DRAFT

Water Quality Improvement Plan for

Hawthorn Lake

Mahaska County, Iowa

Total Maximum Daily Load for:
Algae

Prepared by:
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Iowa Department of Natural Resources
Water Quality Monitoring and Assessment Section
2024

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Units of measure:

ac	acre	m	meter
cfs	cubic feet per second	mg	milligram
cfu	colony-forming unit	Mg	megagram (= 1 mt)
cm	centimeter	mi	mile
cms	cubic meters per second	mL	milliliter
d	day	mo	month
g	gram	mt	metric ton (= 1 Mg)
ha	hectare	orgs	E. *coli* organisms
hm	hectometer	ppm	parts per million
hr	hour	ppb	parts per billion
in	inch	s	second
kg	kilogram	t	ton (English)
km	kilometer	yd	yard
L	liter	yr	year
lb	pound		

Other abbreviations:

AFO	animal feeding operation
BMP	best management practice
Chl-a	chlorophyll a
DNR	Iowa Department of Natural Resources
E. coli	Escherichia coli
ET	Evapotranspiration
GM	geometric mean (pertains to WQS for *E. coli*, = 126 orgs/100 mL)
LA	load allocation
LDC	load duration curve
N	nitrogen
ortho-P	ortho-phosphate
P	phosphorus
SSM	single-sample max (pertains to WQS for *E. coli*, = 235 orgs/100 mL)
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
WLA	waste load allocation
WQIP	water quality improvement plan
WQS	water quality standards

General Report Summary

What is the purpose of this Water Quality Improvement Plan (WQIP)?
This WQIP serves multiple purposes. First, it is a resource for increased understanding of watershed and water quality conditions in and around Hawthorn Lake. Second, it satisfies the Federal Clean Water Act requirement to develop a TMDL for impaired waterbodies. Third, it identifies potential sources of pollution within a watershed. Fourth, 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 Hawthorn Lake from the federal 303(d) list of impaired waters.

What's wrong with Hawthorn Lake?
Hawthorn Lake is listed as impaired on the Draft 2024 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 and sediment, including sediment-bound 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). Phosphorus and sediment within the water column and on the lake bed may become resuspended under certain conditions, as internal loading, which can add to excessive growth of algae. There are currently no permitted point source discharges in the Hawthorn 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 Hawthorn Lake watershed include gully erosion, sheet and rill erosion from various land uses, runoff and subsurface flows from lands that receive manure or fertilizer application, grazed pasture land, poorly functioning septic systems, manure deposited by wildlife, and particles carried by dust and wind (i.e., atmospheric deposition). A portion of the phosphorus carried to the lake eventually settles to the lake bottom and accumulates. Under certain conditions, this accumulated phosphorus can become available for algal uptake and growth through an internal recycling process.

What can be done to improve Hawthorn Lake?
Reducing phosphorus loss from pasture and row crops and implementing or improving existing structural BMPs such as terraces, grassed waterways, and constructed sediment basins in beneficial locations will significantly reduce phosphorus loads to the lake. While best management practices have been implemented on public, as well as private land in recent years, continued monitoring and sampling of the lake and watershed is needed in order to identify locations where additional land management practices can be implemented to further reduce phosphorus loads to the lake.

Who is responsible for a cleaner Hawthorn Lake?
Everyone who lives, works, or recreates in the Hawthorn Lake watershed has a role in water quality improvement. Nonpoint source pollution is unregulated and responsible for all of the sediment and phosphorus loads 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 ecosystem, 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, landowners, and lake users alike. Improving water quality in Hawthorn Lake, while also improving the quality of the surrounding land, will continue to require collaborative participation by various stakeholder groups, with landowners playing an especially important role.

Does a TMDL guarantee water quality improvement?

The Iowa Department of Natural Resources (DNR) recognizes that technical guidance and support are critical to achieving the goals outlined in this 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 Hawthorn Lake could address some of these barriers by providing financial assistance, technical resources, and information/outreach to landowners to encourage and facilitate adoption of conservation practices.

What are the primary challenges for water quality implementation?

In most Iowa landscapes, implementation requires changes in land management and/or agricultural operations. Management decisions may include changes in the number of acres that are actively tilled and the diversity and rotation of crops produced. These changes present challenges to producers by requiring new equipment (e.g., no-till planters), narrowing planting, harvesting, 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 Hawthorn Lake as a recreational resource are certainly attainable goals, and are appropriate and feasible near-term goals for a coordinated watershed improvement effort.

Required Elements of the TMDL

This Water Quality Improvement Plan has been prepared in compliance with the current regulations for TMDL development that were promulgated in 1992 as 40 CFR Part 130.7 in compliance with the Clean Water Act. These regulations and consequent TMDL development are summarized below in Table 1-1.

Table 1-1. Technical Elements of the TMDL.

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Hawthorn Lake, Waterbody ID IA 03-NSK-862, located in S10, T77N, R14W, 1.0 mile south of Barnes City.
Surface water classification and designated uses:	A1 - Primary Contact Recreation B(LW) - Lakes and Wetlands Aquatic Life HH - Human Health (Fish Consumption)
Antidegradation Protection Level	Tier 1
Impaired beneficial use:	A1 - Primary Contact (IR 5a)
TMDL priority level:	Priority Tier 1
Identification of the pollutants and applicable water quality standards (WQS):	Aesthetically objectionable conditions due to algae leading to very poor water transparency
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of WQS:	Excess algae is associated with total phosphorus (TP). The allowable average annual TP load = 1,791.5 lbs/year; the maximum daily TP load = 15.3 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 2,489.2 lbs/year must be reduced by 697.7 lbs/year to meet the allowable TP load. This is a reduction of approximately 28 percent.
Identification of pollution source categories:	There are no permitted point source discharges of phosphorus in the watershed. Nonpoint sources of phosphorus include fertilizer and manure from row crops, sheet and rill erosion from row crops and pasture, wildlife, septic systems, groundwater, atmospheric deposition, and others.
Wasteload allocations (WLAs) for pollutants from point sources:	There are no permitted point source discharges.
Load allocations (LAs) for pollutants from nonpoint sources:	The allowable annual average TP LA is 1,612.3 lbs/year, and the allowable maximum daily LA is 13.7 lbs/day.
A margin of safety (MOS):	An explicit 10 percent MOS is incorporated into this TMDL.
Consideration of seasonal variation:	This TMDL is based on annual TP loading. Although daily maximum loads are provided to address legal uncertainties, the average annual loads are critical to in-lake water quality and lake/watershed management decisions.

Reasonable assurance that load and wasteload allocations will be met:	Reasonable assurances for reductions in nonpoint source pollution are provided by (1) a list of BMPs (see Section 4 of this WQIP) that would provide phosphorus reductions, (2) a group of nonstructural practices that prevent transport of phosphorus, (3) proposed methodology for prioritizing and targeting BMPs on the landscape, and (4) best available data for estimating the efficiency/reduction associated with BMPs.
Allowance for reasonably foreseeable increases in pollutant loads:	Although development within the watershed may continue in the future, an increase in the pollutant load from land use change is not expected.
Implementation plan:	An implementation plan is outlined in Section 4 of this WQIP. 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 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 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:

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

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 WQIP is to provide a TMDL for algae, which has decreased the 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 the primary contact designated use of Hawthorn Lake. The impairments are addressed by development of a TMDL that limits 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 Hawthorn 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 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 landowners. Experience has shown that locally-led watershed plans have the highest potential for success. The Water Quality Monitoring and Assessment Section of the DNR has designed this plan for stakeholder use and may be able to provide technical support for the improvement of water quality in Hawthorn Lake.

2. Description and History of Hawthorn Lake

Hawthorn Lake is located in Pleasant Grove Township, Mahaska County approximately 1.0 mile south of Barnes City. Construction on the Hawthorn Lake dam was completed in 1979 (National Inventory of Dams). The lake is located within the state owned 1,773-acre Hawthorn Lake Wildlife Management Area (WMA), which is managed by the DNR. The lake and park area provide fishing, hiking, canoeing, and other outdoor recreation activities for the public.

Table 2-1 lists some of the general characteristics of Hawthorn Lake and its watershed. Figure 2-1 shows the area 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 the DNR in February of 2017.

Restoration Activities

The Mahaska County Soil and Water Conservation District (SWCD) received a watershed assessment grant from the Iowa Department of Agriculture and Land Stewardship. This assessment was completed in 2007. Subsequent to the assessment restoration activities have included the following:

- In 2010, the water level in Hawthorn Lake was lowered to allow for in-lake restoration work and for the eradication of carp and gizzard shad populations.
- In-lake restoration work included placement of in-lake habitat, shoreline armoring and deepening, and jetty construction repair.
- Landowners have completed a grade stabilization structure, 3,238 feet of terraces, and 2,109 feet of waterways to reduce sediment load to the lake.
- The fishery in the lake was renovated and the lake restocked with bluegills, channel catfish and largemouth bass.
- The DNR designed eight sediment control ponds. Five of the eight structures were constructed in 2012. The remaining structures were completed in 2016.
- Other work includes eradication of woody vegetation from the wildlife management area surrounding the lake. Woody vegetation can prevent vegetation from establishing on the forest floor and contribute to erosion. Following the removal of the vegetation, native grasses are being planted to stabilize the soils. (DNR, 2022a).

Table 2-1. Hawthorn Lake Watershed and Lake Characteristics.

DNR Waterbody ID	ID Code: IA 03-NSK-862
12-Digit Hydrologic Unit Code (HUC)	070801060601
12-Digit HUC Name	Pleasant Creek-North Skunk River
Location	Mahaska County; S10, T77N, R14W; 1.0 mile south of Barnes City
Latitude	41.4761° N (ambient lake monitoring location)
Longitude	-92.4587° W (ambient lake monitoring location)
Designated Uses	A1 - Primary Contact Recreation B(LW) - Lakes and Wetlands Aquatic Life HH - Human health (Fish Consumption)
Antidegradation Protection Level	Tier 1
Tributaries	Unnamed streams
Receiving Waterbody	Pleasant Creek
Lake Surface Area[1]	181 acres
Length of Shoreline	6.29 miles
Shoreline Development Index	3.33
Maximum Depth[1]	29.2 feet
Mean Depth[1]	9.73 feet
Lake Volume[1]	1,796.4 acre-feet
Watershed Area	3,296 acres (includes lake)
Watershed:Lake Ratio[2]	17.1:1
Hydraulic Lake Residence Time[3]	263 days

[1]Per October 2015 bathymetric survey.
[2](Watershed Area - Lake Area) / Lake Area
[3]BATHTUB model prediction for average annual conditions (2011 - 2022).

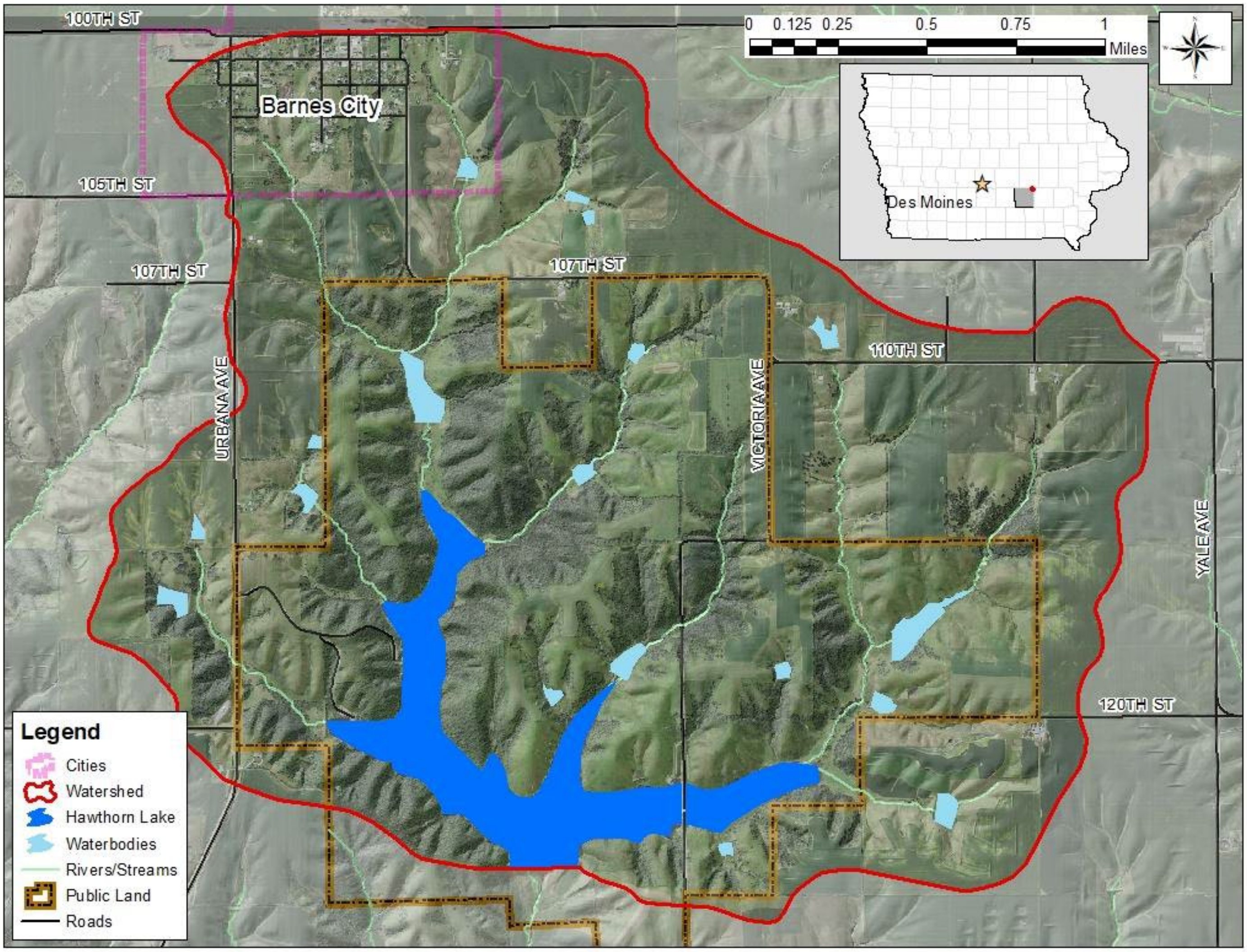

Figure 2-1. Area Map.

Water Quality History

Water quality data have been collected through the statewide survey of Iowa Lakes, which was conducted from 2000 through 2021 by Iowa State University (ISU). A statewide ambient lake monitoring program conducted in 2006 - 2008 by the State Hygienic Laboratory (SHL) also provided data on the water quality in Hawthorn Lake.

However, for the purposes of this report, only data collected after the lake was drained and refilled in 2010-2011 will be used. This will include the data collected from 2011-2022.

2.1 Hawthorn Lake

Hydrology

Using the Thiessen Polygon method, it was determined that the Montezuma weather station best represented the average precipitation at Hawthorn Lake. Daily precipitation data were obtained for the Montezuma Station from the Iowa Environmental Mesonet downloadable from the IEM.

Daily potential evapotranspiration (PET) data were obtained from the Iowa Ag Climate Network, downloadable from the IEM (IEM, 2023b). The Iowa State Climatologist provides quality control of these data. Daily observations between 2011-2022 were used in climate assessment and model development. Table 2-2 reports weather station information.

Table 2-2. Weather Station Information for Hawthorn Lake.

Data	Temperature/Precipitation	Potential ET
Network	IACLIMATE	ISU AgClimate/ISU Soil Moisture
Station Name (ID)	Montezuma (IA5650)	Cedar Rapids (A131329)/ Cedar Rapids (CIRI4)
Latitude	41.58°	41.91°/41.91°
Longitude	-92.55°	-91.62°/-91.62°

Source: https://mesonet.agron.iastate.edu/climodat

Average annual precipitation near Hawthorn Lake for the analysis period was 37.6 inches. The annual average precipitation during this time period was equal to the 30-year annual average of 37.6 inches. Figure 2-2 illustrates the annual precipitation totals, along with lake evaporation (estimated as 100 percent of annual PET). This chart shows an inverse relationship between precipitation and lake ET, mainly due to climatological factors such as cloud cover and temperature. Wet years of 2014, 2015, 2018, and 2019 show a surplus of precipitation, while the dry years of 2012, 2017, and 2022 show a precipitation deficit in comparison to lake ET. 2020 was also a dry year however, the graph shows precipitation exceeds lake ET, which is due to missing PET data.

Precipitation varies greatly by season in central Iowa, with approximately 68 percent of annual rainfall taking place in half of the year (April through September). Monthly average precipitation 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 monthly moisture deficit occasionally occurs.

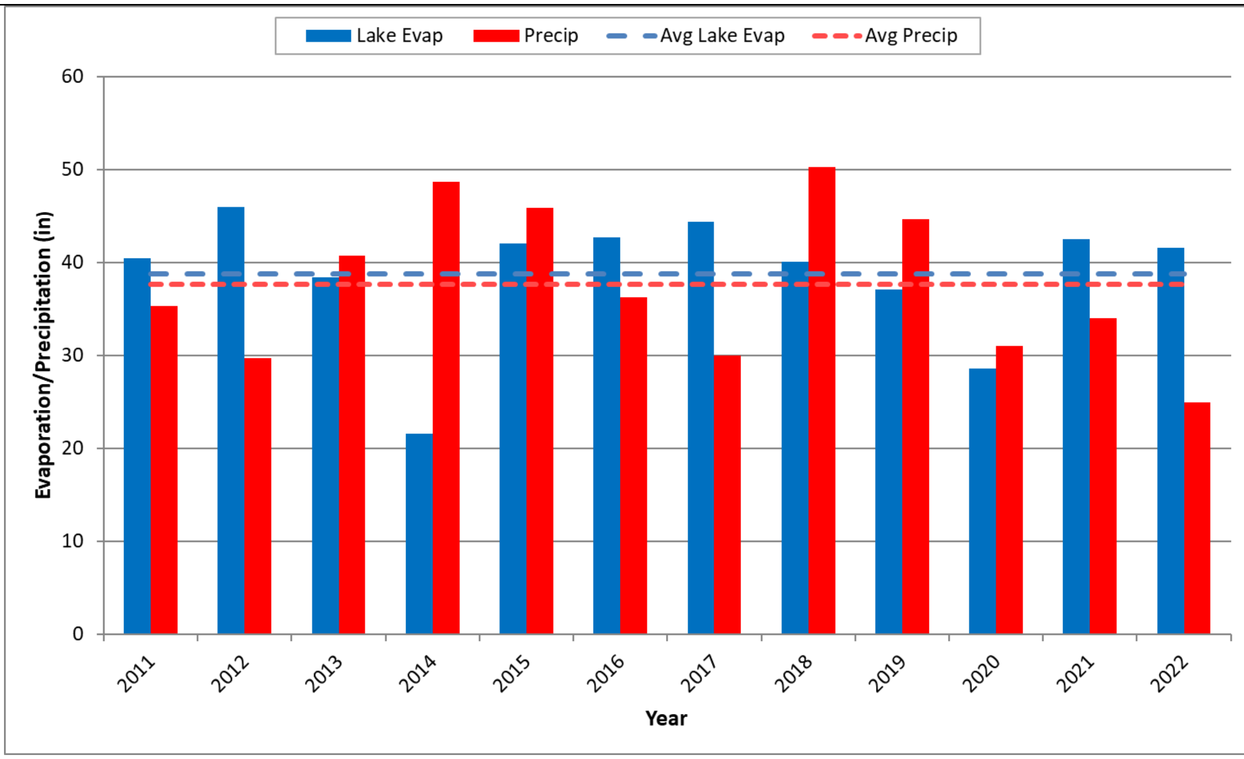

Figure 2-2. Annual Precipitation and Estimated Lake Evaporation.

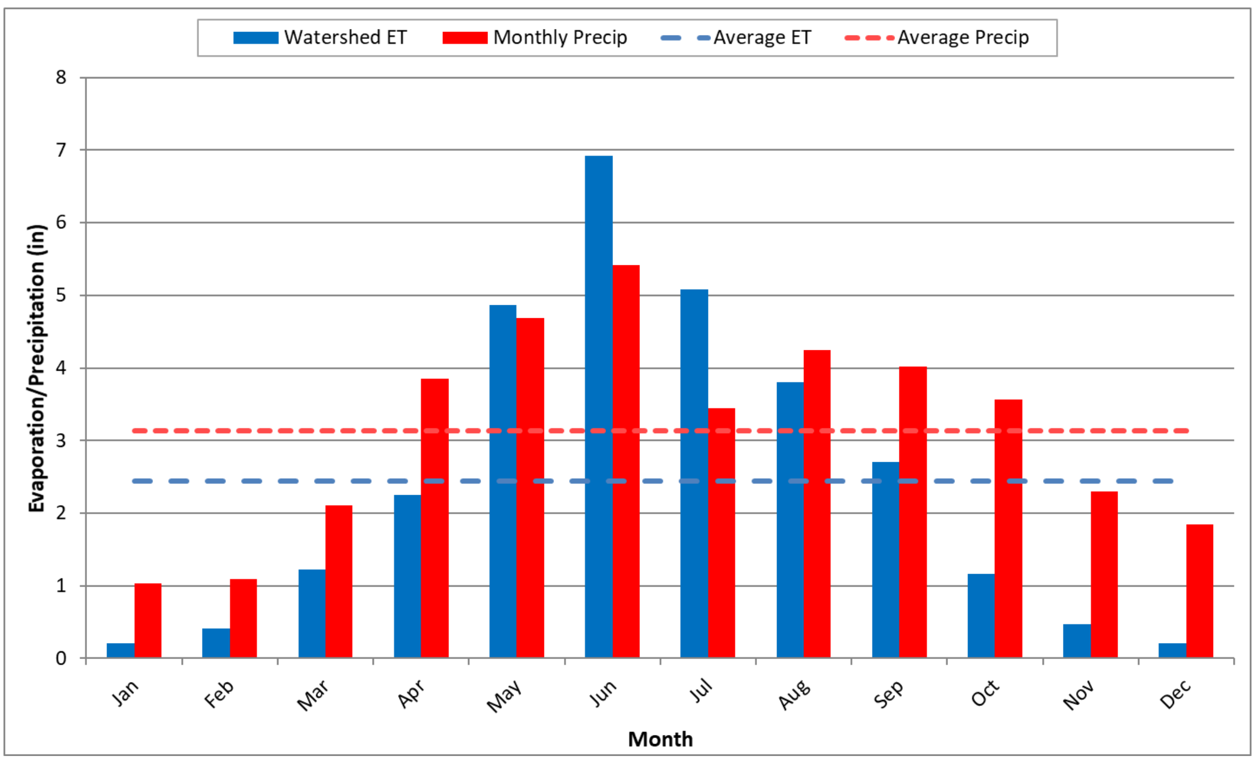

Figure 2-3. Monthly Precipitation and Estimated ET for the Watershed.

