Therefore, phosphorus 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 2014 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 2001-2014
- Water quality data collected by the State Hygienic Laboratory (SHL) at the University of Iowa in 2005 and 2008-2012 as part of the Ambient Lake Monitoring Program and/or TMDL monitoring
- Precipitation and PET data at Kanawha, Iowa, from the NWS COOP program (IEM, 2016a) and the ISU Ag Climate Network (IEM, 2016b), respectively
- 3-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)
- Aerial images (various years) collected and maintained by DNR
- Lake bathymetric data collected in 2015

Interpreting Eldred Sherwood Lake Data
The 2014 305(b) assessment was based on results of the ambient monitoring program conducted from 2008 through 2012 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 2001-2014. 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) is a frequently-used measure of biomass productivity in lakes. Higher TSI values are associated with higher levels of productivity and / or turbidity, and therefore, lower water quality. TSI values increase with increasing TP and Chl-a concentrations, and decrease with increasing Secchi depth. In simplified terms, the higher the TSI, the lower water quality. Iowa DNR’s assessment methodology for lakes includes TSI impairment thresholds of 65 and delisting criteria of 63 for both Chl-a and Secchi depth. 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 chlorophyll-a) are in the red-shaded box on the top half of Figure 3-2. Data incorporated into the 2014 305(b) report is in the blue-shaded box (2008-2012) in Figure 3-2. Growing season mean TSI values are shown in Figure 3-3.

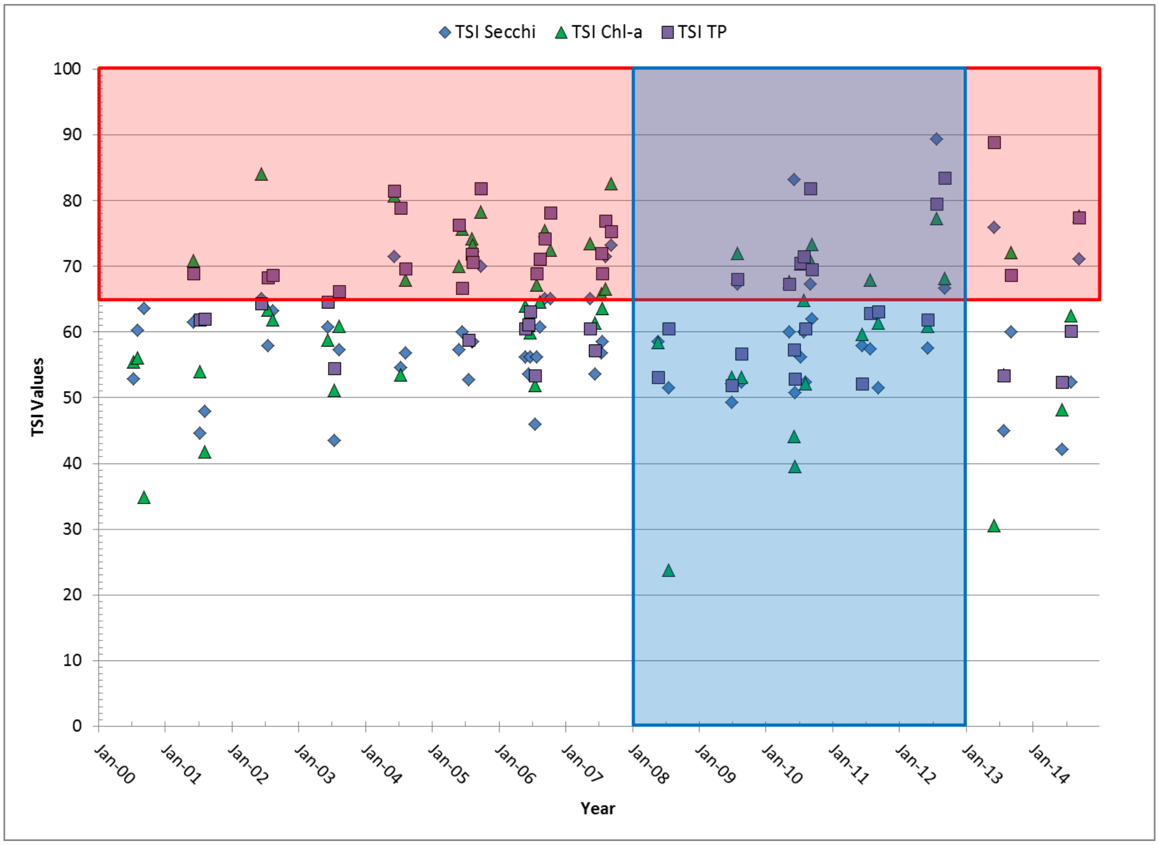


Figure 3-2. Growing season TSI values for individual samples (2001-2014)

Averaging the growing season water quality values for each year (2001-2014) results in overall annual average TSI values of 56 for Secchi depth, 68 for chlorophyll-a, and 69 for phosphorus. The water clarity trend is negative, with increasing TSI values for chlorophyll-a, and TP, and not improving for Secchi depth (Figure 3-3). Averaging growing season water quality data used in the 2014 Water Quality Assessment (2008-2012) results in average TSI values of 57 for Secchi depth, 65 for chlorophyll-a, and 67 for TP. Note the correlation between chl-a, and TP TSI values, which provides some evidence of the importance of phosphorus for algal growth.

Subsequent analyses evaluate relationships between the three indices of in-lake water quality. Figure 3-4 shows the correlation between total phosphorus and Secchi depth TSI values. Figure 3-5 shows the correlation between chlorophyll-a and total phosphorus. Figure 3-6 shows the correlation between Secchi depth and chlorophyll-a. The R^2 values between the various TSI indices are summarized in Table 3-1 below. The regression shows moderate correlation between the three indices, with the strongest correlation observed between TP and chlorophyll-a. This suggests reducing phosphorus exports to the lake may improve water clarity and water quality by reducing algae in Eldred Sherwood Lake.

Table 3-1. TSI annual mean values and R^2 values when compared linearly

TSI indicator	Total Phosphorus	Chlorophyll-a
Secchi depth	0.298	0.214
Chlorophyll-a	0.336	---

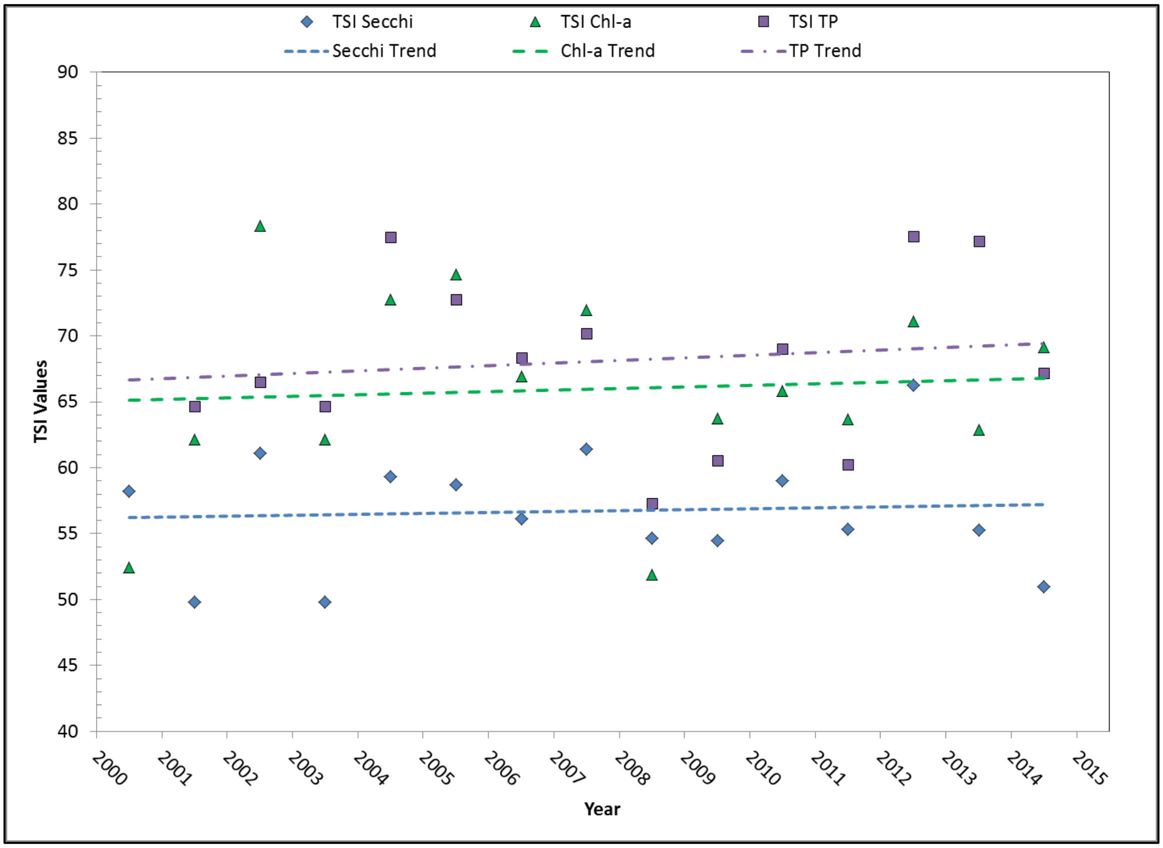


Figure 3-3. Growing season mean TSI values (2001-2014)

