Water Quality Improvement Plan
for

Windmill Lake

Taylor County, Iowa

Total Maximum Daily Load
For Algae and Turbidity

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General Report Summary

What is the purpose of this report?

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

What is wrong with Windmill Lake?

Windmill Lake is subject to extreme algae blooms and high levels of non-algal turbidity that can lead to poor visibility and make the lake unappealing to users. This violates Iowa's narrative water quality standard protecting against aesthetically objectionable conditions. Water sampling has found very high levels of suspended algae, chlorophyll-a, total phosphorus (TP), and inorganic suspended solids, which are causing the poor water transparency. The high levels of phosphorus are driving the algal blooms and a large population of cyanobacteria. Algal blooms and cyanobacteria can make swimming or wading hazardous, and discourage use of the lake.

What is causing the problem?

Large quantities of phosphorus entering the lake contribute to algal growth, which reduces water clarity. Most phosphorus enters Windmill Lake attached to sediment that washes in from surface erosion and runoff. The sediment also contributes to the non-algal turbidity problem. The erosion and runoff is precipitation driven but also varies with slope and landuse.

Within this watershed there are areas of steeper slope and large areas of Highly Erodible Land (HEL) that can contribute higher amounts of sediment-attached phosphorus than what is seen in flatter areas. After phosphorus enters the lake it can become available for algae within the lake to use. In general, three things are needed for algal growth: light, nitrogen and phosphorus. Of these three, phosphorus is typically the limiting factor in Iowa lakes. By limiting phosphorus, algal growth is also limited. Therefore, the nutrient management strategy for controlling algae should focus on reducing total phosphorus.

What can be done to improve Windmill Lake?

Reducing phosphorus loads entering the lake from the watershed is the most important step for long-term water quality improvement. Because most phosphorus enters the lake attached to sediment, methods to reduce sediment inputs will reduce the phosphorus loading as well as address the non-algal turbidity impairment. Until the external phosphorus loads are reduced, in-lake remediation steps will not be cost effective since high levels of phosphorus will continue to enter the lake. However, once watershed issues are addressed, directly addressing phosphorus accumulated within the lake may have substantial water quality benefits. The average annual TP load to Windmill Lake from 2005-2014 was estimated to be 805.8 lbs. per year. In order to meet the requirements to remove Windmill Lake from the impaired waters list, the load coming in to the lake must be reduced by 64 percent to not exceed the recommended annual load of 290.6 lbs. per year.

A combination of Best Management Practices (BMPs) including land management and control structures are often required to obtain reductions in sediment and phosphorus to meet water quality standards. Reducing phosphorus loss from row crops through strategic timing and methods of manure and fertilizer application, increasing use of conservation tillage methods, and implementing or improving existing structural BMPs such as terraces, grass waterways, and constructed wetlands in beneficial locations will be necessary to improve the water quality in Windmill Lake. Special attention should be given to row crops on steep slopes, where the adoption of cover crops or perennial strips may be especially beneficial. See Section 4, page 26 for more information.

Who is responsible for a cleaner Windmill Lake?

Everyone who lives and works nearby, or wishes to utilize a healthy Windmill Lake, has an important role to play in improving and maintaining the lake. Nonpoint source pollution is unregulated and responsible for the vast majority of sediment and phosphorus entering the lake. Therefore, voluntary management of land, animals, and the lake itself will be required to achieve measurable improvements in water quality. Many of the practices that protect and improve water quality also benefit soil fertility and structure, the overall health of the agricultural 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, land owners, and lake users alike. Improving water quality in Windmill Lake, while also improving the quality of the surrounding land, will require collaborative participation by various stakeholders, with land owners playing an especially important role.

The future of Windmill Lake depends on citizens and landowners adopting land use changes. The best chance for success in improving Windmill Lake lies with private citizens working with government agencies that can provide technical, and in some cases, financial support for improvement efforts. Citizens interested in making a difference in Windmill Lake should contact their local soil and water conservation district or the Iowa DNR Watershed Improvement Section for information on how to get involved.

Does a TMDL guarantee water quality improvement?

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

What are the primary challenges for water quality improvement?

In most Iowa landscapes, implementation requires changes in land management and/or agricultural operations. Management decisions may include changes in the number of acres that are actively tilled and the diversity and rotation of crops produced. These changes present challenges to producers by requiring new equipment (e.g., no-till planters), narrowing planting, harvesting, fertilization windows, and necessitating more active, complex farm management. Additionally, potential short-term losses in yields are more easily recognized and quantified than long-term benefits to soil health and sustained productivity. It is not easy to overcome existing incentives and the momentum of current practices. Promoting a longer-term view with an emphasis on long-term soil fertility, production, agricultural ecosystem health, and reduced input costs will be essential for successful, voluntary implementation by willing conservation partners.

How should this document be used?

Because this document serves several purposes, not everyone will benefit from the entire document. While EPA will be interested in the technical segments that address the TMDL and loading calculations, for stakeholders in and around the Windmill Lake watershed, the most pertinent information will be found in sections 4 and 5. These sections address what can be done to improve the water quality in Windmill Lake.

Technical Summary

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Waterbody ID Code: IA 05-PLA-00430-L_0 Location: Taylor County, S36T69NR35W, 4 mi E of New Market.
Surface water classification and designated uses:	Class A1 Primary Contact Recreation Class B(LW) Aquatic Life Class HH Human Health
Impaired beneficial uses:	Class A1 Primary Contact Recreation
Identification of the pollutant and applicable water quality standards:	The Class A1 (primary contact recreation) uses are assessed (monitored) as "not supported" due to aesthetically objectionable conditions due to poor water transparency caused by algae blooms and non-algal turbidity.
Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	Excess algae blooms and subsequent chlorophyll a concentrations and high levels of turbidity are attributed to total phosphorus (TP). The allowable average annual TP load = 290.6 lbs./year; the maximum daily TP load = 3.2 lbs./day.
Quantification of the amount or degree by which the current pollutant load in the waterbody, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain water quality standards:	The existing annual load of 805.8 lbs./year must be reduced by 544.3 lbs./year to meet the allowable TP load. This is a reduction of nearly 68 percent.
Identification of pollution source categories:	There are no permitted or regulated point source discharges of phosphorus in the watershed. Nonpoint sources include fertilizer and manure from row crops, erosion, and atmospheric deposition.
Wasteload allocations for pollutants from point sources:	There are no permitted or regulated point source discharges in the watershed. Therefore the WLA in this TMDL is zero.
Load allocations for pollutants from	The allowable annual average TP LA is

nonpoint sources:	261.5 lbs. per year, and the allowable maximum daily LA is 2.9 lbs. per day, resulting in a 68 percent reduction from existing conditions.
A margin of safety:	An explicit MOS of 10 percent is incorporated into this TMDL. The annual MOS is 29.1 lbs. of P and the daily MOS is 0.3 lbs. of P.
Consideration of seasonal variation:	The critical period for in-lake water quality is the growing season. These conditions are reflected in the TMDL because the monitoring data and in-lake model are based on the growing season. However, it is annual average loads to the lake that drive growing season water quality, therefore the TMDL is based on annual TP loading.
Allowance for reasonably foreseeable increases in pollutant loads:	Because there are no urban areas in the watershed and significant land use change is unlikely, there are no allowances for reasonably foreseeable increases in pollutant loads.
Implementation plan:	An implementation plan is outlined in Section 4 of this Water Quality Improvement Plan. Phosphorus loading and associated impairments are addressed through a variety of voluntary nutrient and soil management strategies and structural BMPs.

1. Introduction

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

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

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

Windmill Lake, located in Taylor County in southwestern Iowa, is on the impaired waters list because it is not meeting its designated uses for primary contact recreation (swimming, wading) due aesthetically objectionable conditions from poor water transparency caused by algae blooms and non-algal turbidity (Figure 1-1).

Figure 1-1. Photo of Windmill Lake algae and turbidity problems

One purpose of this Water Quality Improvement Plan (WQIP) for Windmill Lake is to provide a TMDL for algae and turbidity. The second purpose of the plan is to provide local stakeholders and watershed managers with a tool to promote awareness of water quality issues, develop a watershed management plan, and implement water quality improvement projects. The algae impairment is addressed by development of a TMDL that limits total phosphorus (TP) loads to the lake. Additionally, because most of the phosphorus entering the lake is attached to sediment, efforts to reduce sediment inputs will address both the phosphorus targets and reduce the non-algal turbidity.

This TMDL includes an assessment of the existing phosphorus load to the lake and a determination of how much phosphorus the lake can tolerate and still support its designated uses. The allowable amount of phosphorus that the lake can receive is the loading capacity, or the TMDL target load.

The plan includes a description of potential solutions to the impairments. This group of solutions is more precisely defined as a system of best management practices (BMPs) that will improve water quality in Windmill Lake, with the ultimate goal of meeting water quality standards and supporting designated uses. These BMPs are outlined in the Section 4 Implementation Plan.

The Iowa Department of Natural Resources (IDNR) 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 progress towards water quality standards, maximize cost efficiency, and prevent unnecessary or ineffective implementation of costly BMPs. A water quality monitoring plan designed to help assess water quality improvement and BMP effectiveness is provided in Section 5.

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

2. Description and History of Windmill Lake

2.1. History and Land Use

Windmill Lake is a 23.9 acre man-made lake that was constructed in the 1970s and is surrounded by a 549.5 acre watershed in Taylor County (Figure 2-1). This results in a watershed-to-lake ratio of 23 to 1. The Taylor County Conservation Board maintains and operates the Windmill Lake County Park that surrounds the lake. Recreational opportunities include fishing, boating, camping, and swimming. The Center for Agricultural and Rural Development (CARD) at Iowa State University estimates that between 2002 and 2005, Windmill Lake averaged about 7,205 visitors per year, and while that number jumped to 9,648 visitors in 2009 it was still one of the five least visited lakes in Iowa.

Windmill Lake is located within the Rolling Loess Prairies-Western Corn Belt Plains ecoregion (47f) (Prior 1991; Griffith et al., 1994). Loess deposits on well drained plains and open low hills characterize the Rolling Loess Prairies ecoregion. Loess deposits tend to be thinner than those found in 47e to the west, generally less than 25 feet in depth except along the Missouri River where deposits are thicker. Potential natural vegetation is a mosaic of mostly tallgrass prairie and areas of oak-hickory forest. Although cropland agriculture is widespread, this region has more areas of woodland and pasture than neighboring 47e.

Land uses within the watershed are dominated by agriculture (Table 2-1). There are no permitted discharges within this watershed.

