Water Quality Improvement Plan
for

Black Hawk Lake

Sac County, Iowa

Total Maximum Daily Load
for Algae and Turbidity

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Watershed Improvement Section
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General Report Summary

What is the purpose of this report?

This report serves multiple purposes. First, it is a resource for guiding locally-driven water quality improvements in Black Hawk Lake. Second, it satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) report for impaired waterbodies. Black Hawk Lake is an important water resource for many Iowans. As an impaired waterbody, it is eligible for financial assistance to improve water quality. This document is meant to help guide watershed improvement efforts to remove Black Hawk Lake from the federal 303(d) list of impaired waters.

What's wrong with Black Hawk Lake?

Black Hawk Lake is not supporting its Class A1 (primary contact recreation) designated use. Primary contact recreation includes activities that involve prolonged and direct human contact with the water such as swimming, wading, and water skiing. Poor water transparency caused by algae and turbidity, which violates the narrative water quality criterion for surface water to be free of "aesthetically objectionable conditions," is preventing the primary contact recreation use from being fully supported.

(Note: In addition to algae and turbidity, E. coli levels, which may indicate the presence of potentially harmful bacteria and viruses (also called pathogens), have occasionally impaired recreation in Black Hawk Lake. The bacteria impairment is marginal, and phosphorus reduction measures (discussed in Section 4 of this report), in combination with control of the waterfowl population at the swimming beach, will likely result in removal of this impairment. Water quality improvement activities will be implemented as part of a long-term watershed management plan, which is already under development. Therefore, a numeric E. coli limit will not be developed at this time. If implementation of the watershed management plan fails to correct the bacteria problem, a bacteria TMDL will be developed at a later date.)

What is causing the problem?

Pollutants that affect water quality, such as sediment, nutrients, and bacteria, can originate from point or nonpoint sources, or a combination of both. Point sources of pollution are easily identified sources that enter a stream or lake at a distinct location, such as a wastewater treatment outfall. Nonpoint sources of pollution are discharged in a more indirect and diffuse manner, and often are more difficult to locate and quantify. Nonpoint source pollution is usually carried with rainfall or snowmelt over the land surface and into a nearby lake or stream. The area of land that drains to a lake or stream is called a watershed. Watershed runoff often carries nonpoint source pollution that degrades water quality.

The City of Breda, in Carroll County, operates a wastewater treatment facility, which is the only permitted point source discharger of pollution to Black Hawk Lake. The vast majority of sediment and nutrients in the lake come from nonpoint sources including wildlife, livestock, cropland, pets, and humans that live, work, and play in and around the lake.

What can be done to improve Black Hawk Lake?

To improve the water quality and overall health of Black Hawk Lake, the amount of phosphorus entering the lake must be reduced. A combination of land and animal management practices must be implemented on public and private lands in the watershed to obtain required reductions. Reducing nutrient loss from row crops through better timing and methods of manure and fertilizer application, increasing use of conservation tillage methods, and implementing structural BMPs such as terraces, grass waterways, and constructed wetlands in strategic locations will significantly reduce pollutant loading to the lake. Elimination of direct stream access by grazing livestock, implementation of urban stormwater BMPs, increasing sediment capacity of Provost Slough, targeted in-lake dredging, and fishery management/restoration will also improve water quality in the lake. Preventing waterfowl from gathering at the beach and ensuring septic systems throughout the watershed are functioning properly will also benefit water clarity and reduce bacteria inputs to the lake.

Who is responsible for a cleaner Black Hawk Lake?

Everyone who lives, works, or plays in the Black Hawk Lake watershed has a role in water quality improvement. Because phosphorus loads from the sole regulated point source (Breda wastewater lagoon) are relatively small, voluntary management of land and animals will be required to see positive results. Much of the land draining to the lake is in agricultural production, and financial assistance is available from government agencies to individual landowners willing to adopt best management practices (BMPs). Homeowners can have their septic systems inspected to ensure they function properly. The Iowa Department of Natural Resources (IDNR) can embark on a combination of in-lake restoration alternatives to increase water clarity of the lake. Improving water quality in Black Hawk Lake will require a collaborative effort of citizens and agencies with a genuine interest in protecting the lake now and in the future.

Technical Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Black Hawk Lake, Waterbody ID IA 04-RAC-00475-L_0, located in S35, T87N, R36W, at Lake View in Sac County
Surface water classification and designated uses:	A1 – Primary contact recreation B(LW) – Aquatic life (lakes/wetlands) HH – Human health (fish consumption)
Impaired beneficial uses:	A1 – Primary contact recreation
TMDL priority level:	High
Identification of the pollutants and applicable water quality standards (WQS):	Carlson’s Trophic State Indices (TSI) for total phosphorus, chlorophyll-a, and Secchi depth place Black Hawk Lake in the hypereutrophic range, with very poor water transparency. This violates the narrative water quality criterion for “aesthetically objectionable conditions” per Iowa’s water quality standards.
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of WQS:	The algae and turbidity impairments are attributed to total phosphorus (TP). The allowable average growing season TP load = 9,366 lbs/season; the maximum daily TP load = 219 lbs/day.
Quantification of the amount or degree by which the current pollutant loads in the waterbody, including the pollutants from upstream sources that are being accounted for as background loading, deviate from the pollutant loads needed to attain and maintain WQS:	The existing growing season load of 42,620 lbs/season must be reduced by 33,254 lbs/season to meet the allowable TP load. This is a reduction of 78.0 percent.
Identification of pollution source categories:	The Breda Sewage Treatment Plant (STP) is the only permitted point source discharger of phosphorus in the watershed. Nonpoint sources of phosphorus include fertilizer and manure from row crops, sheet and rill erosion, cattle in streams, livestock grazing, waterfowl, other wildlife, septic systems, atmospheric deposition, and others.

Wasteload allocations (WLAs) for pollutants from point sources:	The Breda STP is receiving a growing season TP WLA of 936 lbs/season, which equates to a 37 lb/day maximum daily load during the growing season.
Load allocations (LAs) for pollutants from nonpoint sources:	The allowable growing season average TP LA is 7,493 lbs/season, and the allowable maximum daily LA is 160 lbs/day.
A margin of safety (MOS):	An explicit MOS of 10 percent is used for TMDL calculations. This is equivalent to 937 lbs/season and 22 lbs/day.
Consideration of seasonal variation:	The TMDL is based on growing season TP loading (April to September). Although daily maximum loads are provided to address legal uncertainties, the average growing season loads are critical to in-lake water quality and lake/watershed management decisions.
Reasonable assurance that load and wasteload allocations will be met:	For the Breda STP, reasonable assurance is provided through the NPDES permit. For nonpoint sources, reasonable assurance is provided by: (1) development of a comprehensive watershed management plan that addresses the pollutant of concern, (2) local stakeholders already planning for implementation, (3) development of detailed requirements for watershed planning to ensure that 319 applications meet EPA requirements, and (4) ongoing monetary support for nonpoint source pollution reduction. See Section 3.4 for more detailed discussion of reasonable assurance.
Allowance for reasonably foreseeable increases in pollutant loads:	Because there are no urbanizing areas in the watershed and significant land use change is unlikely, there is no allowance for reasonably foreseeable increases in pollutant loads.