Rainfall runoff, direct precipitation, evapotranspiration, 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 Cedar Rapids, Iowa and lake morphometry.

During years of below average precipitation, residence time increases. In wet years, the opposite is true as residence time decreases. In lakes with smaller watershed to lake ratios the residence time may be longer than lakes with larger watershed to lake ratios.

Morphometry

According to the most current bathymetric data (October 2015), the surface area of Hawthorn Lake is 182 acres. Estimated water volume of the main lake is 1,796 acre-feet (ac-ft), with a mean depth of 13.3 ft and a maximum depth of 29 ft in the southern portion of the lake (2015 bathymetric data). The reservoir, like most constructed stream impoundments, has an irregular shape, with several small dissected arms that lead to upland overland flow paths. The high shoreline index of 3.33 suggests that the watershed of Hawthorn Lake has a large impact on lake water quality. Shoreline index values greater than 1.0 suggest the shoreline is highly dissected and indicative of a high degree of watershed influence (Dodds, 2000). This influence can be in the form of sediment (and associated phosphorus) loading from the watershed. High indexes 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 Hawthorn Lake. Lake morphometry and bathymetry data are shown in Figure 2-4.

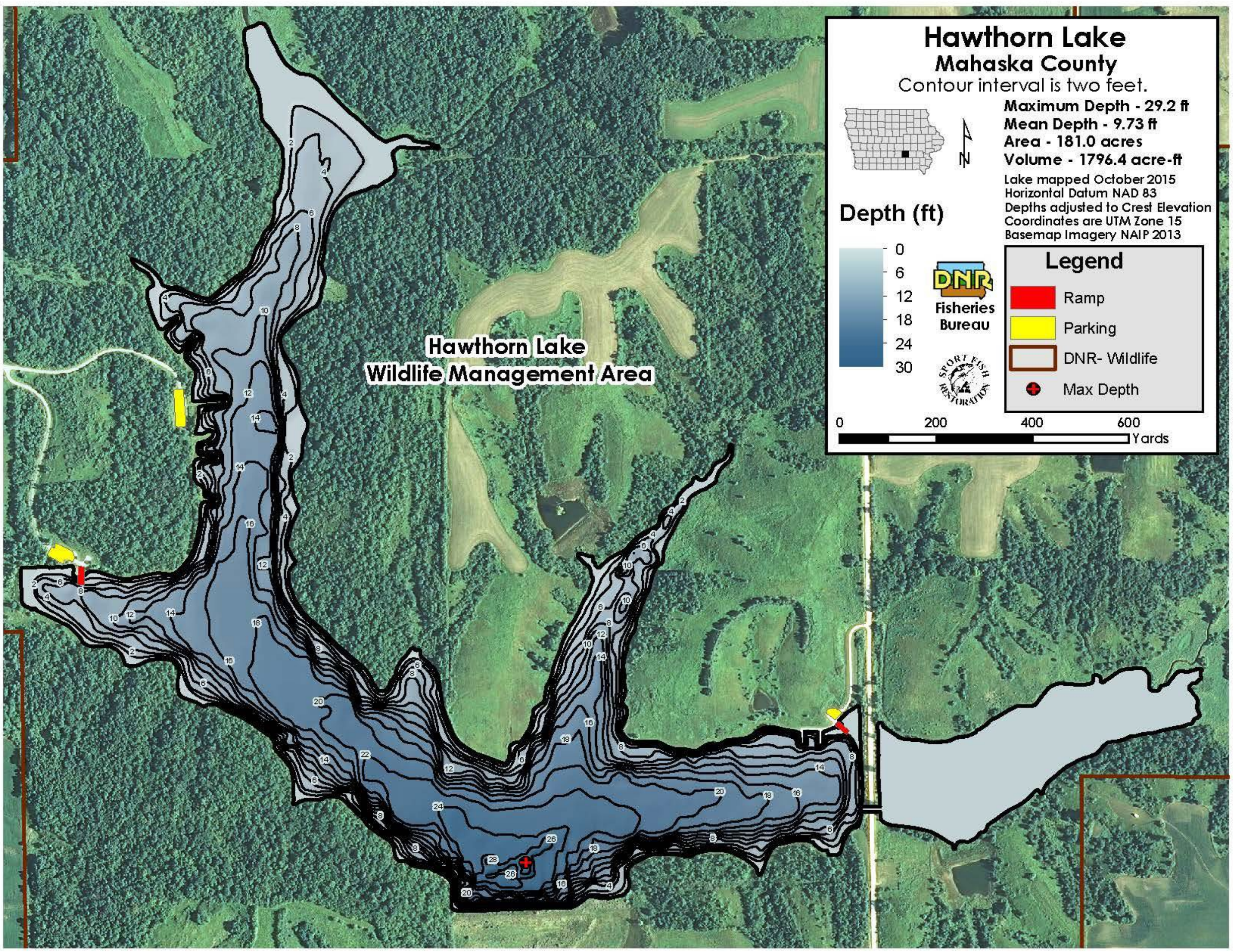

Figure 2-4. 2015 Bathymetric Map of Hawthorn Lake

2.2 The Hawthorn Lake Watershed

The watershed boundary of Hawthorn Lake encompasses 3,296 acres (including the lake) and is illustrated in Figure 2-1. The watershed-to-lake ratio is 17.1:1. The larger the ratio the more influence the watershed has on the water quality in the lake and more mitigation efforts will be required in the watershed to see water quality improvements. Conversely, a smaller ratio indicates that the watershed may not influence water quality in the lake as much as in situ influences. The ratio of 17.1:1 means for every acre of lake there are 17.1 acres of watershed contributing runoff, sediment, and potential pollutants to the lake. A successful lake restoration program will be based on both watershed and lake-based solutions. Mitigation of watershed influence will be required, and in-lake techniques may have relatively short effective life spans in the absence of watershed improvements and renovations. A prudent watershed management strategy should focus on problem areas that can be most easily addressed and implementation of 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.

Land Use

Land use information for the watershed was developed using the Cropland Data Layer (CDL) for 2022, which was obtained from the United States Department of Agriculture - National Agricultural Statistics Service. Review of previous CDL's and aerial photographs confirmed that land use has changed very little, if any, since 2010. The dominant land use is User Defined, which is made up of un-grazed grassland and alfalfa and hay, and makes up approximately 32 percent of the watershed. The next largest land use is row crop, which makes up approximately 26 percent of the watershed. (Table 2-3 and Figure 2-5).

Table 2-3. Hawthorn Lake Watershed Land Uses.

Land Use	Description	Area (acres)	Percent (%)[2]
Forest	Bottomland, Coniferous, Deciduous	644.8	19.6
Pasture	Grazed Grassland	345.1	10.5
Residential	Farmsteads, Farm Buildings, Residential Development	161.0	4.9
Row Crop	Corn and Soybeans	927.1	28.1
Roads	Roads and Impervious Surfaces	58.7	1.8
User Defined	Un-grazed Grassland, Alfalfa/Hay	932.1	28.3
Water/Wetland[1]	Water and Wetland	227.1	6.9
Total		**3,295.9**	**100.1**

[1]Includes Hawthorn Lake Surface Area.
[2]Total does not add up to 100% due to rounding.

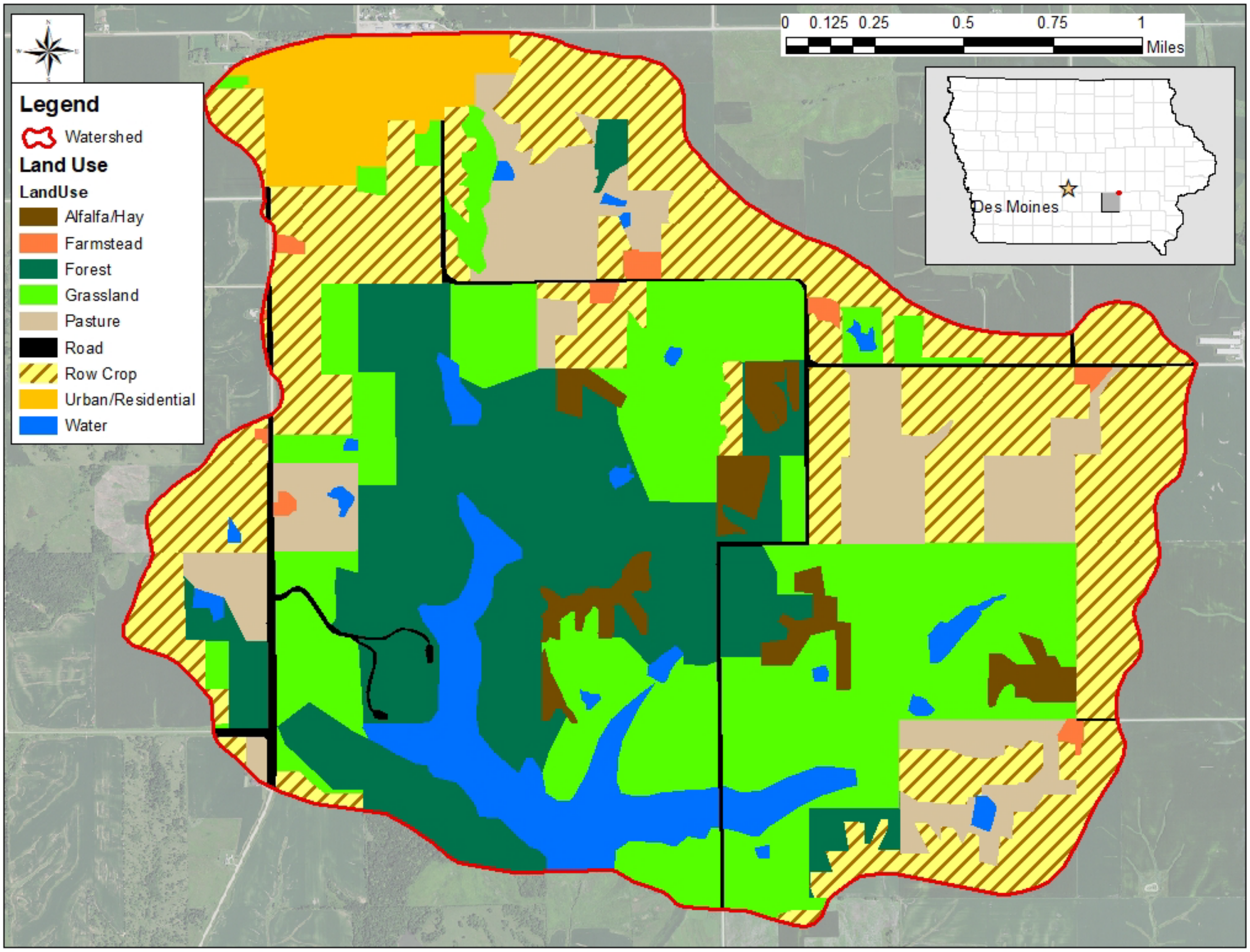

Figure 2-5. Hawthorn Lake Watershed Land Use Map.

Soils, Climate, and Topography

The Hawthorn Lake watershed is in the Rolling Loess Prairie Level IV ecoregion. This is a subregion of Pre-Illinoian glacial deposits. In the southeast, the valleys can be steep and forested and toward the central and west portions the land becomes hillier (Griffith et al., 1994).

As seen from Table 2-4 there are 19 different soil types in the watershed. The Clinton and Lindley soils are the most prevalent, making up approximately 51 percent of the soils in the watershed. Table 2-4 shows the soils, area, percent area of the watershed, general description, and typical slopes of each soil in the watershed (USDA-NRCS, 2021).

Table 2-4. Predominant Soils of the Hawthorn Lake Watershed.

Soil Name	Area (ac)	Area (%)	Description	Hydric Soil Group	Typical Slopes (%)
Clinton	962.0	29.2	Silt loam; eroded (above 5% slopes); moderately well drained soils.	C	2-18
Lindley	731.37	22.2	Loam; well drained soils.	C	9-25
Water	227.7	6.9	--	--	--
Hedrick	207.6	6.3	Silt loam; moderately eroded (above 5% slopes); moderately well drained soils.	C	2-14
16 Soil Types	1,167.3	35.40	---	C, C/D, D	0-25
Totals	**3,296.0**	**100.0**	**Varies**		**Varies**

The elevations in the watershed range from a maximum of 910.1 feet to a minimum of 794.8 feet (North American Vertical Datum 1988 -NAVD 88). The average slope of the watershed is 10.1 percent with strongly sloping (8 -15 percent slope) regions making up approximately one-third of the watershed at approximately 31 percent. Table 2-5 shows the percentage breakdown of slope classifications throughout the watershed, and Figure 2-6 illustrates the distribution of the slopes within the Hawthorn Lake watershed.

Table 2-5. Slope Classifications of the Hawthorn Lake Watershed.

Slope Class (%)	Area (%)	Description of Slope Class
Class A (0 - 2)	13.5	Nearly Flat
Class B (2 - 5)	16.0	Gently sloping
Class C (5 - 8)	16.0	Moderately Sloping
Class D (8 - 15)	31.4	Strongly Sloping
Class E (15 - 30)	21.8	Moderately Steep
Class F (> 30)	1.3	Steep to Very Steep
Total	100.0	---

The combination of soil classification, slope, topography, and hydrologic soil group (discussed more in Appendix D) indicate that the majority of agricultural areas in the Hawthorn Lake watershed would not be tile drained. The absence of drainage district data and anecdotal data on tile drainage location also indicate that minimal drainage is present in the watershed. However, agricultural management practices related to tile drainage may change in the future, which would lead to changes in watershed loading and its effects on Hawthorn Lake.

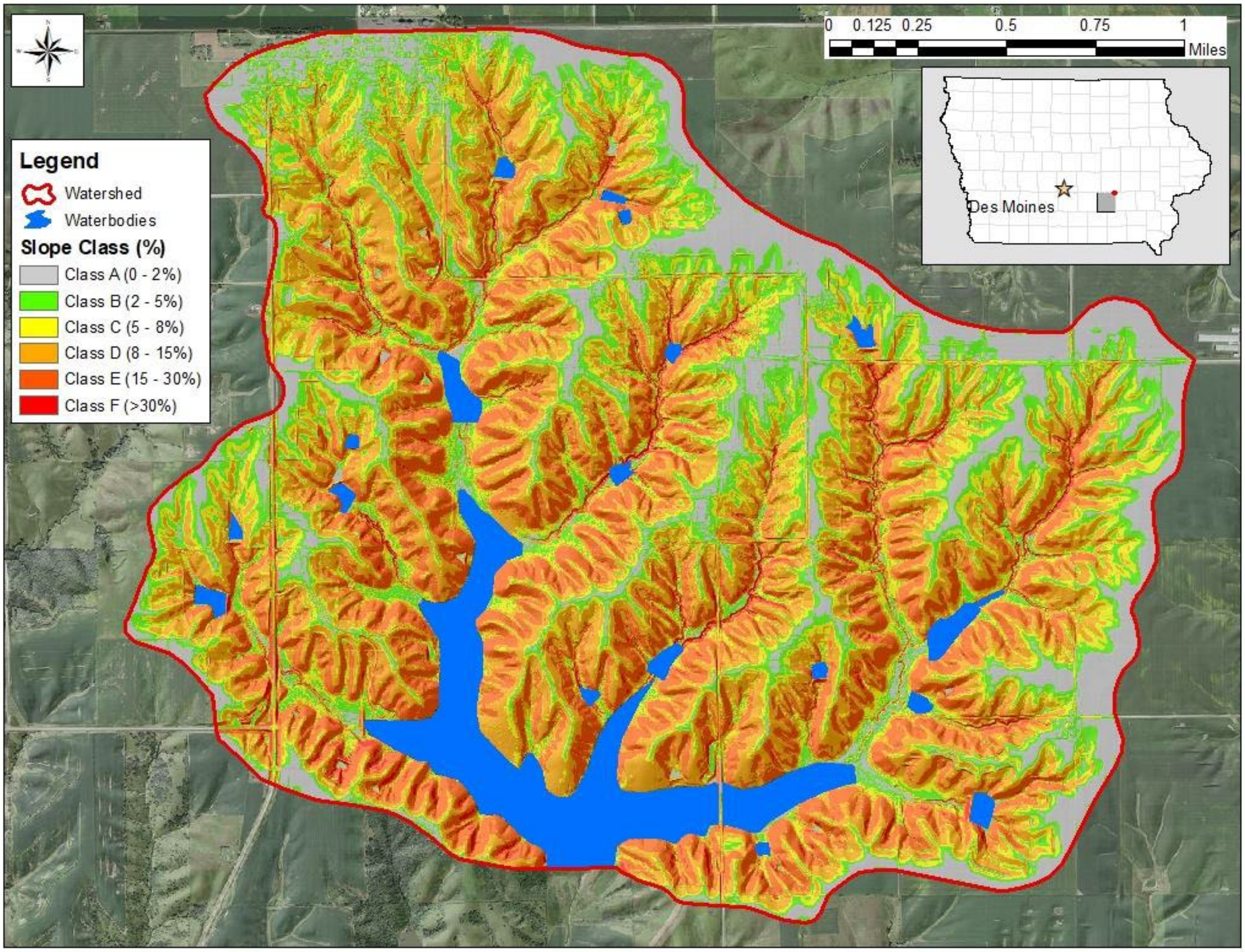

Figure 2-6. Slope Classifications in the Hawthorn Lake Watershed.

3. TMDL for Algae

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

3.1 Problem Identification

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

Primary Contact Recreational Use - Class A1
Lakes and Wetlands Aquatic Life - Class B(LW)
Human Health - Class HH

The Draft 2024 Section 305(b) Water Quality Assessment Report states that the Class A1 (primary contact) designated use in Hawthorn Lake was assessed as "“…not supported” due to aesthetically objectionable conditions caused by algal blooms.”. The 2024 assessment can be accessed at https://programs.iowadnr.gov/adbnet/Segments/862/Assessment/2024.

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].

In 2010 the State of Iowa enacted an antidegradation policy. This policy was designed to maintain and protect high quality waters and existing water quality in other waters from unnecessary pollution. Applicable protection levels (or tiers) as defined by the Iowa Administrative Code (IAC) 567-61.2 are cited below.

- 567-61.2(2)(a) Tier 1 protection. Existing surface water uses and the level of water quality necessary to protect the existing uses will be maintained and protected.

Although the State of Iowa does not have numeric criteria for sediment, nutrients, or algae (chl-a), the 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 the overall median growing season (summer) Carlson’s Trophic State Index (TSI) value for either chl-a or Secchi depth are greater than or equal to 65 (DNR, 2022). In order to de-list the algae impairments for Hawthorn Lake, the overall median growing season for chl-a TSI and Secchi depth TSI value must be 63 or less for one listing cycle, per DNR de-listing methodology (DNR, 2023).

Problem Statement
Water quality assessments indicate that Hawthorn Lake is impaired because the primary contact use in the lake is ""…not supported" due to aesthetically objectionable conditions caused by algal blooms.". High levels of algal production fueled by phosphorus loads to the lake caused the impairment. TP loads must be reduced in order to reduce algae and fully support the lake's designated use. Excess nutrients, particularly phosphorus, can cause eutrophic conditions associated with the impairment to Hawthorn Lake. Phosphorus laden sediment deposits can also cause transparency issues.

Data Sources and Monitoring Sites
Sources of data used in the development of this TMDL include those used in the Draft 2024 305(b) report, several sources of additional water quality data, and non-water quality related data used for model development. Sources include:

- Ambient Lake Monitoring and / or TMDL monitoring including:
    - Results of available statewide surveys of Iowa lakes sponsored by the DNR and conducted by Iowa State University 2000-2022.
- Precipitation data at Oskaloosa, Iowa, the ISU Iowa Environmental Mesonet. (IEM, 2023a)
- PET data at Cedar Rapids, Iowa, the ISU Ag Climate Network (IEM, 2023b)
- 3-m Digital Elevation Model (DEM) available from the 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 the DNR
- Lake bathymetric data collected in October 2015
- 2012 SPARROW Models for the Midwest (USGS, 2024)

Interpreting Hawthorn Lake Data
The Draft 2024 305(b) assessment was based on results of the ambient monitoring program conducted from 2018 through 2022 by ISU. Assessment of available in-lake water quality in this TMDL utilized available ISU data from 2011-2022 and DNR data from 2018. All in-lake 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 are shown in Appendix C.