Table 2-1. Land uses in the Windmill Lake watershed

Landuse	Acres	Percent
Farmstead and Residential	1.4	0.5%
Forest	20.9	2.9%
Grassland	34.1	5.1%
Pasture	232.7	36.1%
Road	19.4	3.4%
Cropland	223.7	25.7%
Water	41.2	7.1%
Total	**573.4**	**100%**

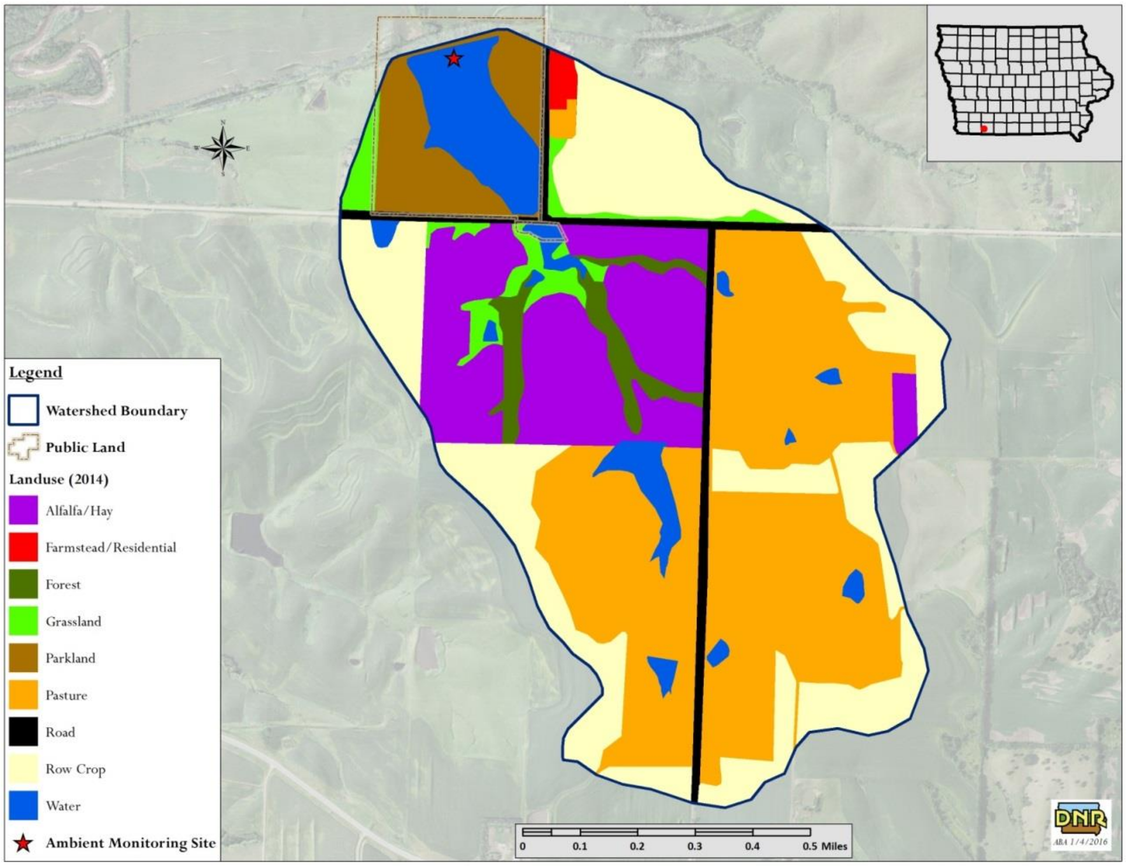

Figure 2-1. Windmill Lake watershed and landuse

2.2. Hydrology and Morphometry

The nearest weather stations to the Windmill Lake watershed are in Bedford, IA approximately 7 miles to the southeast and Clarinda, IA approximately 10 miles to the west (Iowa Environmental Mesonet). Because the watershed is between the two stations, the average of the two stations was used. The average annual precipitation for the watershed from the 2005-2014 assessment timeframe was 39.2 inches. The long term average (LTA) (1951 to present) for the area is 36.1 inches (Figure 2-2). The driest month is January with an average of 0.91 inches of precipitation and the wettest month is June with an average of 5.1 inches of precipitation. The lowest average temperature occurs in January at 12.5 degrees Fahrenheit and the highest average temperature occurs in July at 87.5 degrees Fahrenheit.

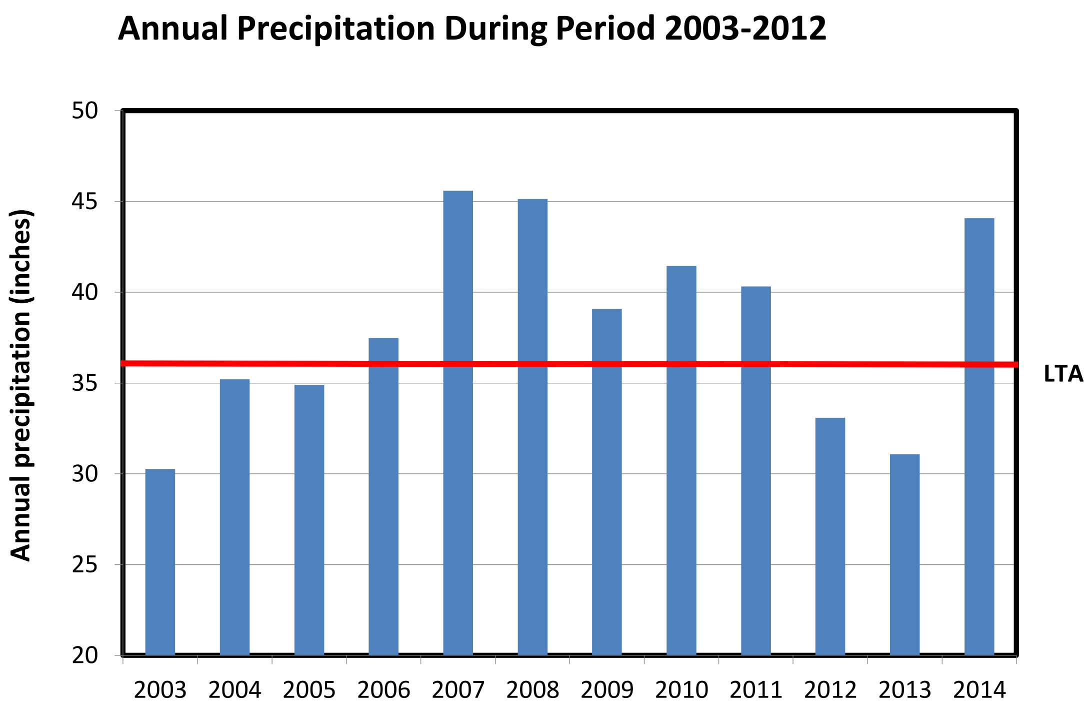

Figure 2-2. Annual precipitation at Windmill Lake, Iowa (average of data from both weather stations) *LTA is the long term average since 1951 for both sites

A 900-foot long, 35-foot high earthen dam controls outflow at the northern end of the lake. The surface area of Windmill Lake varies significantly with water level. At normal pool, the surface area is reported at 23.9 acres. A 2010 bathymetric survey found that the maximum depth is 17.2 feet, with an average depth of 8.3 feet (Figure 2-3).

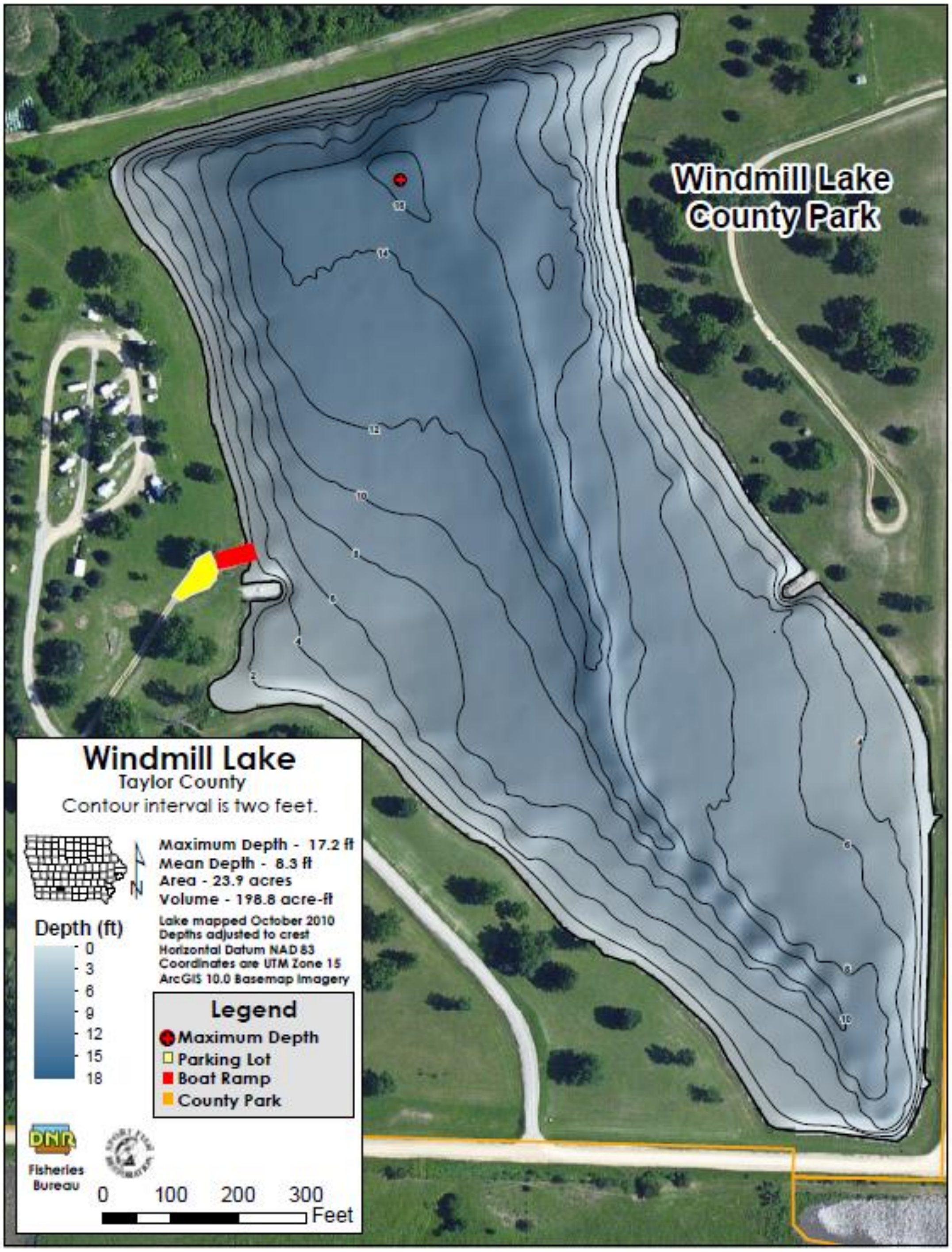

Figure 2-3. Bathymetric map of Windmill Lake

Rainfall runoff, direct precipitation, evapotranspiration, shallow groundwater flow, and deep aquifer recharge are all part of the lake's hydrologic system. The hydraulic residence time varies seasonally and is weather dependent. The average residence time for the lake is 82 days. Estimated residence time is based on annual precipitation statistics, estimates of average annual inflow from the Spreadsheet Tool for Estimating Pollutant Load (STEPL), and a water balance calculated within the BATHTUB model.

3. Total Maximum Daily Load (TMDL) for Algae and Turbidity

A Total Maximum Daily Load (TMDL) is required for Windmill Lake by the Federal Clean Water Act. This section of the Water Quality Improvement Plan (WQIP) describes the pollutant, in this case phosphorus, leading to the algal and non-algal turbidity impairments and the maximum amount of total phosphorus (TP) the lake can assimilate and still support primary contact recreation in Windmill Lake.

3.1. Problem Identification

As previously stated, the primary contact recreation (Class A1) uses at Windmill Lake are not supported due to elevated chlorophyll a (algae) levels, algal turbidity, and non-algal turbidity. Table 3-1 outlines the common terminology used when discussing algal and turbidity lake impairments.

Table 3-1. Algae and turbidity related parameters

Parameter	Physical Meaning
Secchi Depth, meters	Measures water column transparency and used as a translator for turbidity. The greater the Secchi depth, the more transparent the water
Chlorophyll-a, mg/L	Because chlorophyll-a is produced during photosynthesis, it can be used to measure algae concentration in the water column.
Total Phosphorus, mg/L	Total phosphorus is often the limiting factor in algal blooms, or simply, this is usually what algae will run out of first. By controlling phosphorus levels, algal activity can be reduced.
TSS, mg/L	Total Suspended Solids. The quantitative measure of matter (organic and inorganic material) suspended in the water column.
Turbidity, NTU	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.

Most phosphorus enters Windmill Lake attached to sediment that washes in from surface erosion and runoff. The erosion and runoff is precipitation driven but also varies with slope and landuse. After phosphorus enters the lake it can become available for algae within the lake to use in their lifecycle processes. In general, three things are needed for algal growth: light, nitrogen and phosphorus. Of these three, phosphorus is typically the limiting factor in Iowa lakes. Therefore, when excess phosphorus is introduced into a lake, there is nothing keeping algal growth in check.