Implementation plan:	An implementation plan is outlined in Section 4 of this Water Quality Improvement Plan. Phosphorus loading and the associated impairments will be addressed through an NPDES permit WLA for the Breda STP and a variety of voluntary land use, livestock, manure application, and erosion control strategies.

1. Introduction

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

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

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

One purpose of this Water Quality Improvement Plan (WQIP) for Black Hawk Lake, located in Sac County in northwest Iowa, is to serve as the TMDL for algae and turbidity impairments to water clarity. The second purpose of the plan is to provide local stakeholders and watershed managers with a tool to promote awareness of water quality issues, assist the development of a comprehensive watershed management plan and subsequent applications for funding, and guide implementation of water quality improvement projects. Algae and turbidity, which impair primary contact recreation in the lake, are addressed collectively by development of total phosphorus (TP) limits in the TMDL.

The 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 meet its designated uses. The allowable amount of pollutant that the lake can receive is the loading capacity, also called the TMDL target load. The plan also includes a description of potential solutions to the water quality problems. This group of solutions is more precisely defined as a system of best management practices (BMPs) that will improve water quality in Black Hawk Lake, with the ultimate goal of meeting water quality standards and supporting designated uses. These BMPs are outlined in the implementation plan in Section 4.

(Note: Indicator bacteria, specifically Escherichia coli (E. coli), occasionally prevent Black Hawk Lake from meeting its primary contact recreation designated use. The bacteria impairment is marginal, and it is likely that implementation of alternatives described in the implementation plan of this document, and in the comprehensive watershed improvement plan under development by local stakeholders, will result in compliance with bacteria standards. Therefore, a TMDL for E. coli is not being prepared at this time.)

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 will help ensure gradual 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 WQIP will be of little value to water quality improvement unless 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 WQIP for stakeholder use and is committed to providing ongoing technical support for the improvement of water quality in Black Hawk Lake.

2. Description and History of Black Hawk Lake

Black Hawk Lake is a natural lake that borders the east edge of the City of Lake View, located in Sac County in northwest Iowa (Figure 2-1). The Iowa Department of Natural Resources (IDNR) maintains and operates Black Hawk State Park and Black Hawk Wildlife Management Area, both adjacent to the lake. Two parks owned and operated by the City of Lake View, Speaker Park and Crescent Beach Park, are also adjacent to the lake. IDNR identified Black Hawk Lake as a major recreational area based on factors such as visitation rates, campground use, and population within a 50-mile radius of the lake. The Center for Agricultural and Rural Development (CARD) at Iowa State University estimates that between 2002 and 2005, Black Hawk Lake averaged over 146,000 annual visitors. Those visitors spent an average of $19 million per year, which supported 379 jobs and $5.1 million of labor income in the region (CARD, 2008).

Table 2-1 lists some of the general characteristics of Black Hawk Lake and its watershed, as it exists today. Estimation of physical characteristics such as surface area, depth, and volume are based on the bathymetric survey conducted by IDNR in 2006.

Table 2-1. Black Hawk Lake watershed and lake characteristics.

IDNR Waterbody ID	IA 04-RAC-00475-L_0
12-Digit Hydrologic Unit Code (HUC)	071000060401
12-Digit HUC Name	Wall Lake Inlet
Location	Sac County, S35, T87N, R36W
Latitude	42° 18’ N
Longitude	95° 1' W
Designated Uses	A1 – Primary contact recreation B(LW) – Aquatic life (lakes and wetlands) HH – Human health (fish consumption)
Tributaries	Carnarvon Creek, unnamed tributaries
Receiving Waterbody	Unnamed stream to Indian Creek to North Raccoon River
Lake Surface Area	922 acres (main lake = 760; inlet slough = 162)
Maximum Depth	15.1 feet (main lake)
Mean Depth	5.97 feet (main lake)
Lake Volume	4,487.7 acre-feet (main lake)
Length of Shoreline	11.4 miles (60,134 feet)
Watershed Area	13,156 acres (excludes lake and inlet slough)
Watershed:Lake Ratio	14.3:1
Lake Residence Time	86 days (2005-08 growing season average.) 133 days (2005-08 annual average)