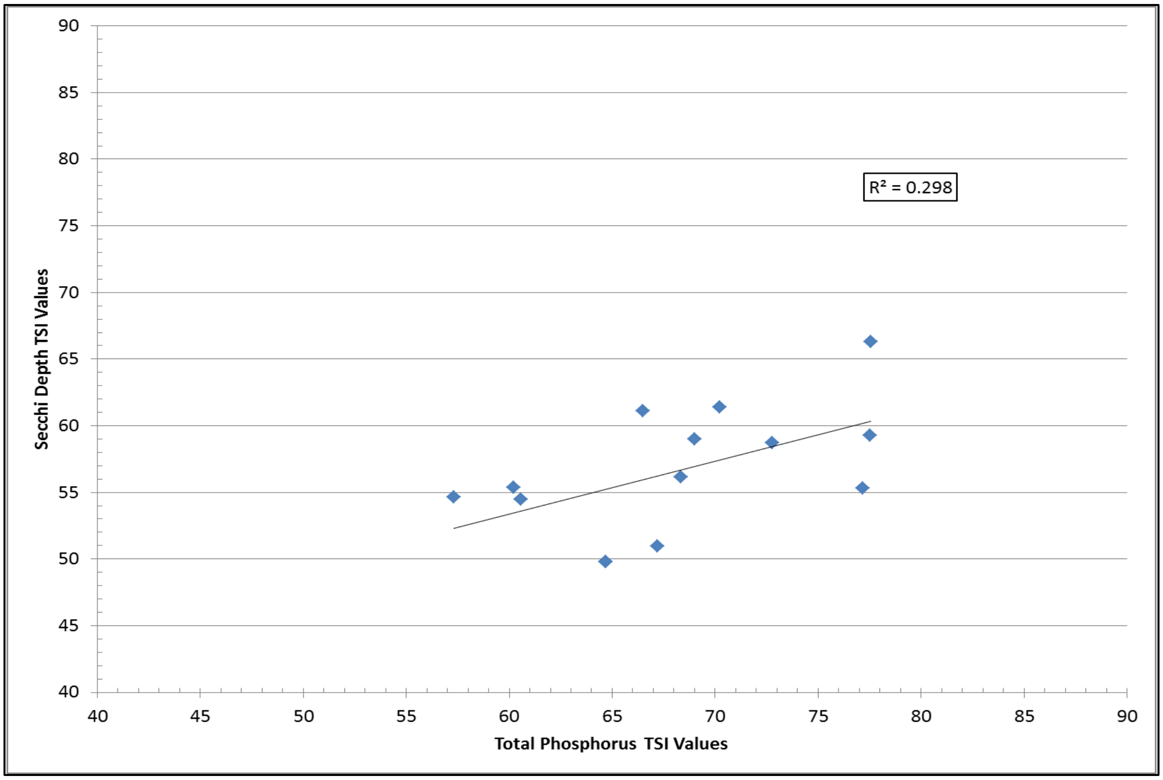


Figure 3-4. Annual mean TSI values for total phosphorus and Secchi depth

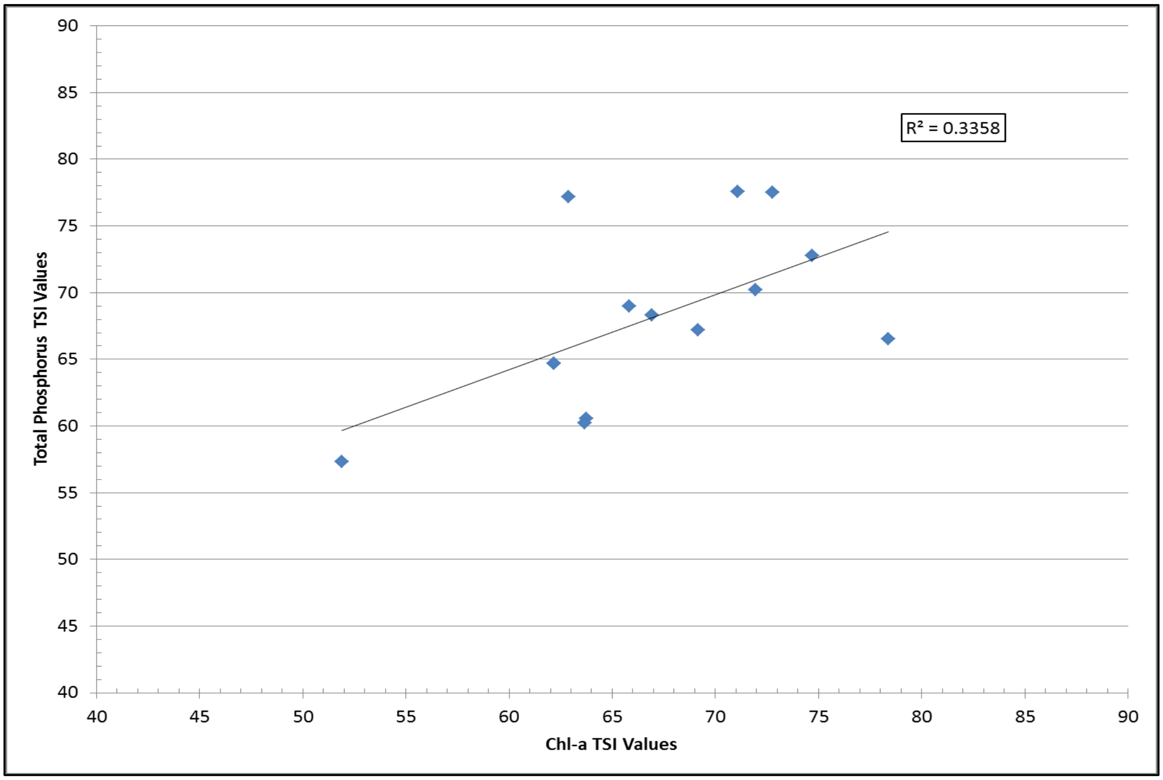


Figure 3-5. Annual mean TSI values for total phosphorus and chlorophyll-a

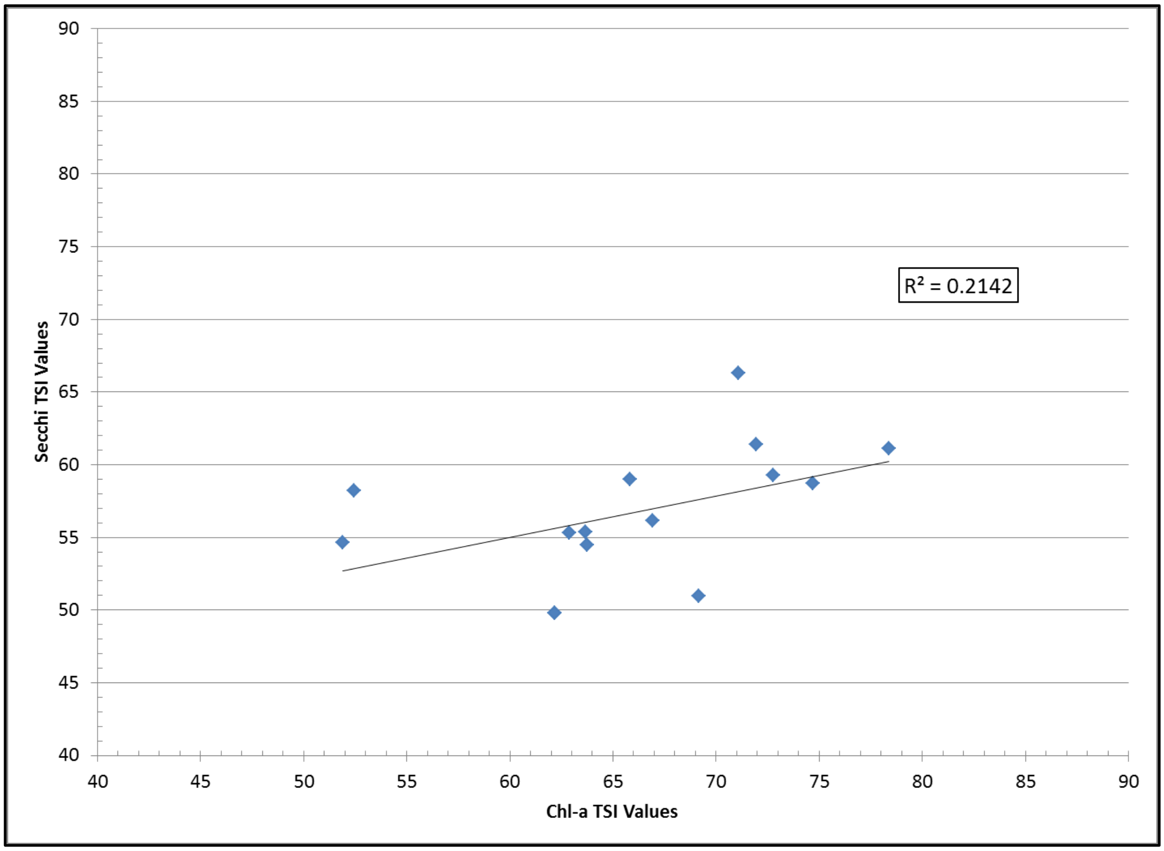


Figure 3-6. Annual mean TSI values for Secchi depth and chlorophyll-a

Carlson's TSI was used to evaluate the relationships between TP, algae (chlorophyll-a), and transparency (Secchi depth) in Eldred Sherwood 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.

Figures 3-7 and 3-8 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 split between positive and negative deviations, with a slight majority (36 of 57 samples) lying below the x-axis, and a majority of samples to the right of the Y-axis in Figure 3-7. These metrics are indicative of low non-algal turbidity levels and algal limitation that is caused by TP limitation, depending on conditions at the time the water quality sample was collected. In addition, the lack of samples in top left quadrant, indicating finely suspended particles, and the low number of samples in bottom left quadrant (15 of 60 samples) show that excess nutrients causing algal blooms may not be causing non algal turbidity issues.

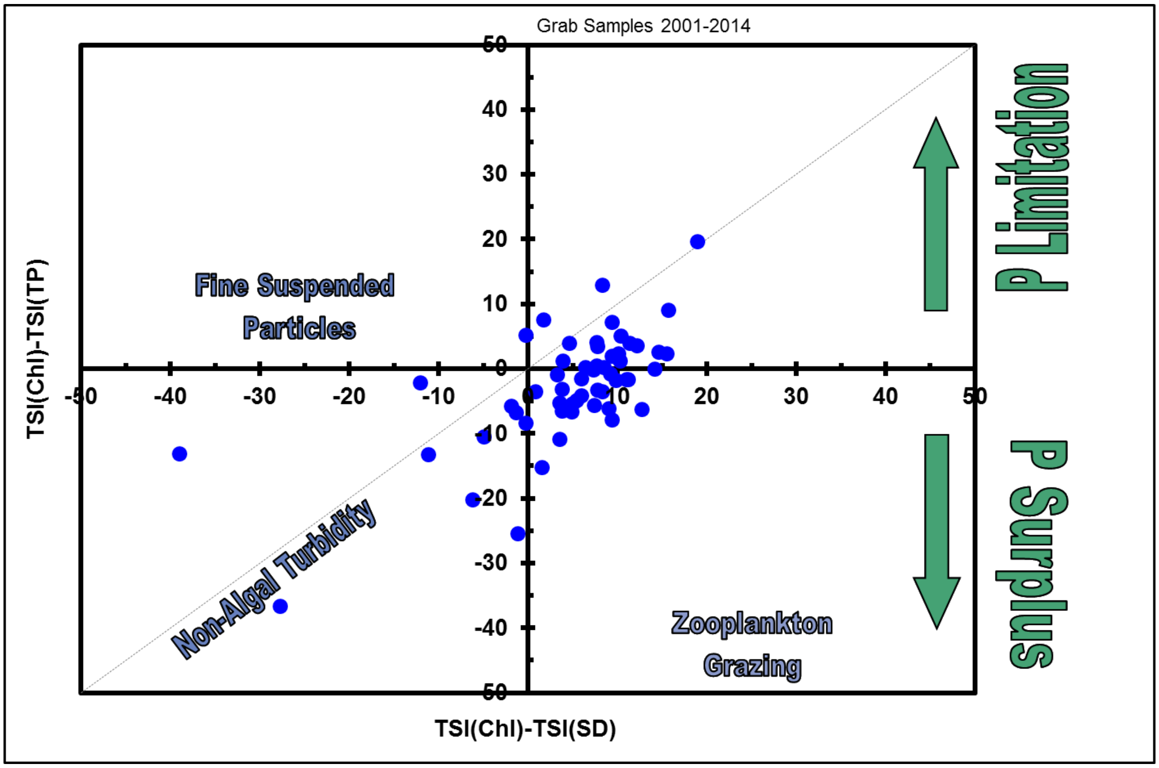


Figure 3-7. Phosphorus TSI deviations (2001-2014 grab samples)

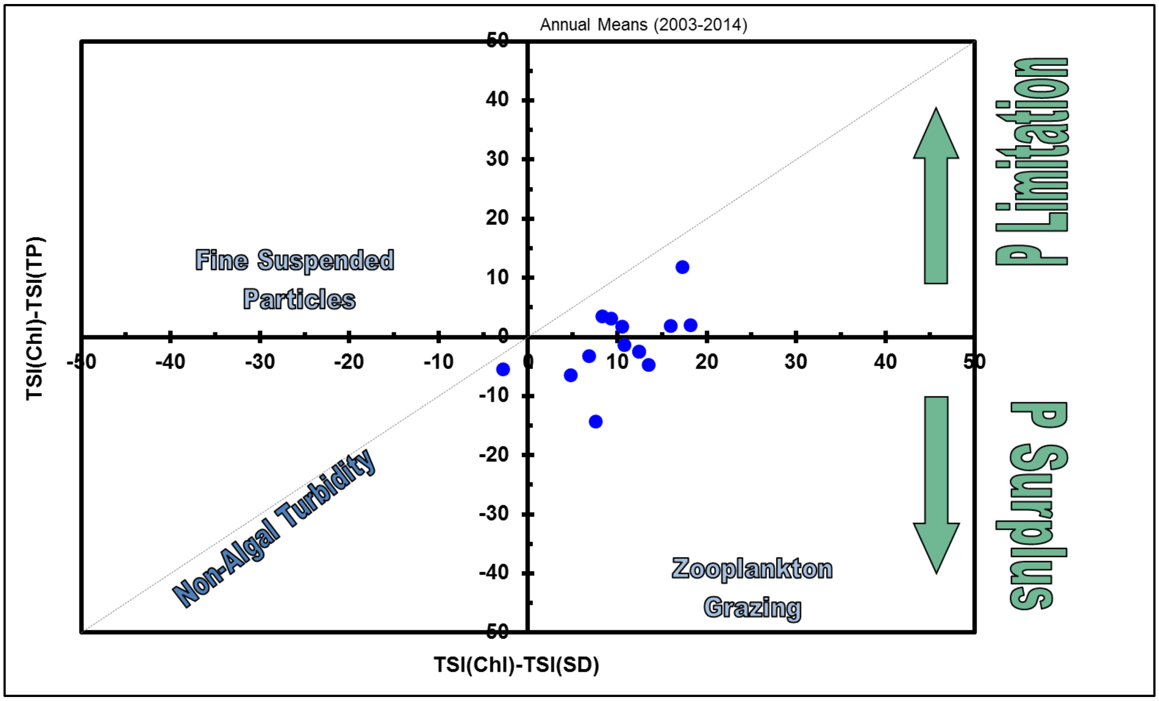


Figure 3-8. Phosphorus TSI deviations (2001-2014 annual averages)

Neither Secchi depth, chlorophyll-a, nor TP annual average TSI values show any correlation to annual or growing season precipitation (Figure 3-9). High chlorophyll-a and TP levels are observed in both wet and dry years, and both conditions must be considered when developing the TMDL.

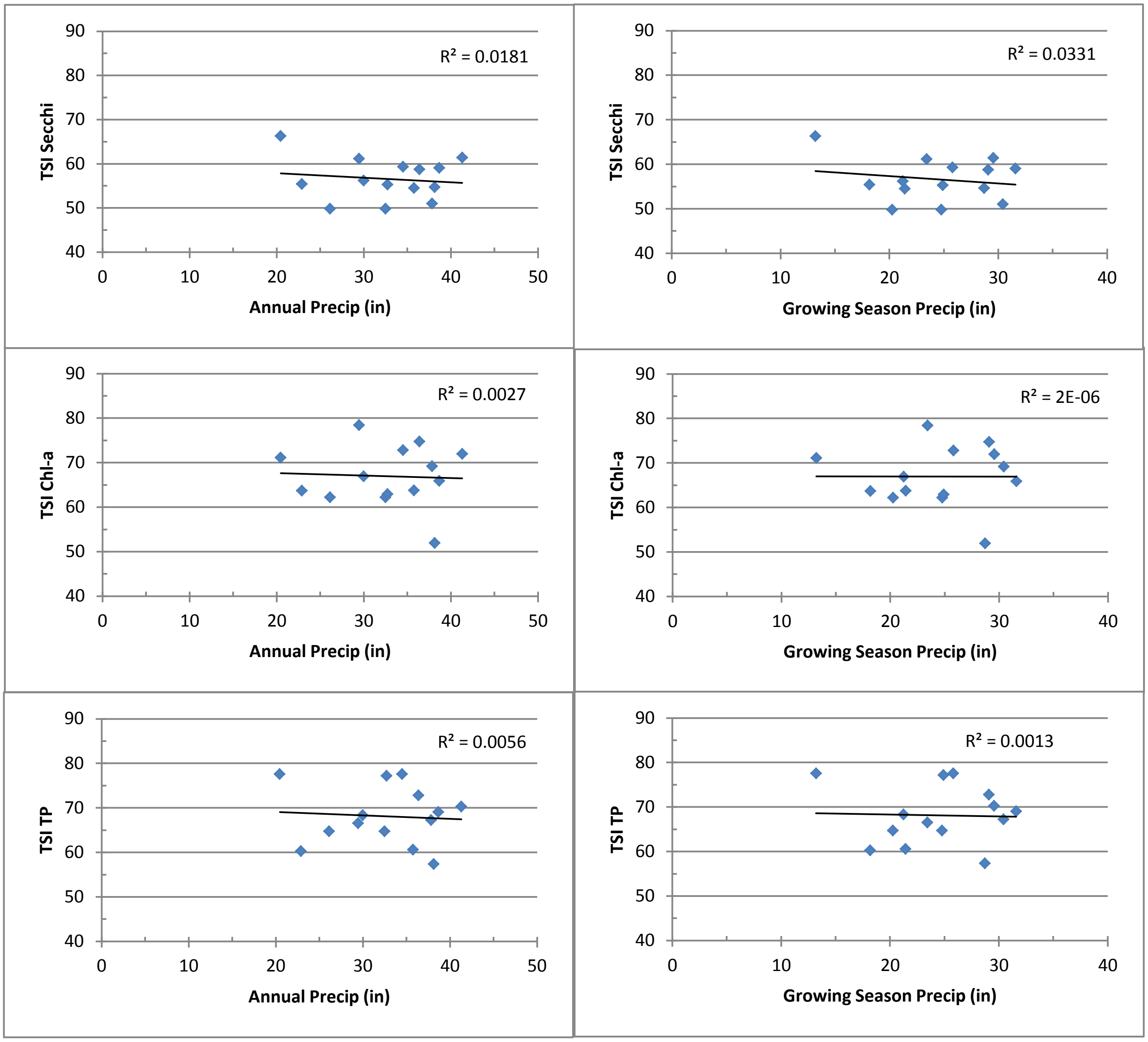


Figure 3-9. TSI values plotted against annual and growing season precipitation

Within lakes, the main two nutrients necessary for algal bloom development are nitrogen and phosphorus. When one nutrient is in short supply relative to the other, this nutrient supply will be exhausted first during growth. Once this nutrient is no longer available, growth is limited. Generally, in Iowa lakes, phosphorus is the limiting nutrient. Ratios of total nitrogen (TN) to total phosphorus (TP) can provide clues as to which nutrient is limiting growth in a given waterbody.