By limiting phosphorus, algal growth is also limited. Table 3-2 sums up the total nitrogen (TN): total phosphorus (TP) ratios for this lake. In this analysis the lake was either P limited (TN:TP > 17) or N and P-co-limited (TN:TP between 10 and 17) for the majority samples exceeding a chlorophyll-a TSI of 65. Use of TN:TP ratios to assess limitation was taken from MPCA (2005) and Carlson and Simpson (1996).Table 3-3 shows the relationship between TSI values for Secchi depth, Chl-a and TP. Results show that the highest TSI Chl-a values occur when the lake is P-limited. Therefore, nutrient management for controlling algae should focus on reducing TP.

Table 3-2. TN:TP ratio analysis

Range	N-limited	Co-Limited	P-limited
	<10	**10 to 17**	**>17**
Number of samples	4	18	12
Percent	12%	53%	35%

Table 3-3. TN:TP ratio and TSI summary for Windmill Lake

Samples Collected	# of Samples	Mean Secchi TSI	Mean Chl-a TSI	Mean TP TSI
All samples 2001-2014	34	71.9	66.7	70.8
N-limited (<10)	4	72.2	66.6	69.3
Co-Limited (10-17)	18	72.9	66.2	73.2
P-limited (>17)	12	70.9	67.0	67.5

Algal blooms are aesthetically objectionable and can make swimming or wading unpleasant or even hazardous. Algae proliferate quickly and when large blooms die off the decaying mass can lead to oxygen depletion and/or release of harmful cyanotoxins.

Problem Statement

The impairment caused by the algal blooms and non-algal turbidity is for aesthetically objectionable conditions. For 303(d) listing purposes, aesthetically objectionable conditions are present in a waterbody when the median summer chlorophyll-a or Secchi depth Trophic State Index (TSI) exceeds 65 (IDNR, 2008). Trophic state is the level of ecosystem productivity, typically measured in algal biomass. TSI is a standardized scoring system that places trophic state on an exponential scale of Secchi depth, chlorophyll-a, and total phosphorus. TSI values for chlorophyll-a range between 0 and 100, each 10 scale units represent a doubling of algal biomass. Additionally, high levels of inorganic suspended solids, or non-algal turbidity, lead to elevated TSI for Secchi depth and are also grounds for listing under aesthetically objectionable conditions.

Understanding how TSI describes the overall lake system and not just the water clarity requires introducing the additional concept of eutrophication. Eutrophication is the process by which a body of water acquires a high concentration of nutrients, especially phosphorus and nitrogen, which typically promotes excessive growth of algae (Art 1993). Table 3-4 relates TSI values to their corresponding eutrophic state and gives additional details of impacts on the lake system, recreation and aquatic life.

Table 3-4. Implications of TSI Values on lake attributes

TSI Value	Attributes	Primary Contact Recreation Problems	Aquatic Life (Fisheries)
50-60	eutrophy: anoxic hypolimnia; macrophyte problems possible	[none]	Warm water fishes only; walleye and some perch; bass may be dominant
60-70	blue green algae dominate; algal scums and macrophyte problems occur	weeds, algal scums, and low transparency discourage swimming and boating	Crappie, bluegill, sunfish, and bass
70-80	hyper-eutrophy (light limited). Dense algae and macrophytes	weeds, algal scums, and low transparency discourage swimming and boating	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

Note: Modified from Carlson and Simpson (1996).

Using the median values from 2008-2012 sampling, the TSI for Secchi depth was 76, which would place the lake in between the eutrophic and hypereutrophic categories. The TSIs for chlorophyll-a (67) and total phosphorus (70) place Windmill Lake in the hypereutrophic category. These values suggest very high levels of suspended algae in the water column, leading to extremely poor water transparency, likely due to the high levels of phosphorus. Additionally, the levels of inorganic suspended solids are also high, which suggests that non-algal turbidity is also an issue in Windmill Lake. The median concentration of inorganic suspended solids for the monitoring period was 10.9 mg/L and ranked in the worst 15 percent of all monitored lakes in Iowa.

There is also evidence that Windmill Lake has a problem with cyanobacteria, which can produce toxins that are harmful to both humans and animals. During the assessment period, cyanobacteria made up 71% of the phytoplankton biomass at the lake and the median concentration placed Windmill Lake in the worst 25 percent of all lakes sampled.

In order to de-list a lake impaired by algae from the 303(d) list, the median growing season TSIs must not exceed 63 in two consecutive listing cycles, per IDNR de-listing methodology. To avoid exceeding a TSI value of 63, the median summer chlorophyll a concentration must not exceed 27 micrograms per liter (µg/L). Chapter 61.3(2) of the WQS contains the general water quality criteria, which are applicable to all surface waters.

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

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

- a. *Such waters shall be free from substances attributable to point source wastewater discharges that will settle to form sludge deposits.*
- b. *Such waters shall be free from floating debris, oil, grease, scum and other floating materials attributable to wastewater discharges or agricultural practices in amounts sufficient to create a nuisance.*
- c. *Such waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor or other aesthetically objectionable conditions.*
- d. *Such waters shall be free from substances attributable to wastewater discharges or agricultural practices in concentrations or combinations which are acutely toxic to human, animal, or plant life.*
- e. *Such waters shall be free from substances, attributable to wastewater discharges or agricultural practices, in quantities which would produce undesirable or nuisance aquatic life.*

Interpreting Windmill Lake Data

Sources of data used in the development of this TMDL include those used in the 2012 and 2014 draft 305(b) report, several sources of additional water quality data, and non-water quality related data used for model development (Table 3-5).

Table 3-5. List of data and sources

Data	Source
Precipitation	• NWS COOP stations at Bedford and Clarinda (2003-2014)
In-Lake Water Quality	• Ambient lake data (2005-2014) - see Appendix C
Land Cover and Landuse	• USDA NASS and CLU coverages
Topography	• 10m DEM from Iowa DNR GIS library
Lake Bathymetry	• Iowa DNR mapping

From 2005-2014, the measured TSI values consistently surpassed the water quality standard of 65 for TSI Chlorophyll-a, TSI Secchi depth, and TSI total phosphorus (Figure 3-1). All points 65 and above are violations of Iowa WQS.

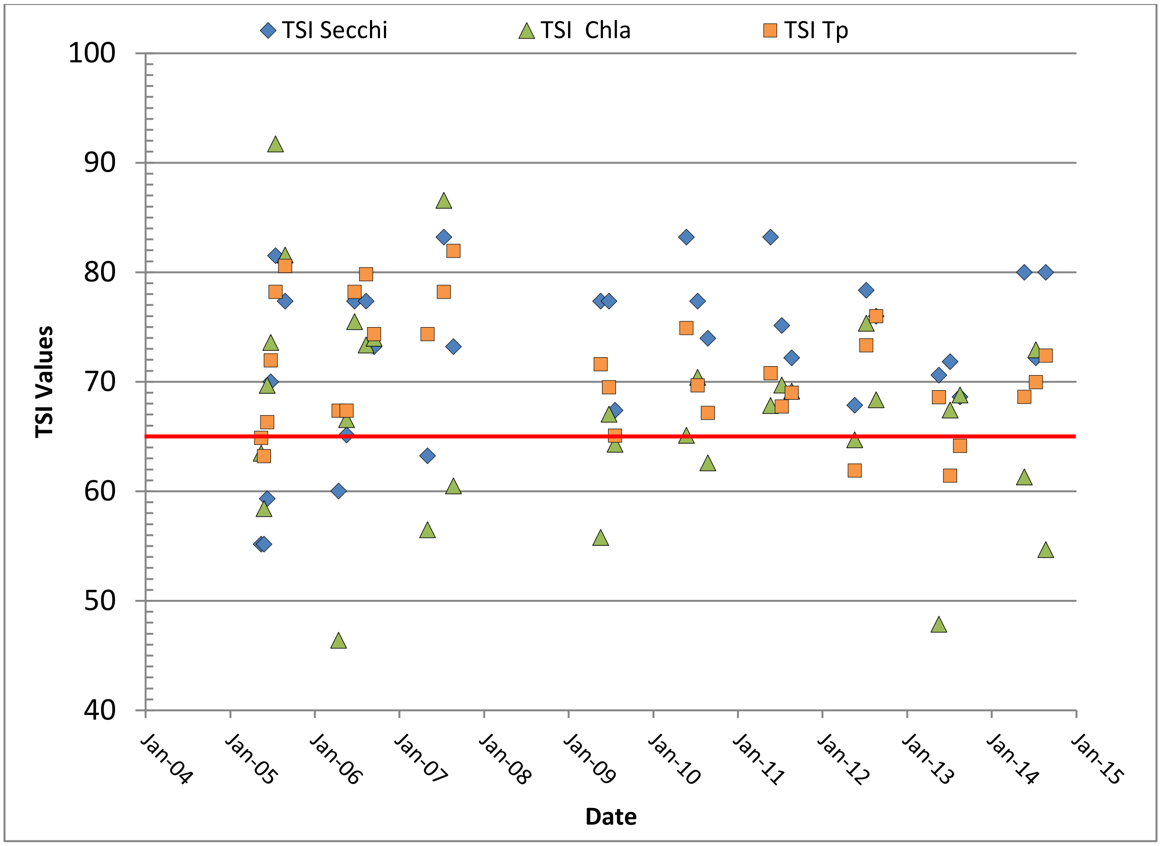

Figure 3-1. TSI values for sampling seasons 2005-2014

Because most of the phosphorus entering the lake is attached to sediment, efforts to reduce sediment inputs will address both the phosphorus targets and reduce the non-algal turbidity.

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, the average annual TP load to Windmill Lake from 2005-2014, including watershed, internal, and atmospheric loading was estimated to be 790.5 lbs. per year. While internal load may be an issue seasonally, the external load was sufficient to produce the levels of chlorophyll-a and TP observed in the lake. After external loading is reduced, addressing the internal load may be a valid option for speeding up water quality improvement in Windmill Lake. However, for this TMDL the net annual internal load is assumed to be zero.

Identification of pollutant sources

The existing TP load to Windmill Lake is entirely from nonpoint sources of pollution. There are no point sources operating under a National Pollution Discharge Elimination System (NPDES) permit or regulated by other Clean Water Act programs. Table 3-6 reports estimated annual average TP loads and resulting water quality based on the STEPL and BATHTUB simulation of 2005-2014 conditions.

Table 3-6. Average Annual Total Phosphorus input

Source	Description	Total Load (lbs./yr)	Percent (%)
Cropland	Corn and Soybean	477	59.1
Pasture	Grazed and ungrazed private	222	26.3
Grassland	Public parkland, ungrazed private, savanna	8	1.0
Urban	City, town, farmstead, road	50	6.3
Atmosphere	Wind and rain	6	0.8
Forest	Timber, forest, and scrub lands	3	0.5
Total		**806**	**100.00**

The STEPL model incorporates both livestock and wildlife manure into the cropland TP source by relating livestock and wildlife densities to TP concentration in runoff from agricultural land. In the case of the Windmill Lake model, animal populations are not large enough to increase runoff TP concentrations. This does not mean that TP loads from manure application and wildlife are zero, but instead, incorporates the relatively small impacts of these sources into the cropland source.

The STEPL model developed for the TMDL assesses landuse inputs of phosphorus and allows for quantification of inputs. Figure 3-2 quantifies percentage of the phosphorus load per land use. This will allow for better targeting when considering phosphorus reduction strategies. Section 4 of this document will further discuss strategies to reduce phosphorus.