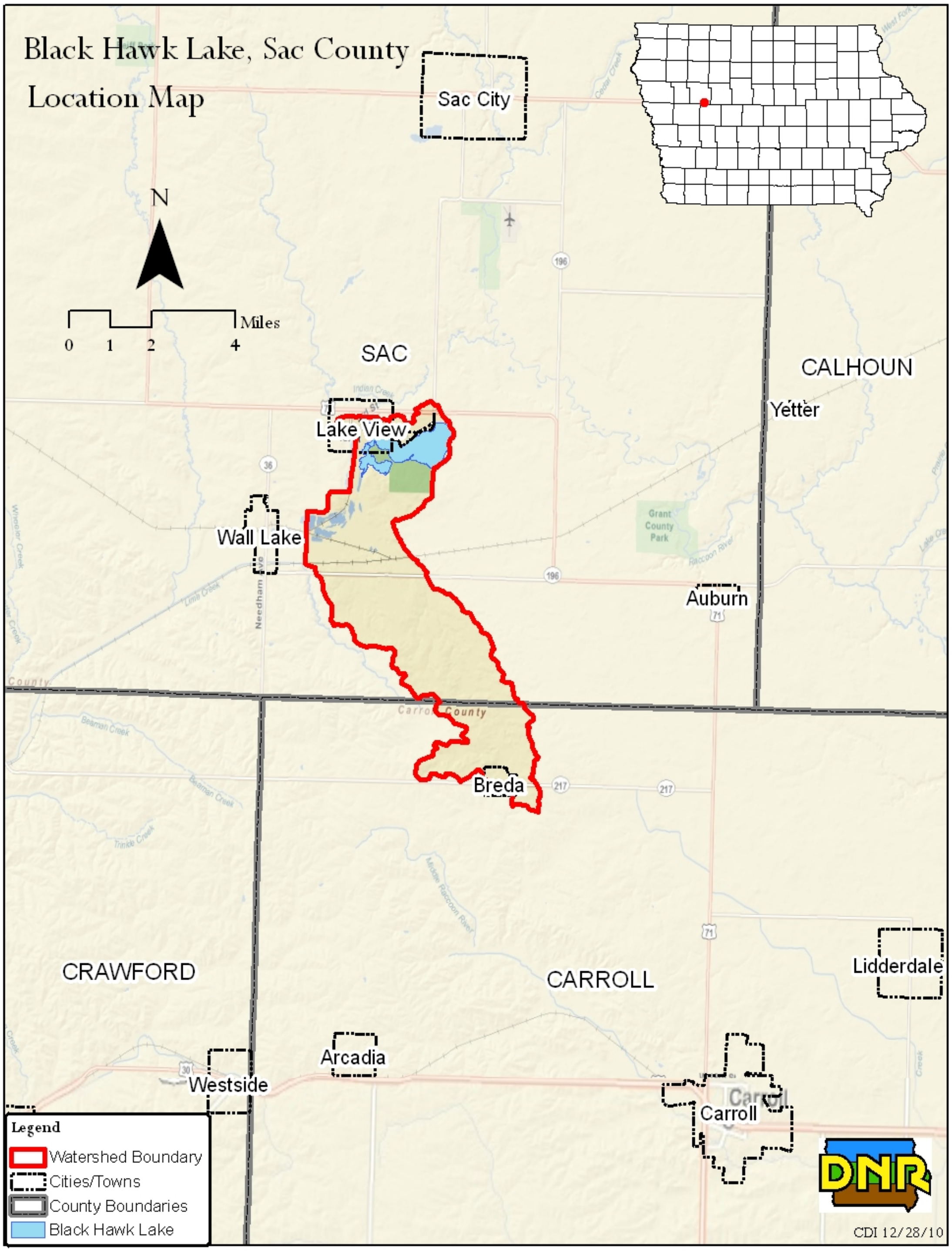

Figure 2-1. Watershed location map.

Black Hawk Lake has been known by at least three other names since European settlers first arrived in the area (Hanson, 1983). Prior to the Louisiana Purchase, the lake was referred to as Boyer Lake. By 1850, the name had been changed to Walled Lake and later to Wall Lake. Wall Lake became known as Black Hawk Lake in the 1930s, and the lake bears this name today. However, the twelve-digit Hydrologic Unit Code (HUC-12) name in the IDNR GIS coverage remains "Wall Lake Inlet". Black Hawk Lake has been the subject of much study in the past century, and restoration efforts date back to the 1930s.

2.1. Black Hawk Lake

Hydrology
Black Hawk Lake is a natural lake that lies within the North Raccoon River HUC-8 and Indian Creek – North Raccoon River HUC-10. It is the southern-most glacial lake in the State of Iowa (Hanson, 1983 and Shetye, 1991). The lake does have a man-made outlet structure, which was constructed to safely release water and eliminate low land flooding at the east end of the lake during high water (Bachman et. al., 1983). The date of construction of the current dam is unknown, but a historical narrative suggests that some type of dam existed prior to 1893 (Hanson, 1983). The original outlet structure was removed to protect Lake View from flooding, but a new dam was later rebuilt. Major surface water inflows include one major inflow stream, Carnarvon Creek, and several small unnamed tributaries to Carnarvon Creek. Local overland flow also enters the lake through storm sewers and tile drains. The lake outlet discharges over a 38-foot long semi-circular concrete dam, with a spillway crest elevation of 1,220.50 feet (NGVD 1929). Figure 2-2 shows a photograph of the spillway, taken upstream of the road culvert through which discharge flows into an unnamed outlet stream. Outflows travel east and then north for approximately six miles in this unnamed stream before discharging to Indian Creek and eventually the North Raccoon River, which flows south toward Des Moines.

Figure 2-2. Discharge spillway at the east end of Black Hawk Lake.

In addition to runoff and surface water inflow, direct precipitation and groundwater are part of the lake's hydrologic system. Like all natural lakes, groundwater plays an important role in the hydrology of Black Hawk Lake. In a study of the water budget of several Iowa lakes, Hanson (1983) estimated that on average, groundwater accounted for approximately 80 percent of the inflow to Black Hawk Lake from 1970 to 1982. The overall water balance during the 11-year study period was positive, meaning that inflows exceeded evaporation and seepage losses. Data for 1976 and 1977, two of the driest years on record, were not available for Hanson's study. This certainly influenced the study findings, and it is likely that groundwater contributions were negligible, or even negative, during these two years. The overall water balance estimations would not have been as positive if data from 1976 and 1977 would have been available (Bachman et al., 1983). Hydraulic residence times reported in Table 2-1 are based on simulated hydrology (2005-08) using a calibrated SWAT model and a water balance calculated using the BATHTUB model. No physical measurement of residence time is available. Calculation of residence time based on average annual 2005-2008 outflow (estimated using a rating curve) and the lake volume reported in Table 2-1 is 118 days, which is comparable to the 133 days simulated using the watershed and in-lake models.

There are four National Weather Service (NWS) COOP stations within 23 miles of Black Hawk Lake for which daily precipitation data is available through the Iowa Environmental Mesonet (IEM). Station locations in order of closest proximity are Sac City (12.3 miles), Carroll (14.9 miles), Denison (21.4 miles), and Rockwell City (22.7 miles). Daily changes in lake stage were correlated to observed daily precipitation from each of the individual stations, to available NEXRAD data, and to areal average daily precipitation calculated using the Thiessen polygon method. Application of the Thiessen polygon method results in area-weighted precipitation based only on the Sac City and Carroll stations (i.e., the calculation eliminates the more distant Denison and Rockwell City stations). The Thiessen polygon precipitation data has the strongest correlation to the daily change in lake stage.

Weather station information is provided in Table 2-2. A map of the precipitation gages is shown in Figure 2-3. Figure 2-4 shows the annual precipitation amounts at both gages from 1997-2009, along with the Thiessen polygon average for the entire period (31.8 inches).

Table 2-2. Weather station information for Sac City and Carroll, Iowa.

IEM Station ID	IA7312	IA1233
Station Name	Sac-City	Carroll-2-SSW
Latitude	42.43	42.07
Longitude	-95.00	-94.85
Average Water Year Precipitation (1997-2009)	31.7 inches	32.4 inches

Source (IEM, 2010)