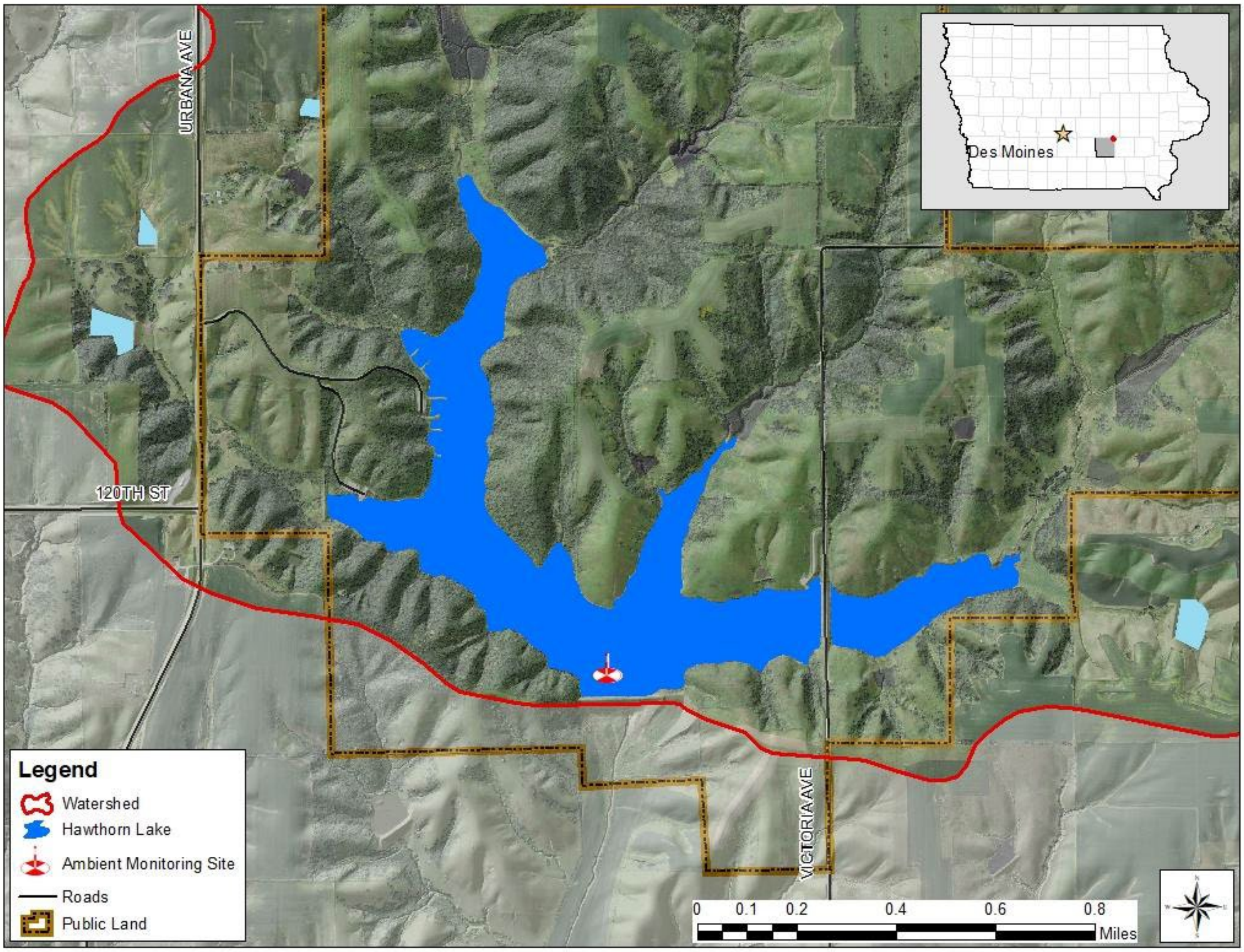

Figure 3-1. Ambient Monitoring Location for Water Quality Assessment.

Carlson's Trophic State Index (TSI) was used to evaluate the relationships between TP, algae (chl-a), and transparency (Secchi depth) in Hawthorn Lake. TSI values are not a water quality index but an index of the trophic state of the waterbody. However, the TSI values for Secchi depth and chl-a can be used as a guide to establish water quality improvement targets.

If the TSI values for the three parameters are the same, the relationships between the TP, algae, and transparency are strong. If the TP TSI value is higher than the chl-a TSI, it suggests there are limitations to algal growth besides phosphorus. Figure 3-2 is a plot of the individual TSI values throughout the analysis period (2011-2022). TSI values that exceed the 303(d)-listing threshold of 65 (for chl-a and Secchi depth) are contained within the orange box and TSI values from the Draft 2024 305(b) (2018-2022) assessment period are within the blue box. Table 3-1 shows the average and median TSI values for Secchi depth, chl-a, and TP during the Draft 2024 305(b) assessment period (2018-2022).

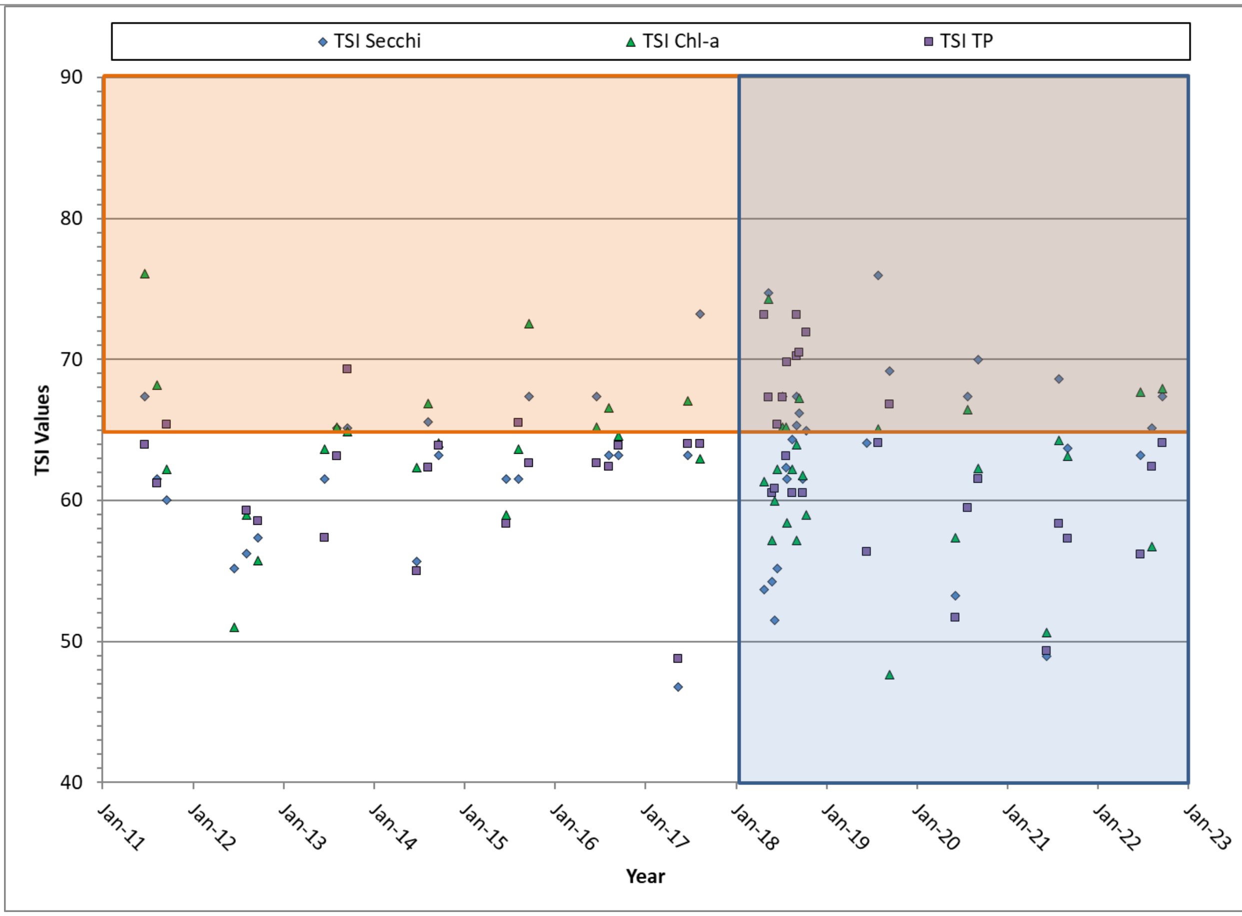

Figure 3-2. TSI Values for Individual Samples in the Analysis Period.

Table 3-1. Hawthorn Lake's Average and Median TSI Values for the Draft 2024 IR Assessment Period (2018-2022).

	Secchi Depth	Chlorophyll-a	Total Phosphorus
Average TSI Values	63	60	64
Median TSI Values	64	62	64

Annual median TSI values for the analysis period can be seen in Figure 3-3. The water clarity trend for the analysis period shows an increasing TSI value for Secchi depth, which indicates a decreasing Secchi depth. The trend for both TSI TP and TSI chl-a (algae) is decreasing which indicates a decrease in phosphorus and chlorophyll concentrations, respectively. It is also observed that TSI values for chl-a and TP are almost parallel to one another, which could indicate a correlation between chl-a and TP. However, the chl-a TSI value in 2019 is abnormally low, skewing the trend line. The low chl-a value could be a result of 1) the phosphorus being tied to sediment and not available for algal production, 2) a higher concentration of zooplankton than normal feeding on the algae consequently reducing the amount of algae in the lake, or 3) sample error. Further review indicates chl-a TSI values do not exceed 70 and with the exception of 2011, 2016, and 2022, the chl-a TSI values do not exceed the impairment threshold of 65.

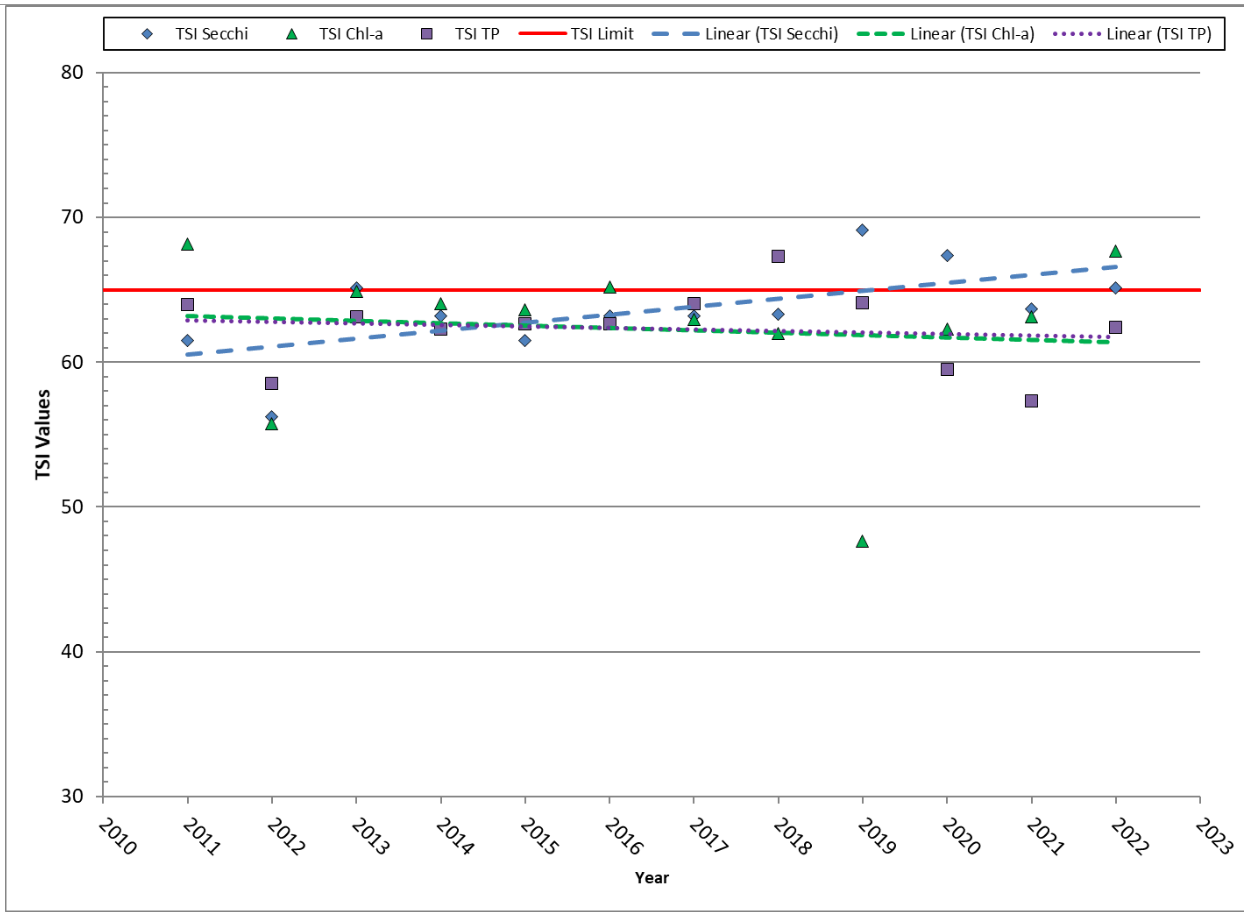

Figure 3-3. Annual Median TSI Values at Hawthorn Lake.

Table 3-2 shows the overall average and median TSI values for Secchi depth, chl-a, and TP for the analysis period. The values from the table show little or no differences between the TSI values, which suggest that all parameters could be correlated. Table 3-3 describes the implications of TSI scores on attributes of lakes.

Table 3-2. Hawthorn Lake's Average and Median TSI Values for the Analysis Period (2011-2022).

	Secchi Depth	Chlorophyll-a	Total Phosphorus
Average TSI Values	61.3	63.9	63.2
Median TSI Values	63.2	63.1	62.6

Table 3-3. Implications of TSI Values on Lake Attributes.

TSI Value	Attributes	Primary Contact Recreation	Aquatic Life (Fisheries)
50-60	Eutrophy: anoxic hypolimnia; macrophyte problems possible	[none]	Warm water fisheries only; percid fishery[1]; bass may be dominant
60-70	Cyanobacteria (blue green algae) dominate; algal scums and macrophyte problems occur	Weeds, algal scums, and low transparency discourage swimming and boating	Centrarchid fishery[2]
70-80	Hyper-eutrophy (light limited). Dense algae and macrophytes	Weeds, algal scums, and low transparency discourage swimming and boating	Cyprinid fishery (e.g., common carp and other rough fish)
>80	Algal scums; few macrophytes	Algal scums, and low transparency discourage swimming and boating	Rough fish dominate; summer fish kills possible

[1]Fish commonly found in percid fisheries include walleye and some species of perch
[2]Fish commonly found in centrarchid fisheries include crappie, bluegill, and bass
Note: Modified from Carlson and Simpson (1996).

Figure 3-4 and Figure 3-5 illustrates a method for interpreting the meaning of the deviations between Carlson's TSI values for TP, Secchi depth, and chl-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 chl-a TSI and TP TSI is less than zero (Chl TSI < TP TSI), the data point will fall below the X-axis. This suggests phosphorus may not be the limiting factor in algal growth. The X-axis, or zero line, is related to TN:TP ratios of greater than 33:1 (Carlson, 1996). Because phosphorus is thought to become limiting at ratios greater than 10:1, TP deviations slightly below the X-axis do not necessarily indicate nitrogen limitation. Another way of interpreting this would be the greater the negative deviation the more likely it is that something other than phosphorus limits algal growth.

Points to the left of the Y-axis (Chl TSI < SD TSI) represent conditions in which transparency is reduced by non-algal turbidity. Points to the right reflect situations in which transparency is greater than chl-a levels would suggest, meaning that large particles, rather than fine clay particles, influence water clarity. Deviations to the right may also be caused by high zooplankton populations that feed on algae, keeping the algal populations lower than expected given other conditions.

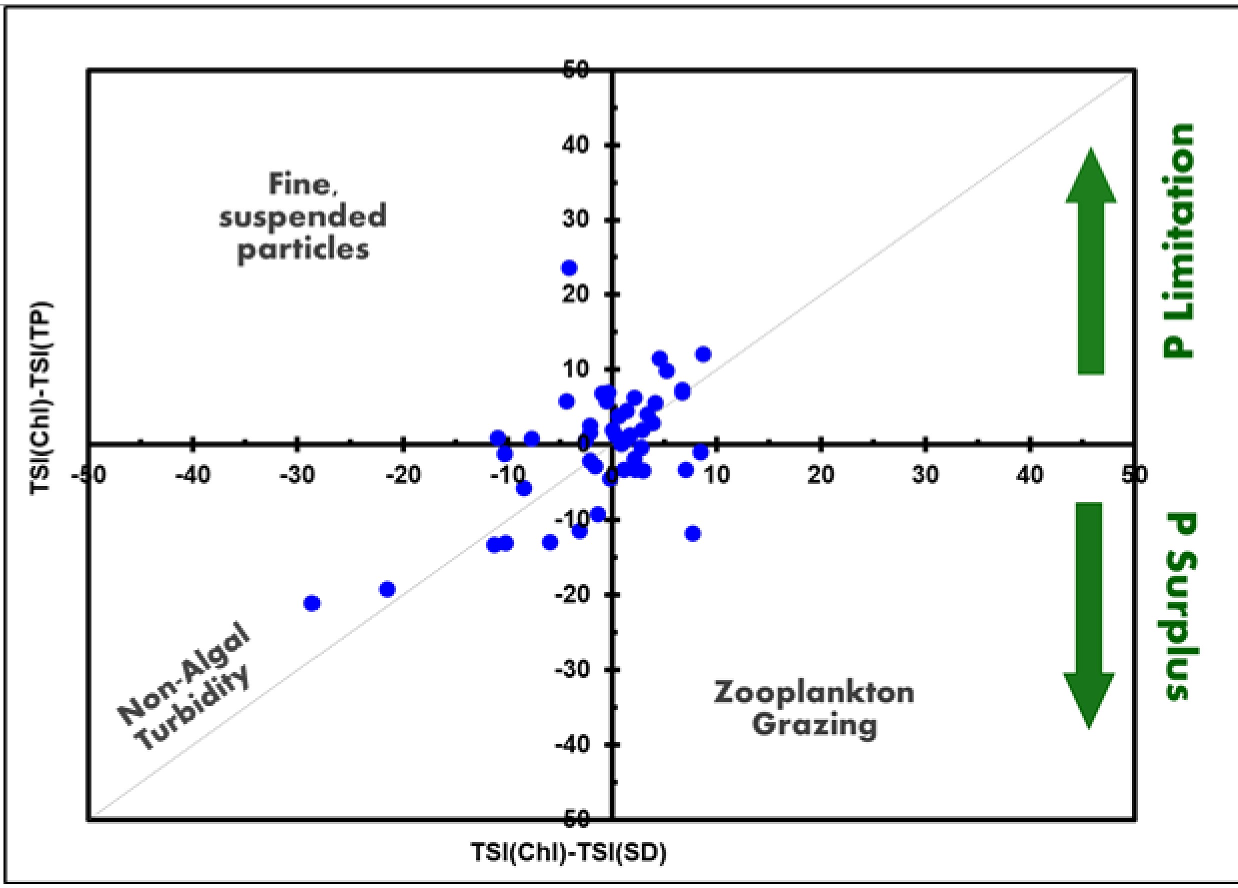

Figure 3-4. Phosphorus TSI Deviations Grab Samples for Analysis Period.

Chl-a and TP TSI deviations are split between positive and negative deviations with approximately 57 percent (26 of 46) above the x-axis and approximately 43 percent (20 of 46) below the x-axis as shown in Figure 3-4. The highest percentages of deviations are located in the upper right-hand quadrant (16 of 46 samples, 35%). The second highest percentage of deviations are located in the bottom left hand quadrant (12 of 46, 26%). The remaining samples are distributed closely with 22 percent located in the upper left hand (10 of 46, 22%) and 17 percent located in the lower right hand (8 of 46, 17%) quadrants. Samples located in the upper right-hand quadrant would indicate large particles dominate and that phosphorus limits the growth of algae. Samples in the lower left-hand quadrant would indicate smaller particles dominate and something other than phosphorus limits the algae growth. Samples in the lower right-hand quadrant suggest transparency is limited by large particles, with a surplus of phosphorus, and possible limited algae growth due to zooplankton grazing.

Individual samples are split evenly to the left (22) and right (24) of the y-axis implying there is no clear pattern as to whether fine or large particles dominate. The number of samples above the x-axis (26) is slightly greater than the number of samples below (20) the x-axis, which implies that phosphorus is the limiting nutrient, this will be discussed more later.

TSI annual average deviations (Figure 3-5) indicate a similar result with six years to the left of the y-axis and seven-years to the right of the y-axis. There are nine-years above the x-axis and three-years below the x-axis. This would suggest that most years phosphorus is the limiting nutrient.