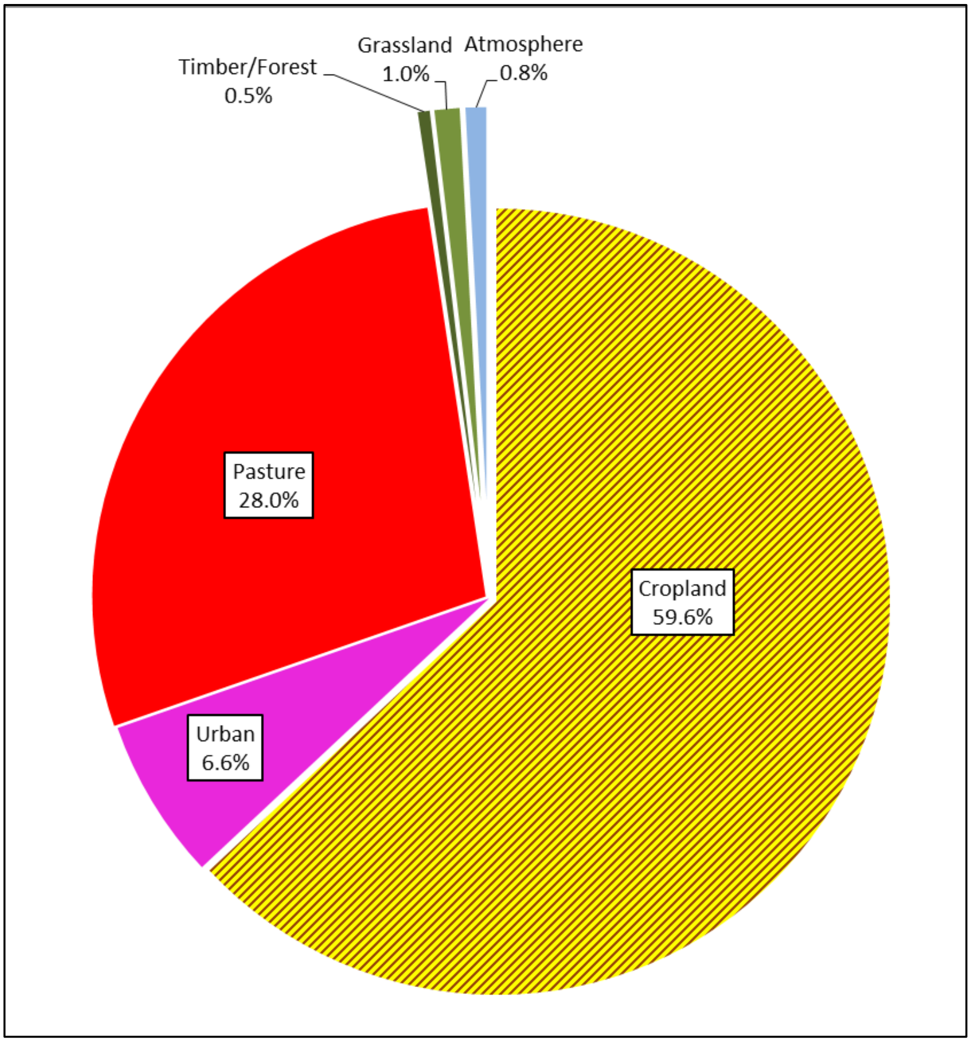

Figure 3-2. Percentage of the phosphorus load per source

3-2. TMDL Target

General description of the pollutants

As established in the previous sections, Windmill Lake is impaired for excessive algal growth and non-algal turbidity. Data interpretation indicates that phosphorus load reduction will best address these impairments. The non-algal turbidity is caused by suspended or re-suspended sediments entering the lake. Much of the phosphorus enters the lake attached to those sediments. Therefore, practices to reduce phosphorus will also reduce the sediment levels. Beginning with this section, the primary focus of this document will be quantifying and reducing phosphorus loads to remediate the water clarity issues.

Selection of environmental conditions

The critical period for the occurrence of algal blooms resulting from high phosphorus levels in the lake is the growing season (April through September). However, long-term phosphorus loads lead to buildup of phosphorus in the reservoir and contribute to blooms regardless of when phosphorus first enters the lake. Additionally, the combined watershed and in-lake modeling approach using EPA's Spreadsheet Tool for Estimating Pollutant Loads (STEPL) and BATHTUB lends itself to analysis of annual average conditions. Therefore, both existing and allowable TP loads to Windmill Lake are expressed as annual averages. Phosphorus loads are also expressed as daily maximums to comply with EPA guidance.

Decision criteria for water quality standards attainment

The narrative criteria in the water quality standards require that Windmill Lake be free from "aesthetically objectionable conditions." There are no numeric criteria associated with water clarity, therefore attainment of the standard is based on maintaining relatively good water clarity compared to other Iowa lakes. The primary metric for water quality standards attainment set forth in this TMDL is obtaining and maintaining a chlorophyll a TSI of no greater than 63, which corresponds to a chlorophyll-a concentration of 27 µg/L. IDNR will de-list the impairment if the chlorophyll-a TSI is 63 or less in two consecutive 303(d) listing cycles, per the methodology Iowa DNR uses to develop the Integrated Report.

Chapter 61.3(2) of the WQS contains the general water quality criteria, which are applicable to all surface waters. These narrative criteria require that waters be free from "aesthetically objectionable conditions." See Appendix B for more information on "General and Designated Uses of Iowa's Waters."

Due to Windmill Lake having algal and non-algal sources for the designated use impairment, water quality standard attainment must address both impairment sources. Phosphorus reduction will decrease Chl-a TSI as a limit of growth on algal blooms, and will increase Secchi depth TSI as TP reduction will result in a reduction of sediment to the lake as well. The target model in BATHTUB was set at achieving a chl-a TSI of 63 as shown in Table 3-7 below. The reduction to meet the algal impairment will also sufficiently lower the Secchi depth TSI below the impairment level to a value of 59.1 as shown below.

Table 3-7. Existing and target water quality (ambient monitoring location)

Parameter	2005-2012 Mean	[1]TMDL Target
Secchi Depth	0.5 m	1.1 m
TSI (Secchi Depth)	69.7	59.1
Chlorophyll-a	67.8 µg/L	27.1 µg/L
TSI (Chlorophyll-a)	72.0	63.0
TP	108.8 µg/L	58.6 µg/L
TSI (TP)	71.8	62.8

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

Compliance point for WQS attainment

The TSI target for listing and delisting of Windmill Lake is measured at the ambient monitoring location. Due Windmill Lake's smaller size, it was modeled as a single segment and the surrounding watershed was not divided (see Figure D-1, Appendix D). To maintain consistency with other Clean Water Act programs implemented by the Iowa DNR, the TMDL target is based on water represented by the ambient monitoring location in Windmill Lake.

Departure from load capacity

The target TP load, also referred to as the load capacity, for Windmill Lake is 290.6 lbs. per year. To meet the target loads, an overall reduction of 64 percent of the existing TP load of 805.8 lbs. per year is required. This will require BMPs in addition to those already implemented during previous watershed improvement efforts. The implementation plan included in Section 4 describes potential BMPs, potential TP reductions, and considerations for targeted selection and location of BMPs.

Allowance for increases in pollutant loads

There is no allowance for increased phosphorus loading included as part of this TMDL. There are no incorporated unsewered communities in the watershed. Therefore, it is unlikely that a future wasteload allocation (WLA) would be needed for a new point source discharge.

3.3. Pollutant Allocation

Wasteload allocation
There are no permitted point source dischargers of phosphorus or CAFOs in the Windmill Lake watershed. Therefore, the wasteload allocation (WLA) is zero.

Load allocation

Nonpoint sources to Windmill Lake include loads from agricultural land uses, septic systems and background sources in the watershed, including wildlife and atmospheric deposition (from dust and rain). Changes in agricultural land management and implementation of structural best management practices (BMPs) can reduce phosphorus loads and improve water quality in Windmill Lake. Changes in atmospheric inputs are impractical and would not reach the necessary load reduction to ensure attainment of WQS. Therefore, there are no recommendations to alter atmospheric inputs as part of any future implementation strategy.

The load allocation for this lake is:

Annual = LA 261.5 lbs. TP/year **TMDL (daily) =** LA 2.9 lbs. TP/day

Margin of safety

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

Annual = MOS 29.1 lbs. TP/year **TMDL (daily) =** MOS 0.3 lbs. TP-day

3.4. TMDL Summary

The following equation represents the total maximum daily load (TMDL) and its components for Windmill Lake:

TMDL = LC = ∑ WLA + ∑ LA + MOS

Where: TMDL = total maximum daily load
LC = loading capacity
∑ WLA = sum of wasteload allocations (point sources)
∑ 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 Windmill Lake watershed, the general equation above can be expressed for the Windmill Lake algae and non-algal turbidity TMDL.

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

Annual = LC = ∑ WLA (0 lbs.-TP/year) + ∑ LA (261.5 lbs.-TP/year)
+ MOS (29.1 lbs.-TP/year) = **290.6 lbs.-TP/year**

Expressed as the allowable maximum daily load as required by EPA (see Appendix F):

TMDL= LC = ∑ WLA (0 lbs.-TP/day) + ∑ LA (2.9 lbs.-TP/day)
+ MOS (0.3 lbs. TP-day) = **3.2 lbs.-TP/day**

4. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources (DNR) recognizes that technical guidance and support are critical to achieving the goals outlined in this Water Quality Improvement Plan (WQIP). Therefore, this general 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 represents a package of potential tools that will help achieve water quality goals if appropriately utilized. It is likely that only a portion of BMPs included in this plan will be feasible for implementation in the Windmill Lake watershed. Additionally, there may be potential BMPs not discussed that should be considered. This implementation plan should be used as a guide or foundation for detailed and comprehensive management/restoration plan development by local stakeholders.

Collaboration and action by residents, landowners, lake patrons, and local agencies will be essential to improve water quality in Windmill Lake and support its designated uses. Locally-driven efforts have proven to be the most successful in obtaining real and significant water quality improvements. Improved water quality in Windmill Lake results in economic and recreational benefits for people that live, work, and play 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 additional BMPs and land management changes in the watershed.

The primary focus of this implementation plan will be reducing phosphorus and sediment loads to remediate the aesthetically objectionable conditions. Successful phosphorus controls will reduce algal blooms in the lake. Reduction of sediment inputs will reduce the amount of phosphorus entering the lake as well as the non-algal turbidity.

4.1. General Approach & Reasonable Timeline

Watershed management and BMP implementation to reduce sediment and phosphorus inputs and subsequent algal blooms in the lake should utilize a phased approach to improving water quality. The preliminary phase(s) should consist of planning and implementation of watershed BMPs required to meet water quality standards (WQS). A reasonable timeline for long term watershed projects aimed at improving water quality is usually measured in years or decades and depends on stakeholder interest, availability of funds, landowner participation, and time needed for design and construction of any structural BMPs.

4.2. Watershed Best Management Practices

No stand-alone BMP will be able to sufficiently reduce nutrient loads to Windmill Lake. Rather, a comprehensive package of BMPs will be required to reduce sediment and phosphorus transport to the lake. The majority of phosphorus and sediment that enters the lake is from lands in corn and soybean production, and grazed lands. Each source has distinct sediment and phosphorus transport pathways; therefore, each requires different BMPs and strategies. 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.

Best management practices are dictated by landscape. The effectiveness of any practice is dependent on being installed within the right area and landuse. The soils and slopes of each ecoregion largely determine the erosion rates of soils in natural landscapes. Highly erodible land (HEL) is classified by the Natural Resource Conservation Service (NRCS) as land, which if used to produce an agricultural commodity, would have an excessive annual rate of erosion as determined by the Universal Soil Loss Equation (USLE). Figure 4-1 depicts the HEL lands within the Windmill Lake watershed and where these lands intersect with the cropland. 400 acres of the watershed are considered highly erodible. These areas should be considered high priority for the proper BMPs to reduce erosion.