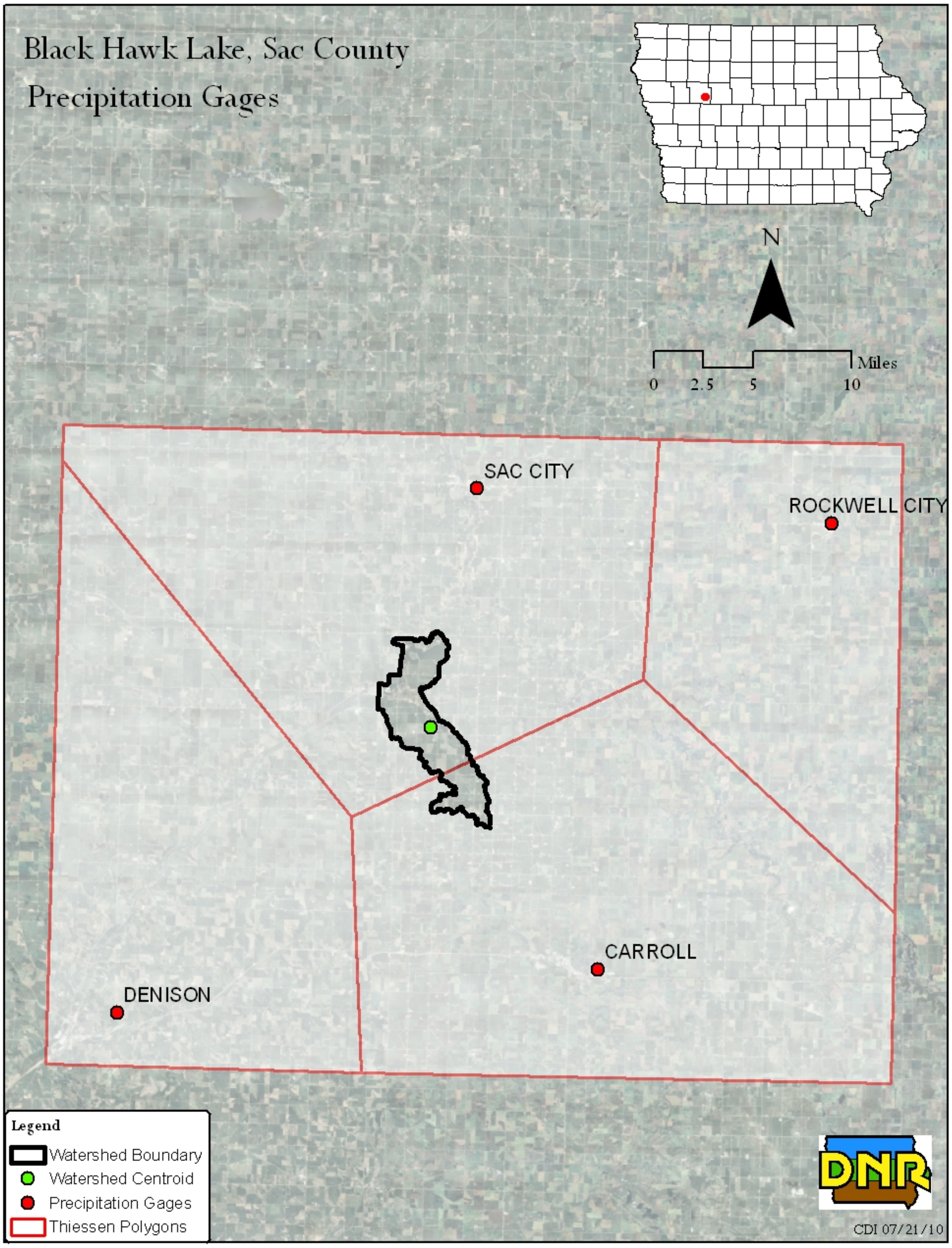

Figure 2-3. Map of nearby precipitation gages and Thiessen polygon.

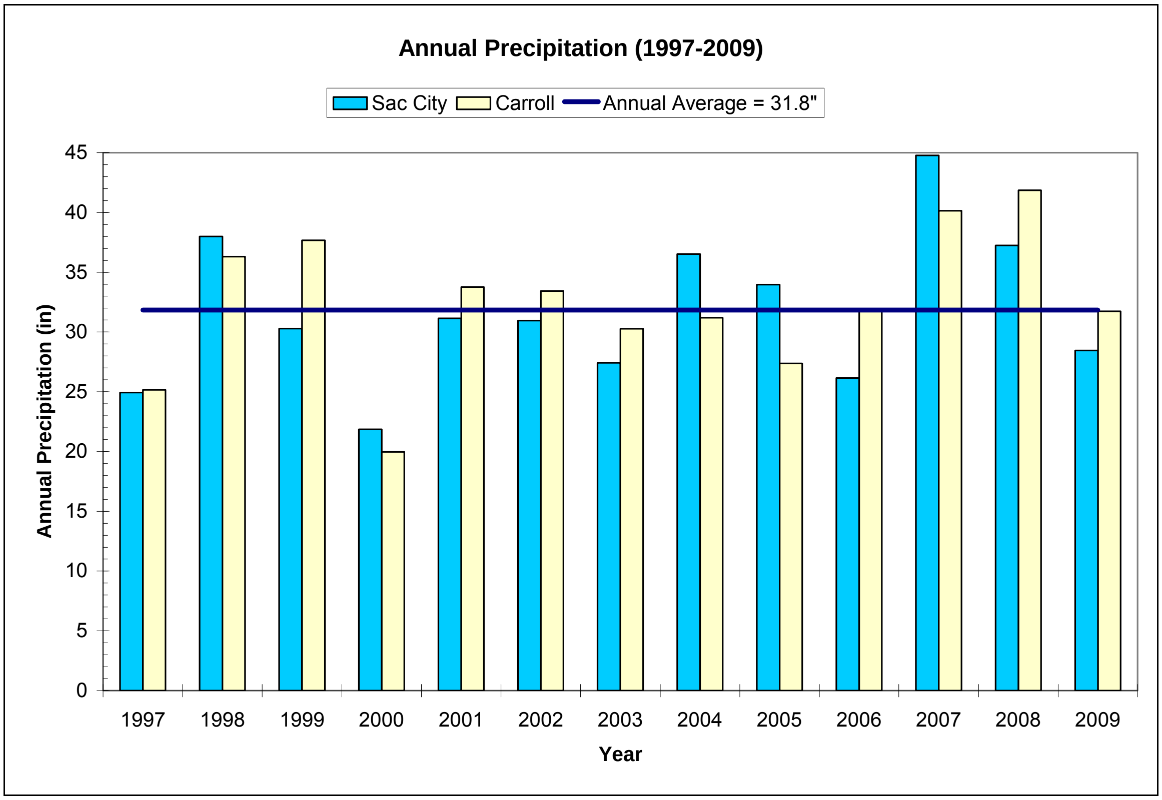

Figure 2-4. Annual water year precipitation at Sac City and Carroll, Iowa.

The United States Geological Survey (USGS) maintains a water stage recorder in Black Hawk Lake. The lake gage is Station 05482315, which has a period of record of April 1970 to the current year (2010), with several years of missing data. Table 2-3 summarizes the station details and available data. Daily precipitation calculated using the Thiessen polygon method for the Sac City and Carroll rain is illustrated, along with daily mean lake stage, in Figure 2-5.

Table 2-3. USGS lake gage information for Black Hawk Lake.

Station Number	05482315
Latitude	42°18'15"
Longitude	95°02'30"
[1]Datum Elevation (NGVD 1929)	1213.50 feet
Drainage Area	23.3 square miles
Location	South shore across from swimming beach at Lake View and 2 miles upstream from lake outlet.
Period of record	April 1970 to September 1975, April 1978 to September 1992, October 1994 to present.