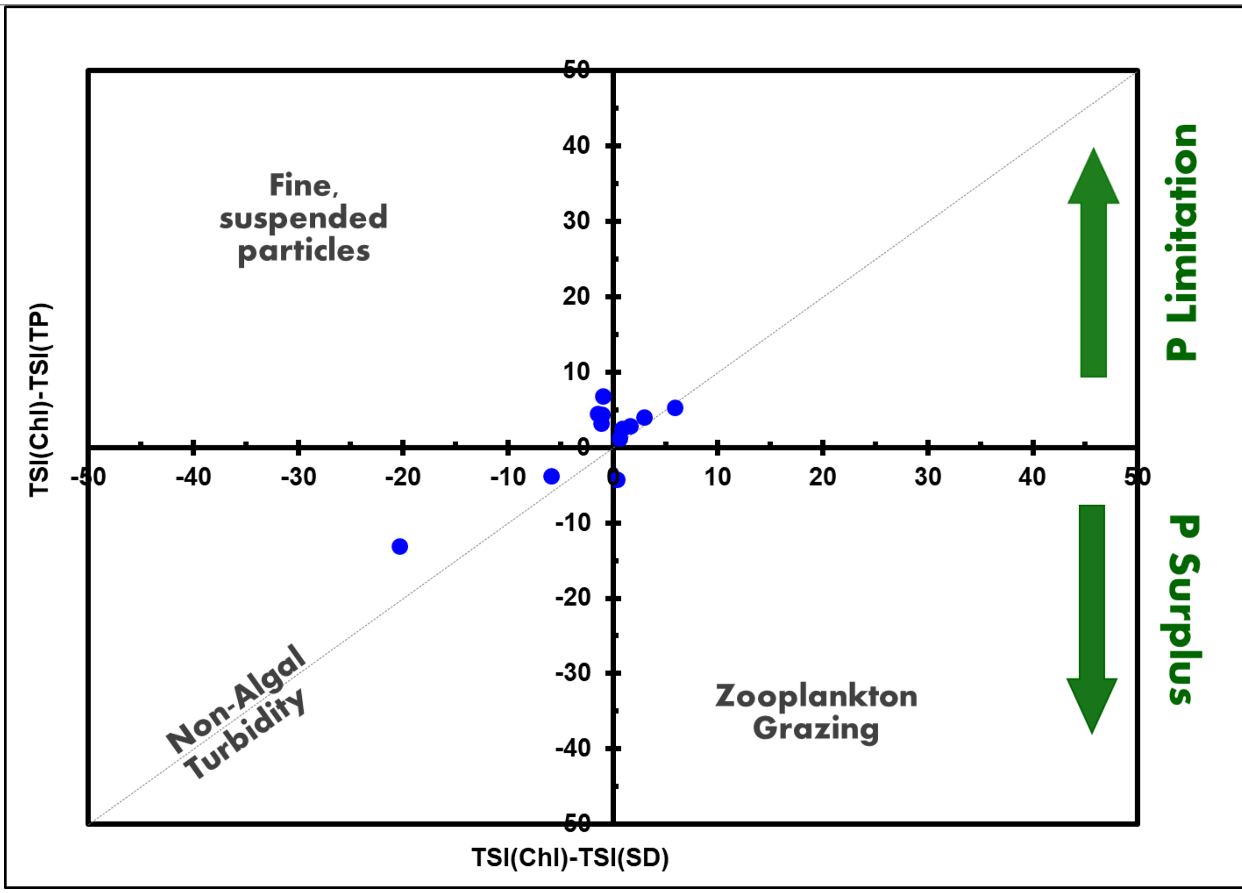

Figure 3-5. TSI Annual Average Deviations for Analysis Period.

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 nitrogen to phosphorus can provide clues as to which nutrient is limiting growth in a given waterbody.

The overall TN:TP ratio in water quality samples from Hawthorn Lake, using average grab sample concentrations from the analysis period is 23.0. 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). P-limited 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. As Figure 3-6 shows, TN:TP ratios suggest that Hawthorn Lake is limited by phosphorus approximately 68 percent of the time, co-limited 26 percent of the time, and nitrogen limited approximately six percent of the time.

This analysis reveals that water quality improvement of algal blooms and turbidity via TP reduction is most feasible. If phosphorus reductions are not accompanied by reductions in algal blooms, then reductions in nitrogen may prove necessary to reduce algae to an acceptable level.

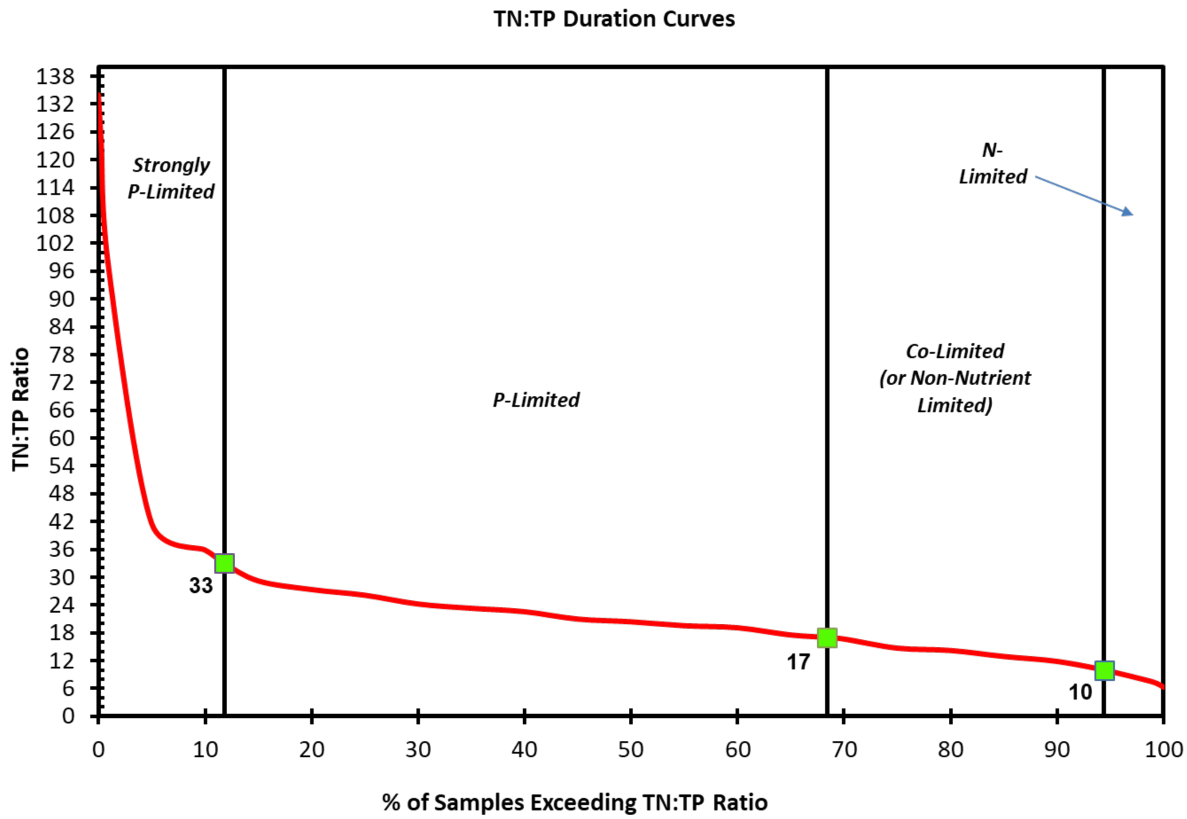

Figure 3-6. Distribution of TN:TP Values in Hawthorn Lake (2011-2022)

Chl-a TSI values do not show a significant correlation to annual or growing season precipitation. However, Secchi depth and TP TSI values show some correlation to annual or growing season precipitation as shown in Figure 3-7. This suggests that high chl-a levels are observed in both wet and dry years.

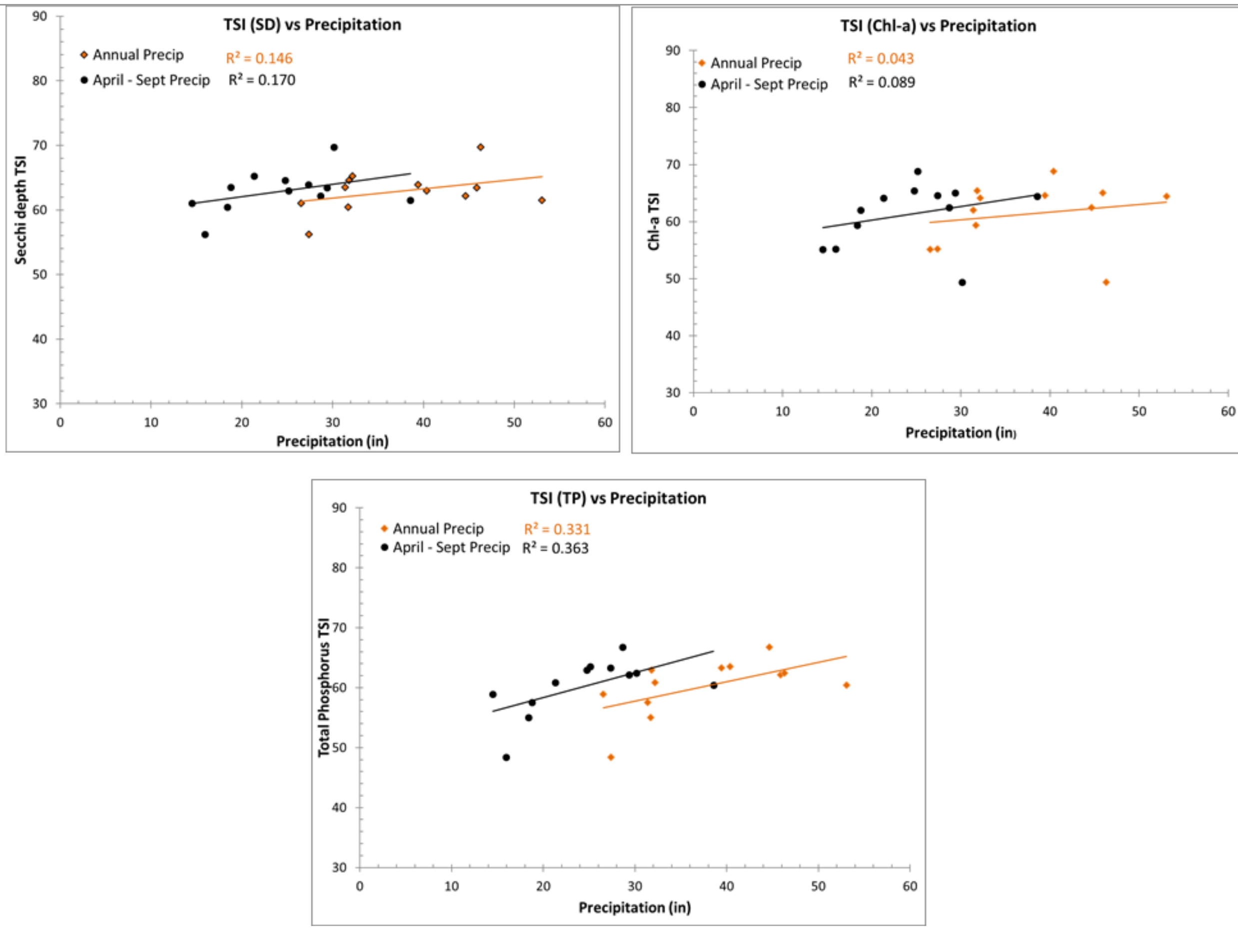

Figure 3-7. TSI Values vs Annual and Growing Season Precipitation.

3.2 TMDL Target

General Description of the Pollutant

The Draft 2024 305(b) assessment attributes poor water quality in Hawthorn 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 chl-a and Secchi depth as phosphorus reduction practices are implemented. If phosphorus reductions are not accompanied by reductions in algal blooms, then reductions of nitrogen may prove necessary to reduce algae to an acceptable level. However, phosphorus should be reduced first, as it is the primary limiting nutrient in algal growth. Additionally, reductions in nitrogen that result in nitrogen limitation favor growth of harmful cyanobacteria, which have the ability to fix nitrogen from the atmosphere. These bacteria, often referred to as blue-green algae, can emit cyanotoxins to the water, which can harm humans, pets, and wildlife if ingested.

Table 3-4 reports the simulated chl-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 Secchi depth TSI target of 63 complies with the narrative “free from aesthetically objectionable conditions” criterion. Meeting this target will result in delisting Hawthorn Lake if attained in two consecutive 303(d) listing cycles. Note that TP values in Table 3-4 are not TMDL targets. Rather, they represent in-lake water quality resulting from TP load reductions required to obtain the chl-a and Secchi depth TSI targets in Hawthorn Lake.

Table 3-4. Existing and Target Water Quality (Ambient Monitoring Location).

Parameter	2011-2022[1]	2018-2022[2]	TMDL Target Conditions
Secchi Depth (meter)	0.91	0.89	0.97
TSI (Secchi Depth)	61.3	61.7	60.4
Chlorophyll-a (µg/L)	29.7	26.8	27.2
TSI (Chlorophyll-a)	63.9	62.9	63.0
TP (µg/L)	60.2	65.5	54.1
TSI (TP)	63.2	64.4	61.7

[1]Modeled Period, Mean Values.
[2]Draft 2024 Assessment/Listing Cycle Values.

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 Hawthorn 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 chlorophyll-a and Secchi depth TSI targets of 63 using analyses 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 available water quality data collected by ISU and the DNR from 2011-2022.

The BATHTUB model is driven by weather, lake morphometry (i.e., size and shape), watershed hydrology, and sediment and nutrient loads predicted by the STEPL model. STEPL utilizes simple equations to predict sediment and nutrient loads from various land use and animal sources, and includes a tool that estimates potential sediment and nutrient reductions resulting from implementation of Best Management Practices (BMPs). STEPL input included local soil, land use, 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 (tributary concentrations) in the calibrated BATHTUB model until the TSI values for chlorophyll-a and Secchi depth were no greater than 63 for the lake segment in which ambient monitoring data is collected. The load response curve from the BATHTUB model output is illustrated in Figure 3-8. The annual target TP loading capacity of Hawthorn Lake is 1,791.5 lbs/yr.

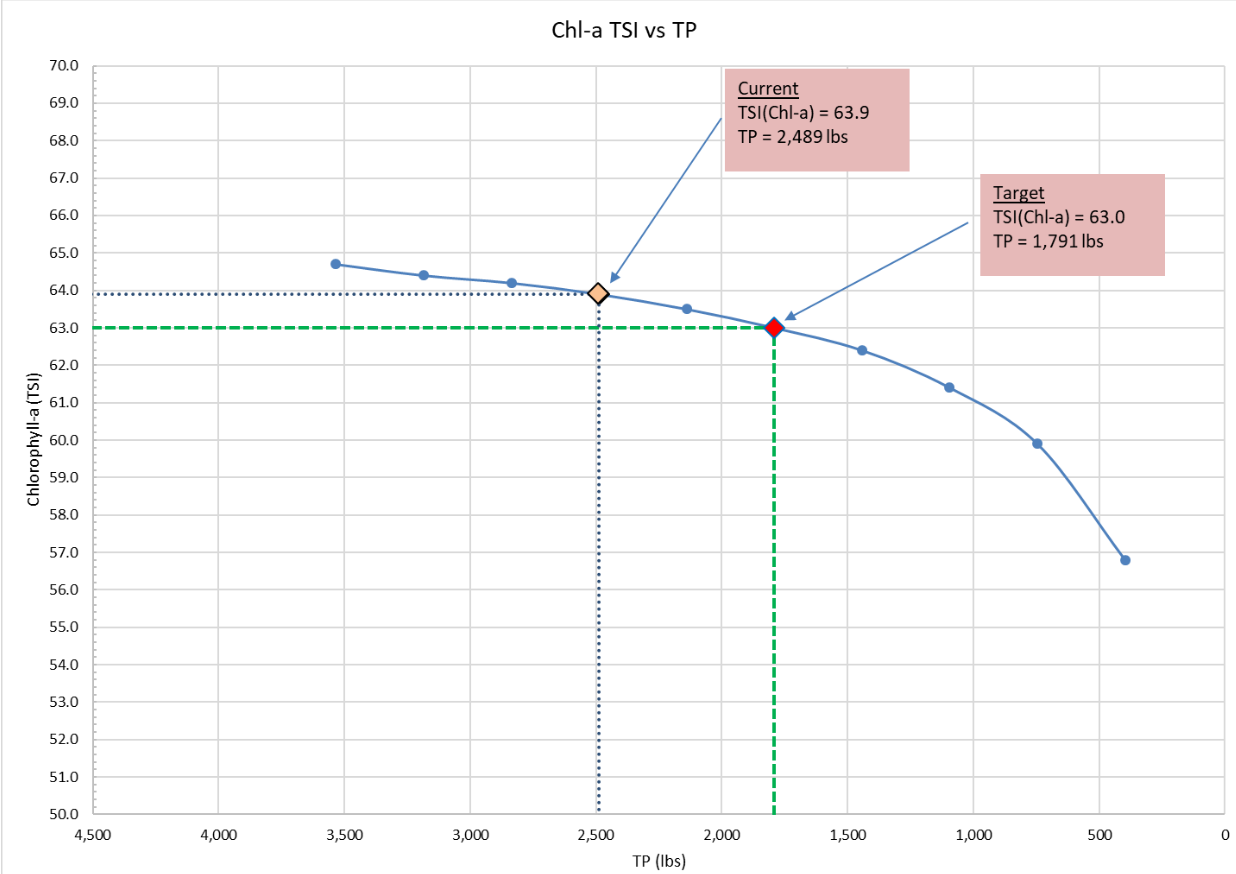

Figure 3-8. Simulated Load Response between Chl-a TSI and TP Load.

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 Hawthorn Lake for TP is expressed as a daily maximum load, in addition to the annual loading capacity of 1,791.5 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 annual 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., annual) 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, 2006), 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 1,791.5 lbs/yr is equivalent to an average daily load of 6.8 pounds per day (lbs/day) and a maximum daily load of 15.3 lbs/day.

Decision Criteria for WQS Attainment

The narrative criteria in the water quality standards require that Hawthorn Lake support primary contact for recreation. The metrics for WQS attainment for de-listing the impairments are a chl-a TSI and Secchi depth TSI of 63 or less for one 303(d) listing cycles (DNR, 2023).

Compliance Point for WQS Attainment

The TSI target for listing and delisting of Hawthorn 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 D-1). To maintain consistency with other Clean Water Act programs implemented by the 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 Hawthorn 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 2011-2022, the annual TP load to Hawthorn Lake was estimated to be 2,489.2 lbs/yr. The simulation period (for existing conditions) includes assessment period (for the Draft 2024 Integrated Report) as well as prior and subsequent years where monitoring data was available.

Departure from Load Capacity

The TP loading capacity for Hawthorn Lake is 1,791.5 lbs/yr and 15.3 lbs/day (maximum daily load). To meet the target loads, an overall reduction of 28 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 Hawthorn Lake is entirely from nonpoint sources of pollution and natural background sources. Table 3-5 reports estimated annual average TP loads to the lake from all known sources, based on the STEPL simulation of average annual conditions from the analysis period. The predominant sources of phosphorus to Hawthorn Lake include erosion from row crops. Row crops comprise approximately 26 percent of the watershed and approximately 62 percent of the phosphorus load to the lake. (Table 3-5 and Figure 3-9).

Table 3-5. Average Annual TP Loads from Each Source.