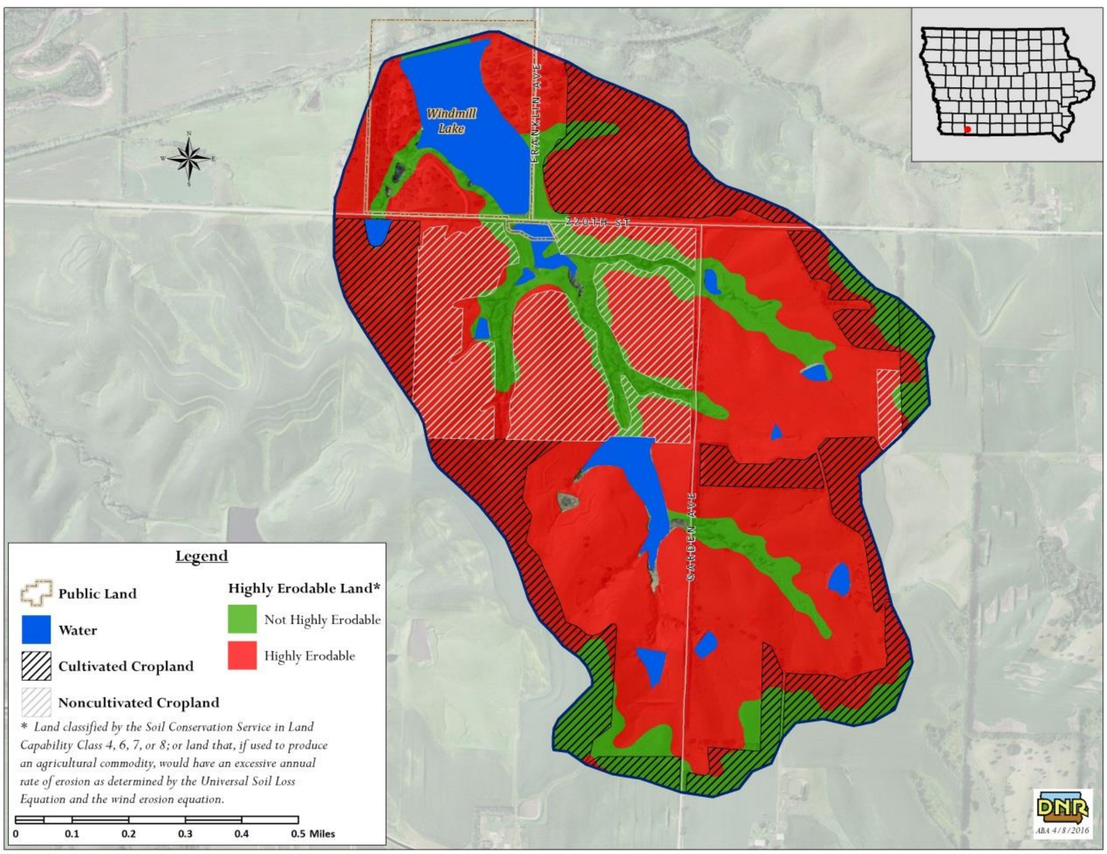

Figure 4-1. The highly erodible land within the Windmill Lake Watershed

Any BMPs placed with the Windmill Lake watershed will need to be regularly inspected for efficiency. Terraces need to be maintained and catchments need to be evaluated for reduced capacity and if they are effectively retaining phosphorus. Within the Windmill Lake watershed there are some small retention ponds and structures already constructed. However, communication with county conservation staff indicated that these have not been maintained and are effectively full. For modeling purposes, any existing structures were considered to have negligible impact on phosphorus loads to the lake. However, if they were restored and maintained, they could greatly reduce the phosphorus and sediment loads to the lake.

Potentially beneficial BMPs include additional terraces on high slopes, grass waterways and sediment control structures or wetlands. Other management practices could also be operational such as conservation tillage, perennial strips, cover crops, nutrient application strategies, and reducing livestock access to the tributary stream. Ultimately, a combination of structural and operational BMPs will yield the best results in reducing phosphorus. Tables 4-1 and 4-2 give more detailed information on structural and operational BMPs.

Table 4-1. Structural BMPs

BMP or Activity	Secondary Benefits	[1] Potential TP Reduction
Terraces	Soil conservation, prevent in-field gullies, prevent wash-outs	50%
[2]Sediment Control Structures	Some ecological services, gully prevention	85%
[3]Wetlands	Ecological services, potential flood mitigation, aesthetic value	20%

[1]Adopted from USDA-ARS (2004). Actual reduction percentages may vary widely across sites and runoff events.
[2] Reductions reported by Section 2:Nonpoint Source Nutrient Reduction Science Assessment (2012), Iowa Nutrient Reduction Strategy. Value assumes structures are sized/designed properly and routinely maintained.
[3]Note: TP reductions in wetlands vary greatly depending on site-specific conditions. Increasing surface area, implementing multiple wetlands in series, and managing vegetation can increase potential TP reductions

Table 4-2. Potential land management BMPs

BMP or Activity	[1] Potential TP Reduction
Conservation Tillage:	
Moderate vs. Intensive Tillage	50%
No-Till vs. Intensive Tillage	70%
No-Till vs. Moderate Tillage	45%
Cover Crops	50%
Diversified Cropping Systems	50%
In-Field Vegetative Buffers	50%
Phosphorus Nutrient Application Techniques:	
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%
Riparian Buffers	45%

[1]Adopted from USDA-ARS (2004). Actual reduction percentages may vary widely across sites and runoff events.
[2]Note: Tillage incorporation can increase TP in runoff.

4.3. In Lake Best Management Practices

Phosphorus recycled between the bottom sediment and water column of the lake can, at times, contribute bioavailable phosphorus to the water column. The average annual contribution of TP to the system from internal loading appears to be very small in Windmill Lake. 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, which are typically dry with low external loading

However, 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 Windmill Lake are of large enough magnitude to fully explain observed in-lake water quality. 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 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.

While not considered a significant source in this TMDL, shorelines in man-made reservoirs are subject to erosion from water level fluctuations and wave action. Assessing shorelines in spring and fall for eroding areas and stabilization with bio-engineering or hard armoring techniques may improve habitat and water clarity near the shoreline.

Descriptions of potential in-lake restoration methods are included in Table 4-3. Phosphorus reduction percentages of each alternative will vary and depend on a number of site-specific factors. It is 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 part of a comprehensive watershed management plan that includes practices that 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	[1]Relative TP Reduction
Targeted dredging	Targeted dredging in shallow inlet areas would create pockets of deep-water habitat for predatory fish that would help control rough fish populations. Strategic dredging would also increase the sediment capacity of the inlet areas, thereby reducing sediment loads to the larger, open water area of the lake	Med
In-Lake Dredging	Dredging is seldom cost-effective on a large scale and as a stand-alone measure; dredging should be focused on areas of known sediment deposition or to create deep-water habitat as part of fisheries management. A cost benefit analysis may be necessary to examine the feasibility of large-scale dredging in Windmill Lake.	Med-High
Shoreline stabilization (public areas)	Helps establish and sustain vegetation, which provides local erosion protection and competes with algae for nutrients. Cumulative effects of widespread stabilization projects can be beneficial. The entire shoreline of Windmill Lake is publicly owned, making this alternative possible in all areas of the lake.	Low

[1]Reductions (High/Med/Low) are relative to each other and based on numerous research studies and previous IDNR projects.

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 water quality improvements made in the watershed and document the status of the waterbody in terms of achieving Total Maximum Daily Loads (TMDLs) and Water Quality Standards (WQS).

Future monitoring in the Windmill Lake watershed can be agency-led, volunteer-based, or a combination of both. The Iowa Department of Natural Resources (IDNR) Watershed Monitoring and Assessment Section administers a water quality monitoring program, called IOWATER, that provides training to interested volunteers. More information can be found at the program web site: http://www.iowater.net/Default.htm

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

Failure to prepare an approved QAPP will prevent data collected from being used to assess a waterbody's status on the state's 303(d) list – the list that identifies impaired waterbodies.

5.1. Monitoring Plan to Track TMDL Effectiveness

Future data collection in Windmill Lake to assess water quality trends and compliance with water quality standards (WQS) is expected to include monitoring conducted as part of the Iowa DNR Ambient Lake Monitoring Program. Unless there is local interest in collecting additional water quality data, future sampling efforts will be limited to this basic monitoring program.

The Ambient Lake Monitoring Program was initiated in 2000 in order to better assess the water quality of Iowa lakes. Currently, 137 of Iowa's lakes are being sampled as part of this program, including Windmill Lake. Typically, one location near the deepest part of the lake is sampled, and many chemical, physical, and biological parameters are measured. Sampling parameters are reported in Table 5-1. At least three sampling events are scheduled every summer, typically between Memorial Day and Labor Day. While the ambient monitoring program can be used to identify trends in lake water quality, it does not lend itself to calculation of watershed loads, identification of individual pollutant sources, or the evaluation of BMP implementation.

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

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

5.2. Expanded Monitoring for Detailed Assessment and Planning

Data available from the Iowa DNR Ambient Lake Monitoring Program will be used to assess general water quality trends and WQS 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. Existing resources will not allow more detailed monitoring data to be collected by DNR. Only through the interest and action of local stakeholders will funding and resources needed to acquire this important information become available.

Table 5-2 outlines the detailed monitoring plan by listing the components in order, starting with the highest priority recommendations. While it is unlikely that available funding will allow collection of all recommended data, this expanded plan can be used to help identify and prioritize monitoring data needs.

Table 5-2. Expanded monitoring plan

Parameter(s)	Intervals	Duration	[1]Location(s)
Routine grab sampling for flow, sediment, P, algae and N	Every 1-2 weeks	April through October	Ambient and Tributaries
Continuous pH, DO, turbidity and temperature	15-60 minute	April through October	Ambient and Tributaries
Runoff event flow, TSS/ISS, P	Continuous flow, composite WQ	3 events between April and October	Tributaries

[1]Final location of tributary sites should be based on BMP placement, landowner permission, and access/installation feasibility.

Routine weekly or bi-weekly grab sampling with concurrent in-lake and tributary data (ambient location and tributaries in Figure 5-1) would help identify potential sources and hot spots in water quality and nutrient loading. Data collection should commence before additional BMPs are implemented in the watershed to establish baseline conditions. This data could form the foundation for assessment of general water quality trends; however, more detailed information will be necessary to evaluate loading processes, storm events, and reduce uncertainty. Therefore, routine grab sampling should be viewed only as a starting point for assessing trends in water quality.

Reliable long-term flow data is also important because hydrology drives many important processes related to water quality, including erosion and phosphorus transport. A good hydrologic data set will be necessary to evaluate the success of BMPs such as reduced-tillage, sediment control structures, terraces and grass waterways, riparian buffers, and wetlands.

If funding is available, lake managers should consider deploying a data logger at the ambient monitoring location and possibly in tributaries to measure pH, temperature, and dissolved oxygen (DO) on a continuous basis. This information will help answer questions about the causes and effects of algal blooms and will provide spatial resolution for evaluation of water quality in different areas of the lake. Routine grab sampling, described previously, should be coordinated with deployment of data loggers.

The proposed expanded / monitoring information would assist utilization of watershed and water quality models to simulate various scenarios and water quality response to BMP implementation. Monitoring parameters and locations should be continually evaluated. Adjustment of parameters and / or locations should be based on BMP placement, newly discovered or suspected pollution sources, and other dynamic factors. The Iowa DNR Watershed Improvement Section can provide technical support to locally led efforts in collecting further water quality and flow monitoring data in the Windmill Lake watershed.