[1]Prior to January 22, 2001, datum 5.0 feet higher (1218.5 feet)

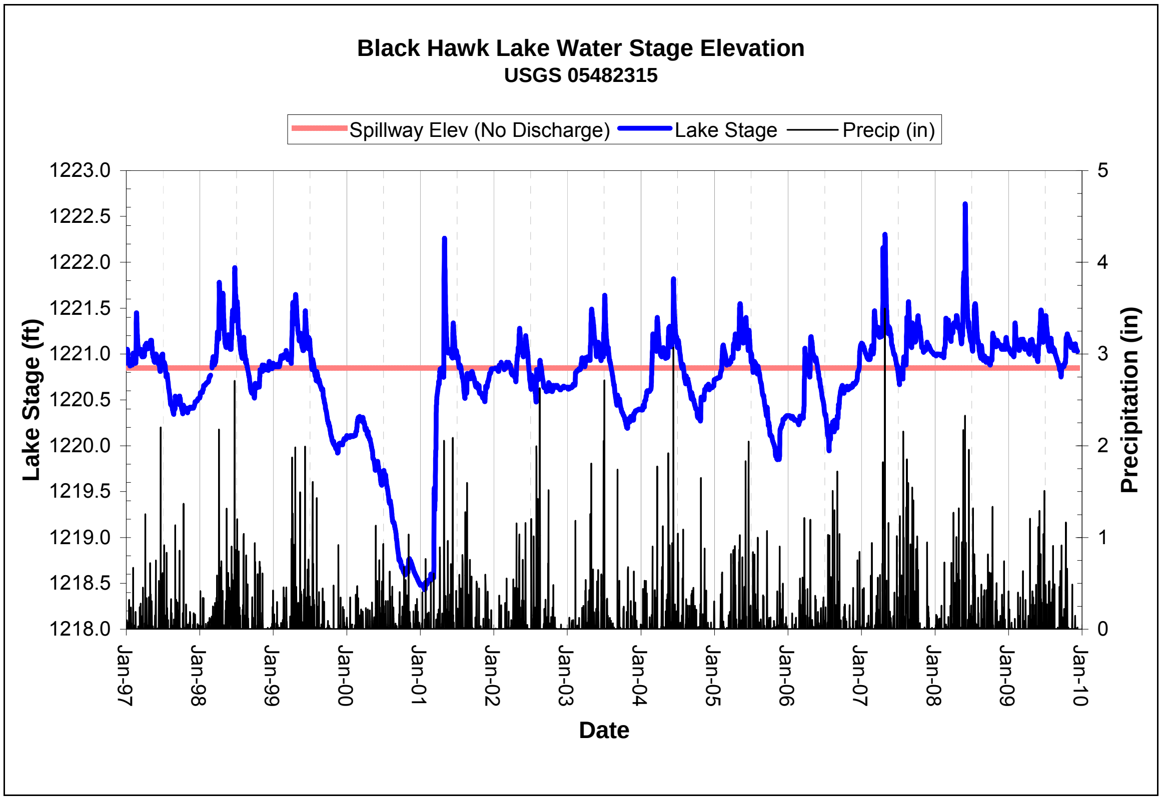

Figure 2-5. Daily lake stage and precipitation (1997-2009).

Analysis of Figure 2-5 reveals several noteworthy trends. First, during most years the spillway is discharging a majority of the time, indicating that the water balance is normally positive (inflows exceeded losses). This is consistent with the water budget estimated from 1970 through 1983 (Hanson, 1983; Bachman et al, 1983). Second, in nearly every year, lake stage is highest from April through June. Third, the lowest stage and frequent zero discharge periods typically occur between October and December. Lastly, particularly high lake levels (and corresponding flows) were observed in May 2001, May 2007, and June 2008.

Morphometry & Substrate

The surface area of Black Hawk Lake is 922 acres, according to the bathymetry maps prepared by IDNR. This includes 760 acres of open water lake area (IDNR, 2006) and 162 acres in the inlet slough (IDNR, 2009, unpublished data), both illustrated in Figure 2-6. The lake is a natural lake with an irregular shape. The shoreline development index of the lake is 2.67 (Bachman et al., 1994). Values greater than 1.0 suggest the shoreline is highly dissected and indicative of a high degree of watershed influence (Dodds, 2000).

The morphology of Black Hawk Lake has been studied and altered a number of times in the past 100 years. According to historical studies and bathymetry maps, the depth and volume of Black Hawk Lake has varied due to ongoing sedimentation and past dredging efforts. Table 2-4 reports the findings of previous morphometry studies.

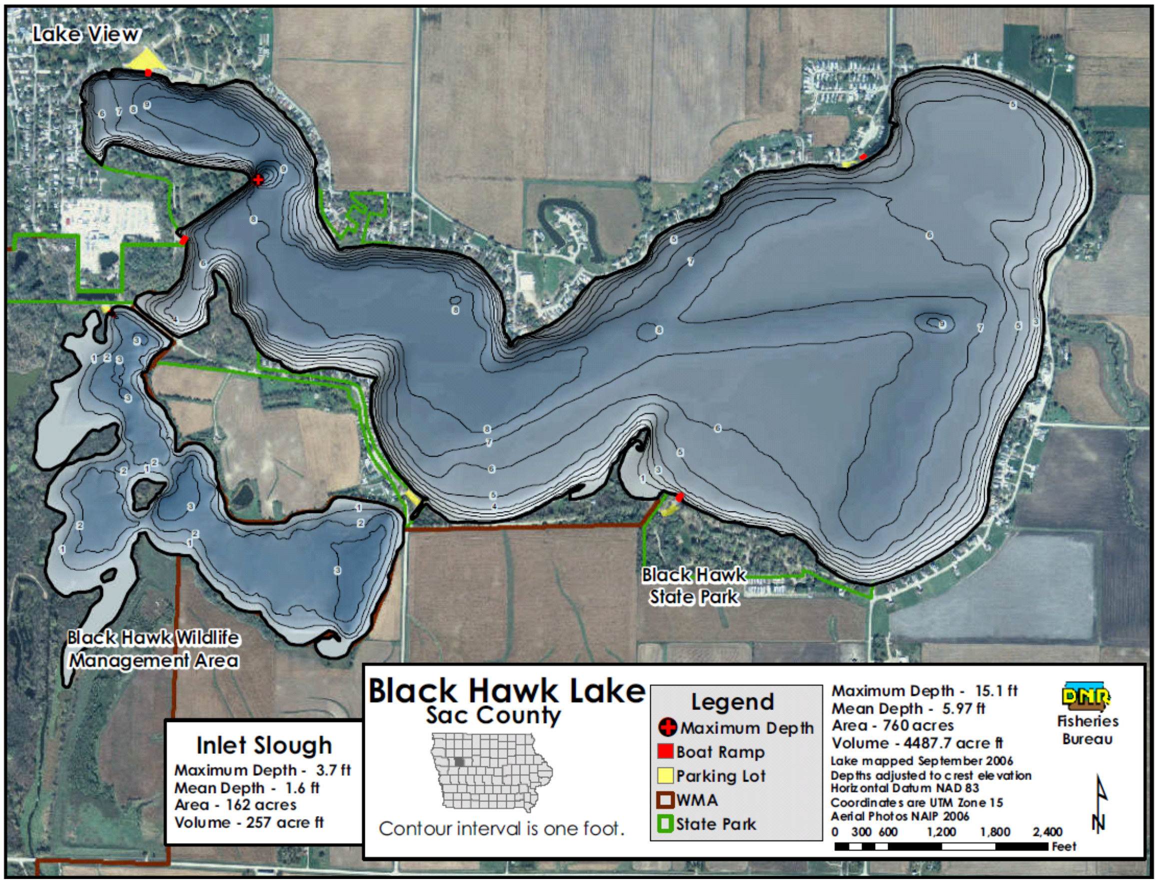

Figure 2-6. Aerial photograph and bathymetry of Black Hawk Lake.