The overall TN:TP ratio in water quality samples from Eldred Sherwood Lake, using average growing season mean concentrations from 2001-2014, is 169. According to a study on blue-green algae dominance in lakes, ratios greater than 17 suggest a lake is phosphorus, rather than nitrogen, limited (MPCA, 2005). Carlson states that phosphorus may be a limiting factor at TN:TP ratios greater than 10 (Carlson and Simpson, 1996). Ratios that fall between 10 to 17 are often considered "co-limiting," meaning either nitrogen or phosphorus is the limiting nutrient or light is limited due to high non-algal turbidity.

Analysis of the TN:TP ratio in Eldred Sherwood Lake samples reveals that the lake is P-limited 89 percent of the time and co-limited 4.3 percent of the time. Table 3-2 lists the number of occurrences for each limitation when chl-a and Secchi depth are above impairment levels. In addition, mean nitrogen levels in the Eldred Sherwood system can be a significant factor in the P-limiting conditions in all samples. Mean chl-a values were the highest in co-limited and P-limited water quality conditions, indicating the relative importance of P vs. N in reducing algal growth.

Table 3-2. TN:TP ratio summary in Eldred Sherwood Lake

Samples Collected	# of Samples	N-limited (< 10)	Co-Limited (10-17)	P-limited (>17)
All samples 2001-2014	46	3 (6.5%)	2 (4.3%)	41 (89.1%)
Samples with Chl-a TSI > 65	21	3 (14.3%)	2 (9.5%)	16 (76.2%)
Samples with Secchi TSI > 65	13	3 (23.1%)	2 (15.4%)	8 (61.5%)

When the chl-a TSI exceeds 65, the lake is either P-limited or co-limited over 85 percent of the time. This analysis reveals that water quailty improvement via TP reduction is most feasible, since N is in such rich supply that it very rarely limits algal growth in Eldred Sherwood Lake. Additionally, nitrogen limitation favors 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.

3.2. TMDL Target

General description of the pollutant

The 2014 305(b) assessment attributes poor water quality in Eldred Sherwood 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. Phosphorus should be reduced first, as it is the primary limiting nutrient in algal growth.

Table 3-3 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 Eldred Sherwood Lake if attained in two consecutive 303(d) listing cycles. Note that TP and Secchi depth values in Table 3-3 represent in-lake water quality resulting from TP load reductions required to obtain the chlorophyll-a target in Eldred Sherwood Lake.

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

Parameter	2008-2012 Mean	[1]TMDL Target
Secchi Depth	1.20 m	1.5 m
TSI (Secchi Depth)	57	55
Chlorophyll-a	33.1 μg/L	27.3 μg/L
TSI (Chlorophyll-a)	65	63
TP	78.5 μg/L	54.7 μg/L
TSI (TP)	67	62

[1]Target is chlorophyll-a TSI of 63 or less

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 Eldred Sherwood 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 2008 through 2012, consistent with the assessment period for the 2014 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 landuse 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, landuse, 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 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 3-10. The annual loading capacity of Eldred Sherwood Lake is set at 421 kg/yr (929 lbs/yr).

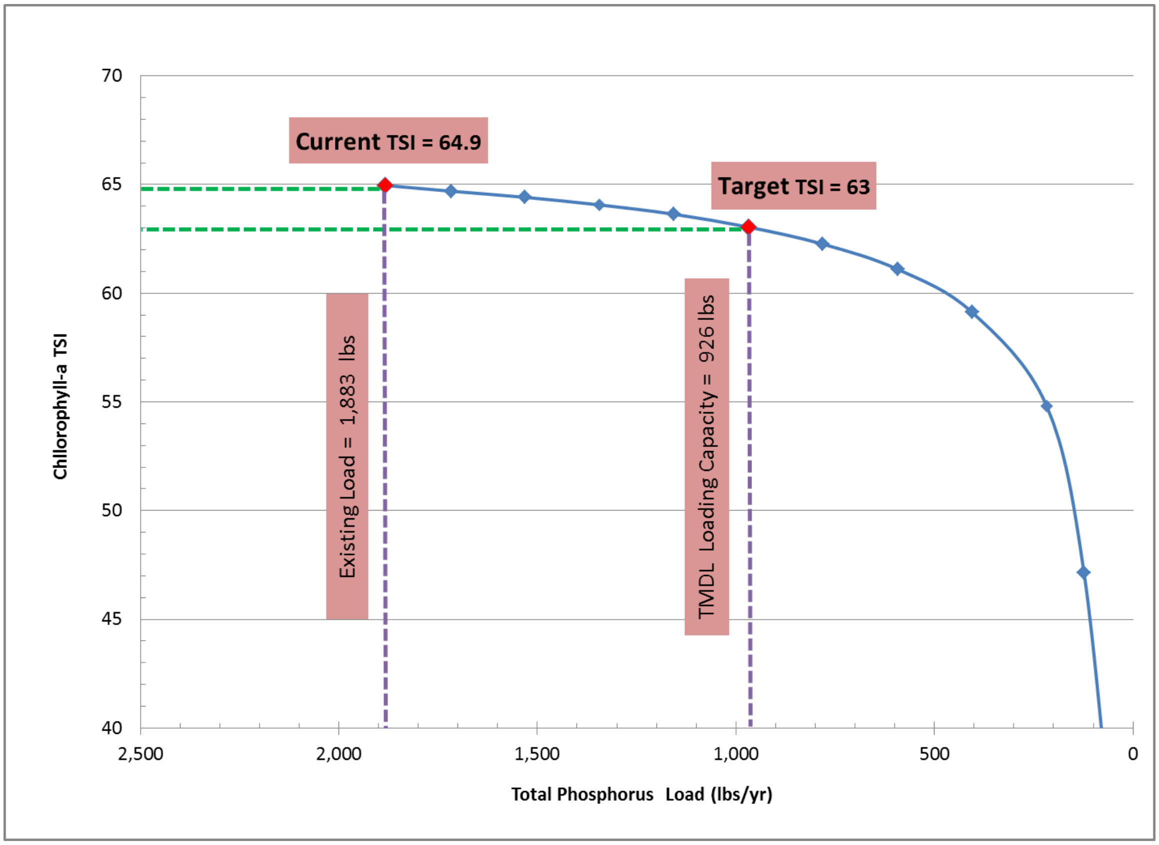


Figure 3-10. Simulated load response between chlorophyll-a TSI and TP load

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 Eldred Sherwood Lake for TP is expressed as a daily maximum load, in addition to the annual loading capacity of 929 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 929 lbs/yr is equivalent to an average daily load of 2.5 pounds per day (lbs/day) and a maximum daily load of 10.2 lbs/day.

Decision criteria for WQS attainment
The narrative criteria in the water quality standards require that Eldred Sherwood Lake be free from "aesthetically objectionable conditions." The metrics for WQS attainment for de-listing the impairments are a chlorophyll-a TSI of 63 or less in two consecutive 303(d) listing cycles.

Compliance point for WQS attainment
The TSI target for listing and delisting of Eldred Sherwood 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 such as the 305(b) assessment and 303(d) listing process, the TMDL target is based on water quality of Segment 1, which best represents the ambient monitoring location in Eldred Sherwood 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 Wetlands, Oceans, and Watersheds (OWOW), 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 2008 and 2012, the annual TP load to Eldred Sherwood Lake was estimated to be 1,883 lbs/yr. The simulation period (for existing conditions) is the same as the assessment period (for the 2014 Integrated Report). This period was relatively wet, with only two years (2011 and 2012) of the five-year span having below average precipitation. Because both dry and wet 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 Eldred Sherwood Lake is 929 lbs/yr and 10.2 lbs/day (maximum daily load). To meet the target loads, an overall reduction of 50.7 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 Eldred Sherwood Lake is entirely from nonpoint sources of pollution. Table 3-4 reports estimated annual average TP loads to the lake from all known sources, based on the STEPL simulation of average annual conditions from 2008-2012. The predominant sources of phosphorus to Eldred Sherwood Lake include erosion from land in row crop production and soluble phosphorus from tile drainage discharge. Row crops in various rotations comprise over 90 percent of the land area of the watershed (Table 2-3), and over 89 percent of the phosphorus load to the lake (Figure 3-11 and Table 3-4). Other contributing sources of phosphorus include developed areas such as roads, residential, and other urban areas (8.8 percent); erosion and runoff from grassland and timber areas (0.6 percent); and septic systems in the watershed (0.5 percent).

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 phosphorus levels 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 Eldred Sherwood Lake. The elevated flushing rate, which stems from the large watershed-to-lake ratio of 118-to-1, likely contributes to the low significance of internal loading in Eldred Sherwood 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. Reduction of internal lake loads is a valid water quality improvement strategy, 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. Any future residential development may contribute similar sediment loads and therefore will not increase phosphorus to the lake system. Eldred Sherwood Lake Park, which circumscribes the lake, is unlikely to undergo significant landuse changes. There are currently no incorporated unsewered communities in the watershed; therefore it is unlikely that a future WLA would be needed for a new point source discharge. Any future development of animal feeding operations (AFO) qualifying as large concentrated animal feeding operations (CAFO) or meeting the requirements for NPDES permits as small or medium sized CAFOs will not be allowed to discharge to surface water.

Table 3-4. Average annual TP loads from each source (2008-2012)

Source	Descriptions and Assumptions	TP Load (lb/yr)	Percent (%)
Row Crops	Sheet and rill erosion from corn and soybeans dominated agriculture	1312.7	69.7
Groundwater	Agricultural tile discharge	366.6	19.5
	Other sources	11.2	0.6
Developed	Urban areas, roads, and farmsteads	165.7	8.8
Septic Systems	Private wastewater systems, infiltration/inflow from deficient systems	9.7	0.5
Grassland	Non-grazed grassland, CRP	8.8	0.5
Timber/Forest	Ungrazed timber, including shrub/scrub	2.5	0.1
All others	Wildlife, atmospheric deposition	6.0	0.3
Total		**1883.1**	**100**

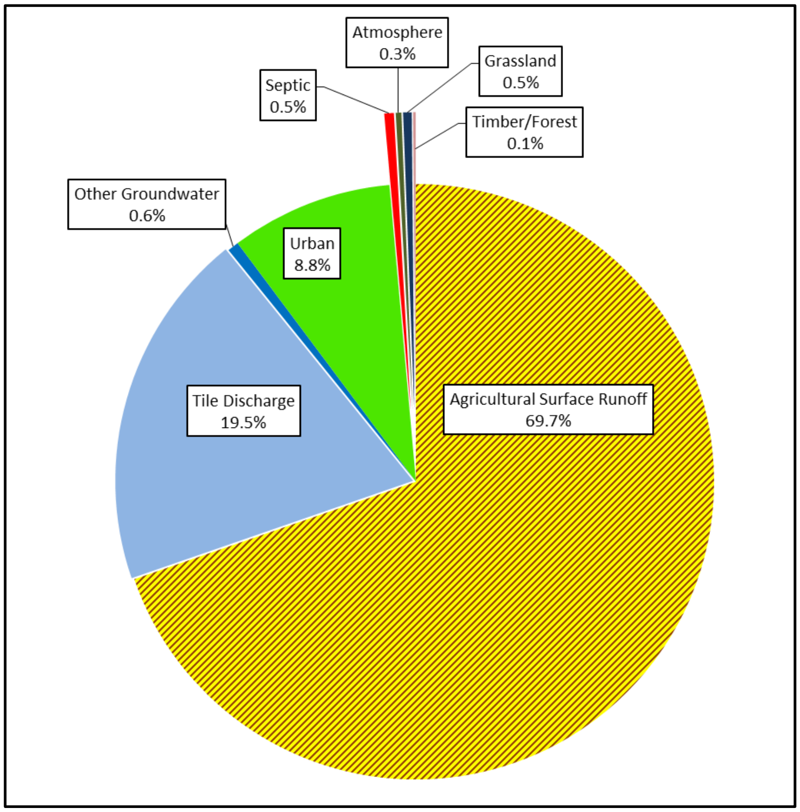


Figure 3-11. Relative TP loads by source

3.4. Pollutant Allocation

Wasteload allocation

There are no permitted point source dischargers of phosphorus in the Eldred Sherwood Lake watershed.

Load allocation

Nonpoint sources of phosphorus to Eldred Sherwood Lake include erosion from land in row crop production, erosion from grasslands, erosion from timber/wooded areas, transport from developed areas (roads, residences, etc.), wildlife defecation, and atmospheric deposition (from dust and rain), and significant groundwater contributions. Septic systems in this watershed, which are not regulated or permitted under the Clean Water Act, but can fail or drain illegally to ditches, also contributed phosphorus to the lake during the assessment period. 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 Eldred Sherwood Lake. Based on the inventory of sources, management and structural practices targeting phosphorus losses via tile drainage and erosion of land in row crop production offer the largest potential reductions in TP loads.

Table 3-5 shows an example load allocation scenario for the Eldred Sherwood Lake watershed that meets the overall TMDL phosphorus target. The LA is 833.1 lbs/year, with a maximum daily LA of 9.1 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 potentially achieve water quality goals.

Table 3-5. Example load allocation scheme to meet target TP load

TP Source	Existing Load (lb/year)	LA (lb/year)	NPS Reduction (%)
Row Crops	1312.7	500	62
Groundwater	377.7	230.3	40
Developed	165.7	83.0	50
Septic Systems	9.7	9.7	0
Grassland	8.8	4.7	50
Timber/Forest	2.5	2.5	0
[1]All others	6.0	6.0	0
Total	**1883.1**	**836.2**	**55.6%**

[1] Atmospheric contributions, direct lake contributions by waterfowl

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 (92.9 lbs/year, 1.0 lbs/day) was utilized in the development of this TMDL. These uncertainties may include seasonal changes in nutrient concentrations of influent to Eldred Sherwood Lake, the unknown importance of internal loading, bioavailability of phosphorus, and in-lake relationships between chl-a and phosphorus.