Source	Descriptions and Assumptions	TP Load (lbs/yr)	Percent (%)
Pastureland	Seasonally Grazed Grassland	168.1	6.8%
Row Crops	Sheet and rill erosion from corn and soybeans dominated agriculture	1,547.7	62.2%
User Defined	Ungrazed grassland and Alfalfa/Hay	224.8	9.0%
Forest	Forested park grounds surrounding lake	292.9	11.8%
Urban	Urban areas, roads, and farmsteads	2.8	0.1%
Groundwater	Agricultural tile discharge, natural groundwater flow	162.4	6.5%
All Others	Wildlife, atmospheric deposition, septics	90.5	3.6%
Total		**2,489.2**	**1.00**

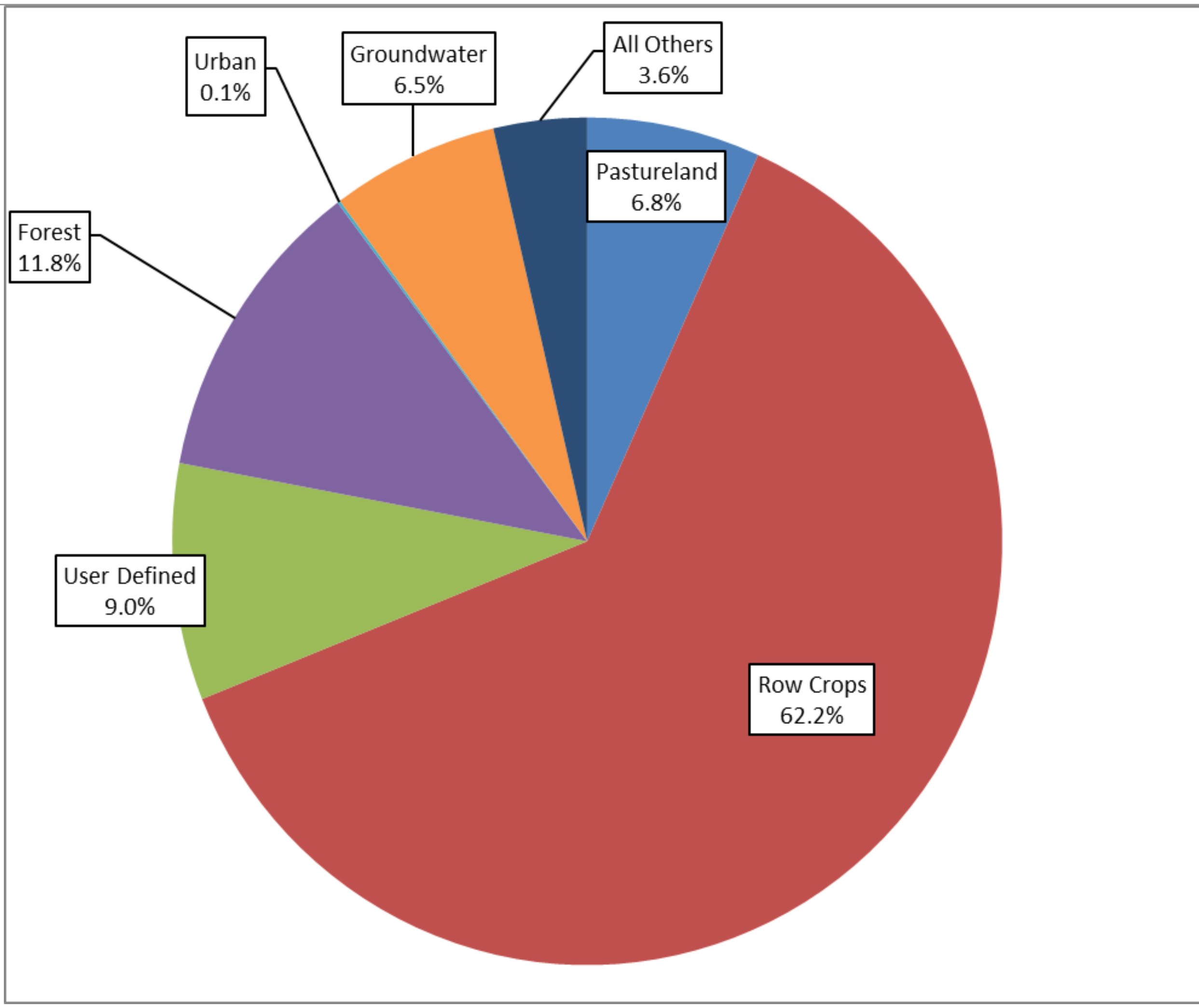

Figure 3-9. Relative TP Loads by Source.

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 Hawthorn Lake. 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 row crops and ungrazed grassland, such as alfalfa and hay. It is likely that current land uses will remain consistent with only minimal changes in the future. Any future residential or urban development may contribute similar sediment loads and therefore will not increase phosphorus to the lake system. 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 have zero discharge permits.

3.4 Pollutant Allocation

Wasteload Allocation

There are no permitted point source dischargers of phosphorus in the Hawthorn Lake watershed. The City of Barnes City is located in the northern part of the watershed, with a portion of the city's incorporated limits outside of the watershed. The city operates a two-cell controlled discharge lagoon. However, the treatment facility and effluent discharge location are located approximately one-quarter mile northeast of the city limits, outside the watershed. In addition, the city is a small community and does not operate under an NPDES municipal separate storm sewer system (MS4) permit. Therefore, storm sewer runoff is part of the nonpoint source load to the lake and considered in the load allocation. It is assumed that a portion of existing septic systems are failing or directly discharging to tile drains and are included as nonpoint sources. There are no active CAFOs in the watershed. Therefore, the WLA is set to zero (0) and all of the loading capacity is allocated as a gross allotment to the load allocation.

Load Allocation

The load allocation consists of nonpoint sources and natural background sources. Nonpoint sources of phosphorus to Hawthorn Lake include erosion and loss of manure and fertilizer from land in row crop production, erosion and manure from pasture and other grasslands, stream and gully erosion, erosion from timber/wooded areas, transport from developed areas (roads, residences, etc.), wildlife defecation, atmospheric deposition (from dust and rain), and 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, can also contribute phosphorus to the lake. Without additional site-specific information, it is difficult to separate natural background sources from nonpoint sources. Consequently, the load allocation is presented as a gross allotment.

It is seldom feasible or economical to achieve large load reductions from natural/background sources. However, 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 Hawthorn Lake. Based on the inventory of sources, management and structural practices targeting land in row crop production offer the largest potential reductions in TP loads.

Table 3-6 shows an example of a load allocation scenario for the Hawthorn Lake watershed that meets the overall TMDL phosphorus target. The LA is 1,612.3 lbs/year, with a maximum daily LA of 13.7 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 3-6 are not required, but provide one of many possible combinations of reductions that would achieve water quality goals.

Table 3-6. Example Load Allocation Scheme to Meet Target TP Load.

TP Source	Existing Load (lbs/year)	LA (lbs/year)	NPS Reduction (%)
Pastureland	168.1	100.9	40
Row Crops	1,547.7	928.6	40
User Defined[1]	224.8	134.9	40
Forest	292.9	175.7	40
Urban	2.8	1.7	40
Groundwater	162.4	162.4	0
All Others[2]	90.5	90.5	0
Total	**2,489.2**	**1,594.7**	**--**

[1]Ungrazed grassland and Alfalfa/Hay.

[2]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. These uncertainties may include seasonal changes in nutrient concentrations of influent to Hawthorn Lake, changes in internal recycling that may be seasonal in nature, and maintenance and efficiency of existing BMPs. Implicit and explicit considerations were used in establishing the MOS for this TMDL. Ultimately, an explicit MOS of 10 percent (179.1 lbs/year, 0.49 lbs/day) was utilized.

The 10 percent explicit MOS is deemed appropriate for the following reasons:

1) The STEPL model over predicts a TP load that is approximately 3.5 percent higher than the SPARROW calibration site.
2) The BATHTUB model over predicts a TP load approximately 4.2 percent higher than observed loadings.
3) Model shows good agreement between predicted and observed loadings, after calibration, indicating that the model reasonably reflects the conditions in the lake.
4) Using an explicit 10 percent MOS provides an additional level of conservatism in the final TMDL calculations.

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 the assumption that nonpoint source load reductions will occur, the TMDL should provide reasonable assurance that nonpoint source control measures will achieve expected load reductions. There are no permitted or regulated point source discharges contributing phosphorus to Hawthorn Lake and the WLA is zero, therefore reasonable assurance of point source reductions is not applicable. Reasonable assurance for reduction of nonpoint sources is provided by the list of potential best management practices that would deliver phosphorus reductions, a group of nonstructural practices that prevent transport of phosphorus, a proposed methodology for prioritizing and targeting BMPs on the landscape, and monitoring for best available data for estimating the reductions associated with implemented BMPs.

3.5 TMDL Summary

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

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

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)

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

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

$$\boldsymbol{TMDL} = LC = \Sigma\, WLA(0\ lbs - TP/year) + \Sigma\, LA(1612.3\ lbs - TP/year) + MOS(179.1\ lbs - TP/year) = \mathbf{1791.5}\ \boldsymbol{lbs - TP/year}$$

Expressed as the maximum daily load:

$$\boldsymbol{TMDL} = LC = \Sigma\, WLA(0\ lbs - TP/day) + \Sigma\, LA(13.7\ lbs - TP/day) + MOS(1.6\ lbs - TP/day) = \mathbf{15.3}\ \boldsymbol{lbs - TP/day}$$

4. Implementation Planning

An implementation plan is not a requirement of the Federal Clean Water Act. However, the DNR recognizes that technical guidance and support are critical to achieving the goals outlined in this 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 Hawthorn 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 Hawthorn 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 Hawthorn Lake in the 1970's, agricultural producers have updated management practices, implemented grassed waterways and conservation tillage 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. In addition, sedimentation basins were constructed to aid in the improvement of the water quality of Hawthorn Lake by settling out sediment laden runoff.

4.2 Future Planning and Implementation

General Approach

Watershed management and BMP implementation to reduce algae in the lake should utilize a phased approach to improving water quality. The existing loads, loading targets, a general listing of BMPs needed to improve water quality, and a monitoring plan to assess progress are established in this WQIP. Completion of the WQIP should be followed by the development of a watershed management plan by a local planning group. The watershed plan should include more comprehensive and detailed actions to better guide the implementation of specific BMPs. Tasks required to obtain real and significant water quality improvements include continued monitoring, assessment of water quality trends, assessment of WQS attainment, and adjustment of proposed BMP types, location, and implementation schedule to account for changing conditions in the watershed.

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. Monitoring should continue throughout implementation of BMPs and beyond to document water quality improvement.

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, or other state and federal funding sources, as available. Establishment of specific short, intermediate, and long-term water quality goals and milestones would also be needed 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 "hotspots" that may exist.

4.3 Best Management Practices

No stand-alone BMP will be able to sufficiently reduce phosphorus loads to Hawthorn Lake. Rather, a comprehensive package of BMPs will be required to reduce sediment and phosphorus loads to the lake, which can cause elevated algal growth and turbidity issues. The majority of phosphorus enters the lake via nutrient loss from cropland, ungrazed grassland and forested land through sheet / rill and gully erosion. 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 and turbidity issues caused primarily by excess phosphorus loads to the lake and in 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 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 fertilizer application and avoiding over-application may have even greater benefits to water quality. Application of fertilizer 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) constructed wetlands may be considered where appropriate. Table 4-1 summarizes land management BMPs and associated phosphorus reduction estimates.

Table 4-1. Potential Land Management BMPs (Prevention Strategies).

BMP or Activity	Potential TP Reduction[1]
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:	
Deep Tillage Incorporation vs. Surface Broadcast[2]	-15%
Shallow Tillage Incorporation vs. Surface Broadcast[2]	-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). Actual reduction percentages may vary widely across sites and runoff events.
[2]Note: Tillage incorporation can increase TP in runoff in some cases.

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 Hawthorn 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 4-2. Potential Structural BMPs (Mitigation Strategies).

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

[1]Adopted from Dinnes (2004). 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

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. 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.

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

The Spreadsheet Tool for Estimating Pollutant Load (STEPL) model was used in TMDL development to predict phosphorus loads to Hawthorn Lake. Figure 4-1 shows the annual phosphorus export from each subbasin in the Hawthorn Lake watershed STEPL model. Phosphorus export rates range from 441 to 1,260 lbs/year. The darker shaded basins indicate the heaviest phosphorus export rates and the lighter shaded basins indicate the lowest export rates relative to the subbasins in this study.

Figure 4-2 shows the annual phosphorus export rate per acre of subbasin. Export rates range from 0.39 to 1.22 lbs/acre-year. The darker shaded basins indicate the heaviest phosphorus export rates and the lighter shaded basins indicate the lowest export rates relative to the subbasins in this study.

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

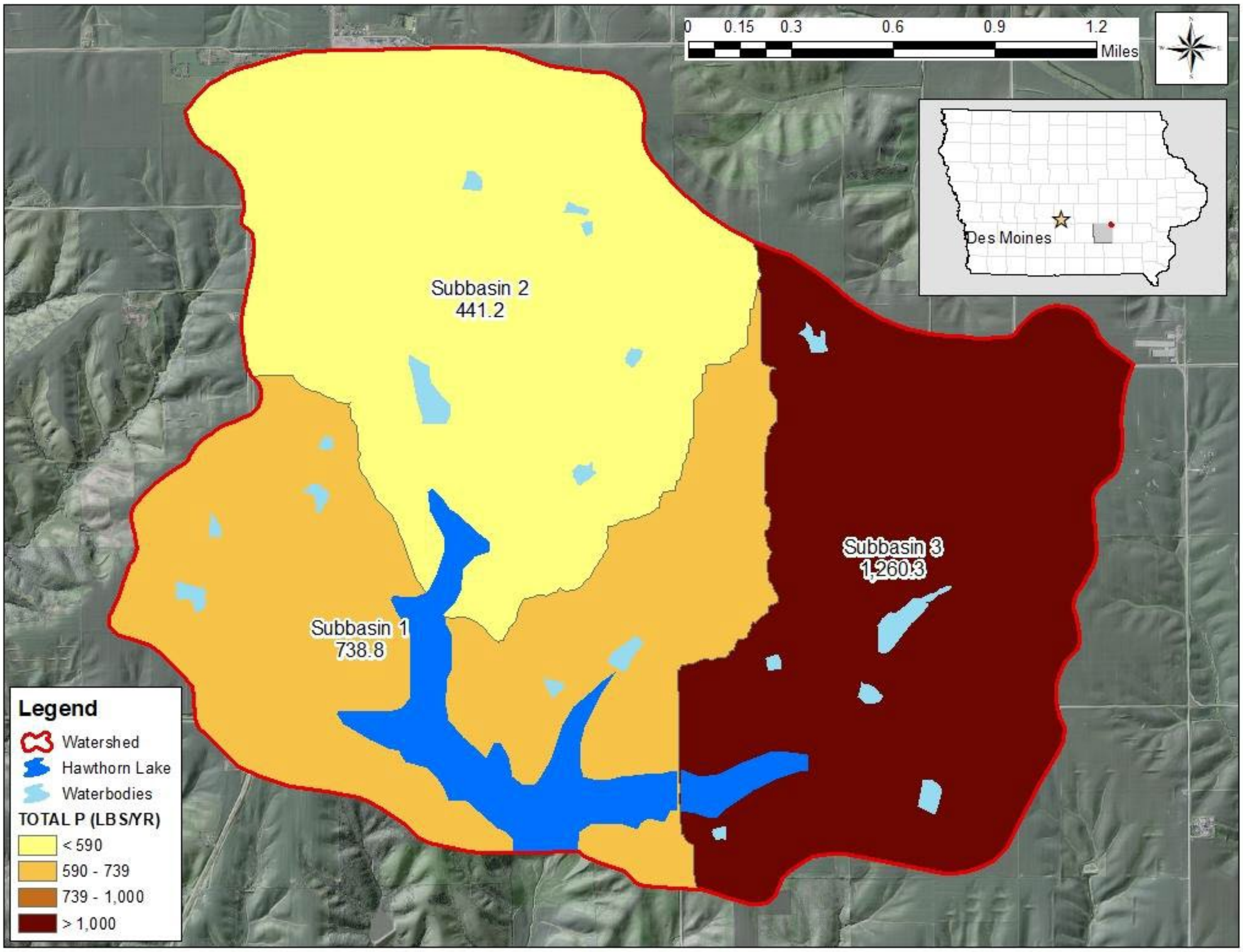

Figure 4-1. Predicted TP Load from each STEPL Subwatershed.

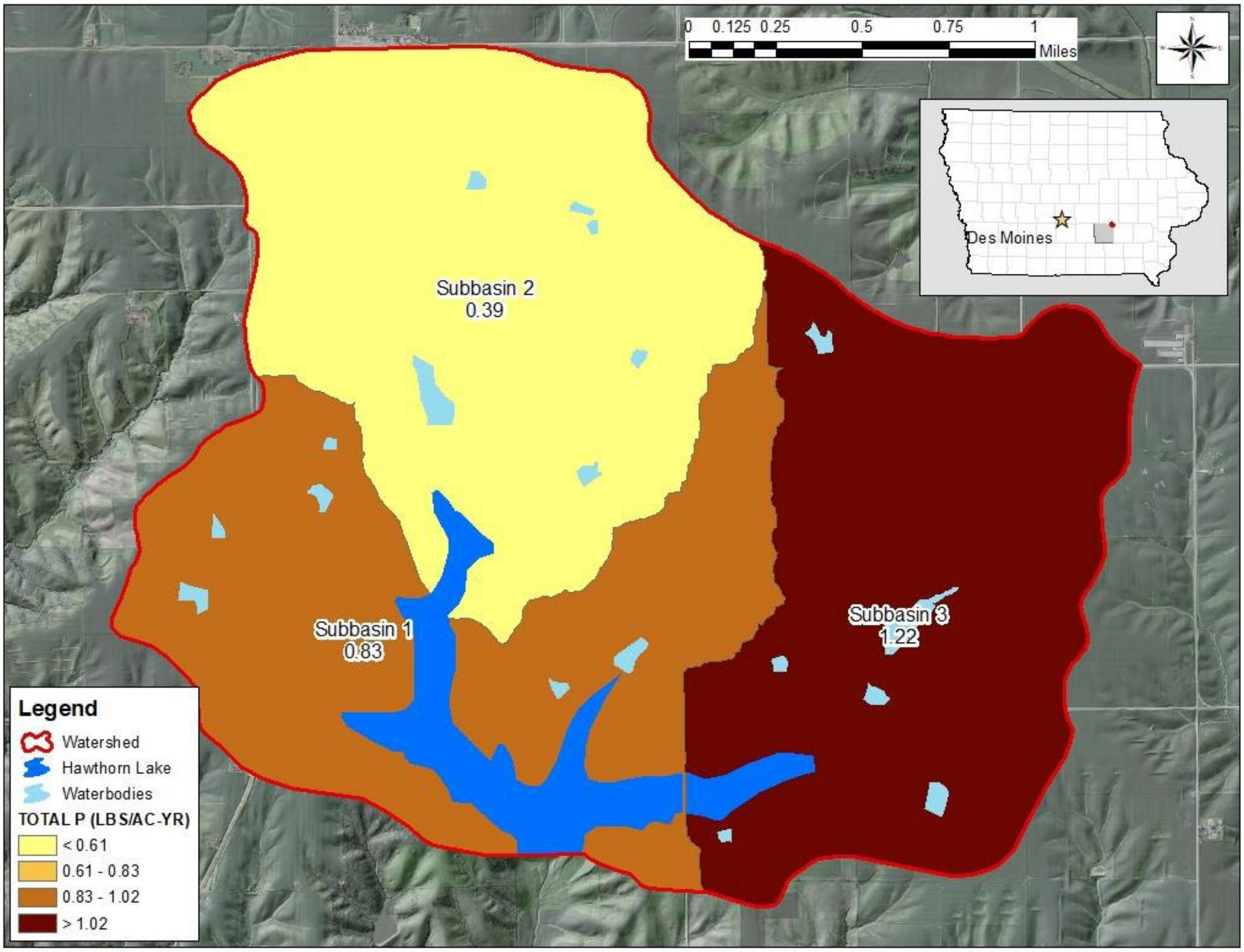

Figure 4-2. Predicted per-Acre TP Export for each STEPL Subwatershed.

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 Hawthorn Lake. The reservoir has a watershed-to-lake ratio (17.1:1), so external inputs are typically greater than 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 Hawthorn 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 difficult 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 continued fisheries management. The reduction of in-lake phosphorus as a result of this practice is variable, but the overall health of the aquatic ecosystem may be improved, which typically improves overall water quality as well.
Targeted dredging and sediment basin improvement	Strategic dredging would also increase the sediment capacity, thereby reducing sediment and phosphorus loads to the main body where ambient conditions are monitored.
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.
Phosphorus stabilization	Adding compounds, such as alum, to the water column can help stabilize phosphorus that may be resuspended from the lake bottom. This additive precipitates a layer of floc that removes phosphorus as it settles to the lake bottom, and can combine with phosphorus as it is released from sediment.

Holistic Approach

An example of a holistic implementation plan would involve prevention, mitigation, and remediation practices across the Hawthorn Lake watershed. These may include any of the practices from Table 4-3 at any scale. Extending grass waterways in conjunction with renovation of existing terraces and contour buffers in corn and soybean ground will help mitigate soil loss from row crop ground. Further adoption of agricultural prevention measures like those listed in Table 4-1 will retain topsoil in the soil profile of the fields and prevent erosion. Potential in-lake strategies such phosphorus stabilization treatments in Hawthorn Lake are included as well.

5. Future Monitoring

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

Future monitoring in the Hawthorn Lake watershed can be agency-led, volunteer-based, or a combination of both. For those interested in participating in a volunteer based water quality monitoring program more information can be found at the program website: http://www.iowadnr.gov/Environmental-Protection/Water-Quality/Water-Monitoring/Volunteer-Water-Monitoring.

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/01-18-2017.567.61.pdf

Failure to prepare an approved QAPP will prevent data collected from being used to evaluate waterbodies 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 Hawthorn Lake to assess water quality trends and compliance with water quality standards (WQS) will include monitoring conducted as part of the DNR Ambient Lake Monitoring Program. The Ambient Lake Monitoring Program was initiated in 2000 in order to better assess the water quality of Iowa lakes. 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 year over the growing season (summer), typically between mid-May and late September. 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)	Secchi Depth	Chlorophyll a
Orthophosphate	Temperature	Phycocyanin
Total Kjeldahl Nitrogen (TKN)	Dissolved Oxygen (DO)	Microcystin
Ammonia	Turbidity	
Un-ionized Ammonia	Total Suspended Solids (TSS)	
Nitrate + Nitrite Nitrogen	Total Fixed Suspended Solids	
Alkalinity	Total Volatile Suspended Solids	
pH	Specific Conductivity	
Total Dissolved Solids	Thermocline Depth	
	Lake Depth	

5.2 Expanded Monitoring for Detailed Analysis

Given current resources and funding, future water quality data collection in the Hawthorn Lake watershed to assess water quality trends and compliance with WQS will be limited. Unless there is local interest in collecting additional water quality data, it will be difficult to implement a watershed management plan and document TMDL effectiveness and water quality improvement.