Table 2-4. Historical morphometry information for Black Hawk Lake.

Year	1916	1935	1973	1981	2006
Area (acres)	798	798	755	755	729
Volume (ac-ft)	4,012	3,373	4,325	3,880	4,488
Mean depth (ft)	5.0	4.3	5.7	5.1	7.5
Max depth (ft)	7.0	6.0	12.0	10.3	15.1

(Bachman et al., 1983; Hanson, 1983)

The mean depths reported from the 1916 study suggest that Black Hawk Lake has historically been a relatively shallow lake. Erosion and sedimentation caused the volume and depth of Black Hawk Lake to decrease from 1916 to 1935. A dredging project was completed in 1938, which increased mean depth and volume significantly. This project also resulted in the creation of a park adjacent to the lake using dredged spoils, which decreased the lake surface area from 798 to 755 acres (Bachman et al., 1983). The impact of dredging (prior to 1973) can been seen by comparing the depth and volume observed in the 1938 and 1973 bathymetry data, even though substantial sedimentation occurred between 1938 and 1973 (Shetye, 1991). Dredging also occurred in 1991-1992 and 1994-1995. The fact that sedimentation is a known problem in the lake suggests that substrate (bottom material) consists largely of silt, which has been trapped in the lake over many years. Sediment cores collected in the winter of 1934-1935 revealed that in most areas of the lake, substrate consists of silt overlying sand, with a layer of clay beneath the sand (Hanson, 1983). Summaries of past dredging efforts and sedimentation studies are reported in the recently completed diagnostic/feasibility study developed by Iowa State University for IDNR (IDNR and ISU, 2010).

2.2 The Black Hawk Lake Watershed

The drainage area to Black Hawk Lake is a 13,156-acre watershed, not including the surface area of the main body of the lake or Provost Slough. The lake to watershed ratio of over 14 to 1 is higher than the average for natural lakes in Iowa, and indicates that watershed characteristics have a potentially large impact on water quality in Black Hawk Lake. However, the ratio is low enough that water quality improvement can be achieved with a comprehensive package of best management practices (BMPs) that includes watershed restoration alternatives. The potential for successful lake restoration efforts is generally considered good in cases where the watershed to lake ratio is less than 20:1

Land Use
IDNR developed a statewide land cover database in 2002. Additionally, IDNR staff involved in the development of this Water Quality Improvement Plan (WQIP) conducted a windshield survey of land cover in the fall of 2008 and again in the fall of 2009. The 2008 and 2009 windshield survey data was collected at a more-refined scale, and is considered more accurate than the 2002 data for modeling purposes. The 2002 land cover data is helpful in determining likely crop rotation patterns and changes in land use composition of the watershed over the past eight years.

Land cover information reveals that row crop agriculture is the most dominant feature of the Black Hawk Lake watershed. Most of the agricultural land is in a corn-soybean rotation. Approximately 68 percent of the watershed is assumed to have tile drainage, based on row crop land use, slopes less than 5 percent, and soil types known to require tile drainage for row crop production. Other land uses include alfalfa, pasture, grasslands, timbered areas, and urban areas of residential and commercial/industrial uses. Table 2-5 reports the generalized land uses by acre and percent of watershed according to 2008 windshield assessment.

Table 2-5. Land use composition of the Black Hawk Lake watershed (2008).

2008 Land Use	Description	Area (Acres)	% of Watershed
Corn	--	6,936	52.7
Soybeans	--	2,878	21.9
Grass/Hay/Pasture	grassland, parks, alfalfa, pasture	888	6.7
Timber	Forest, vineyard	245	1.9
Water/Wetland	wetlands and ponds (excludes lake)	764	5.8
Other	urban uses, roads, farmsteads, etc.	1,445	11.0
	Totals =	13,156	100

Figure 2-7 compares the relative land use composition in 2002 and 2008. The amount of corn increased from approximately 38 percent to nearly 53 percent of the watershed from

2002 to 2008, while the percent of soybeans and grass/hay/pasture both declined significantly. A map of 2008 land cover is provided in Figure 2-8.