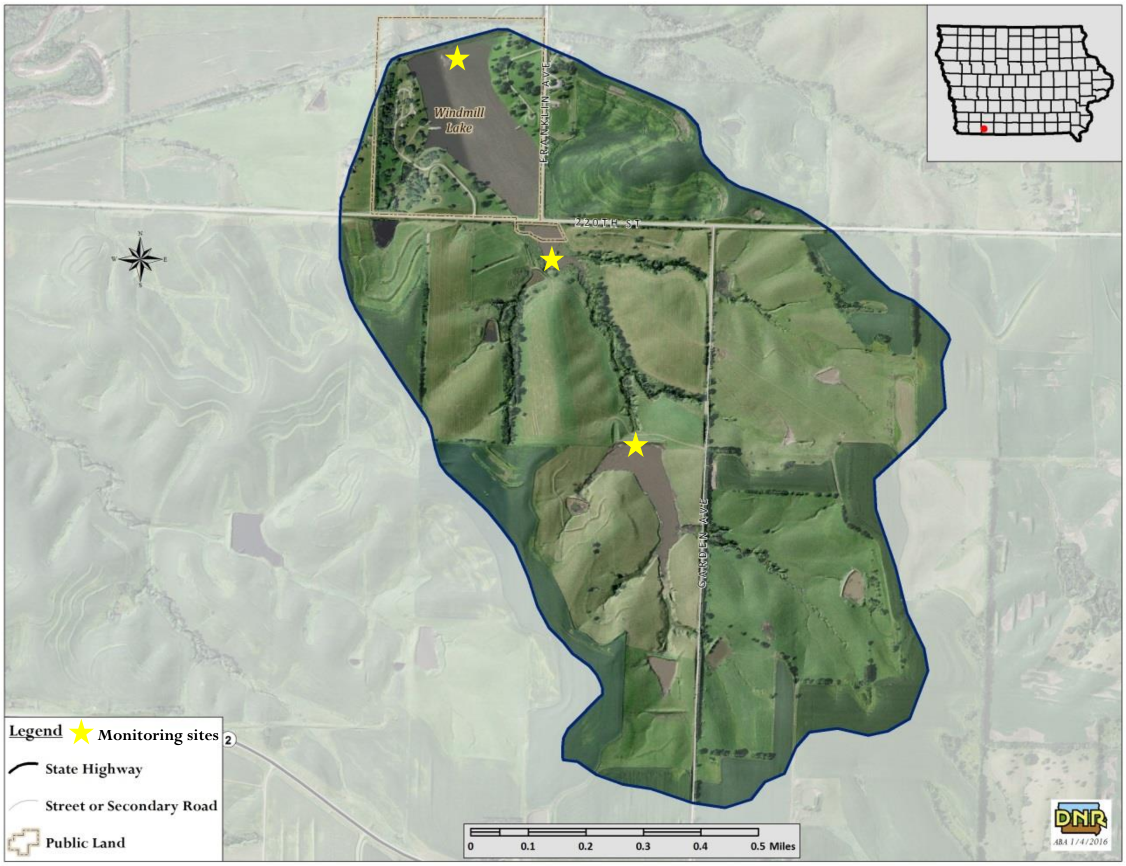

Figure 5-1. Potential monitoring sites for Windmill Lake

6. Public Participation

Public involvement is important in the Total Maximum Daily Load (TMDL) process since it is the land owners, tenants, and citizens who directly manage land and live in the watershed that determine the water quality in Windmill Lake. During the development of this TMDL, efforts were made to ensure that local stakeholders were involved in the decision-making process to agree on feasible and achievable goals for the water quality in Windmill Lake.

6.1. Public Meetings

A public meeting was held on April 7th, 2016 at the Bedford Fire House located at 702 Dodge Street, Bedford, IA. The meeting was held from 6:00 to 7:30 pm. Farmers and land owners were represented at the meeting, as were several local organizations and leaders including the Taylor County Soil and Water Conservation District commissioner, Taylor County Conservation Board members, Taylor County supervisors, and members of the Natural Resource Conservation Service (NRCS), and local news media.

6.2. Written Comments

A public comment period was initiated via a press release on March 24th, 2016. Comments were accepted until April 25th, 2016. IDNR received no public comments on the Windmill Lake TMDL.

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

303(d) list: Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface waterbodies (creeks, rivers, wetlands, and lakes) that do not support their general and/or designated uses. Also called the state's "Impaired Waters List."

305(b) assessment: Refers to section 305(b) of the Federal Clean Water Act, it is a comprehensive assessment of the state's public waterbodies' ability to support their general and designated uses. Those bodies of water which are found to be not supporting or only partially supporting their uses are placed on the 303(d) list.

319: Refers to Section 319 of the Federal Clean Water Act, the Nonpoint Source Management Program. Under this amendment, States receive grant money from EPA to provide technical & financial assistance, education, & monitoring to implement local nonpoint source water quality projects.

AFO: Animal Feeding Operation. A lot, yard, corral, building, or other area in which animals are confined and fed and maintained for 45 days or more in any 12-month period, and all structures used for the storage of manure from animals in the operation. Open feedlots and confinement feeding operations are considered to be separate animal feeding operations.

AU: Animal Unit. A unit of measure used to compare manure production between animal types or varying sizes of the same animal. For example, one 1,000 pound steer constitutes one AU, while one mature hog weighing 200 pounds constitutes 0.2 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 1000 animal units confined on site, or an AFO of any size that discharges pollutants (e.g. manure, wastewater) into any ditch, stream, or other water conveyance system, whether man-made or natural.
CBOD5:	5-day Carbonaceous Biochemical Oxygen Demand. Measures the amount of oxygen used by microorganisms to oxidize hydrocarbons in a sample of water at a temperature of 20°C and over an elapsed period of five days in the dark.
CFU:	A Colony Forming Unit is a cell or cluster of cells capable of multiplying to form a colony of cells. Used as a unit of bacteria concentration when a traditional membrane filter method of analysis is used. Though not necessarily equivalent to most probably number (MPN), the two terms are often used interchangeably.
Confinement feeding operation:	An animal feeding operation (AFO) in which animals are confined to areas which are totally roofed.

Credible data law:	Refers to 455B.193 of the Iowa Administrative Code, which ensures that water quality data used for all purposes of the Federal Clean Water Act are sufficiently up-to-date and accurate. To be considered "credible," data must be collected and analyzed using methods and protocols outlined in an approved Quality Assurance Project Plan (QAPP).
Cyanobacteria (blue-green algae):	Members of the phytoplankton community that are not true algae but are capable of photosynthesis. Some species produce toxic substances that can be harmful to humans and pets.
Designated use(s):	Refer to the type of economic, social, or ecological activities that a specific waterbody is intended to support. See Appendix B for a description of all general and designated uses.
DNR (or IDNR):	Iowa Department of Natural Resources.
Ecoregion:	Areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources based on geology, vegetation, climate, soils, land use, wildlife, and hydrology.
EPA (or USEPA):	United States Environmental Protection Agency.
Ephemeral gully erosion:	Ephemeral gullies occur where runoff from adjacent slopes forms concentrated flow in drainage ways. Ephemerals are void of vegetation and occur in the same location every year. They are crossable with farm equipment and are often partially filled in by tillage.
FIBI:	Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.
FSA:	Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.
General use(s):	Refer to narrative water quality criteria that all public waterbodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated uses.
Geometric Mean (GM):	A statistic that is a type of mean or average (different from arithmetic mean or average) that measures central tendency of data. It is often used to summarize highly skewed data or data

with extreme values such as wastewater discharges and bacteria concentrations in surface waters. In Iowa's water quality standards and assessment procedures, the geometric mean criterion for *E. coli* is measured using at least five samples collected over a 30-day period.

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

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

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

HEL: Highly Erodible Land. Defined by the USDA Natural Resources Conservation Service (NRCS), it is land, which has the potential for long-term annual soil losses to exceed the tolerable amount by eight times for a given agricultural field.

IDALS: Iowa Department of Agriculture and Land Stewardship

Integrated report: Refers to a comprehensive document that combines the 305(b) assessment with the 303(d) list, as well as narratives and discussion of overall water quality trends in the state's public waterbodies. The Iowa Department of Natural Resources submits an integrated report to the EPA biennially in even numbered years.

LA: Load Allocation. The portion of the loading capacity attributed to (1) the existing or future nonpoint sources of pollution and (2) natural background sources. Wherever possible, nonpoint source loads and natural loads should be distinguished. (The total pollutant load is the sum of the wasteload and load allocations.)

LiDAR: Light Detection and Ranging. Remote sensing technology that uses laser scanning to collect height or elevation data for the earth's surface.

Load: The total amount of pollutants entering a waterbody from one or multiple sources, measured as a rate, as in weight per unit time or per unit area.

Macrophyte: An aquatic plant that is large enough to be seen with the naked eye and grows either in or near water. It can be floating, completely submerged (underwater), or partially submerged.

MOS: Margin of Safety. A required component of the TMDL that accounts for the uncertainty in the response of the water quality of a waterbody to pollutant loads.

MPN: Most Probable Number. Used as a unit of bacteria concentration when a more rapid method of analysis (such as Colisure or Colilert) is utilized. Though not necessarily equivalent to colony forming units (CFU), the two terms are often used interchangeably.

MS4: Municipal Separate Storm Sewer System. A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) owned and operated by a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to state law) having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under state law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act (CWA) that discharges to waters of the United States.

Nonpoint source pollution: Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related either to land or water use including failing septic tanks, improper animal-keeping practices, forestry practices, and urban and rural runoff.

NPDES: National Pollution Discharge Elimination System. The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under Section 307, 402, 318, and 405 of the Clean Water Act. Facilities subjected to NPDES permitting regulations include operations such as municipal wastewater treatment plants and industrial waste treatment facilities, as well as some MS4s.

NRCS: Natural Resources Conservation Service (United States Department of Agriculture). Federal agency that provides technical assistance for the conservation and enhancement of natural resources.

Open feedlot: An unroofed or partially roofed animal feeding operation (AFO) in which no crop, vegetation, or forage growth or residue cover is maintained during the period that animals are confined in the operation.

Periphyton: Algae that are attached to substrates (rocks, sediment, wood, and other living organisms). Are often located at the bottom of a wetland, lake, or stream.

Phytoplankton: Collective term for all photosynthetic organisms suspended in the water column. Includes many types of algae and cyanobacteria.

Point source pollution: Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources are generally regulated by a federal NPDES permit.

Pollutant: As defined in Clean Water Act section 502(6), a pollutant means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.

Pollution: The man-made or man-induced alteration of the chemical, physical, biological, and/or radiological integrity of water.

PPB: Parts per Billion. A measure of concentration that is the same as micrograms per liter (µg/L).

PPM: Parts per Million. A measure of concentration that is the same as milligrams per liter (mg/L).

RASCAL: Rapid Assessment of Stream Conditions Along Length. RASCAL is a global positioning system (GPS) based assessment procedure designed to provide continuous stream and riparian condition data at a watershed scale.

Riparian: Refers to areas near the banks of natural courses of water. Features of riparian areas include specific physical, chemical, and biological characteristics that differ from upland (dry) sites.

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

municipal sewage prior to discharge to a waterbody according to the conditions of an NPDES permit.

SWCD: Soil and Water Conservation District. Agency that provides local assistance for soil conservation and water quality project implementation, with support from the Iowa Department of Agriculture and Land Stewardship.

TDS: Total Dissolved Solids: The quantitative measure of matter (organic and inorganic material) dissolved, rather than suspended, in the water column. TDS is analyzed in a laboratory and quantifies the material passing through a filter and dried at 180 degrees Celsius.

TMDL: Total Maximum Daily Load. As required by the Federal Clean Water Act, a comprehensive analysis and quantification of the maximum amount of a particular pollutant that a waterbody can tolerate while still meeting its general and designated uses. A TMDL is mathematically defined as the sum of all individual wasteload allocations (WLAs), load allocations (LAs), and a margin of safety (MOS).

Trophic state: The level of ecosystem productivity, typically measured in terms of algal biomass.

TSI (or Carlson's TSI): Trophic State Index. A standardized scoring system developed by Carlson (1977) that places trophic state on an exponential scale of Secchi depth, chlorophyll, and total phosphorus. TSI ranges between 0 and 100, with 10 scale units representing a doubling of algal biomass.

TSS: Total Suspended Solids. The quantitative measure of matter (organic and inorganic material) suspended, rather than dissolved, in the water column. TSS is analyzed in a laboratory and quantifies the material retained by a filter and dried at 103 to 105 degrees Celsius.

Turbidity: A term used to indicate water transparency (or lack thereof). Turbidity is the degree to which light is scattered or absorbed by a fluid. In practical terms, highly turbid waters have a high degree of cloudiness or murkiness caused by suspended particles.

UAA: Use Attainability Analysis. A protocol used to determine which (if any) designated uses apply to a particular waterbody. (See Appendix B for a description of all general and designated uses.)

USDA: United States Department of Agriculture

USGS: United States Geologic Survey (United States Department of the Interior). Federal agency responsible for implementation and maintenance of discharge (flow) gauging stations on the nation's waterbodies.

Watershed: The land area that drains water (usually surface water) to a particular waterbody or outlet.

WLA: Wasteload Allocation. The portion of a receiving waterbody's loading capacity that is allocated to one of its existing or future point sources of pollution (e.g., permitted waste treatment facilities).

WQS: Water Quality Standards. Defined in Chapter 61 of Environmental Protection Commission [567] of the Iowa Administrative Code, they are the specific criteria by which water quality is gauged in Iowa.