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 Eldred Sherwood 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 Eldred Sherwood Lake watershed, the general equation above can be expressed for the Eldred Sherwood 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 (836.2 lbs-TP/year)
+ MOS (92.9 lbs-TP/year) = **929.1 lbs-TP/year**

Expressed as the maximum daily load:

TMDL = LC = Σ WLA (0 lbs-TP/day) + Σ LA (9.2 lbs-TP/day)
+ MOS (1.0 lbs-TP/day) = **10.2 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 Eldred Sherwood 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 Eldred Sherwood 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

Since the development of the Eldred Sherwood Lake watershed in the 1970's, there has been continued work by landowners and public entities to ensure the viability and sustainability of the lake system. Agricultural producers have adopted grassed waterways, riparian corridors, conservation tillage, and more recently subsurface conservation drainage practices. These practices help prevent and mitigate soil loss from the landscape, which can in turn decrease nutrient and pollutant loading to the lake system.

4.2. Future Planning and Implementation

General Approach
Future watershed management and BMP implementation efforts in the Eldred Sherwood Lake watershed should utilize a phased approach. Given the watershed-to-lake ratio and the morphology of this lake system, attainment of existing water quality standards may take considerable time to see improvement in the watershed. 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 maximize water uptake and nutrient uptake by cover crops and riparian species in buffer strips along drainage ditches.

Projects with multiple benefits (e.g., wildlife habitat, soil conservation, and water quality) may do more to protect and preserve the use of Eldred Sherwood Lake for future generations than those focused solely on water quality. Additional funding avenues including, but not limited to 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. Sustained improvement may be a more appropriate short term goal than impairment delisting.

Tracking milestones and progress
This WQIP, including the proposed monitoring plan outlined in Section 5, 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 be eligible for additional funding from available sources. A path to full attainment of water quality standards and designated uses must be included for most funding sources, 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 Eldred Sherwood 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 Eldred Sherwood Lake. The majority of phosphorus enters the lake via nutrient loss from agricultural fields through sheet and rill erosion and tile drainage. Both of these sources have 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 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. Land retirement programs such as the conservation reserve program (CRP), and conservation reserve enhancement program (CREP) may be considered where appropriate.

The Eldred Sherwood Lake watershed has no grazed pastures, but the possibility of landuse change in the future is still present. 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 or 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, saturated buffers, riparian buffers, and wetlands can play a valuable role in reduction of sediment and nutrient transport to Eldred Sherwood 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; subsurface drainage characteristics, proximity to waterbodies; tillage practices, and method, timing, and amount of commercial fertilizer application.

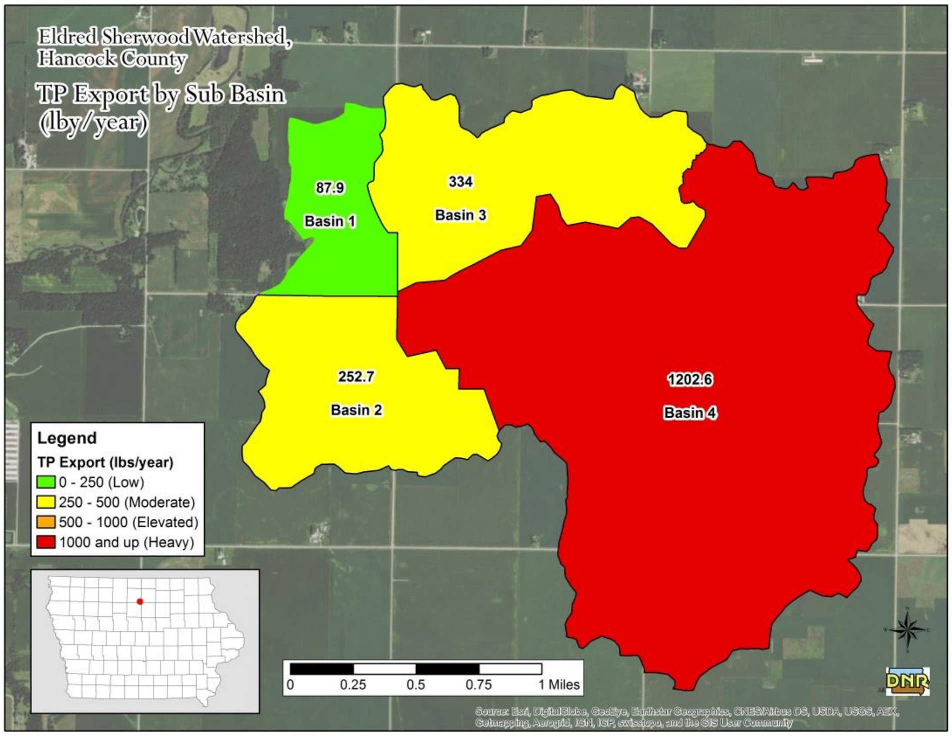
Table 4-2. Potential structural BMPs (mitigation strategies)

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%
Riparian Buffers	Ecological services, aesthetic value, alternative agriculture	45%
Saturated Buffers	Nitrate removal	[4]Varies

[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] Limited research in total phosphorus reduction values

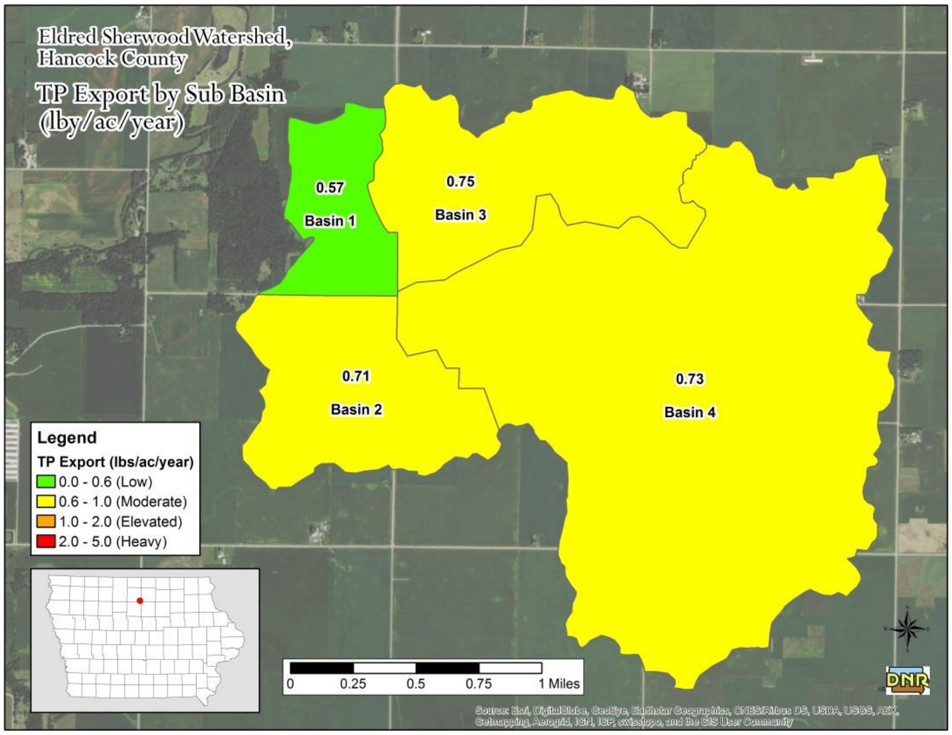
The Spreadsheet Tool for Estimating Pollutant Load (STEPL) model was used in TMDL development to predict phosphorus loads to Eldred Sherwood Lake. Figure 4-1 shows the annual phosphorus export from each subbasin in the Eldred Sherwood Lake watershed STEPL model. Red-shaded basins indicate the heaviest phosphorus export and green shaded bars indicate the lowest export rates relative to the subbasins in this study. The figures reveal that more phosphorus is annually exported from Subbasins 2, 3 and 4 (252.7 lbs, 334.0 lbs, 1202.6 lbs, respectively). Subbasin 1 has the lowest TP export at 87.9 lbs. Figure 4-2 shows TP losses for each subbasin after adjusting for drainage area. On a per-area basis, Subbasins 2, 3 and 4 have very similar export rates between 0.71 and 0.75 pounds per acre per year (lbs/ac/yr).

Subbasin-level information indicates that best management practices reducing phosphorus export should concentrate on upstream sub basins and tile discharge pathways. The drainage ditch running east to west towards Eldred Sherwood Lake conveys flow from both drainage districts and 80% of surface runoff of the watershed. There is potential to target this area to reduce phosphorus transport to Eldred Sherwood Lake.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 4-2. Predicted per-acre TP loss for each STEPL subwatershed

More detailed information should be collected in order to target specific BMPs to specific areas (e.g., fields or drainage ditches) 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 has the potential to be a contributor of bioavailable phosphorus to lakes. The average annual contribution of TP to the system from internal loading appears to be relatively small in Eldred Sherwood 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 Eldred Sherwood Lake watershed are of large enough magnitude to fully account for observed in-lake phosphorus and subsequent algae 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 impacts 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. 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. Resident rough fish can be a problem and could be controlled through this method.
Targeted dredging and sediment basin improvement	Targeted dredging in shallow inlet areas would create pockets of deep-water habitat for predatory fish that would help control rough fish populations.
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 Eldred Sherwood 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).

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: https://www.legis.iowa.gov/docs/iac/chapter/567.61.pdf

Failure to prepare an approved QAPP will prevent collected data from being used to evaluate the 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 Eldred Sherwood Lake to assess water quality trends and compliance with 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 sampled as part of this program, including Eldred Sherwood 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 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 Thermocline Depth Lake Depth	Chlorophyll a Phytoplankton (mass and composition) Zooplankton (mass and composition)

5.2. Expanded Monitoring for Detailed Analysis

Data available from the Iowa DNR Beach Monitoring Program and the Iowa DNR Ambient Lake Monitoring Program will be used to assess general water quality trends and WQS violations and attainment. More detailed monitoring data is required to reduce the level of uncertainty associated with water quality trend analysis, better understand the impacts of implemented watershed projects (i.e., BMPs), and guide future water quality modeling and BMP implementation efforts.

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. Locations for expanded monitoring in the Eldred Sherwood Lake watershed have been chosen to take into account drainage district boundaries and can be used in assigning nutrient concentrations to each district if deployed in such a manner.

Table 5-2. Recommended monitoring plan

Parameter(s)	Intervals	Duration	[1]Location(s)
Routine grab sampling for flow, sediment, P, and N	Every 1-2 weeks	April through October	Ambient location in Eldred Sherwood Lake, tile inlets upstream
Continuous flow	15-60 minute	April through October	Eldred Sherwood Lake inlet & outlet
Continuous pH, DO, and temperature	15-60 minute	April through October	Ambient location in Eldred Sherwood Lake
Storm event flow, sediment, P, and N	Flow weighted sampling during storm flow	5 events between April and October	Ambient location in Eldred Sherwood Lake
Shoreline mapping, bathymetry studies	After dredging or construction, every 5 years	Design lifespan of waterbody	Near dredging operations, or near lake inlets

[1] Tributary, tile drain, and gully site selection to be based on suspected pollutant source location, BMP placement, landowner permission, and access/installation feasibility.

It may be useful to divide the recommended monitoring plan into several tiers based on ease of deployment and cost effectiveness. This will help stakeholders and management personnel best direct their resources. This monitoring plan may be reevaluated at any time to change the management strategy. Data collection should commence before BMPs are implemented in the watershed to establish baseline conditions. Selection of tributary sites should consider location of BMPs, location of historical data (for comparative purposes), landowner permission (if applicable), and logistical concerns such as site access and feasibility of equipment installation (if necessary). This data could form the foundation for assessment of water quality trends; however, more detailed information will be necessary to make any statements about water quality trends with certainty. Therefore, routine grab sampling should be viewed only as a starting point for assessing trends in water quality.

Level 1
The most basic of monitoring plan would continue the existing monitoring done at the ambient location of Eldred Sherwood Lake.

Level 2
Grab sampling of the Eldred Sherwood Lake ambient monitoring point should be continued on a bi-weekly basis. Grab samples on a seasonal basis at the inlets would be done to support data provided by the main lake.

Level 3
If automated sampling devices cannot be procured, then grab samples should continue on a routine and event based schedule to define subsurface flow from the east-west drainage ditch. Flow data may be recorded by area-velocity measurements, or manual flow readings based on developed rating curves. Locations and sampling approaches would include the ambient monitoring station, upstream inlets, and the main tile drainage ditch to the southeast.

Level 4
Automated data recorded by ISCO devices would provide information on continuous flow, and continuous pH, DO, and temperature. Routine grab sampling for flow, sediment, P, and N will help provide a check on the automated sampling. In addition to routine sampling, runoff event sampling for event flow, sediment, N, and P will help show the effects of high recurrence interval events. Locations and sampling approaches would include the ambient monitoring station, Eldred Sherwood Lake beach, inlets from upstream tributaries, and tile discharge ditch to the southeast. Reliable long-term flow data is also important because hydrology drives many important processes related to water quality, and a good hydrologic data set will be necessary to evaluate the success of BMPs such as reduced-tillage, saturated buffers, terraces and grassed waterways, riparian buffers, and wetlands.

The proposed monitoring information would assist utilization of watershed and water quality models to simulate various scenarios and water quality response to BMP implementation. 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 Iowa DNR Watershed Improvement Section can provide technical support to locally led efforts in collecting further water quality and flow monitoring data in the Eldred Sherwood Lake watershed. A look at how these proposed monitoring plans may be deployed in the Eldred Sherwood Lake watershed is shown in Figure 5-1.

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 Eldred Sherwood Lake watershed.