Data available from the 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 Hawthorn Lake watershed have been chosen to take into account subbasin boundaries and can be used in assigning nutrient concentrations to each subbasin if deployed in such a manner.

Table 5-2. Recommended Monitoring Plan.

Parameter(s)	Intervals	Duration	Location(s)[1]
Routine grab sampling for flow, sediment, P, and N	Every 1-2 weeks	April through October	Ambient location in Hawthorn Lake, plus secondary locations
Continuous flow	15-60 minute	April through October	Hawthorn Lake inlet & outlet
Continuous pH, DO, and temperature	15-60 minute	April through October	Ambient location in Hawthorn Lake
Runoff event flow, sediment, P, and N	15-60 minute intervals during runoff	5 events between April and October	All lake inlets & outlets and select tributary sites
Wet and dry weather flow, sediment, P, and N	Hourly during wet and dry weather	10 to 14-day wet weather periods if continuous sampling is not feasible	All lake inlets & outlets and select tributary sites
Event or continuous tile drain flow, N, and P sampling	15-60 minute	10 to 14-day wet weather periods if continuous sampling is not feasible	Select gully locations
Erosion pin grid	Seasonally, after heavy rainfall events	April through October	Select gully locations
Shoreline mapping, bathymetry studies	Before and after dredging or construction, every 5 years	Design lifespan of waterbody	Hawthorn Lake and upstream sedimentation basins.

[1]Tributary 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 new BMPs are implemented or existing ones are renovated 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. Possible monitoring scenarios above the current monitoring condition are described below.

Basic Monitoring

Targeted grab sampling of the Hawthorn Lake ambient monitoring point should be continued on a bi-weekly basis. Grab samples on a seasonal basis at the inlet would be done to support data provided by the main lake.

Targeted Monitoring

Grab samples should continue on a routine and runoff event based schedule. Flow data may be recorded with manual flow readings based on developed rating curves. Locations and sampling approaches would include the ambient monitoring station and upstream inlets.

Advanced Monitoring

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, inlets and outlets of newly constructed sedimentation basins, and outlets from upstream tributaries such as roadway culverts. 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.

To further gather information on erosion in the watershed, a “rapid assessment of stream conditions along length” (RASCAL) procedure would be done on gullies and channels that show significant erosion. An initial assessment will provide a benchmark of current conditions and will allow stakeholders to identify potential problem areas for implementation of BMPs.

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 DNR Watershed Improvement Section may provide technical support to locally led efforts in collecting further water quality and flow monitoring data in the Hawthorn Lake watershed. A look at how these proposed monitoring plans may be deployed in the Hawthorn Lake watershed is shown in Figure 5-1.

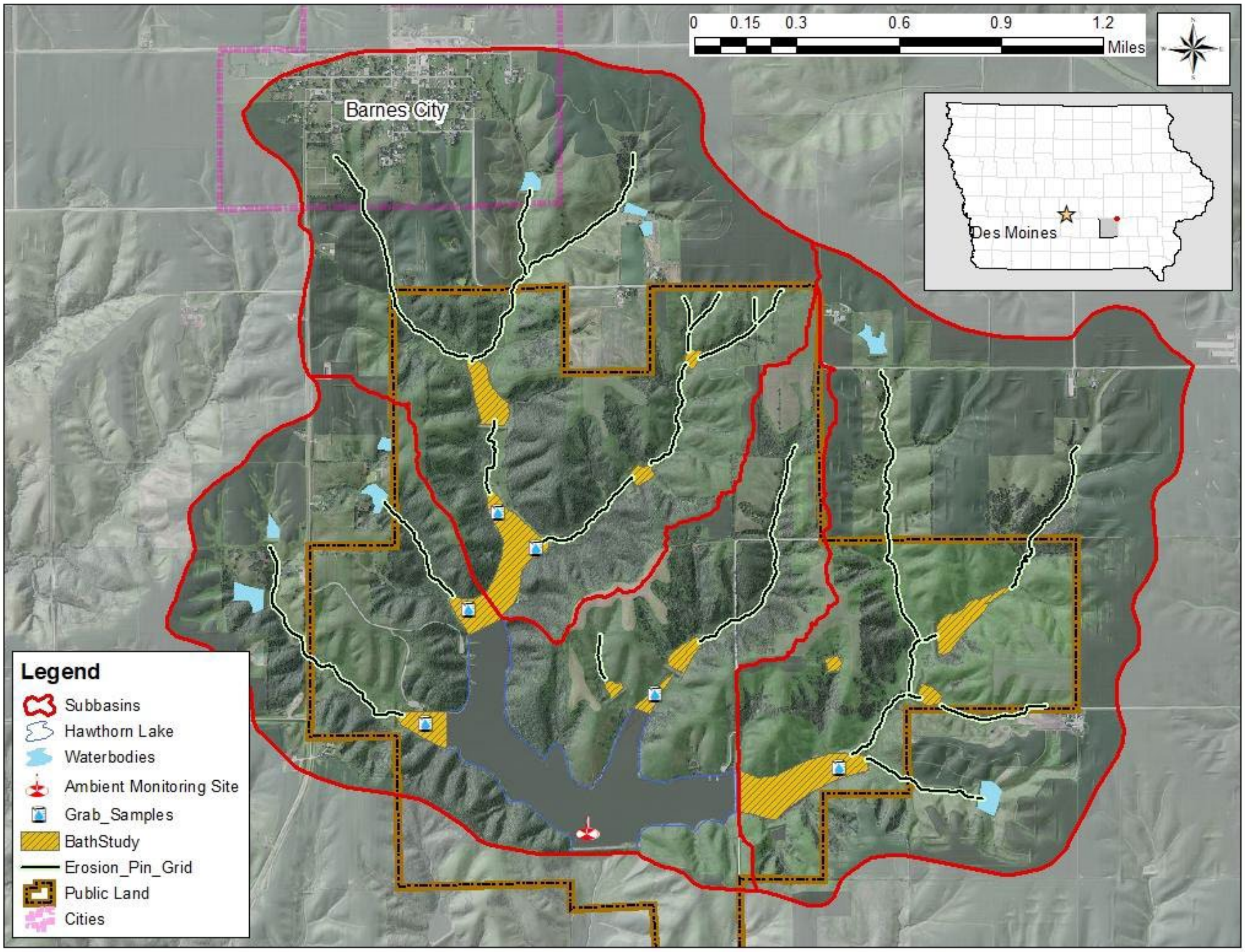

Figure 5-1. Potential Monitoring Locations.

6. Public Participation

Public involvement is important in the Total Maximum Daily Load (TMDL) process since it is the landowners, tenants, and citizens who directly manage land and live in the watershed that determine the water quality in Hawthorn Lake.

6.1 Public Meeting

A virtual on-line presentation was prepared to present the results of the TMDL. A link to the presentation can be located on the DNR's website at https://www.iowadnr.gov/environmental-protection/water-quality/watershed-improvement/water-improvement-plans. A line to the presentation will remain on the DNR's TMDL webpage through the public comment period.

6.2 Written Comments

A press release was issued on July 18, 2024 to begin a 30-day public comment period which ends on August 19, 2024. All comments received by the DNR during the 30-day public notice period will be included in Appendix I.

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Appendix A. Glossary of Terms, Abbreviations, and Acronyms

A.1. Terms

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 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 the most probable number (MPN), the two terms are often used interchangeably.

Confinement feeding operation: An animal feeding operation (AFO) in which animals are confined to areas which are totally roofed.

Credible data law: Refers to 455B.193 of the Iowa Administrative Code, which ensures that water quality data used for all purposes of the Federal Clean Water Act are sufficiently up-to-date and accurate. To be considered "credible," data must be collected and analyzed using methods and protocols outlined in an approved Quality Assurance Project Plan (QAPP).

Cyanobacteria (blue-green algae): Members of the phytoplankton community that are not true algae but are capable of photosynthesis. Some species produce toxic substances that can be harmful to humans and pets.

Designated use(s): Refer to the type of economic, social, or ecological activities that a specific waterbody is intended to support. See Appendix B for a description of all general and designated uses.

DNR: Iowa Department of Natural Resources.

Ecoregion: Areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources based on geology, vegetation, climate, soils, land use, wildlife, and hydrology.

EPA (or USEPA): United States Environmental Protection Agency.

Ephemeral gully erosion: Ephemeral gullies occur where runoff from adjacent slopes forms concentrated flow in drainage ways. Ephemerals are void of vegetation and occur in the same location every year. They are crossable with farm equipment and are often partially filled in by tillage.

FIBI: Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.

FSA: Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.

General use(s): Refer to narrative water quality criteria that all public waterbodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated uses.

Geometric Mean (GM): A statistic that is a type of mean or average (different from arithmetic mean or average) that measures central tendency of data. It is often used to summarize highly skewed data or data with extreme values such as wastewater discharges and bacteria concentrations in surface waters. In Iowa's water quality standards and assessment procedures, the geometric mean criterion for *E. coli* is measured using at least five samples collected over a 30-day period.

GIS: Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.

Groundwater: Subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.

Gully erosion: Soil movement (loss) that occurs in defined upland channels and ravines that are typically too wide and deep to fill in with traditional tillage methods.

HEL: Highly Erodible Land. Defined by the USDA Natural Resources Conservation Service (NRCS), it is land that 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. Sources include but are not limited to municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river. 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 in the A.2. Scientific Notation section.

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: 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 (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 Geological 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 567 IAC Chapter 61, 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.

A.2. 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

B.1. Introduction

Iowa's water quality standards (567 IAC Chapter 61) 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 designated uses 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 and 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, surface waters in Iowa are divided into two main categories: *general* use segments and *designated* use segments. This is an important distinction, because the water quality criteria that are applied to the waterbody will differ depending on what classification the waterbody is given.

B.2. 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 are dry almost all 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 567 IAC Chapter 61.3(1), which became effective on February 9, 2022.

General use waters are protected for the following beneficial uses: 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 567 IAC Chapter 61.3(2), which became effective on February 9, 2022.

B.3. 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 recreation, drinking water sources, or aquatic life. There are 11 different designated uses (Table B-1) that may apply, and a waterbody may have more than one designated use. For definitions of the uses and more detailed descriptions, consult section 567 IAC 61.3(1), which became effective on February 9, 2022.

Table B-1. Designated Uses for Iowa Waterbodies.

Class	Designated use	Brief comments
A1	Primary contact recreational	Prolonged/direct contact with the water. Supports swimming, water skiing, etc.
A2	Secondary contact recreational	Accidental/incidental contact with the water. Supports shoreline activities, fishing, and commercial and recreational boating.
A3	Children's recreational	Uses by children are common. Primarily occurs in urban or residential areas. Supports use by children.
B(CW1)	Cold water aquatic life - Type 1	Supports coldwater fish (e.g. trout) populations
B(CW2)	Cold water aquatic life - Type 2	Typically, unable to support consistent trout populations but can support other organisms.
B(WW-1)	Warm water aquatic life - Type 1	Supports game and nongame fish populations.
B(WW-2)	Warm water aquatic life - Type 2	Smaller streams that are able to support nongame fish, but cannot maintain game fish populations.
B(WW-3)	Warm water aquatic life - Type 3	Intermittent streams with perennial pools that can support organisms that can survive in relatively harsh aquatic conditions.
B(LW)	Warm water aquatic life - lakes and wetlands	Artificial and natural impoundments with "lake-like" conditions.
C	Drinking water supply	Raw water source of potable water supply.
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.

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 DNR (TMDL) monitoring efforts.

C.1. Individual Sample Results

Table C-1. ISU and TMDL Water Quality Sampling Data (Ambient Location[1]) for Hawthorn Lake.

Source	Date[2]	Secchi (m)	Chl-a (µg/L)	TP (µg/L)	Secchi TSI	Chl-a TSI	TP TSI	Non-Algal Turbidity (1/m)
ISU	6/20/2011	0.6	103.0	63.5	67.4	76.1	64.0	-0.908
ISU	8/8/2011	0.9	46.0	52.4	61.5	68.2	61.2	-0.039
ISU	9/19/2011	1.0	25.0	70.0	60.0	62.2	65.4	0.375
ISU	6/18/2012	1.4	8.0	5.0	55.2	51.0	27.3	0.514
ISU	8/6/2012	1.3	18.0	45.9	56.2	59.0	59.3	0.319
ISU	9/19/2012	1.2	13.0	43.5	57.4	55.8	58.5	0.508
ISU	6/18/2013	0.9	29.0	40.1	61.5	63.6	57.3	0.386
ISU	8/5/2013	0.7	34.0	60.0	65.1	65.2	63.1	0.579
ISU	9/18/2013	0.7	33.0	92.1	65.1	64.9	69.3	0.604
ISU	6/23/2014	1.4	25.4	34.1	55.7	62.3	55.0	0.106
ISU	8/11/2014	0.7	40.4	56.6	65.6	66.9	62.3	0.461
ISU	9/21/2014	0.8	30.2	63.1	63.2	64.0	63.9	0.494
ISU	6/22/2015	0.9	18.0	43.0	61.5	59.0	58.3	0.661
ISU	8/10/2015	0.9	29.0	70.6	61.5	63.6	65.5	0.386
ISU	9/20/2015	0.6	72.0	57.9	67.4	72.6	62.6	-0.133
ISU	6/22/2016	0.6	34.0	57.9	67.4	65.2	62.6	0.817
ISU	8/8/2016	0.8	39.0	57.0	63.2	66.5	62.4	0.275
ISU	9/19/2016	0.8	32.0	63.1	63.2	64.6	63.9	0.450
ISU	5/15/2017	2.5	1.7	22.1	46.8	35.5	48.8	0.359
ISU	6/26/2017	0.8	41.0	63.8	63.2	67.0	64.0	0.225
ISU	8/14/2017	0.4	27.0	63.8	73.2	62.9	64.0	1.825
TMDL	4/30/2018	1.55	23.0	120.0	53.7	61.4	73.1	
TMDL	5/17/2018	0.36	86.0	80.0	74.7	74.3	67.3	
TMDL	5/31/2018	1.49	15.0	240.0	54.3	57.2	83.1	
ISU	6/11/2018	1.8	20.0	51.1	51.5	60.0	60.8	0.056
TMDL	6/20/2018	1.40	25.0	70.0	55.2	62.2	65.4	
TMDL	7/13/2018	0.60	34.0	80.0	67.4	65.2	67.3	
TMDL	7/27/2018	0.85	34.0	60.0	62.3	65.2	63.1	
ISU	7/30/2018	0.9	17.0	95.1	61.5	58.4	69.8	0.686
TMDL	8/22/2018	0.74	25.0	1,100.0	64.3	62.2	105.1	
TMDL	9/6/2018	0.69	30.0	120.0	65.3	64.0	73.1	
ISU	9/9/2018	0.6	15.0	98.0	67.4	57.2	70.2	1.292
TMDL	9/18/2018	0.65	42.0	100.0	66.2	67.3	70.5	
TMDL	10/1/2018	0.90	24.0	50.0	61.5	61.8	60.5	
TMDL	10/18/2018	0.71	18.0	110.0	64.9	59.0	71.9	

Source	Date[2]	Secchi (m)	Chl-a (µg/L)	TP (µg/L)	Secchi TSI	Chl-a TSI	TP TSI	Non-Algal Turbidity (1/m)
ISU	6/19/2019	0.8	1.6	37.5	64.0	35.3	56.4	1.284
ISU	8/5/2019	0.3	33.5	64.1	76.0	65.0	64.1	2.193
ISU	9/18/2019	0.5	5.7	77.4	69.1	47.6	66.8	1.745
ISU	6/11/2020	1.6	15.3	27.1	53.2	57.4	51.7	0.243
ISU	7/29/2020	0.6	38.5	46.5	67.4	66.4	59.5	0.704
ISU	9/10/2020	0.5	25.3	53.5	70.0	62.3	61.5	1.368
ISU	6/14/2021	2.2	7.7	23.0	49.0	50.7	49.3	0.272
ISU	8/2/2021	0.6	30.8	43.0	68.6	64.2	58.3	1.048
ISU	9/9/2021	0.8	27.5	40.0	63.7	63.1	57.3	0.602
ISU	6/28/2022	0.8	43.9	37.0	63.2	67.7	56.2	0.153
ISU	8/16/2022	0.7	14.3	57.0	65.1	56.7	62.4	1.071
ISU	9/27/2022	0.6	44.9	64.0	67.4	67.9	64.1	0.544
Average	**--**	**0.91**	**29.7**	**60.2**	**61.3**	**63.9**	**63.2**	**0.598**
Standard Deviation	**--**	**0.45**	**19.12**	**24.53**	**--**	**--**	**--**	**--**
Coefficient of Variation	**--**	**0.50**	**0.64**	**0.41**	**--**	**--**	**--**	**--**

[1]Ambient monitoring location = STORET ID 22620001

[2]Data between 2018 - 2022 were used for the Draft 2024 Water Quality Assessment Period.

C.2. Annual Mean Data

Table C-2. Precipitation, Annual Mean TSI Values, and NAT for Hawthorn Lake.

Date	Annual Precipitation (in)	Apr-Sep Precipitation (in)	Secchi TSI	Chl-a TSI	TP TSI	NAT (1/m)
2011	40.4	25.1	62.6	70.4	63.6	-0.2500
2012	27.4	15.9	56.2	55.8	53.8	0.4442
2013	39.4	27.4	63.8	64.6	64.1	0.5043
2014	53.1	38.6	60.8	64.6	60.9	0.2599
2015	45.9	29.4	63.2	66.7	62.5	0.2583
2016	31.8	24.8	64.5	65.5	63.0	0.4886
2017	26.5	14.5	57.0	61.5	60.5	0.2304
2018	44.6	28.7	60.8	63.7	67.5	0.3288
2019	46.3	30.2	68.9	56.2	63.1	1.5178
2020	31.4	18.8	61.5	62.7	58.1	0.4519
2021	31.7	18.4	57.9	60.9	55.5	0.3127
2022	32.2	21.3	65.1	65.3	61.3	0.5694
Average	**37.6**	**24.4**	**62.7**	**61.6**	**61.7**	**0.4264**

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 Hawthorn Lake in Mahaska County, Iowa. This TMDL targets an allowable phosphorus load that will satisfy the primary contact recreation impairment (see Section 3 of this document for details). Reduction of phosphorus is expected to reduce algal blooms and non-algal turbidity, which decrease water clarity and impair the ability of the public to enjoy the recreational benefits of the lake.

The Spreadsheet Tool for Estimating Pollutant Load (STEPL), version 4.4, 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 Hawthorn Lake and its watershed. This section of the WQIP discusses the modeling approach and development of the STEPL watershed and BATHTUB lake models.

D.1. Modeling Approach

Data from a 12-year period of record, 2011-2022, were analyzed and used to develop watershed and lake models for the simulation and prediction of phosphorus loads and in-lake response. This simulation period is supplemental to the water quality assessment period (2018-2022) upon which the Draft 2024 Integrated Report and 303(d) list were generated.

D.2. STEPL Model Description

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

The watershed was divided into three subbasins to help quantify the relative pollutant loads stemming from different areas of the watershed and to assist with targeting potential BMP locations. The basins were created to coincide with the natural drainage network and physical features as shown in Figure D-1. Hydrology and pollutant loadings are summarized for each subbasin and also aggregated as watershed totals.

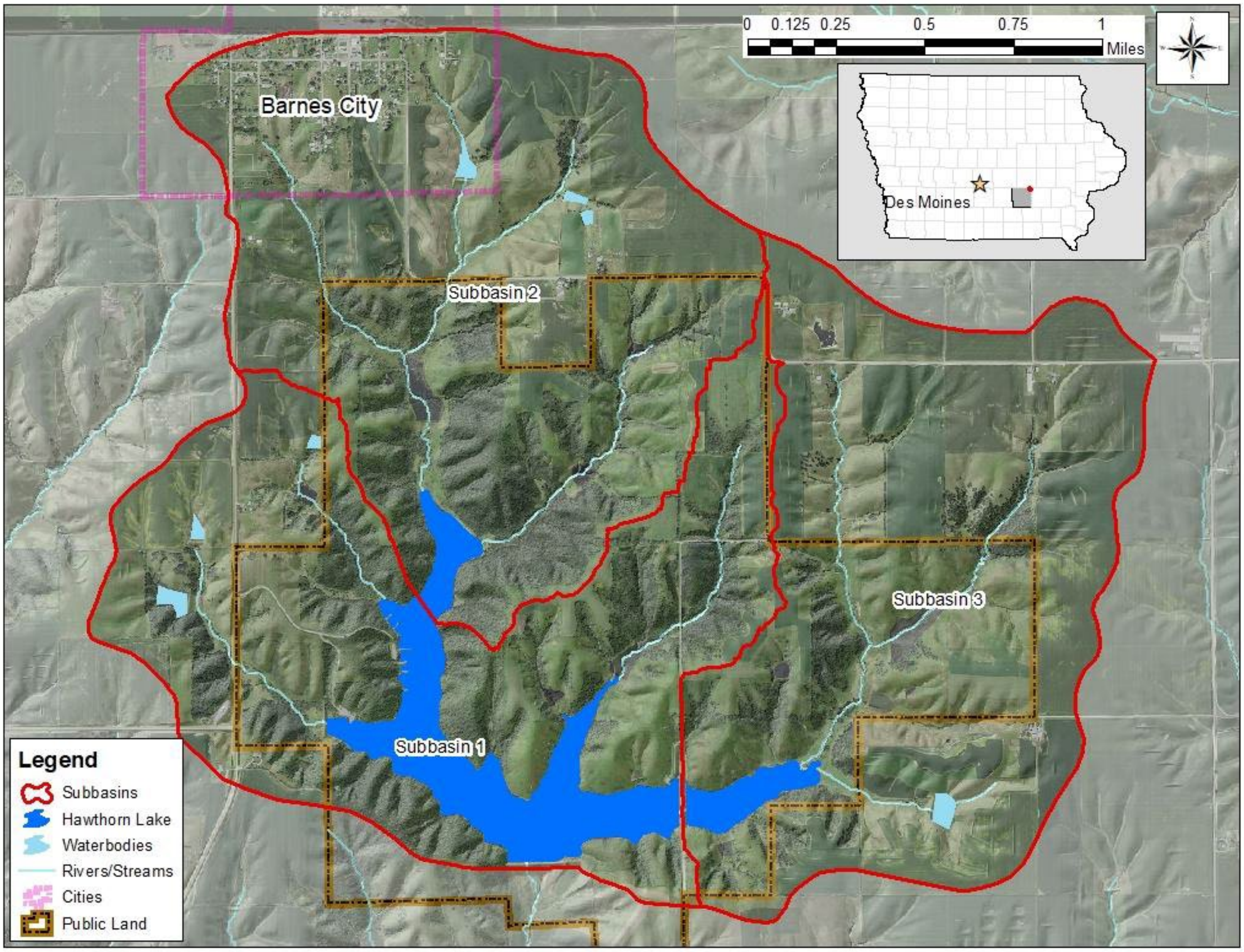

Figure D-1. STEPL Subbasin Map.