WWTF: Wastewater Treatment Facility. General term for a facility that treats municipal, industrial, or agricultural wastewater for discharge to public waters according to the conditions of the facility's NPDES permit. Used interchangeably with wastewater treatment plant (WWTP).

Zooplankton: Collective term for all animal plankton suspended in the water column which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

Scientific Notation

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

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

Here are some examples of scientific notation.

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

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

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

Introduction

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

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

General Use Segments

A general use segment water body is one which 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 which consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use water body, consult section 61.3(1) in the state's published water quality standards.

General use waters are protected for the beneficial uses listed above, which are: livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses. The criteria used to ensure protection of these uses are described in section 61.3(2) in the state's published water quality standards.

Designated Use Segments

Designated use segments are water bodies which maintain flow throughout the year, or at least hold pools of water which are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are a total of thirteen different designated use classes (Table B-1) which may apply, and a water body may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published water quality standards

Table B-1. Designated use classes for Iowa water bodies

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

Appendix C --- Water Quality Data

Table C-1. Water Quality Data for Windmill Lake from sampling 2005-2014

Date	Secchi (m)	Chlorophyll a (µg/L)	TP (µg/L)	TSS (mg/L)	TSI Secchi	TSI Chlorophyll a	TSI TP
6/1/05	1.4	28.50	67.39	28.80	55.1	63.5	64.9
6/14/05	1.4	17.00	60.00	6.00	55.1	58.4	63.2
6/28/05	1.0	53.64	74.37	10.50	59.3	69.7	66.3
7/12/05	0.5	80.00	110.00	24.00	70.0	73.6	71.9
8/2/05	0.2	507.68	168.81	36.00	81.5	91.7	78.2
9/13/05	0.3	180.00	200.00	25.00	77.4	81.5	80.6
5/2/06	1.0	5.00	80.00	4.00	60.0	46.4	67.3
6/6/06	0.7	39.00	80.00	12.00	65.1	66.5	67.3
7/11/06	0.3	97.00	170.00	24.00	77.4	75.5	78.2
8/29/06	0.3	78.00	190.00	16.00	77.4	73.3	79.8
10/3/06	0.4	83.00	130.00	23.00	73.2	73.9	74.3
5/22/07	0.8	14.00	130.00	10.00	63.2	56.5	74.3
7/31/07	0.2	300.00	170.00	43.00	83.2	86.6	78.2
9/11/07	0.4	21.00	220.00	9.00	73.2	60.5	81.9
5/6/08	1.2	3.00	70.00	7.00	57.4	41.4	65.4
7/9/08	0.6	54.00	110.00	14.00	67.4	69.7	71.9
6/9/09	0.3	13.00	107.50	48.30	77.4	55.8	71.6
7/14/09	0.3	41.00	92.80	35.20	77.4	67.0	69.5
8/10/09	0.6	31.00	68.30	17.30	67.4	64.3	65.1
6/14/10	0.2	33.72	135.18	35.00	83.2	65.1	74.9
8/2/10	0.3	57.80	93.94	21.50	77.4	70.4	69.7
9/15/10	0.4	26.06	78.90	22.00	74.0	62.6	67.1
6/14/11	0.2	44.40	101.55	58.85	83.2	67.8	70.8
8/8/11	0.4	53.76	82.15	21.80	75.1	69.7	67.7
9/12/11	0.4	50.82	89.77	31.33	72.2	69.1	69.0
6/12/12	0.6	32.26	54.80	17.60	67.9	64.7	61.9
7/31/12	0.3	95.60	121.10	23.42	78.4	75.3	73.3
9/12/12	0.3	46.91	145.55	36.66	76.0	68.4	76.0
6/11/13	0.5	5.80	87.23	25.50	70.6	47.8	68.6
7/30/13	0.4	42.53	53.10	23.20	71.8	67.4	61.4
9/10/13	0.6	49.04	64.05	16.60	68.6	68.8	64.1
6/16/14	0.3	22.88	87.30	43.40	80.0	61.3	68.6
8/5/14	0.4	74.64	95.80	22.50	72.2	72.9	69.9
9/16/14	0.3	11.63	113.40	43.33	80.0	54.7	72.4
Average	**0.5**	**67.5**	**108.94**	**24.70**	**69.6**	**71.9**	**71.8**

Appendix D --- Watershed Modeling Methodology

Watershed and in-lake modeling were used in conjunction with observed water quality data to develop the Total Maximum Daily Load (TMDL) for phosphorus as the primary cause for the algae and non-algal impairments to Windmill Lake in Taylor County, Iowa. The Spreadsheet Tool for Estimating Pollutant Load (STEPL), version 4.1, was utilized to simulate watershed hydrology and pollutant loading. In-lake water quality simulations were performed using BATHTUB 6.14, 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 Windmill Lake and its watershed. This section of the Water Quality Improvement Plan (WQIP) discusses the overall modeling approach, as well as the development of the STEPL watershed model.

D.1. 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 developed 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 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/or local soil and precipitation data. Precipitation inputs include average annual rainfall amount and rainfall correction factors that describe the intensity (i.e., runoff producing) characteristics of long-term precipitation.

Land use characteristics that affect STEPL estimates of hydrology and pollutant loading include land cover types, presence/population of agricultural animals, wildlife populations, population served by septic systems, and characteristics of 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.

D.2. Meteorological Input

Precipitation Data

The STEPL model includes a pre-defined set of weather stations from which the user must choose to obtain precipitation-related model inputs. For the purpose of Windmill Lake, data from the Bedford station for the 2005-2014 sampling period was selected. The Bedford weather station is 7 miles from Windmill Lake. While local variation in weather patterns might make this an unreliable source for short-term simulations, it is adequate for long-term average precipitation data. Annual average rainfall is 39.2 inches, which is a key input parameter for STEPL and BATHTUB. Default rainfall correction factors from the Lenox station (20 miles away) were used in the absence of sufficient data from the Bedford station to calculate these values.

D.3. Watershed Characteristics

The Windmill Lake watershed is only 532 acres in size and therefore not divided into smaller subbasins within the STEPL model (Figure D-1).

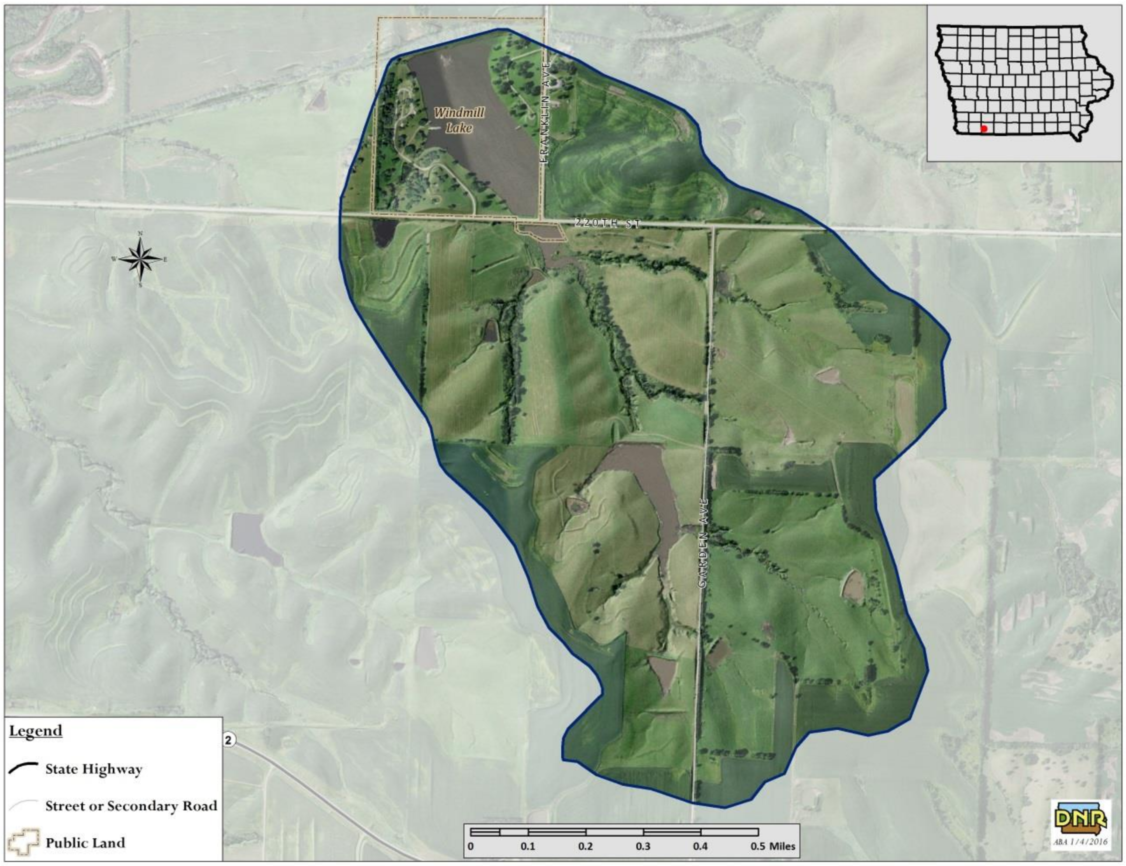

Figure D-1. Map of watershed used to develop STEPL model

Soils and Slopes and Curve Numbers

The hydrologic soil group (HSG) and the USLE K-factor are the critical soil parameters in the STEPL model. Watershed soils are predominantly HSG type B and C soils. Infiltration parameters were averaged between B and C classes to more accurately describe the watershed. USLE inputs were obtained from a previous RUSLE assessment completed for the Windmill Lake watershed.

USLE K-factors vary spatially and by land use. K-factors for each landuse and subwatershed are entered into the “Input” worksheet in the STEPL model. USLE land slope (LS) factors were obtained from a previous RUSLE assessment, and were entered under the sole subwatershed of the Windmill Lake watershed. The STEPL model includes default curve numbers (CN) selected automatically based on HSG and land use inputs. The STEPL default CN was left in place for other land uses.

Sediment Delivery Ratio

The total 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. By selecting to treat all subbasins as one watershed, STEPL will calculate a SDR for the entire watershed. The SDR for Windmill Lake was 0.3.

Existing BMPs

Although there are some small retention ponds within the watershed, communications with county conservation personnel indicated these ponds were full and not maintained. There are extensive uses of other practices such as contour farming, strip farming, and terraces within the Windmill Lake watershed.

D.4. Animals

Agricultural Animals and Manure Application

The STEPL model utilizes livestock type, livestock population data, manure production rates, and the amount of time (in months) that manure is applied to determine the nutrient runoff concentration in runoff from manure application areas. Nutrient loading from manure application is the resulting concentration multiplied by annual runoff volume.

Livestock

There are no confined animal feeding operations within the Windmill Lake watershed.

Wildlife

STEPL assumes that wildlife add to the manure deposited on the land surface in similar fashion to livestock. If animal densities are significant, nutrient concentration in runoff is increased. For Windmill Lake, an estimate of 20 geese, 8 deer, and 20 raccoons per square mile were used, based on conversation with Taylor County Conservation. These are likely over estimates of wildlife populations. Even with overestimates of geese, furbearers and deer populations, wildlife contributions are relatively insignificant (in terms of nutrient loading to the lake) and do not increase STEPL nutrient runoff parameters.

Landuse

Table D-1 provides the acres of landuse per watershed used to develop the STEPL model. The outputs of the model provided both a load to enter into BATHTUB and a breakdown of the TP input from land uses. This output suggests slightly less than sixty percent of the TP load comes from the row cropped regions. The row cropped lands in the HEL depicted in Section 4 should be of highest priority.

Table D-1. Subbasin landuse inputs for STEPL (acres)

Watershed	Urban	Cropland	Pastureland	Grassland	Feedlots
W1	20.8	223.7	232.7	34.1	0

The model was developed based on the average conditions observed from 2004 to 2014. No special consideration was given to wet or dry periods since relationships between precipitation and TSI values or chlorophyll a concentrations could not be established, and because long-term average annual loading is what drives eutrophication in this system.