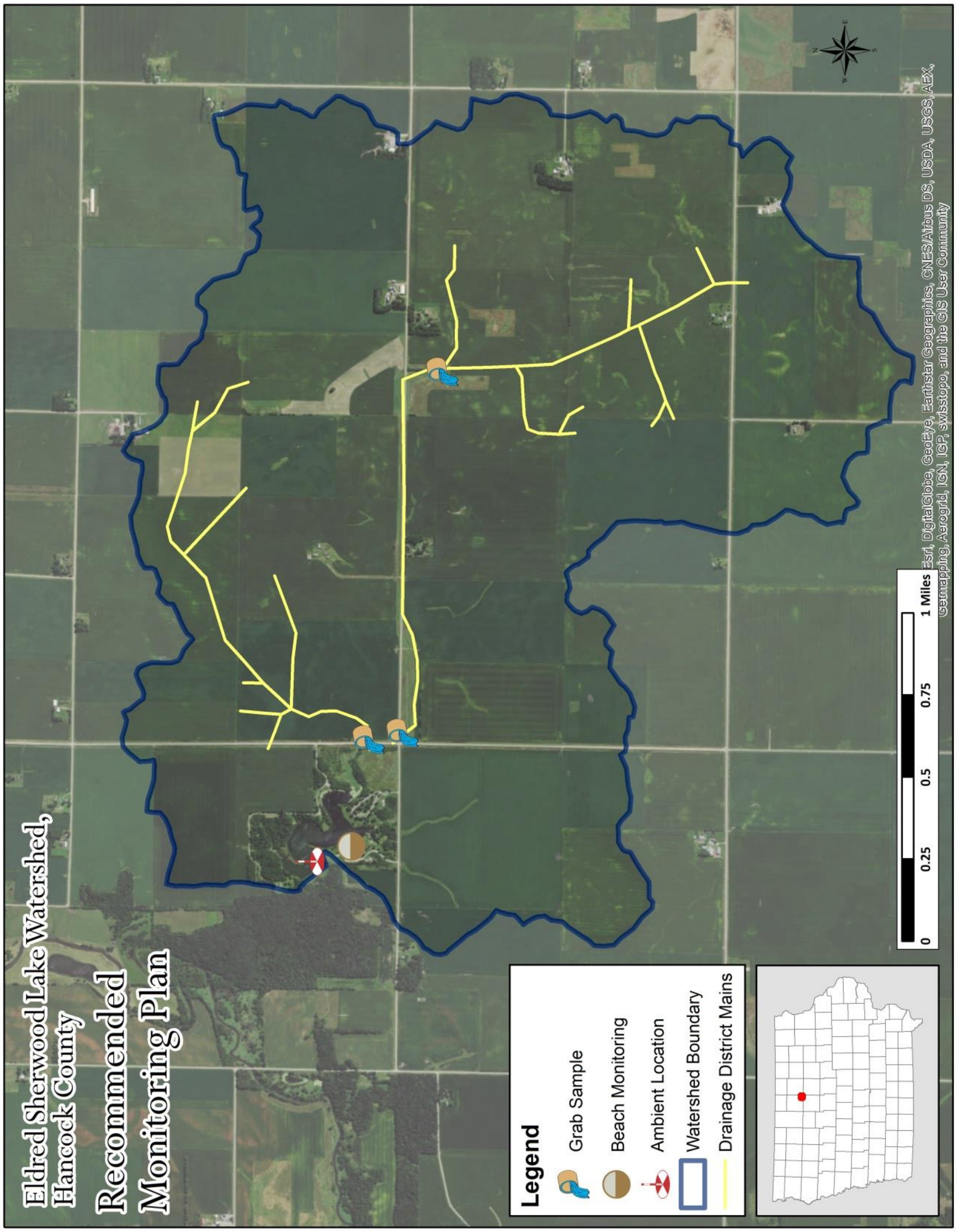


Figure 5-1. Potential monitoring locations

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 Eldred Sherwood Lake.

6.1. Public Meetings

Stakeholder Meetings
April 8, 2016
A preliminary meeting and site investigation with park director to inventory landuse, soil, and topography of Eldred Sherwood Lake watershed and park grounds was held. Location and number of tile drainage ditches were noted.

June 22, 2016
A secondary site investigation was completed to collect water quality samples. Further investigations of the watershed, lake, and park were held. Discussions with the park director on future public presentations took place.

Public Presentations
October 12, 2016
A public meeting to present the results of the TMDL study, obtain stakeholder input, and discuss next steps for community-based watershed planning will be held at the Klemme Community Center from 6:00pm – 7:30 pm.

6.2. Written Comments

The public comment period will begin after internal reviews are concluded and two weeks prior to the required public meeting. The public comment period will continue two weeks after the required public meeting. All comments received during the public comment period will be included in Appendix I of this document, along with an official response from DNR.

7. References

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography. 22(2):361-369.

Carlson, R, and J. Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. 96 pp.

Center for Agricultural and Rural Development (CARD). 2009. Iowa State University. Iowa Lakes Valuation Project. Information specific to Eldred Sherwood Lake available at http://www.card.iastate.edu/lakes/lake_usage.aspx?id=72. Accessed in December, 2013.

Dinnes, D.L. 2004. Assessments of practices to reduce nitrogen and phosphorus nonpoint source pollution of Iowa's surface waters. Iowa Department of Natural Resources; USDA-ARS National Soil Tilth Laboratory, Ames, Iowa.

Dodds, W. 2000. Freshwater Ecology: Concepts and Environmental Applications. Draft textbook. Division of Biology, Kansas State University, Manhattan, Kansas.

Iowa Environmental Mesonet (IEM). 2016a. 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 2016.

Iowa Environmental Mesonet (IEM). 2016. 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 2016.

Prior, Jean Cutler. *Landforms of Iowa*. Iowa City: U of Iowa for the Dept. of Natural Resources, 1991. Print.

U.S. Department of Agriculture – Farm Service Agency (USDA-FSA). 2016. http://www.fsa.usda.gov/Internet/FSA_File/clu_2007_infosheetpdf.pdf. Accessed August 2016.

U.S. Department of Agriculture – National Agricultural Statistical Summary (USDA-NASS). 2016. http://nassgeodata.gmu.edu/CropScape/. Accessed March 2016.

U.S. Environmental Protection Agency (EPA). 1991. Technical Support Document for Water Quality-based Toxics Control. EPA/505/2-90-001. EPA Office of Water, Washington, DC.

U.S. Environmental Protection Agency (EPA). 2006. 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. Memorandum from Benjamin Grumbles, Assistant Administrator, EPA Office of Water, Washington, DC.
U.S. Environmental Protection Agency (EPA). 2007. Options for Expressing Daily Loads in TMDLs (Draft). EPA Office of Wetlands, Oceans & Watersheds, Washington, DC.

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.

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, landuse, 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)	TN (mg/L)	pH
ISU	10-Jul-00	1.63	12.71	*	12.65	8.53
ISU	31-Jul-00	0.98	13.53	*	9.88	8.69
ISU	6-Sep-00	0.78	1.55	*	2.15	8.46
ISU	4-Jun-01	0.90	60.88	89.95	16.66	9.00
ISU	9-Jul-01	2.90	10.88	54.97	12.68	8.47
ISU	6-Aug-01	2.30	3.12	55.43	8.82	8.37
ISU	10-Jun-02	0.70	232.44	65.39	9.35	8.67
ISU	15-Jul-02	1.15	28.32	86.04	7.63	8.46
ISU	12-Aug-02	0.80	24.24	88.06	10.94	8.43
ISU	9-Jun-03	0.95	17.82	66.25	12.73	8.65
ISU	14-Jul-03	3.15	8.17	32.98	12.50	8.42
ISU	11-Aug-03	1.20	22.06	74.29	7.27	8.72
ISU	7-Jun-04	0.45	165.60	214.85	14.74	9.25
ISU	12-Jul-04	1.45	10.30	178.89	10.45	8.39
ISU	9-Aug-04	1.25	45.06	94.37	10.63	8.32
UHL	25-May-05	1.20	56.00	150.00	14.20	8.60
ISU	13-Jun-05	1.00	99.38	76.66	13.89	8.66
ISU	18-Jul-05	1.65	*	44.60	12.50	8.84
UHL	4-Aug-05	1.10	85.00	110.00	8.50	8.60
ISU	8-Aug-05	1.10	77.61	101.35	7.22	9.10
UHL	21-Sep-05	0.50	130.00	220.00	2.10	8.60
UHL	23-May-06	1.30	30.00	50.00	10.90	8.60
ISU	12-Jun-06	1.55	22.14	52.43	10.94	8.98
UHL	20-Jun-06	1.30	20.00	60.00	9.30	8.50
ISU	17-Jul-06	2.65	8.78	30.57	7.61	8.35
UHL	26-Jul-06	1.30	42.00	90.00	6.10	8.40
ISU	14-Aug-06	0.95	31.98	104.34	2.50	8.91
UHL	6-Sep-06	0.70	97.00	130.00	1.40	8.60
UHL	10-Oct-06	0.70	72.00	170.00	1.90	8.50
UHL	15-May-07	0.70	79.00	50.00	12.10	8.80
ISU	11-Jun-07	1.55	23.04	39.91	13.11	8.29
ISU	16-Jul-07	1.25	36.14	110.96	4.73	8.82
UHL	18-Jul-07	1.10	29.00	90.00	5.00	9.00
ISU	6-Aug-07	0.45	39.00	156.93	1.47	8.80
UHL	5-Sep-07	0.40	200.00	140.00	5.80	8.80
UHL	22-May-08	1.10	17.00	30.00	10.20	8.30
UHL	15-Jul-08	1.80	0.50	50.00	10.60	8.70
ISU	25-Jun-09	2.10	10.00	27.60	11.60	8.20
ISU	30-Jul-09	0.60	68.00	84.70	11.30	8.40
ISU	20-Aug-09	1.70	10.00	38.30	7.30	7.60
UHL	5-May-10	1.00	44.00	80.00	*	8.30

Continued on next page

Source	DATE	Secchi (m)	Chl-a (µg/L)	TP (µg/L)	TN (mg/L)	pH
UHL	3-Jun-10	0.20	4.00	40.00	*	8.30
ISULL	7-Jun-10	1.90	2.50	29.36	*	8.01
UHL	8-Jul-10	1.30	58.00	100.00	*	8.30
ISULL	26-Jul-10	1.00	32.92	107.64	*	8.18
UHL	5-Aug-10	1.70	9.00	50.00	*	8.20
UHL	1-Sep-10	0.60	61.00	220.00	*	8.40
ISULL	9-Sep-10	0.87	78.61	93.34	*	8.18
ISU	9-Jun-11	1.15	19.45	27.91	*	8.31
ISU	25-Jul-11	1.19	44.76	58.80	*	8.48
ISU	6-Sep-11	1.80	23.00	60.11	*	7.97
ISU	4-Jun-12	1.18	21.92	54.90	6.34	8.85
ISU	23-Jul-12	0.13	117.64	187.40	3.54	8.95
ISU	3-Sep-12	0.63	46.44	247.00	1.84	8.54
ISU	3-Jun-13	0.33	1.00	358.25	14.07	7.70
ISU	22-Jul-13	2.83	10.36	30.40	13.83	8.57
ISU	2-Sep-13	1.00	69.32	87.80	6.57	9.11
ISU	9-Jun-14	3.45	5.99	28.40	15.80	8.43
ISU	28-Jul-14	1.70	25.84	48.70	18.61	8.15
ISU	7-Sep-14	0.46	121.00	161.30	11.53	7.51

[1] Ambient monitoring location = STORET ID 22410002
* 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	32.49	24.79	58.24	52.44	*
2002	29.47	23.44	49.77	62.16	64.69
2003	26.12	20.27	61.12	78.38	66.50
2004	34.51	25.81	49.77	62.16	64.69
2005	36.39	29.09	59.30	72.78	77.52
2006	29.98	21.24	58.74	74.70	72.79
2007	41.30	29.58	56.15	66.91	68.32
2008	38.15	28.71	61.39	71.95	70.21
2009	35.77	21.44	54.65	51.88	57.31
2010	38.66	31.59	54.48	63.75	60.58
2011	22.88	18.19	59.01	65.82	69.00
2012	20.46	13.21	55.36	63.66	60.21
2013	32.72	24.91	66.28	71.09	77.56
2014	37.86	30.43	55.29	62.89	77.18

[1] Ambient monitoring location = STORET 22410002

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 Eldred Sherwood Lake in Hancock 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 4.3, 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 Eldred Sherwood 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 14-year period of record, 2001-2014, 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 2008-2012 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 2014 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 landuse 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 landuses. 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. These basins were created to coincide with the topography and distribution of drainage districts throughout the Eldred Sherwood Lake watershed. 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 Eldred Sherwood Lake are included in the STEPL model. Therefore, rainfall data from the NWS COOP station at Kanawha, 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 2008-2012 was 31.2 inches/year, slightly below the 14-year (2001-2014) annual average of 32.6 inches. In 2008 – 2010, 37.5 inches of rainfall fell at the Kanawha station, compared to only 21.7 inches in 2011 – 2012. Annual rainfall used in the STEPL model coincided with the 303(d) assessment period in order to simulate dry and wet precipitation patterns.

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 2008-2012 were utilized in parameterization. The rain day correction factor of 0.297 was calculated by dividing the number of days that it rained at least 5 mm 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 2008-2012 Eldred Sherwood Lake STEPL model.

Table D-1. STEPL rainfall inputs (2008-2012 average annual data)

Rain correction factors			
[1]0.803	[2]0.297		
[3]Annual Rainfall	**[4]Rain Days**	**[5]Avg. Rain/Event**	**Input Notes/Descriptions**
31.2	155	0.544	[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 2008-2012 (in)
			[4]Average days of precipitation per year (days)
			[5]Average precipitation per event (in)

D.4. Watershed Characteristics

Topography
The Eldred Sherwood Lake watershed was delineated into 4 subbasins using ArcGIS (version 10.1) and a 3-meter resolution digital elevation model (DEM) developed by the Iowa Department of Natural Resources (DNR). Figure D-1 illustrates the watershed and subbasin boundaries. The subbasins boundaries were chosen to coincide with topography and boundaries of drainage districts in the watershed. Drainage district boundaries do not precisely overlap with STEPL boundaries due to the DEM used to delineate the drainage districts being older and of a lower resolution (10m) than the 3m DEM used to delineate the Eldred Sherwood Lake watershed. By using the drainage districts as a guide for jurisdictional boundaries, the model will be able to accurately allocate phosphorus fate and transport in each district. Drainage infrastructure of each district, such as open ditches and tile mains, are also noted on Figure D-1. These will aide in identifying areas to implement best management practice strategies in water quality improvement programs in the future.

Landuse
A Geographic Information System (GIS) coverage of landuse information was developed using the Cropland Data Layer (CDL) for year 2014, 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 landuses within a single field boundary. STEPL land cover classifications are reported in Table D-2, with landuse distribution previously illustrated in the map (Figure 2-5) and table (Table 2-3) in Section 2-2.