D.3. Meteorological Input

Precipitation Data

The STEPL model includes a predefined 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 Hawthorn Lake are included in the STEPL model. Therefore, rainfall data from the Iowa Environmental Mesonet network were used for modeling purposes. Weather station information and rainfall data were reported in Section 2.1 (See Table 2-2, Figure 2-2, and Figure 2-3). Annual rainfall used in the STEPL model was the 2011-2022 average of 37.6 inches/year, which is the same as the 30-year precipitation average (1993-2022) of 37.6 inches.

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 2011-2022 were utilized in parameterization. The rain day correction factor of 0.436 was calculated by dividing the number of days that it rained at least 5 mm by the number of days with at least 0.254 mm (0.01 inches) 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 Hawthorn Lake STEPL model.

Table D-1. STEPL Rainfall Inputs (2011-2022 Average Annual Data).

Rain Correction Factors			
0.882[1]	0.436[2]		
Annual Rainfall[3]	**Rain Days[4]**	**Avg. Rain/Event[5]**	**Input Notes/Descriptions**
37.6	112	0.681	[1]The percent of rainfall that exceeds 5 mm per event
			[2]The percent of rain events that generate runoff
			[3]Annual average precipitation for modeling period (in)
			[4]Average days of precipitation per year (days)
			[5]Average precipitation per event (in)

D.4. Watershed Characteristics

Topography

The Hawthorn Lake watershed was delineated into three subbasins using ArcGIS (version 10.7) and a 3-meter resolution digital elevation model (DEM) developed by the DNR. The subbasin boundaries were chosen to coincide with natural and artificial boundaries. These will aid in prioritizing areas for future BMP implementation for water quality improvement. Figure D-1 illustrates the watershed and subbasin boundaries.

Land Use

A Geographic Information System (GIS) coverage of land use information was developed using the Cropland Data Layer (CDL) for 2022, which was obtained from the United States Department of Agriculture - National Agricultural Statistics Service (USDA-NASS, 2022). 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, 2017). Because land cover pixels are much smaller than CLU field boundaries, many CLUs have one primary land cover, but small isolated pixels with several minor land cover types. In those cases, the dominant land cover within each CLU boundary was determined using a zonal statistic command within Spatial Analyst. This step served as a land cover "filter" to simplify the data and eliminate small isolated pixels of various land uses within a single field boundary. STEPL land cover classifications are reported in Table D-2, with land use distribution previously illustrated in the map (Figure 2-4) and table (Table 2-3) in Section 2.

Table D-2. STEPL Land Use Acreage Inputs.

Watershed	Urban[1]	Cropland	Pastureland	Forest	User Defined[2]	Total[3]
W1	39.5	125.5	62.1	350.1	317.0	894.2
W2	160.2	344.0	109.1	277.7	249.6	1,140.7
W3	19.9	457.6	173.9	17.1	365.6	1,034.0
[3]Total	**219.7**	**927.1**	**345.1**	**644.8**	**932.1**	**3,068.9**

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

Each land cover type was assigned a specific USLE C-factor based on regional estimates developed by the DNR and Iowa Department of Agriculture (IDALS) personnel during in-field land use assessments. The P-factor values are the STEPL default values. A summary of the C and P factor values are provided in Table D-3

Soils

Soils are discussed in Section 2.2. The hydrologic soil group (HSG) and the USLE K-factor are the critical soil parameters in the STEPL model. Soils in the watershed are predominantly HSG type C (69%) with some C/D and D soils interspersed. HSG values were set at type C, which was the dominant soil type in each subbasin. USLE K-factors are specific to each soil type and were determined based on K values from USGS Web Soil Survey for the Hawthorn Lake watershed. K factors were area-weighted and entered into the "Input" worksheet in the STEPL model (See Table D-3).

Table D-3. C, P, and K Factors for Each Land Use.

Land Use Description	C-Factor	P-Factor	K-Factor
Cropland[1]	0.1730	0.90	0.376 - 0.390
Pastureland	0.0101	1.0	0.359 - 0.369
Forest	0.0098	1.0	0.339- 0.377
User Defined[2]	Varies[3]	1.0	0.352 - .0387

[1]Row Crop = Corn and Soybeans.
[2]User Defined = Ungrazed Grassland and Alfalfa/Hay.
[3]Varies from 0.0071 - 0.0077

Slopes
Slopes are described in more detail in Section 2.2. USLE land slope (LS) factors were obtained using 3-meter LiDAR data for Mahaska County, Iowa and from the subroutine LS-factor, field based, Quantum GIS (QGIS) based on specific land use. LS-factors were then area-weighted to develop land use specific LS-factors for each STEPL subbasin. Resulting LS-factors entered into the "Input" worksheet in the STEPL model vary between 1.027 and 2.787 as shown in Table D-4.

Table D-4. STEPL LS-Factors.

Watershed	Cropland	Pastureland	Forest	User-Defined
W1	0.948	2.274	3.254	2.332
W2	1.171	2.789	3.158	2.389
W3	0.890	3.356	4.172	2.607

Curve Numbers
The STEPL model includes curve numbers (CNs) that were selected within a range of values to calibrate the model to flow data from the SPARROW calibration site. CN values for each subbasin are shown in Table D-5.

Table D-5. STEPL Curve Numbers.

Subbasin	Urban[1]	Cropland	Forest	Pastureland	User Defined[2]
W1[3]	86	79	76	70	71
W2[3]	86	79	76	70	71
W3[3]	86	79	76	70	71

[1]Urban includes all developed areas, including transportation and farmstead areas.
[2]User defined Includes Ungrazed Grassland and Alfalfa/Hay
[3]HSG Type C.

Sediment Delivery Ratio
The sediment load to Hawthorn Lake 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. STEPL calculates the SDR for each subbasin using a simple empirical formula based on drainage area (i.e., subbasin area). The resulting SDR value for the Hawthorn Lake watershed is 0.21.

D.5. Animals

Agricultural Animals and Manure Application

The STEPL model utilizes livestock population data and the duration (in months) that manure is applied to account for nutrient loading from livestock manure application. The number of other types of livestock in the watershed were obtained from the Input Data Server for STEPL located on EPA's website (EPA, 2021), which was provided on a HUC-12 basis. The number of livestock animals in the Hawthorn Lake watershed was estimated by taking the ratio of the subbasin area to the HUC-12 area. Table D-6 lists the estimated number and type of animals, the animal equivalent units (AEU) normalized per acre, and number of months manure is applied.

Based on manure management plans (MMP) on file with the DNR, there are an estimated 8,085 swine, housed in three confinements, that generate liquid manure. There is one unregulated confinement (< 1,000 animal units) in the watershed and two other confinements within one mile of the watershed. Livestock confinements are not allowed to discharge manure, therefore the WLA is zero. However, a portion of the liquid manure generated is land applied to row crops in the Hawthorn Lake watershed. The number of swine used in modeling is shown in Table D-6, which is slightly more conservative than the number determined from MMPs.

It is assumed that manure will be applied to all cropland and pastureland once a year. Once a year was selected because it provided favorable results when comparing model TP loadings to TP loadings from the SPARROW calibration site.

Table D-6. Agricultural Animals and Manure Application.

Watershed	Beef Cattle	Dairy Cattle	Swine (Hog)	Sheep	Horse	Turkey	AEU	# of months manure applied[1]
W1	157	2	2,985	10	2	3	5.9	1
W2	140	2	2,658	9	2	2	1.9	1
W3	144	2	2,731	9	2	2	1.5	1
Totals	**441**	**6**	**8,374**	**28**	**6**	**7**	**9.3**	**--**

[1]Manure is applied once per year to cropland and pastureland.

Livestock Grazing

Based on land use coverage, pastureland is the fourth largest land use in the watershed at 11.2 percent. Erosion from pasture (and other grassland that may be in poor condition) carries sediment-bound phosphorus, which is accounted for by using a sediment nutrient enrichment ratio. The STEPL default enrichment ratio is 2.0. STEPL simulates nutrient loss in pasture and grassland runoff by assuming a phosphorus concentration of 0.3 mg/L in the runoff. Similarly, a phosphorus concentration of 0.063 was used to simulate phosphorus loads from shallow groundwater in grazed areas.

Open Feedlots

There are no open feedlots in the Hawthorn Lake watershed in the DNR Animal Feeding Operations Database. Feedlot operators are not required to report open feedlot information to DNR for feedlots with fewer than 1,000 animal units (AUs). No active open feedlot operations were observed during the December 2021 windshield survey.

Wildlife

Due to insufficient data, population densities were assumed to be as follows: 200 geese and a density of 10 animals per square mile of cropland for all other wildlife.

Septic Systems

The number of septic systems in the watershed was determined by identifying farmsteads in the land use GIS coverage and confirming residences via aerial photography. This procedure resulted in the identification of 17 septic systems in the watershed. It is estimated that 20 percent of these systems are not functioning adequately (i.e., are ponding or leaching). 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 Hawthorn Lake.

D.6. References

U.S. Department of Agriculture - Farm Service Agency (USDA-FSA). 2017. https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/APFO/support-documents/pdfs/clu_infosheet_2017_Final.pdf.

U.S. Department of Agriculture - National Agricultural Statistical Summary (USDA-NASS). 2022. http://nassgeodata.gmu.edu/CropScape/.

U.S. Environmental Protection Agency. 2021. https://ordspub.epa.gov/ords/grts/f?p=109:333

Appendix E. Water Quality Model Development

Two models were used to develop the Total Maximum Daily Load (TMDL) for Hawthorn Lake. Watershed hydrology and pollutant loading was simulated using the Spreadsheet Tool for Estimating Pollutant Load (STEPL), version 4.4. 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 Hawthorn Lake does not simulate dynamic conditions associated with storm events or individual growing seasons. Rather, the model predicts average water quality in the modeling period of 2011-2022, which includes the Draft 2024 Integrated Report (2018-2022). 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 Hawthorn 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.

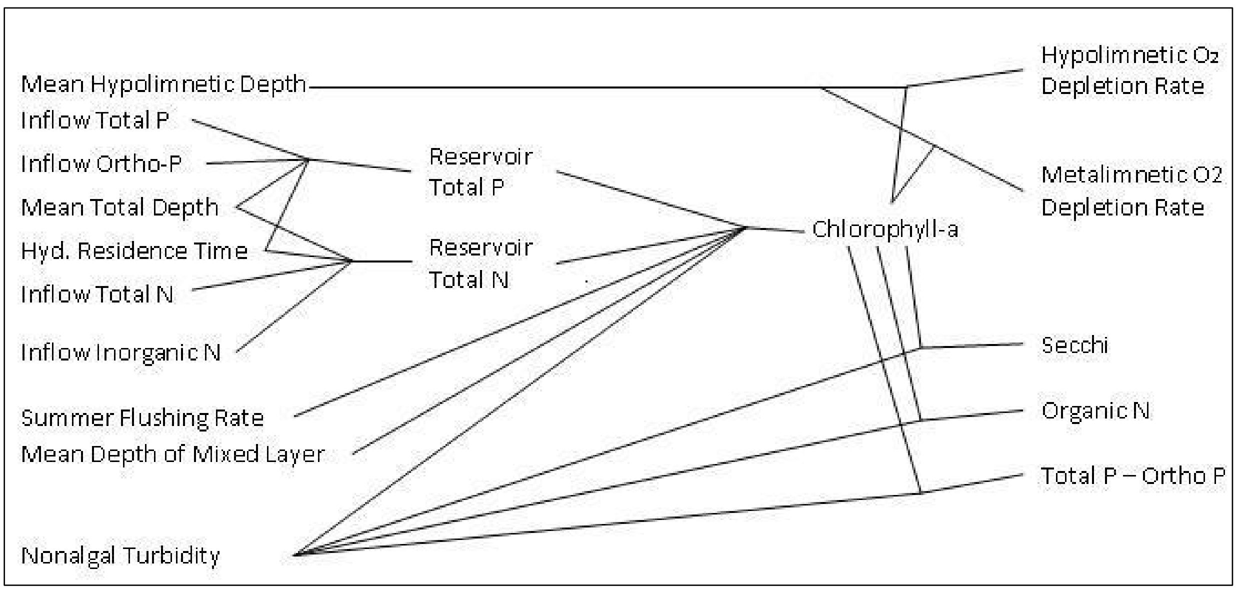

Figure E-1. Eutrophication Control Pathways in BATHTUB (Walker, 1999)

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 Hawthorn 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, chl-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 Hawthorn 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, chl-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 Hawthorn Lake. Preference was given to Models 1 and 2 during evaluation of model performance and calibration of the Hawthorn 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 phosphorus model section was based on observed data agreement compared to the other available phosphorus models. Chlorophyll model selection was based on observed data agreement and applicability based on BATHTUB user manual IR-W-96 table 4.2. Model performance is discussed in more detail in Appendix F.

Table E-1. Model selections for Hawthorn Lake.

Parameter	Model No.	Model Description
Total Phosphorus	02	2nd order, Decay
Total Nitrogen	01	2nd order, Avail. N
Chlorophyll-a	*02	P. Light. T
Transparency	*01	vs CHLA & 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 Hawthorn Lake are reported in Table E-2. Global variables are independent of watershed hydrology or lake morphometry, but affect the water balance and nutrient cycling of the lake. The first global input is the averaging period. Both seasonal and annual averaging periods are appropriate, depending on site-specific conditions. An annual averaging period was utilized to quantify existing loads and in-lake water quality, and to develop TMDL targets for Hawthorn Lake.

Table E-2. Global Variables Data for Simulation Period.

Parameter	Observed Data	BATHTUB Input
Averaging Period	Annual	1.0 years
Precipitation[1]	37.6 in	0.954 m
Evaporation[1]	38.8 in	0.985m
Increase in Storage[2]	0	0
Atmospheric Loads:[3]		
TP	0.3 kg/ha-yr	30 mg/m^2-yr
TN	7.7 kg/ha-yr	770.3 mg/m^2-yr

[1]Precipitation and evaporation data are from 2011-2022 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 12-year assessment period of 2011-2022 from the Iowa Mesonet network collected and discussed in Chapter 2. Potential evapotranspiration data for the same period was obtained from the

Oskaloosa, Iowa weather station via the ISU Ag Climate database (IEM, 2023b). Net change in reservoir storage was assumed to be zero. This 12-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 and non-algal impairments at Hawthorn Lake. It was shown in Section 3.1 (Figure 3-7) that precipitation is not highly correlated with total phosphorus and the impairment seen at Hawthorn Lake. These data were summarized and converted to BATHTUB units 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 in-flowing tributaries) is desirable, the lake can be split into multiple segments. Each segment may have a distinct tributary.

The Hawthorn Lake BATHTUB model includes five segments to facilitate simulation of diffusion, dispersion, and sedimentation that occur as water traverses between the upstream segments and Hawthorn Lake. For the BATHTUB model, subbasin 1 was further divided into 3 subbasins to model the main body of the lake separately from the arms or upper reaches of the lake. The subbasins are designated as subbasin 1-1, 1-2, and 1-3, with subbasin 1-3 being the outlet of the reservoir as shown in Table E-2. The relationship between watershed basins and the BATHTUB segment is shown in Table E-3. The ambient monitoring location is used for listing and delisting purposes: therefore, the TMDL target applies at the ambient monitoring location in that segment.

Segment morphometry was calculated 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.

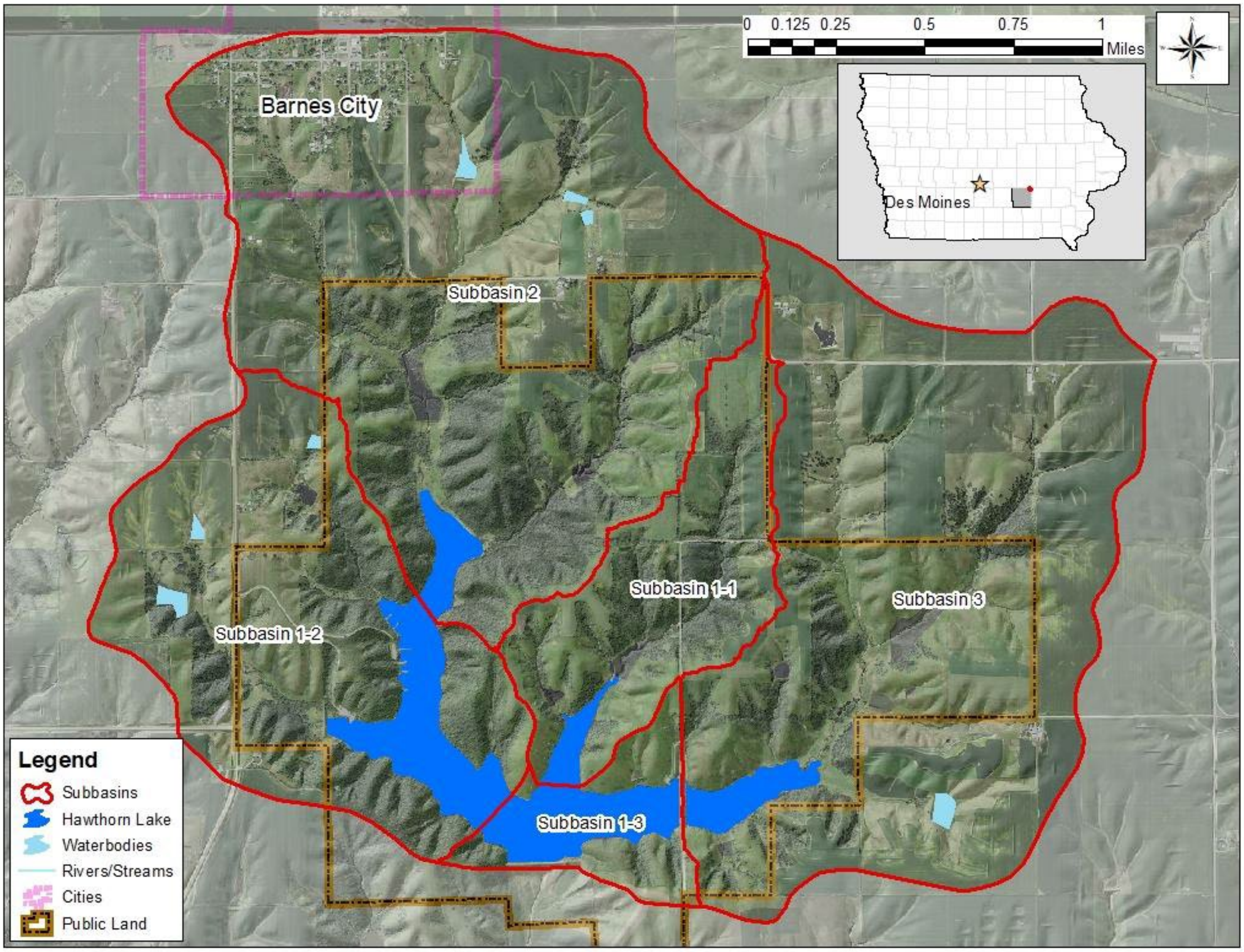

Figure E-2. Hawthorn Lake, Subbasins for BATHTUB Modeling.

Table E-3. Segment Morphometry for the Hawthorn Lake.

Segment	Outflow Segment	Segment Group	Surface Area (km^2)	Mean Depth (m)	Length (km)
01 Segname 1-3[1]	Out of Reservoir	1	0.225	4.65	0.71
02 Segname 1-2[1]	01 Segname 1-3	1	0.291	3.288	1.402
03 Segname 1-1[1]	01 Segname 1-3	1	0.050	2.014	0.676
04 Segname 2	02 Segname 1-2	1	0.081	0.924	0.67
05 Segname 3	01 Segname 1-3	1	0.094	1.82	0.939

[1]Subdivided from Subbasin 1.