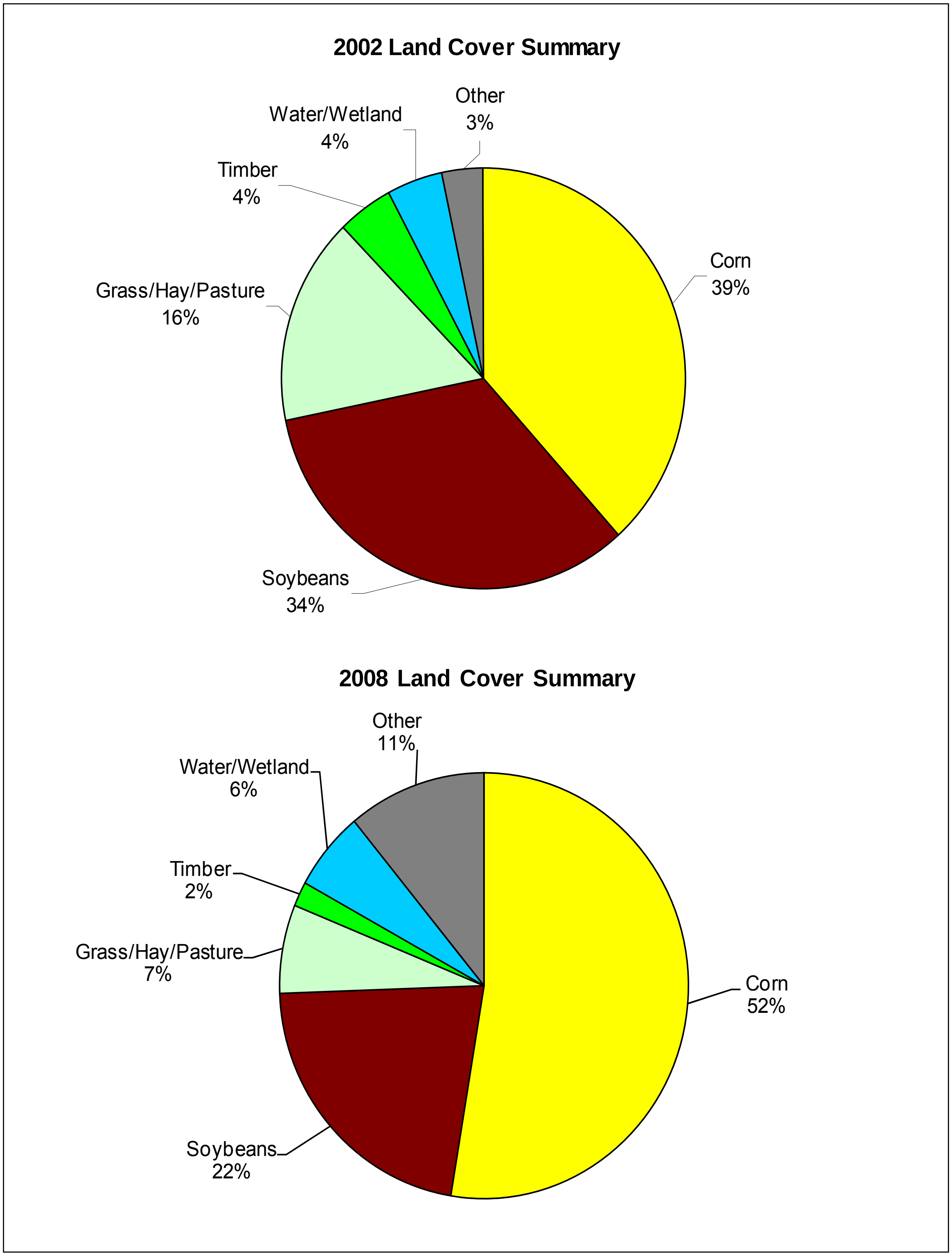

Figure 2-7. Comparison of land cover composition in 2002 and 2008.

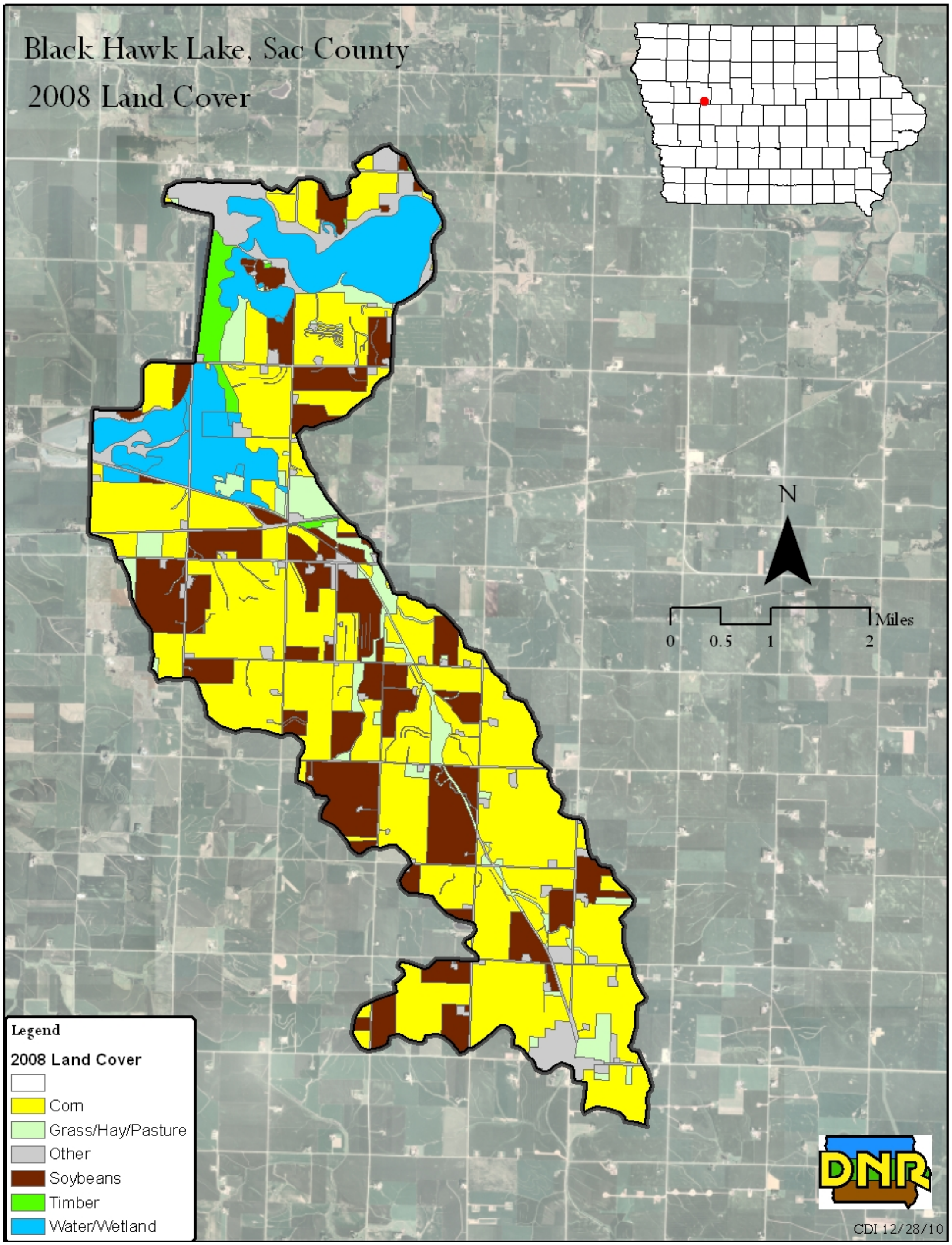

Figure 2-8. Black Hawk Lake watershed land cover (2008).

Many of the natural wetlands that were common in the watershed pre-settlement have been lost. Based on soil characteristics, historic aerial photography, and topography, there was once approximately 1,140 acres of wetlands in the Black Hawk Lake watershed. Historical wetlands were a mix of depressional wetlands in upland areas and riparian wetlands adjacent to stream corridors. Today approximately 490 acres of wetland remain, most of which consist of the Ducks Unlimited (DU) Pond and State

Marsh, located just upstream of the lake. The loss and transformation of wetland distribution in the watershed has affected both hydrology and water quality.

Soils, climate, and topography
Black Hawk Lake is situated in the terminal moraine of the Wisconsin Age Glacier, causing local geological conditions to be somewhat complex (Kittelson, 1992). Nearly two-thirds of the watershed is derived from glacial till within the Des Moines Lobe landform region. Glacial outwash, alluvium, and marsh areas compose the rest of the watershed. The fact that the lake is in an alluvial valley with an extensive area of glacial outwash near the lake suggests that there is a strong hydraulic connection between the lake and local groundwater supplies (Bachman, 1983).