Table D-2. STEPL landuse inputs

Watershed	[1]Urban	Cropland	Pastureland	Forest	[2]User Defined	[3]Total
W1	11.0	81.5	0.0	24.9	35.5	152.9
W2	10.4	347.0	0.0	0.0	0.0	357.4
W3	12.2	430.8	0.0	0.0	0.0	443.0
W4	70.3	1,534.1	0.0	0.0	44.5	1,648.9
[3]Total	103.9	2,393.4	0.0	24.9	80.0	[3]**2,602.2**

[1] Urban includes all developed areas, including roads and farmsteads
[2] Includes non-pasture grassland and conservation reserve programs
[3] Totals exclude open water in STEPL landuse inputs

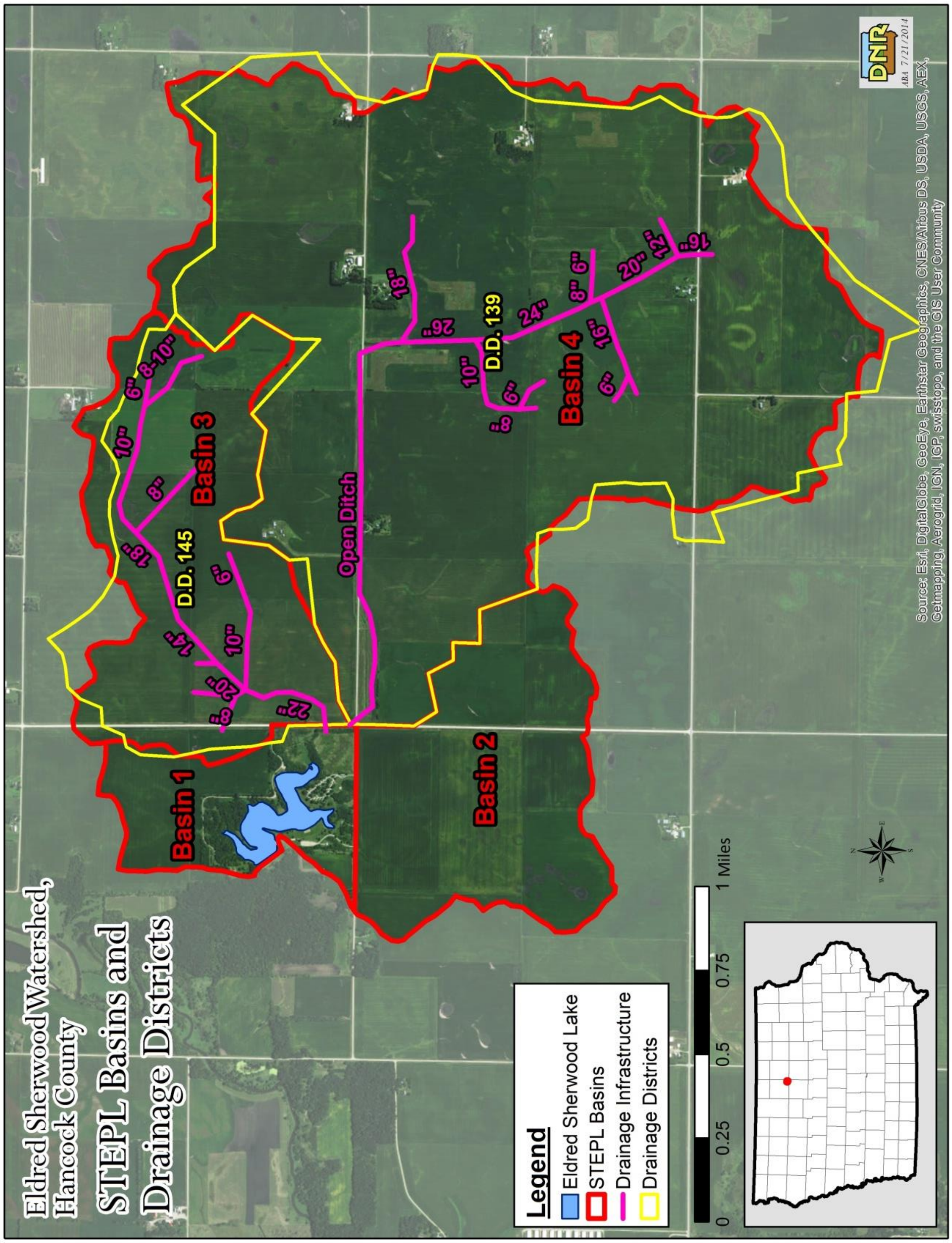


Figure D-1. STEPL subbasin map

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 0.9 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 B/D soils, with some C and D soils in / near prairie potholes. Tile-drained B / D soils have characteristics of B soils, whereas undrained soils behave like type D soils. HSG values were area-weighted for each subbasin and used to modify curve numbers (CNs) in STEPL. Given the wide-spread presence of tile drainage infrastructure in this watershed, area-weighted calculations concluded HSG B is appropriate for all four sub basins. 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 0.22 and 0.91.

Curve Numbers
The STEPL model includes default curve numbers (CNs) selected automatically based on HSG and landuse. In Iowa, and particularly in the Des Moines Lobe Ecoregion, watershed modeling professionals across multiple agencies have found that standard NRCS curve numbers result in overestimation of surface runoff and flow (Iowa DNR and ISU, unpublished data). Therefore, the HSG Type B CNs were modified to better reflect

conditions on the Des Moines Lobe and simulate reasonable subsurface (tile) drainage. Urban landuse curve numbers were developed within STEPL based on percent landuse of the urban subcategories. Adjusted CNs were entered in the “Input” worksheet of STEPL, and are reported in Table D-3. Table D-4 lists the resulting CNs for each landuse and subwatershed in the STEPL model.

Table D-4. STEPL curve numbers

Subwatershed	[1]Urban	Cropland	[2]Pastureland	Forest/Timber	Non-Pasture Grassland
W1	98	68	60	59	58
W2	98	68	60	59	58
W3	98	68	60	59	58
W4	90	68	60	59	58

[1] Urban includes all developed areas, including transportation and farmstead areas
[2] Pastureland includes pasture and alfalfa ground in crop rotations.

Sediment Delivery Ratio

The sediment load to each lake in the Eldred Sherwood Lake watershed will be dependent upon watershed morphology, water velocity, residence time, and other factors. 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. The resulting SDR for the sub basins were calculated outside of STEPL for the entire watershed, based on landform characteristics for the Des Moines Lobe. This value was adjusted using guidance developed by the United States Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS) for each ecoregion in Iowa. The NRCS technical guide includes separate relationships between area and SDR for each ecoregion, and results in an SDR of 0.054, or 5.4 percent, for the Eldred Sherwood Lake watershed. Figure D-2 shows an empirical RUSLE assessment done outside of STEPL, which provides similar sheet and rill erosion rates calculated in STEPL for the Eldred Sherwood Lake watershed.

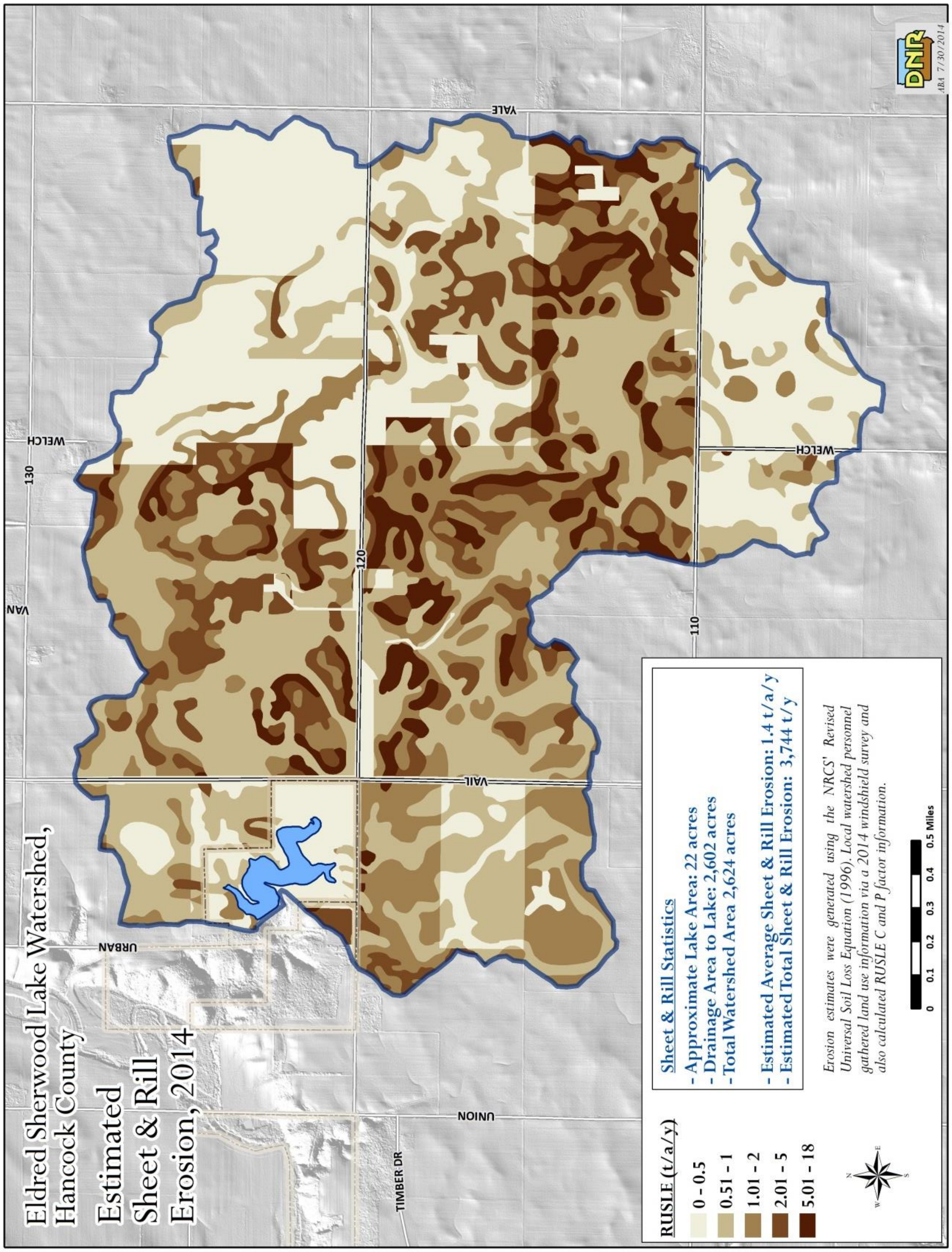


Figure D-2. RUSLE calculated sheet and rill erosion for Eldred Sherwood Lake watershed

Tile Drainage
Like most land in agricultural production in the Des Moines Lobe ecoregion, Eldred Sherwood Lake watershed is heavily tile drained. To account for higher dissolved nutrient concentrations frequently observed in tile drainage, the STEPL default nutrient concentrations for shallow groundwater were increased, based on water quality monitoring data collected in this watershed and in nearby watersheds with the similar characteristics (heavily tile drained, heavily agricultural). The nitrogen concentration was increased to 17.2 mg/L, and the phosphorus concentration increased to 0.09 mg/L, the area-weighted mean values for two tile drains sampled regularly between 2001 and 2002. The adjustments were made in the "Input" worksheet of the Eldred Sherwood Lake STEPL model. Figure D-1 shows the drainage district infrastructure of the Eldred Sherwood Lake watershed. As stated earlier, the STEPL sub basin boundaries were based on drainage districts where applicable.

D.5. Animals

Agricultural Animals and Manure Application
There are no estimated animals in the Eldred Sherwood Lake watershed, but two animal confinements exist outside the watershed delineation; one turkey facility, and one hog confinement. Inspection of manure management plans (MMP) showed that neither facility directly contributed to manure application within the Eldred Sherwood Lake watershed.

There are no livestock confinements within the Eldred Sherwood Lake watershed that are designated as point sources, therefore the WLA is zero. Any future developments in the watershed regarding animal feeding operations will be required to be zero-discharge facilities.

Livestock Grazing
There are no significant cattle grazing operations in the Eldred Sherwood Lake watershed.

Open Feedlots
There are no open feedlots in the Eldred Sherwood Lake watershed in the Iowa DNR Animal Feeding Operations Database. Feedlot operators are not required to report open feedlot information to Iowa DNR for feedlots with less than 1000 animal units (AUs). No active open feedlot operations were observed during the April and June 2016 windshield surveys.

Wildlife
The estimated deer population in the Eldred Sherwood Lake watershed is based on the Hancock County Conversation Board estimate and the deer harvest rate from Hancock County (Park Director, April 8, 2016, personal communication). The estimated county-wide average deer density is approximately 5 deer per square mile, but an average of 10 deer per square mile was entered in the "Animals" worksheet of the STEPL model for Eldred Sherwood Lake watershed to account for increased density of deer around the

lake. Population densities of 10 raccoons, 10 beavers, and 10 other 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 also simulated by STEPL. An estimate of goose population and subsequent phosphorus contributions at Eldred Sherwood Lake were provided by Eldred Sherwood Park staff. On an annual average basis, there are less than 20 geese residing at the lake; however, populations vary throughout the year due to migratory patterns and nesting seasons.

Septic Systems

A GIS coverage of rural residences with private onsite wastewater treatment systems (e.g., septic systems) was developed using aerial images and anecdotal data from various state, county, and local agencies. This procedure resulted in the identification of 8 septic systems in this sparsely populated watershed. It is estimated that 10 percent of these systems are not functioning adequately (i.e., are ponding or leaching), and drain directly to agricultural tile drains and subsequently, to streams. This is a fairly common occurrence in some rural parts of the state. This information is included in the “Inputs” worksheet of the STEPL model for Eldred Sherwood Lake.

D.6. References

U.S. Department of Agriculture – Farm Service Agency (USDA-FSA). 2016. http://www.fsa.usda.gov/Internet/FSA_File/clu_2007_infosheetpdf.pdf. Accessed August 2016.

U.S. Department of Agriculture – National Agricultural Statistical Summary (USDA-NASS). 2016. http://nassgeodata.gmu.edu/CropScape/. Accessed August 2016.

Appendix E --- Water Quality Model Development

Two models were used to develop the Total Maximum Daily Load (TMDL) for Eldred Sherwood Lake. Watershed hydrology and pollutant loading was simulated using the Spreadsheet Tool for Estimating Pollutant Load (STEPL), version 4.3. 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 Eldred Sherwood 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 2014 Integrated Report (2008-2012). 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 Eldred Sherwood 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.