D.5. Other Potential Sources

Septic Systems
Windmill Lake is a small watershed with no private home developments. The park adjacent to the lake has two pit toilets that are pumped out. Therefore, septic systems were not a consideration.

Runoff and Groundwater
STEPL default concentrations were used to calculate nutrient input from runoff and groundwater. For the user-defined grasslands (prairie or ungrazed), the best estimate was provided by using nutrient concentrations calculated from forestland. The groundwater inputs were added into each landuse as needed.

Appendix E --- In-Lake Water Quality Model

A combination of modeling software packages were used to develop the Total Maximum Daily Load (TMDL) for Windmill Lake. Watershed hydrology and pollutant loading was simulated using the Spreadsheet Tool for Estimating Pollutant Load (STEPL), version 4.1. STEPL model development was described in detail in Appendix D of this Water Quality Improvement Plan (WQIP).

In-lake water quality simulations were performed using BATHTUB 6.14, an empirical lake and reservoir eutrophication model. This appendix of the WQIP discusses development of the BATHTUB model. The integrated watershed and in-lake modeling approach allows the holistic analysis of hydrology and water quality in Windmill 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 (Chlorophyll a), and transparency. The model can distinguish between organic and inorganic forms of phosphorus and nitrogen, and simulates hypolimnetic oxygen depletion rates, if applicable / desired. Water quality predictions are based on empirical models that have been calibrated and tested for lake and reservoir applications (Walker, 1985).

E.2. Model Parameterization

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

Model Selections
BATHTUB includes several models for simulating in-lake nutrients and eutrophication response. For TP, TN, chlorophyll a, and transparency, Models 1 and 2 are the most general formulations, based upon model testing results.

Table E-1 reports the models selected for each parameter used to simulate eutrophication response in Windmill Lake. Preference was given to Models 1 and 2 during evaluation of model performance and calibration of the Windmill Lake model. Final selection of model type was based on applicability to lake characteristics, availability of data, and agreement between predicted and observed data. For Windmill Lake, models 1 and 2 produced the best calibrations based on data provided via in-lake sampling, with the exception of chlorophyll a, in which case model 5 resulted in the best calibration.

Table E-1. Model selections for Windmill Lake

Parameter	Model No.	Model Description
Total Phosphorus	01	2ND Order Avail P*
Total Nitrogen	00	Not computed*
Chlorophyll a	05	Jones & Bachman
Transparency	01	vs. Chlorophyll a & Turbidity *
Longitudinal Dispersion	01	Fischer-Numeric *
Phosphorus Calibration	01	Decay rates *
Nitrogen Calibration	01	Decay rates *
Availability Factors	00	Ignore *

* Asterisks indicate BATHTUB defaults

Global Variables

Global input data for Windmill 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 Windmill Lake.

Table E-2. Global variables data for 2004-2014 simulation period

Parameter	Observed Data	BATHTUB Input
Averaging Period	Annual	1.0 year
Precipitation	39.2 in	0.998 m
Evaporation	31.36 in	0.800 m
[1]Increase in Storage	0	0
[2]Atmospheric Loads:		
TP	0.3 kg/ha-yr	30 mg/m^2-yr
TN	11 kg/ha-yr	1,100 mg/m^2-yr

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

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. Due to the small size and uniform shape and depth of Windmill Lake, only one segment was used. Water quality data was analyzed to determine there is no hypolimnetic layer in the lake and complete mixing takes place.

The BATHTUB model developed for Windmill Lake does not simulate dynamic conditions associated with storm events or even between individual growing seasons. Rather, the model predicts the water quality period of 2005-2014. Observed water quality data for the lake is included in Appendix C – Water Quality Data. Table E-3 lists BATHTUB segment inputs for Segment 1 and Table E.4 lists tributary inputs.

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 Windmill Lake BATHTUB models 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. STEPL output requires conversion into forms compatible with BATHTUB. This includes unit conversion and converting STEPL nutrient loads and flows.

Table E-3. Segment 1 inputs

Parameter	Segment 1
Surface Area (km2)	0.097
Mean Depth (m)	2.26
Length (km)	0.53
Mixed layer Depth (m)	2.26
Non-Algal Turbidity (1/m)	0.26
Total Phosphorus (µg/L)	108.9
Chlorophyll a (µg/L)	67.5
Internal Load P (mg/mg2-day)	0

Table E-4. Tributary inputs for BATHTUB

Tributary	Area (km^2)	Flow (hm^3/yr)	TP (µg/L)
Trib 1	2.15	0.955	379.7

E.3. Model Performance and Calibration

The Windmill Lake water quality model was 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 State Hygienic Laboratory (SHL) between 2005 and 2014. 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, and (2) provide good agreement with observed water quality in Windmill Lake. Performance of the BATHTUB model was assessed by comparing predicted water quality with observed data collected in Windmill Lake from 2005 to 2014 in segment 1 of the BATHTUB model. Simulation of TP concentration was critical for

TMDL development, as were chlorophyll a and transparency predictions. The observed data is reported in Appendix C. Table E-5 reports model coefficients used in calibration.

Table E-5. Model Calibration Coefficients

Model Coefficients	Mean	CV
Dispersion Rate	1.00	0.70
Total Phosphorus	1.33	0.45
Chlorophyll a Model	0.88	0.26
Secchi Model	1.00	0.10

E.4. BATHTUB Target Assessment

After calibration the BATHTUB model was used to determine the water quality target. This was done by incrementally reducing loads of TP in all tributaries until the desired Chlorophyll a TSI of 63 was achieved. This is expressed as an annual load and a daily maximum via a statistical approach described in Appendix F.

The model assumes a uniform reduction in loads of all sources. In reality there would be many combinations of practices and pathways to achieve this goal and would most likely not be accomplished by trying to cut 64 percent of the load across all sources equally. In fact, that is most likely not possible. The best approach would be to target the highest contributing sources as discussed in Section 3 of this report and systematically treat watershed based sources. Figure E-2 below provides the load response curve for TSI chlorophyll-a with total Phosphorus loads. This curve predicts reductions in TP will lead to a reduction in chlorophyll-a leading to an overall better water clarity for Windmill Lake.

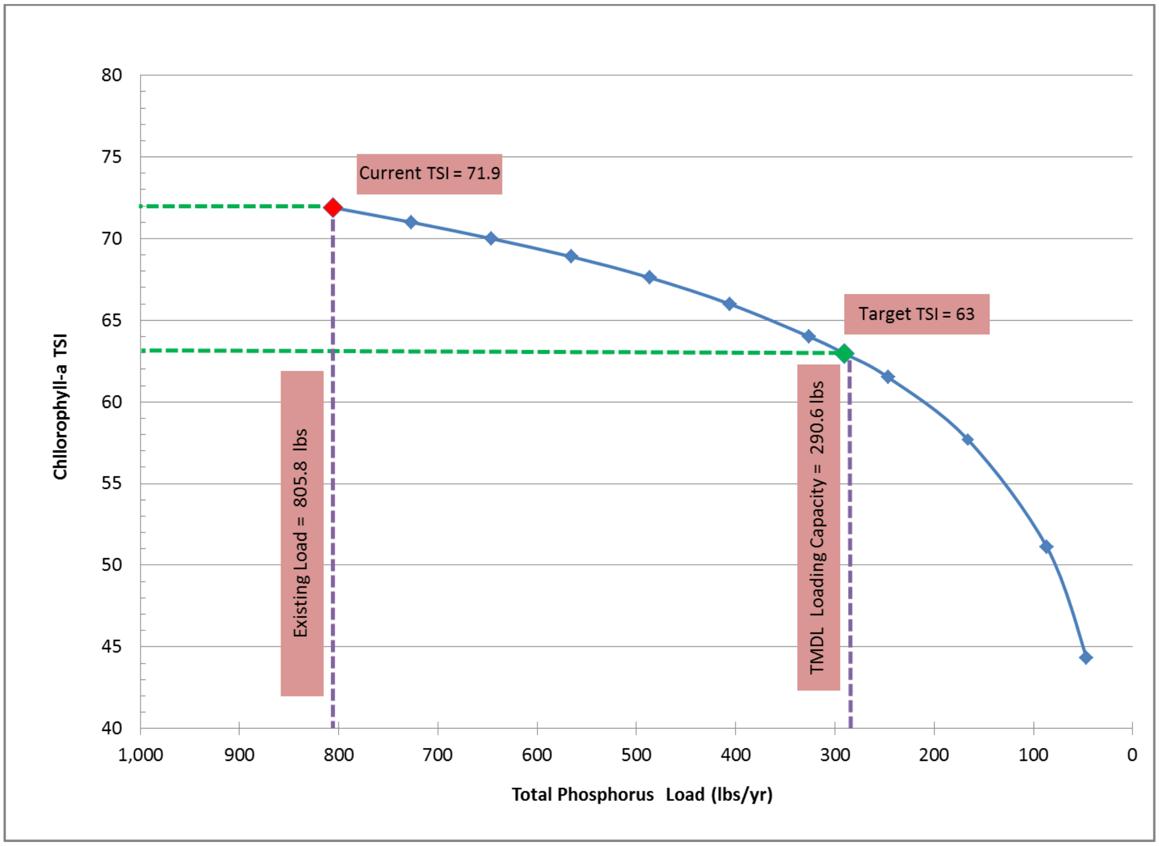

Figure E-1. The load response relationship between TSI chlorophyll a and total P as predicted by BATHTUB

Appendix F --- Establishing 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 recommendations, the loading capacity of Windmill 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 257.9 lbs. per year.

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

The Options for Expressing Daily Loads in TMDLs document presents a similar case study in which a statistical approach is considered an option for identifying a maximum daily load (MDL) that corresponds to the allowable annul 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
σ2 = ln(CV2 + 1)
CV = coefficient of variation

The allowable annual average of 290.6 lbs. /year is equivalent to a long-term average (LTA) daily of 0.8 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 a MDL. The 365-day averaging period equates to a recurrence interval of 99.7 percent and corresponding z-statistic of 2.778, as reported in Table F-1. The coefficient of variation

(CV) is the ratio of the standard deviation to the mean. However, there is insufficient data to calculate a CV as it relates to TP loads to the lake, because the models are based on annual averages over several years. In cases where data necessary for calculating a CV is lacking, EPA recommends using a CV of 0.6 (EPA, 1991). The resulting σ^2 value is 0.31. This yields a TMDL of 3.2 lbs./day. This is without the applied MOS of 10 percent. The TMDL calculation is summarized in Table F-2.

Because there are no permitted/regulated point source discharges in the watershed, the WLA is zero. An explicit MOS of 10 percent is applied. The resulting TMDL, expressed as a daily maximum, is:

TMDL = LC = ∑ WLA (0 lbs.-TP/day) + ∑ LA (2.9 lbs.-TP/day)
+ MOS (0.3, explicit 10 percent) = **3.2 lbs.-TP/day**

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

Averaging Period (days)	Recurrence Interval	Z-score	Coefficient of Variation								
			0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
30	96.8%	1.849	1.41	1.89	2.39	2.87	3.30	3.67	3.99	4.26	4.48
60	98.4%	2.135	1.50	2.11	2.80	3.50	4.18	4.81	5.37	5.87	6.32
90	98.9%	2.291	1.54	2.24	3.05	3.91	4.76	5.57	6.32	7.00	7.62
120	99.2%	2.397	1.58	2.34	3.24	4.21	5.20	6.16	7.05	7.89	8.66
180	99.4%	2.541	1.62	2.47	3.51	4.66	5.87	7.06	8.20	9.29	10.3
210	99.5%	2.594	1.64	2.52	3.61	4.84	6.13	7.42	8.67	9.86	11.0
365	99.7%	2.778	1.70	2.71	4.00	5.51	7.15	8.83	10.5	12.1	13.7

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

Parameter	Value	Description
LTA	2.2	Annual Average
Z Statistic	2.778	Based on 365-day averaging period
CV	0.6	Used CV from annual TP loads
σ^2	0.31	ln (CV^2 + 1)
MDL	**3.2 lbs./day**	**TMDL expressed as daily load**

Appendix G --- Public Comments

The Iowa Department of Natural Resources (IDNR) received no public comments on the Windmill Lake TMDL.