Median water quality parameters observed for the modeling period (2011-2022) are reported in Table E-4. The data in Table E-4 were compared to output in segment “01 Segname 1-3” of the BATHTUB model to evaluate model performance and calibrate the BATHTUB and STEPL models for each scenario. The TMDL and future water quality assessment and listing will be based solely on water quality data from the ambient monitoring location in segment “01 Segname 1-3”.

Table E-4. Ambient Water Quality (2011-2022 Annual Mean) for Hawthorn Lake.

Parameter	Measured Data	BATHTUB Input[1]
Total Phosphorus	60.2 µg/L	60.2 ppb
Total Nitrogen	1.18 mg/L	1,178.5 ppb
Chlorophyll-a	29.7 µg/L	29.7 ppb
Secchi Depth	0.91 m	0.91 m

[1]Measured or monitored data converted to units required by BATHTUB
ppb = parts per billion = micrograms per liter (µg/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 Hawthorn 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. Flow and TP loads for Segments 1-1, 1-2, and 1-3 were developed by taking the ratio of the area of the smaller BATHTUB subbasin to the overall area of subbasin 1 multiplied by the overall average flow and TP load for subbasin 1. Table E-5 summarizes the physical parameters and monitored inputs for Hawthorn Lake.

Table E-5. Flow and Transport Linkages in STEPL and BATHTUB

Tributary Name	BATHTUB Receiving Segment	Total Watershed Area (km^2)	Avg Period Flow Rate (hm^3/yr)	STEPL Total P Concentration (ppb)
Trib 1[1]	--	3.619	0.919	364.8
Trib 1-3[2]	Segname 1-3	0.288	0.073	364.8
Trib 1-2[2]	Segname 1-2	2.173	0.552	364.8
Trib 1-3[2]	Segname 1-3	1.158	0.294	364.8
Trib 2	Segname 2	4.616	1.219	164.2
Trib 3	Segname 3	4.185	1.147	498.4

[1]This is provided as reference information only and was not used in the BATHTUB model.
[2]Subdivided from subbasin 1. Flow and TP loads entered as a ratio of the smaller area to the area of Trib 1 multiplied by the flow rate or Total P of Trib 1.

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). 2023a. Iowa State University Department of Agronomy. Iowa Ag Climate Network. Download available at http://mesonet.agron.iastate.edu/request/coop/fe.phtml. Accessed in March 2023.

Iowa Environmental Mesonet (IEM). 2023b. Iowa State University Department of Agronomy. Iowa Ag Climate Network. Download available at http://mesonet.agron.iastate.edu/agclimate/hist/dailyRequest.php. Accessed in March 2023.

Appendix F. Model Performance and Calibration

The Hawthorn 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 Iowa Department of Natural Resources (DNR) between 2011 and 2022. 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 Hawthorn Lake.

F.1. STEPL Performance and Calibration

The STEPL model is a long-term average annual simulation model, and is incapable of simulating storm events or short-term fluctuations in hydrology and nutrient loads. There is no long-term monitoring data for tributaries in the Hawthorn 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 are similar composition or proximate in location. Values for Hawthorn Lake watershed are before BMP reductions.

Table F-1. Sheet and Rill Erosion in Southern Iowa Drift Plain Watersheds.

Watershed	County	Area (acres)	Proximity (miles)	Erosion[1] (tons/ac/yr)
Windmill Lake	Taylor	532	134	1.9
Lake Iowa	Iowa	1,288	18	1.8
Lake of the Hills	Scott	1,683	92	2.2
Prairie Rose Lake	Shelby	4,655	143	1.9
Thayer Lake	Union	485	89	4.5
Green Valley Lake	Union	5,175	104	2.7
Lake Anita	Adair	2,285	120	3.1
Lake Ahquabi	Warren	3,288	60	4.2
Hawthorn Lake	Mahaska	3,069	--	4.2

[1]Gross annual sheet/rill erosion.

The Hawthorn Lake STEPL model predicts sheet and rill erosion rates that are consistent with those predicted by DNR for other watersheds in the area. The 2011-2022 simulated gross annual average sheet and rill erosion rate was 4.2 tons/ac-yr, compared with average estimated rates between 1.9 to 4.5 tons/acre-year estimated in other watersheds in the Southern Iowa Drift Plain. Note that erosion rates in Table F-1 reflect sheet and rill erosion, not sediment delivered to the lake.

Table F-2 compares the annual average TP export simulated by the Hawthorn Lake STEPL model with past study results in other watersheds in Iowa with an emphasis on the Southern Iowa Drift Plain. TP exports in the Hawthorn Lake watershed are 1.6 pounds per acre per year. The TP export rates are gross rates and do not include reductions due to BMPs throughout the watershed.

Table F-2. Comparison of TP Exports in Southern Iowa Drift Plain Watersheds.

Watershed Location	Source	TP Export (lbs/ac)
Lake Iowa, Iowa County	DNR (Previous TMDL)	1.0
Windmill Lake, Taylor County	DNR (Previous TMDL)	1.5
Lake of the Hills,	DNR (Previous TMDL)	3.0
Badger Creek Lake, Madison County	DNR (Previous TMDL)	2.2
Green Valley Lake, Adair County	DNR (Previous TMDL)	1.7
Thayer Lake, Union County	DNR (Previous TMDL)	2.1
Prairie Rose Lake	DNR (Previous TMDL)	1.5
Lake Anita, Adair County	DNR (Previous TMDL)	1.5
Lake Ahquabi, Warren County	DNR (Previous TMDL)	1.8
Hawthorn Lake, Mahaska County	**STEPL Model (Current TMDL)**	**1.6**

Sparrow Calibration
In addition to comparing erosion rates and TP loads from other reservoirs, the STEPL model was calibrated to flow rate by comparing STEPL values to SPARROW values. SPARROW stands for SPAtially Referenced Regression On Watershed attributes. It is a model developed to describe long-term mean annual streamflow, total nitrogen, total phosphorus, and suspended solids in streams of the midwestern part of the United States. (Robertson and Sadd, 2019)

The flow rates and TP loads developed by STEPL were compared to the calibration site from the SPARROW model. The SPARROW calibration site coincides with the USGS gaging station South Skunk River near Oskaloosa, IA (Station ID 05471500) as shown in Figure F-1. This site was selected as the calibration site for the following reasons: 1) It is a calibration site for both flow and TP; 2) It is in the same ecoregion as the Hawthorn Lake watershed; 3) It is the closest calibration site to the Hawthorn Lake watershed; 4) It is not immediately downstream of a reservoir; and 5) Based on a USGS study (SIR 2012-5232) Hawthorn Lake and the calibration site are in the same local region (local region 1). “A local region is an area in which the streamflows measured at all the streamgages are highly correlated” (Linhart, et al. 2012).

The STEPL model was first calibrated to flow rate by iteratively adjusting the curve numbers (CN) and the soil infiltration fraction for precipitation values within the model. CNs were adjusted within a range of values listed in the runoff curve number tables found in the TR-55 manual (Cronshey, R. 1986). The iterative process of determining the CNs and infiltration fraction value was accomplished using the SOLVER module within EXCEL. A target flow rate value of 2,663 ac-ft/year was set in the SOLVER and values were iteratively changed until the target value was achieved.

Once the flow rate value was acceptable, an evaluation of the TP loadings was done. In this case, after calibrating the flow, the difference between the STEPL TP and SPARROW TP was approximately 3.5%, which was an acceptable value for TP. Consequently, there was no iterative process within STEPL to narrow in on a more precise value. A summary of the CNs, infiltration factor value, flow rate and TP loadings can be seen in Table F-3

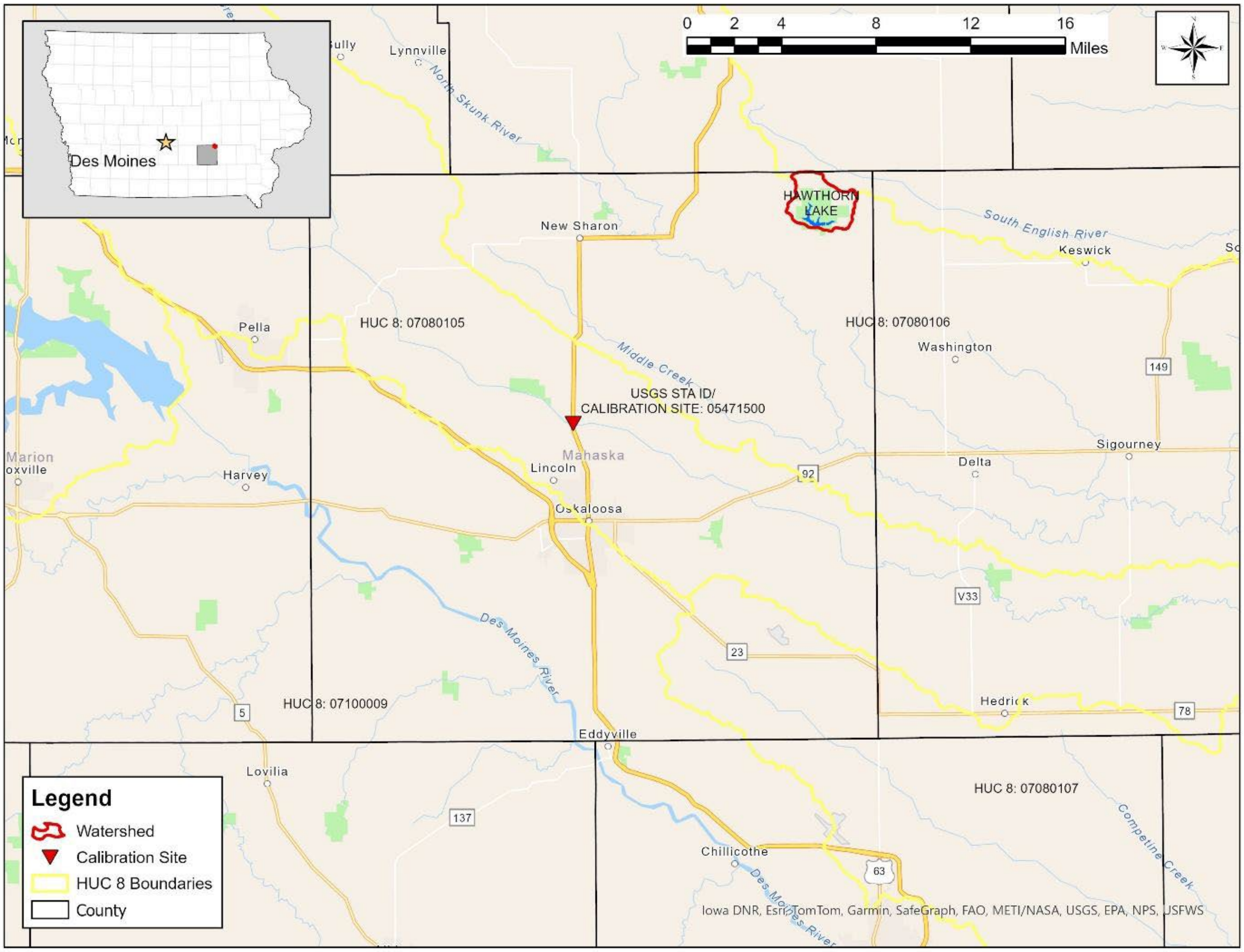

Figure F-1. SPARROW Calibration Site Location.

Table F-3. STEPL Calibration Value Summary.

STEPL Land Use Categories	CN Range	Final CN	Soil Infiltration Fraction of Precipitation	
			Default	Final
Cropland	77 - 88	79	0.150	0.149
Forest	70 - 73	70	0.150	0.149
Pastureland	74 - 86	76	0.150	0.150
Urban	86	86	0.120	0.120
User Defined	71	71	0.150	0.149
Parameter	**Model**		**% DIFFERENCE**	
	STEPL	**SPARROW**		
Flow Rate (ac-ft/yr)	2,663	2,663	0.0%	
TP (lbs/yr)	2,440	2,358	3.5%	

F.2. BATHTUB Model Performance

Performance of the BATHTUB model was assessed by comparing predicted water quality with observed data collected in Hawthorn Lake. Simulation of TP concentration was critical for TMDL development, as was chl-a and transparency predictions.

Calibration

Table F-4 reports the initial modeling results for the observed and predicted annual average TP, chl-a, Secchi depths, observed to predicted ratios, and T-test values in the open water area of Hawthorn Lake (Segment 1-3). More comprehensive observed data is reported in Appendix C.

Table F-4. Initial BATHTUB Modeling Results.

Parameter	Observed[1]	Predicted[2]	Obs/Pred Ratio	T-Test		
Modeling period and TMDL conditions (2011-2022)				**T1**	**T2**	**T3**
Total Phosphorus (µg/L)	60.2	62.4	0.96	-0.09	-0.14	-0.08
Chlorophyll-a (µg/L)	29.7	19.1	1.56	0.69	1.28	0.62
Secchi depth (m)	0.914	1.207	0.76	-0.56	-0.99	-0.52

[1]Average concentration observed at ambient monitoring location.
[2]Average annual concentration predicted in Segment 1-3 of the BATHTUB lake model

Statistical comparisons, such as the T-test, can be used to determine if model calibration is needed or if there is any significant difference between the observed vs the predicted values. The T-test procedure evaluates the means of two data sets to determine if they are significantly different and to check the reasonableness of a model. (Walker, 1999; EPA-R7, 2022). Three t values are produced by the BATHTUB model, T(1), T(2), and T(3). It should be noted that T(1) values are provided only when the coefficient of variation (CV) values are provided as part of the input data for the observed parameters of interest.

T(2) and T(3) values are used to test the applicability of the model. If their absolute values exceed 2 there is less than a five percent chance that nutrient sedimentation dynamics in the reservoir are typical of those in the model development data set. (Walker, 1999). As shown in Table F-4, the absolute T(2) and T(3) values for all parameters of interest are less than two, which would indicate that there is a 95 percent chance that the nutrient sedimentation dynamics in the reservoir are typical of those in the model development data set.

T(1) values can be used to determine if calibration of the model is appropriate. If the absolute value of T(1) is greater than two, there is less than a five percent chance that the observed and predicted means are equal. In this case, it may be desirable to calibrate the model. However, in our model, the absolute value of T(1) for phosphorus is 0.09, which would indicate that there is a 95 percent chance that the observed mean value is not significantly different from the predicted mean value and that calibration of the model is not needed (Walker, 1999). Another observation is that the observed to predicted phosphorus ratio is 0.96, which indicates that the model over predicts phosphorus by approximately four percent, which provides a minimal built-in MOS factor.

However, chl-a had a higher T(1) value and it was decided to do further calibration of chl-a. Table F-5 reports the final modeling results, after calibration and reduction of phosphorus loads from the tributaries, for the observed and predicted annual average TP, chl-a, Secchi depths, along with the calibration coefficients for each parameter of interest. 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 2011-2022.

Calibration coefficients listed alongside the simulated values in Table F-5 were entered in the "Model Coefficients" menu of the BATHTUB model, and apply only to the ambient monitoring segment (Segment 1-3) of Hawthorn Lake. Other lake segments were uncalibrated due to lack of historical water quality data. Calibration coefficients for Hawthorn Lake are within the recommended range according to the BATHTUB user guidance (Walker, 1999).

Initial testing showed phosphorus levels from watershed loading were adequate for meeting observed water quality data in Hawthorn Lake. Internal loading levels were not required and due to lake morphology not appropriate for Hawthorn Lake.

Table F-5. Final BATHTUB Modeling Results.

Parameter	Observed[1]	Predicted[2]	Obs/Pred Ratio	Calibration Coefficient
Modeling period and TMDL conditions (2011-2022)				
Total Phosphorus (µg/L)	60.2	54.1	1.11	1.0
Chlorophyll-a (µg/L)	29.7	27.2	1.09	1.56
Secchi depth (m)	0.914	0.970	0.94	1.0

[1]Average concentration observed at ambient monitoring location.
[2]Average annual concentration predicted in Segment 1-3 of the BATHTUB lake model.

F.3. References

Cronshey, R. 1986. Urban Hydrology for Small Watersheds, TR-55, U.S. Department of Agriculture, Soil Conservation Service, Engineering Division.

Linhart, SM, JF Nania, CL Sanders Jr, and SA Archfield. 2012. Computing daily mean streamflow at ungaged locations in Iowa by using the Flow Anywhere and Flow Duration Curve Transfer statistical methods: U.S. Geological Survey Scientific Investigations Report 2012-5232, 50 p.

Robertson, DM and DA Saad. 2019. Spatially referenced models of streamflow and nitrogen, phosphorus, and suspended-sediment loads in streams of the Midwestern United States: U.S. Geological Survey Scientific Investigations Report 2019-5114, 74 p. including 5 appendixes, https://doi.org/10.3133/sir20195114.

U.S. Environmental Protection Agency Region 7 (EPA-R7). 2022. Region 7 Desktop Manual for Running Eutrophication Model (BATHTUB).

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 Hawthorn 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 644.5 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, 2006), 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
- σ^2 = $\ln(CV^2 + 1)$
- CV = coefficient of variation

The allowable annual average of 1,791.5 lbs/year is equivalent to a long-term average (LTA) daily of 6.8 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 an MDL. The 365-day averaging period equates to a recurrence interval of 99.7 percent and corresponding z statistic of 2.326, as reported in Table G-1. Multipliers Used to Convert an LTA to an MDL.. 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 15.3 lbs/day. The TMDL calculation is summarized in Table G-2. Summary of LTA to MDL Calculation for the TMDL.. An explicit MOS of 10 percent (1.6 lbs) was applied, resulting in a daily LA of 13.7 lbs/day to the daily TMDL equations. The resulting TMDL, expressed as a daily maximum, is:

$$\boldsymbol{TMDL} = LC = \Sigma\, WLA\ (0\ lbs - TP/day) + \Sigma\, LA\ (13.7\ lbs - TP/day) + MOS\ (1.6\ lbs - TP/day)$$
$$= \boldsymbol{15.3\ lbs - TP/day}$$

Table G-1. Multipliers Used to Convert an LTA to an MDL.

Parameter	TMDL	Σ WLA	Σ LA	MOS
LTA (lbs/day)	6.8	0.0	6.1	0.7
Z Statistic	2.326	2.326	2.326	2.326
CV	0.6	0.6	0.6	0.6
σ^2	0.31	0.31	0.31	0.31
MDL (lbs/day)	**15.3**	**0.0**	**13.7**	**1.6**

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

Parameter	Value	Description
LTA	6.8 lbs/day	Annual TMDL (1,791.5 lbs) divided by 365 days
Z Statistic	2.326	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	**15.3 lbs/day**	**TMDL expressed as daily load**

Appendix H. 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.

Table H-1. Project Files and Locations.

Directory\folder path	File name	Description
\\iowa.gov.state.ia.us\...\Hawthorn_Lake \Data\Raw	Various files	All raw data received from others
\\iowa.gov.state.ia.us\...\Hawthorn_Lake \Data\Reduced	Hawl_62_WQ_Dataset R4.xlsx	Summary of in-lake WQ data
\\iowa.gov.state.ia.us\...\Hawthorn_Lake \Data\Reduced\Weather	HAWL_62_Evap-Precip_Data_R2.xlsx	Summary of precipitation and PET data
\\iowa.gov.state.ia.us\...\Hawthorn_Lake \Documents, Presentations\Draft TMDL	Draft TMDL reports	Includes review comments
\\iowa.gov.state.ia.us\...\Hawthorn_Lake \Documents, Presentations\Final TMDL	Final report	Report for submittal to EPA
\\iowa.gov.state.ia.us\...\Hawthorn_Lake \Documents, Presentations\References	Various .pdf and .doc files	References cited in the WQIP and/or utilized to develop model input parameters
\\iowa.gov.state.ia.us\...\Hawthorn_Lake \GIS\GIS_Data	Various shapefiles (.shp) and raster files (.grd)	Used to develop models and maps
\\iowa.gov.state.ia.us\...\Hawthorn_Lake \GIS\Projects	ArcGIS project files	Used to develop models and maps
\\iowa.gov.state.ia.us\...\Hawthorn_Lake \GIS\Maps	Various .pdf and .jpg files	Maps/figures used in the WQIP document
\\iowa.gov.state.ia.us\...\Hawthorn_Lake \Modeling	HAWL 62 STEPL Model Input 09-21-21.xlsx.	Input data for STEPL
\\iowa.gov.state.ia.us\...\Hawthorn_Lake \Modeling	08 TMDL_Equation_Calcs_HAWL-2_CALIB.xlsx	Used to develop the TMDL equation (LA, WLA, and MOS)
\\iowa.gov.state.ia.us...\Hawthorn_Lake\ Modeling\STEPL	08_HAWL_STEPL_Model wBMP-2_CALIB.xlsm,	Used to simulate/predict existing watershed loads
	Various .xlsx files	Used to develop/calculate STEPL model inputs
\\iowa.gov.state.ia.us\...\Hawthorn_Lake \Modeling \BATHTUB	08 BATHTUB_input_HAWL_62 Mean-2	Calculated/converted STEPL outputs to BATHTUB inputs for existing conditions
	Various .btb files	BATHTUB input files for various scenarios
\\iowa.gov.state.ia.us\...\Hawthorn_Lake \Modeling \BATHTUB	08_HAWL_TMDL.btb	BATHTUB model for Hawthorn Lake

Appendix I. Public Comments

Public Comment:

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