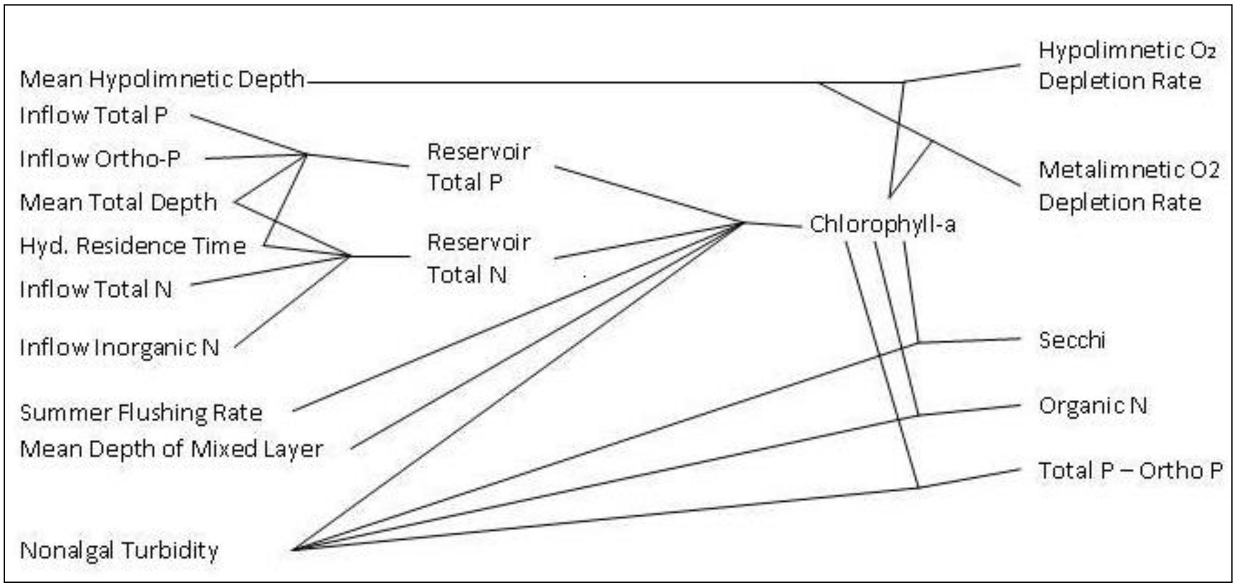


Figure E-1. Eutrophication control pathways in BATHTUB (Walker, 1999)

E.2. Model Parameterization

BATHTUB includes several data input menus and modules to describe lake characteristics, simulation equations, and external (i.e., watershed) inputs. Data menus utilized to develop the BATHTUB model for Eldred Sherwood 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 or 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 Eldred Sherwood Lake BATHTUB model and report input parameters for each menu.

Model Selections

BATHTUB includes several models and 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 Eldred Sherwood Lake. Preference was given to Models 1 and 2 during evaluation of model performance and calibration of the Eldred Sherwood 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 default models were utilized to predict in-lake phosphorus levels because it provided the best agreement with observed data, and because Eldred Sherwood Lake is a manmade impoundment and representative of aquatic systems for which this model was developed. Model performance is discussed in more detail in Appendix F.

Table E-1. Model selections for Eldred Sherwood Lake

Parameter	Model No.	Model Description
Total Phosphorus	02	2^{nd} order, decay
Total Nitrogen	*00	not computed
Chlorophyll-a	*02	P, Light, T
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 Eldred Sherwood 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 from 2008 to 2012 was utilized to quantify existing loads and in-lake water quality, and to develop TMDL targets for Eldred Sherwood Lake.

Table E-2. Global variables data for 2008-2012 simulation period

Parameter	Observed Data	BATHTUB Input
Averaging Period	Annual	1.0 years
[1]Precipitation	31.2 in	0.79 m
[1]Evaporation	29.5 in	0.75 m
[2]Increase in Storage	0	0
[3]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]Precip and evaporation data are from 2008-2012 in order to provide accurate long term data
[2]Change in lake volume from beginning to end of simulation period.
[3]From Anderson and Downing, 2006.

Precipitation was summarized for the 5-year assessment period of 2008-2012 from the National Weather Service Cooperative weather station at Muscatine, Iowa (IEM, 2016a). Potential evapotranspiration data for the same period was obtained from the Kanawha, Iowa weather station via the ISU Ag Climate database (IEM, 2016b). Net change in reservoir storage was assumed to be zero. This 5 year period was chosen in order to reflect the climate during the assessment period when water quality data was collected and analyzed to show the algal impairment at Eldred Sherwood Lake. It was shown in Section 3.1 (Figure 3-9) that precipitation is not highly correlated with total phosphorus and the impairment seen at Eldred Sherwood Lake. For these reasons, it was assumed the assessment period climate conditions may be a more suitable basis for global variable data. 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 Eldred Sherwood Lake BATHTUB model includes two lake segments to facilitate simulation of diffusion, dispersion, and sedimentation that occur as water traverses between the two main receiving arms, and the outlet arm. This relationship is shown in Table E-3. Segment 1 contains 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 the lake system. Figure E-2 shows the location and naming convention of each lake in the BATHTUB model. Table E-4 shows the model variables for the monitored and assessed segment.

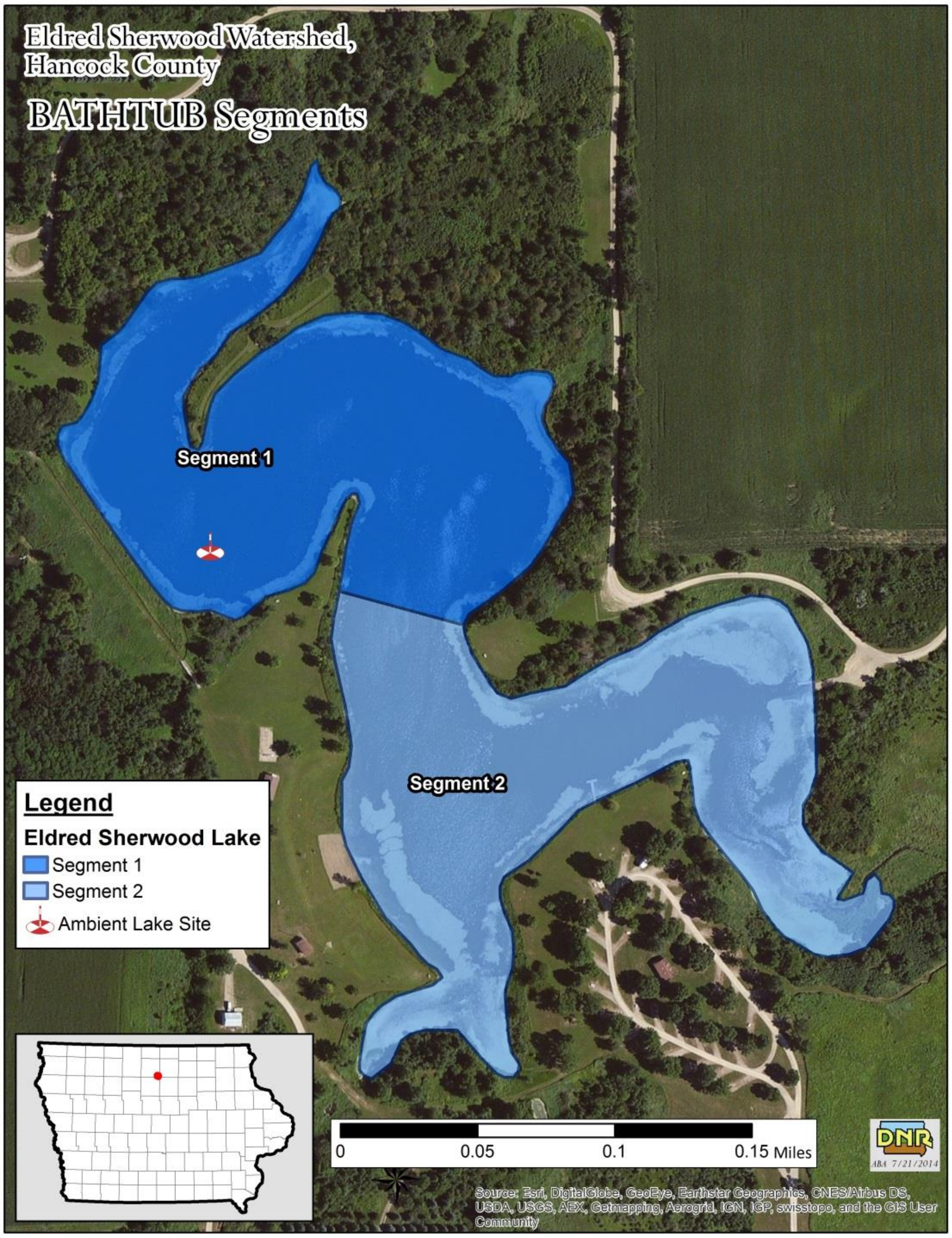


Figure E-2. Lake segmentation in BATHTUB model.

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. Segment physical parameters input into BATHTUB for the lake system area shown in Table E-3.

Table E-3. Segment morphometry for Eldred Sherwood Lake

Segment	Outflow Segment	Segment Group	Surface Area (km^2)	Mean Depth (m)	Length (km)
Segment 1	Out of Reservoir	1	0.043	4.38	0.335
Segment 2	Segment 1	1	0.044	3.23	0.349

Means of the 5 year assessment period water quality parameters observed for the assessment period (2008-2012) are reported in Table E-4. These data were compared to output in Segment 1 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 for Segment 1 in Eldred Sherwood Lake. The TMDL and future water quality assessment and listing will be based solely on water quality data from Segment 1.

Table E-4. Ambient (Segment 1) water quality (2008-2012 assessment period)

Parameter	Measured Data	[1]BATHTUB Input
Total Phosphorus	78.5 µg/L	78.5 ppb
Total Nitrogen	8.1 mg/L	Not computed
Chlorophyll-a	33.1 µg/L	33.1 ppb
Secchi Depth	1.2 m	1.2 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 Eldred Sherwood 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. Table E-5 summarizes the physical parameters and monitored inputs for Eldred Sherwood Lake.

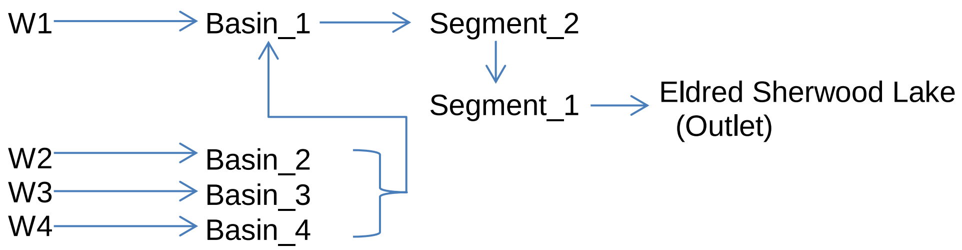
Table E-5. Tributary data for the Eldred Sherwood Lake

Tributary name	BATHTUB Segment	Total Watershed Area (km^2)	Annual Flow Rate (hm^3/yr)	STEPL Total P concentration (ppb)
Basin 1	Segment 2	0.618	0.172	232.0
Basin 2	Segment 2	1.444	0.402	285.4
Basin 3	Segment 2	1.790	0.497	304.7
Basin 4	Segment 2	6.662	1.788	305.1

Tributary data were obtained from the STEPL model, converted to units consistent with BATHTUB, and entered in the tributary data menu. Table E-6 lists the STEPL subbasins that drain to the tributary and also illustrates the connectivity of BATHTUB segments.

Table E-6. Flow and transport linkages in STEPL and BATHTUB

STEPL Subbasin	BATHTUB Tributary	BATHTUB Segment	Waterbody



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). 2016a. 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 2016.

Iowa Environmental Mesonet (IEM). 2016b. 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 2016.

Appendix F --- Model Performance and Calibration

The Eldred Sherwood 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 2014. 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 Eldred Sherwood Lake.

F.1. STEPL Performance and Calibration

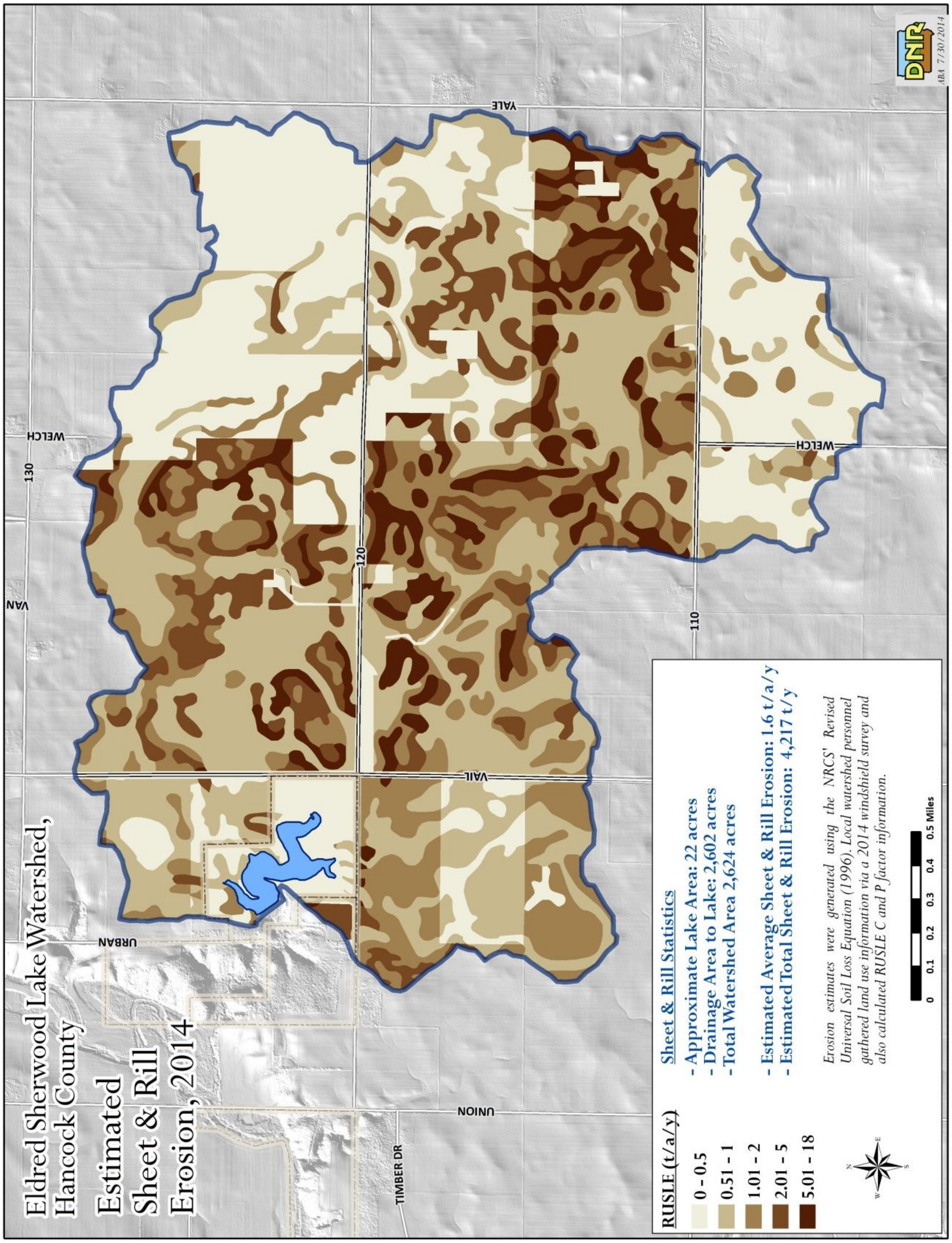
The STEPL model is a long-term average annual simulation model, and is incapable of simulating storm events or short-term fluctuations in hydrology and nutrient loads. There is no long-term monitoring data for tributaries or upstream lakes in the Eldred Sherwood Lake watershed, therefore model calibration 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 Des Moines Lobe ecoregion, which is characterized by shallow wetland basins and potholes, glacial till, with little to no loess present.

Table F-1. Sheet and rill erosion in Des Moines Lobe watersheds

Watershed	County	Area (acres)	Proximity (miles)	Erosion (tons/ac/yr)
Briggs Woods Lake	Hamilton	7,210	37	1.6
Lost Island Lake	Palo Alto	6,270	71	2.2
Silver Lake	Dickinson	17,019	38	1.6
Little Clear Lake	Pocahontas	365	69	1.7
Marrowbone Creek	Carroll	8,916	75	2.4
[1]Eldred Sherwood Lake	**Hancock**	**2,602**	**--**	**1.4**

[1] Annual sheet/rill erosion estimated for this TMDL using STEPL (2008-2012).

The Eldred Sherwood Lake STEPL model predicts sheet and rill erosion rates that are consistent with those predicted by DNR for other watersheds in the ecoregion. The 2008-2012 simulated annual average sheet and rill erosion rate was 1.4 tons/acre, compared with average estimated rates between 1.6 and 2.4 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. Figure F-1 shows the sheet and rill erosion in the Eldred Sherwood Lake watershed.



- Approximate Lake Area: 22 acres
- Drainage Area to Lake: 2,602 acres
- Total Watershed Area 2,624 acres

- Estimated Average Sheet & Rill Erosion: 1.6 t/a/y
- Estimated Total Sheet & Rill Erosion: 4,217 t/y

Erosion estimates were generated using the NRCS' Revised Universal Soil Loss Equation (1996). Local watershed personnel gathered land use information via a 2014 windshield survey and also calculated RUSLE C and P factor information.

Figure F-1. Sheet and rill erosion in the Eldred Sherwood Lake watershed, 2014

Table F-2 compares the annual average TP export simulated by the Eldred Sherwood Lake STEPL model with past study results in other tile-drained watersheds in the Midwest. TP exports in the Eldred Sherwood Lake watershed are 0.72 pounds per acre per year. Because the STEPL model predicted sediment and phosphorus loads similar in magnitude to estimates developed for other local and regional watersheds, Iowa DNR has determined the STEPL model to be adequate for estimation of phosphorus loads to Eldred Sherwood Lake for development of TMDLs and implementation planning. Briggs Woods Lake, the most recent TMDL preceding Eldred Sherwood Lake, had a higher TP export of 1.4 lb/ac due to higher levels of soluble phosphorus in the tile discharge.

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

Watershed Location	Source	TP Export (lb/ac)
East Central Illinois	Royer et al., 2006	0.1 – 1.9
South Fork Iowa River	Tomer et al., 2008	0.4 – 0.6
Skunk River at Augusta, IA	USGS, 2001	2.5
Lake Geode, Henry Co.	Iowa DNR (Previous TMDL)	1.38
Silver Lake, Dickinson Co.	Iowa DNR (Previous TMDL)	0.7
Briggs Woods Lake, Hamilton Co.	Iowa DNR (Previous TMDL)	1.4
Eldred Sherwood Lake, Hancock Co.	STEPL Model (Current TMDL)	0.72

F.2. BATHTUB Model Performance

Performance of the BATHTUB model was assessed by comparing predicted water quality with observed data collected in Eldred Sherwood Lake. Simulation of TP concentration and chlorophyll-a (algae) was critical for TMDL development, and were the focus of calibration efforts. Nitrogen constituents are less important because Eldred Sherwood Lake is not nitrogen limited.

Calibration

Table F-2 reports observed and predicted annual average TP, chlorophyll-a, and Secchi depths in the open water area (Segment 1) of Eldred Sherwood Lake, along with the dispersion model 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 2008-2012, the period on which the 2014 Water Quality Assessment was based.

Calibration coefficients listed alongside the simulated values in Table F-3 were entered in the “Segments” menu of the BATHTUB model, and apply to only the ambient monitoring segment (Segment 1) of Eldred Sherwood Lake. Other lake system segments were uncalibrated due to lack of historical water quality data. Calibration coefficients for Eldred Sherwood Lake are within the recommended range according to the BATHTUB user guidance (Walker, 1999). 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.

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

Parameter	[1]Observed	[2]Predicted	Calibration Coefficient
Assessment period and TMDL conditions (2008-2012)			
[3]Dispersion coefficient	--	--	--
Total Phosphorus (ug/L)	78.5	78.5	1.285
Chlorophyll-a (ug/L)	33.1	33.1	1.328
Secchi depth (m)	1.2	1.2	1.1
Long-term simulation period (2001-2014)			
[3]Dispersion coefficient	--	--	--
Total Phosphorus (ug/L)	93.1	80.8	1.285
Chlorophyll-a (ug/L)	47.0	33.0	1.328
Secchi depth (m)	1.3	1.2	1.1

[1] Average concentration observed at ambient monitoring location
[2] Average annual concentration predicted in Segment 1 of BATHTUB lake model
[3] Dispersion between lakes controlled by introducing multiple segment groups

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 Eldred Sherwood 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 1,150 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 929 lbs/year is equivalent to a long-term average (LTA) daily of 2.5 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 10.2 lbs/day. The TMDL calculation is summarized in Table G-2. An explicit MOS of 10 percent (1.0 lbs) was applied, resulting in a daily LA of 9.2 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 (9.2 lbs-TP/day)
+ MOS (1.0 lbs-TP/day) = **10.1 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	2.5 lbs/day	Annual TMDL (929.1 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	**10.2 lbs/day**	**TMDL expressed as daily load**

Appendix H --- 2014 305(b) Water Quality Assessment

Segment Summary

Waterbody ID Code: IA 02-IOW-03830-L_0
Location: Hancock County, S21, T94N, R24W, 3 mi. NE of Goodell.
Waterbody Type: Lake
Segment Size: 22 Acres
This is a Significant Publically Owned Lake

Segment Classes:

Class A1
Class B(LW)
Class HH

Assessment Comments

Assessment is based on: (1) results of the statewide survey of Iowa lakes conducted from 2009-2012 by Iowa State University (ISU), (2) results of the statewide ambient lake monitoring program conducted in 2008 by University Hygienic Laboratory (UHL), (3) results of the voluntary county beach monitoring program in 2008 and 2010, and (4) information from the Iowa DNR Fisheries Bureau.

Assessment Summary and Beneficial Use Support

Overall Use Support - Partial
Aquatic Life Support - Fully
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 levels of indicator bacteria that exceed Iowa’s water quality standard and aesthetically objectionable conditions caused by algae blooms. The Class B(LW) (aquatic life) uses are assessed (monitored) as “fully supported.” Fish consumption uses remain “not assessed.” Sources of data for this assessment include (1) results of the statewide survey of Iowa lakes conducted from 2009-2012 by Iowa State University (ISU), (2) results of the statewide ambient lake monitoring program conducted in 2008 by University Hygienic Laboratory (UHL), (3) results of the voluntary county beach monitoring program in 2008 and 2010, and (4) information from the Iowa DNR Fisheries Bureau.

EXPLANATION: Results of Iowa DNR city/county beach monitoring from 2008 through 2010 suggest that the Class A1 uses are assessed as “partially supported." Levels of indicator bacteria at Eldred Sherwood Lake beach were monitored once per week during the primary contact recreation season (May through September) of 2008 (11 samples) and periodically in 2010 (2 samples). According to Iowa DNR's assessment methodology two conditions need to be met for results of beach monitoring to indicate "full support" of the Class A1 (primary contact recreation) uses: (1) the geometric mean of the samples from each recreation season of the three-year assessment period are less than the state's geometric mean criterion of 126 E. coli orgs/100 ml and (2) not more than 10% of the samples during any one recreation season exceeds the state's single-sample maximum value of 235 E. coli orgs/100 ml. If a sampling season geometric mean exceeds the state criterion of 126 orgs/100 ml during the three-year assessment period, the Class A1 uses should be assessed as "not supported." Also, if significantly more than 10% of the samples in any one of the three recreation seasons exceed Iowa's single-sample maximum value of 235 E. coli orgs/100 ml, the Class A1 uses should be assessed as "partially supported." This assessment approach is based on U.S. EPA guidelines (see pgs 3-33 to 3-35 of U.S. EPA 1997b).

NOTE: Based on consultation with EPA Region 7 staff in 2011, Iowa DNR's methodology for assessing impairments based on the geometric mean water quality criterion was changed. Prior to the 2012 listing cycle, Iowa DNR calculated geometric means for lakes based on a 30-day periods within the recreational season. Any violation of one of these 30-day periods within 3 years resulted in an impairment of the Class A1 uses of that lake. Because water quality standards do not identify a 30 day period but instead a recreational season, Region 7 concurred that the approach used for rivers and streams with less frequent bacteria data (seasonal geometric means) would be appropriate for identifying §303(d) impairments at lake beaches. Thus, for the 2014 listing cycle, Iowa DNR identified primary contact recreation impairments for lakes when the geometric mean of all samples from the recreation season of a given year exceeded the geometric mean criterion. This does not impact the way Iowa DNR assesses beaches for closure to protect the recreating public in the short term.

At Eldred Sherwood Lake beach, the geometric mean from 2008 was below the Iowa water quality standard of 126 E. coli orgs/100 ml. The geometric mean was 93 E. coli orgs/100 ml in 2008. The geometric mean for samples collected in 2010 was 7 E.coli orgs/100ml. There were no violations to the single-sample maximum criterion in 2010. The percentage of samples exceeding Iowa's single-sample maximum criterion (235 E. coli orgs/100 ml) was 36% in 2008. These results are significantly greater than 10% of the samples and therefore suggests impairment of the Class A1 uses. According to Iowa DNR's assessment methodology and U.S. EPA guidelines, these results suggest "partial support" of the Class A1 uses.

For the 2014 reporting cycle, results from the ISU statewide survey of lakes and the UHL ambient lake monitoring program suggest that the Class A1 (primary contact recreation) uses for Eldred Sherwood Lake are assessed (monitored) as "partially supported" due to aesthetically objectionable conditions from algae. Using the median values from these surveys from 2008-2012(approximately 14 samples), Carlson's (1977) trophic state indices for Secchi depth, chlorophyll a, and total phosphorus were 57, 61, and 62 respectively for Eldred Sherwood Lake. According to Carlson (1977) the Secchi depth value places Eldred Sherwood Lake in the eutrophic category, while the values for chlorophyll a and total phosphorus place Eldred Sherwood Lake in between the eutrophic and the hypereutrophic categories. These values suggest moderately high levels of chlorophyll a and suspended algae in the water, relatively good water transparency, and relatively high levels of phosphorus in the water column. While the TSI values for Eldred Sherwood Lake are below the impairment trigger of 65 for the 2014 reporting cycle, Eldred Sherwood Lake was listed as "partially supporting" the Class A1 uses for the 2010 and 2012 reporting cycles due to algal turbidity. Based on Iowa DNR's assessment methodology, median-based TSI values for both chlorophyll-a and Secchi depth must be 63 or less for two consecutive summer seasons before a lake can be removed from the state's Section 303(d) list (IR Category 5). The median TSI value for chlorophyll a for the 2012 assessment/listing cycle was 64. Because the median TSI value was not less than or equal to 63 for the 2012 assessment/listing cycle, Eldred Sherwood Lake remains listed as "partially supporting" its Class A1 uses for the 2014 Integrated Report.

The levels of inorganic suspended solids at this lake moderately high but do not suggest that non-algal turbidity contributes to the impairment at this lake. The median level of inorganic suspended solids in Eldred Sherwood Lake (2.6 mg/L) and ranked 48th of the 134 lakes sampled by the ISU and UHL programs.

Data from the 2008-2012 ISU and UHL surveys suggest an small population of cyanobacteria exists at Eldred Sherwood Lake. These data show that cyanobacteria comprised 46% of the phytoplankton wet mass at this lake. The median cyanobacteria wet mass (7.7 mg/L)and ranked 15th of the 134 lakes sampled. In 2002, 2003, and 2004 the Hancock County Conservation Board applied copper sulfate (an algaecide) and Aquathol (a herbicide) at the swimming beach and boat ramp areas to control algae and aquatic vegetation. The treatment of the lake with copper sulfate may reduce the amount of cyanobacteria that is seen at Eldred Sherwood Lake during routine sampling.

The Class B(LW) (aquatic life) uses are assessed (monitored) as “fully supported.” Information from the Iowa DNR Fisheries Bureau suggests that nutrients and turbidity, particularly after storm events, remain concerns at this lake. Results from the ISU and UHL lake surveys from 2008-2012 show no violations of the Class B(LW) criteria for ammonia in 14 samples, dissolved oxygen in 14 samples, or pH in 14 samples. These results suggest "full support" of the Class B(LW) uses at Eldred Sherwood Lake.

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

Monitoring and Methods

Assessment Key Dates

5/22/2008	Fixed Monitoring Start Date
9/3/2012	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)
- Water column surveys (e.g. fecal coliform)

Appendix I --- 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\	ESL_Water_Quality_Data.xls	Summary of in-lake WQ data
W:\...\Data\Reduced\Climate	North_Central_Climate.xls	Summary of precipitation and PET data
W:\...\Documents\Draft_TMDL	ESL_Draft_TMDL	Includes review comments
W:\...\Documents\Final_TMDL	ESL_Final_TMDL	For EPA submittal purposes
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	ESL_Conversions.xls	Used to develop phosphorus source inventory and potential load allocation scenario
	TMDL_Equation_Calcs_ESL.xls	Used to develop the TMDL equation (LA, WLA, and MOS)
	ESL_TMDL_Target.btb	Load response curve calcs
W:\...\Modeling\STEPL	STEPL_ESL.xls	Used to simulated/predict existing watershed loads
	Various .xls files	Used to develop/calculate STEPL model inputs
W:\...\Modeling\BATHTUB\InputFiles	ESL_Conversions.xls	Calculated/converted STEPL outputs to BATHTUB inputs for existing conditions
	ESL_Assessment_Period.btb	
	Various .btb files	BATHTUB input files for various scenarios

Appendix J --- Public Comments

Public Comment:

All public comments received during the public comment period will be placed in this section, along with Iowa DNR responses.