Three soil associations dominate the Black Hawk lake watershed: the Clarion-Nicollet-Canisteo, Clarion-Nicollet-Webster, and Marshall-Exira associations. Of these, the Clarion-Nicollet-Canisteo association comprises the largest portion of the watershed. The Clarion-Nicollet-Canisteo association is characterized by nearly level or gently undulating slopes; however, near larger streams, many soils are gently rolling to hilly and a few are steep or very steep (USDA-NRCS, 1979). This association is well to poorly drained and closed depressions or "potholes" are a common feature. The Clarion-Nicollet-Canisteo association is found primarily in upland areas. The Clarion-Nicollet-Webster association is also found in upland areas on nearly level to strongly slope areas, and includes well drained to poorly drained soils. The Marshall-Exira association is characterized by nearly level to moderately steep slopes, is well-drained, and includes silty soils formed in loess on upland areas. Table 2-6 describes the five most common soil types (comprising the largest area) in the watershed.

Table 2-6. Predominant soils in the Black Hawk Lake watershed.

Soil Name	Watershed Areas (%)	Description of Surface Soil Layer	Typical Slopes (%)
Clarion	35	loam, black, well drained,	2-9
Nicollet	13	loam, black, somewhat poorly to moderately well drained	1-3
Webster	11	silty clay loam, black, poorly drained	0-2
Coland	6	clay loam, black, poorly drained	0-2
Canisteo	3	silty clay loam, black, poorly drained	0-2

Source: USDA-NRCS, 1979 and 1982

The climate is typical of the Midwest, with most of the annual rainfall occurring from late spring through early fall. Spring and summer rainfall can be intense, with large amounts of rain occurring in short time spans. High intensity rainfall increases the potential for localized flooding and soil erosion. From 1997 through 2009, average annual precipitation at NWS COOP stations located in Sac City and Carroll, Iowa was 31.7 and 32.4 inches, respectively.

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

A Total Maximum Daily Load (TMDL) is required for Black Hawk Lake by the Federal Clean Water Act. This section of the Water Quality Improvement Plan (WQIP) quantifies the maximum amount of TP the lake can assimilate and still support primary contact recreation in Black Hawk Lake.

3.1. Problem Identification

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

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

The 2008 Section 305(b) Water Quality Assessment Report states that primary contact recreation in Black Hawk Lake is "not supported" due to violations of the state water quality criteria for indicator bacteria and due to poor water clarity caused by algal and non-algal turbidity. The 2008 assessment is included in its entirety in Appendix H. This section details the development of the TMDL for algae and turbidity. The 2008 305(b) report can be accessed at http://programs.iowadnr.gov/adbnet/assessment.aspx?aid=9303.

Applicable water quality standards
The State of Iowa Water Quality Standards are published in the Iowa Administrative Code (IAC), Environmental Protection Rule 567, Chapter 61. Although the State of Iowa does not have numeric criteria for sediment or nutrients, narrative water quality criteria do apply. 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." The WQS can be accessed on the web at http://www.iowadnr.com/water/standards/files/chapter61.pdf.

Problem statement
The 2008 305(b) report assesses water quality in Black Hawk Lake as follows:

> *"…Results of the ISU lake survey and UHL ambient lake monitoring program also suggest that the Class A1 uses are "not supported" at Blackhawk Lake due to poor water transparency due to algal and non-algal turbidity. Using the median values from these surveys from 2002 through 2006 (approximately 27 samples), Carlson's (1977) trophic state indices for Secchi depth, chlorophyll a, and total phosphorus were 75, 70, and 74 respectively for Blackhawk Lake. According to Carlson (1977) the index values for Secchi depth, chlorophyll a, and total phosphorus all place Blackhawk Lake in the hypereutrophic category. These values suggest high levels of chlorophyll a and suspended algae in the water, very poor water transparency, and very high levels of phosphorus in the water column…"*

Data sources
Sources of data used in the development of this TMDL include those used in the 2008 305(b) report, several sources of additional water quality data, and non-water quality related data used for model development. These sources are summarized in the following list:

- Results of statewide survey of Iowa lakes sponsored by IDNR and conducted by Iowa State University (ISU) from 2001-2004
- Water quality data collected by the University of Iowa Hygienic Laboratory (UHL) from 2005-2008 as part of the Ambient Lake Monitoring Program
- Black Hawk Lake stage data collected by an automated gage maintained and operated by the United States Geological Survey (USGS)
- Data and analyses obtained as a result of the Black Hawk Lake Diagnostic Feasibility Study performed for IDNR Lakes Restoration by ISU (IDNR and ISU, 2010)
- National Weather Service (NWS) precipitation data accessed through the Iowa Environmental Mesonet (IEM, 2010)
- Land cover and land use data collected via windshield survey in 2008 and 2009

Water quality data was grouped into two primary data sets for statistical analysis and water quality modeling: (1) In-lake total phosphorus (TP) data collected and analyzed by the Limnology Laboratory at ISU from 2001-2004, and (2) UHL water quality data collected from 2005-2008. These data are provided in Appendix C of this report.

TP data collected by ISU in 2000 were excluded from the analysis due to suspected data quality issues previously noted by IDNR Watershed Monitoring and Assessment (WMA) staff. None of the 2009 observed data were utilized in the assessment of current conditions due to inconsistencies in data and their relationships. In 2009, monitoring efforts in Black Hawk Lake reported very high TP levels concurrent with relatively low chlorophyll-a and inorganic suspended solids (ISS). Additionally, the low chlorophyll-a concentrations in 2009 correspond to relatively high phytoplankton biomass. While some inherent natural variability should be expected in water quality data, the counter-intuitive relationships observed in the 2009 data are concerning. Because it is impossible to know which data are accurate and which are erroneous, none of the 2009 observed data were utilized in assessment of current conditions. Due to similar inconsistencies and suspected data quality issues described above, all chlorophyll-a data collected by ISU in 2001-2007 were excluded from evaluation of model performance, though TP data was utilized. Modeling assumptions, methodology, and performance are discussed in detail in Appendices D, E, and F.

Interpreting Black Hawk Lake data
The 2008 305(b) assessment was based on both ISU and UHL ambient monitoring data from 2002-2006. Assessment of in-lake water quality in this TMDL utilized UHL data from 2005-2008 and ISU TP data from 2001-2004. Data evaluation includes additional statistical analysis of eutrophication-related water quality parameters. The purpose of additional analysis was to gain more insight to the probable cause(s) of poor water clarity

in Black Hawk Lake, investigate more recent water quality trends, and to confirm or qualify the conclusions made in the 2008 assessment.

Carlson's Trophic State Index (TSI) was used to evaluate the relationships between TP, algae (chlorophyll-a), and transparency (Secchi depth) in Black Hawk Lake. If the TSI values for the three parameters are the same, the relationships between the three are strong. If the TP TSI values are higher than chlorophyll TSI, it suggests there are limitations to algal growth besides phosphorus, or that a significant portion of Figure 3-1 illustrates each of the individual TSI values throughout the sampling period. The general trend is that chlorophyll-a TSI values are lower than those for TP and Secchi depth.

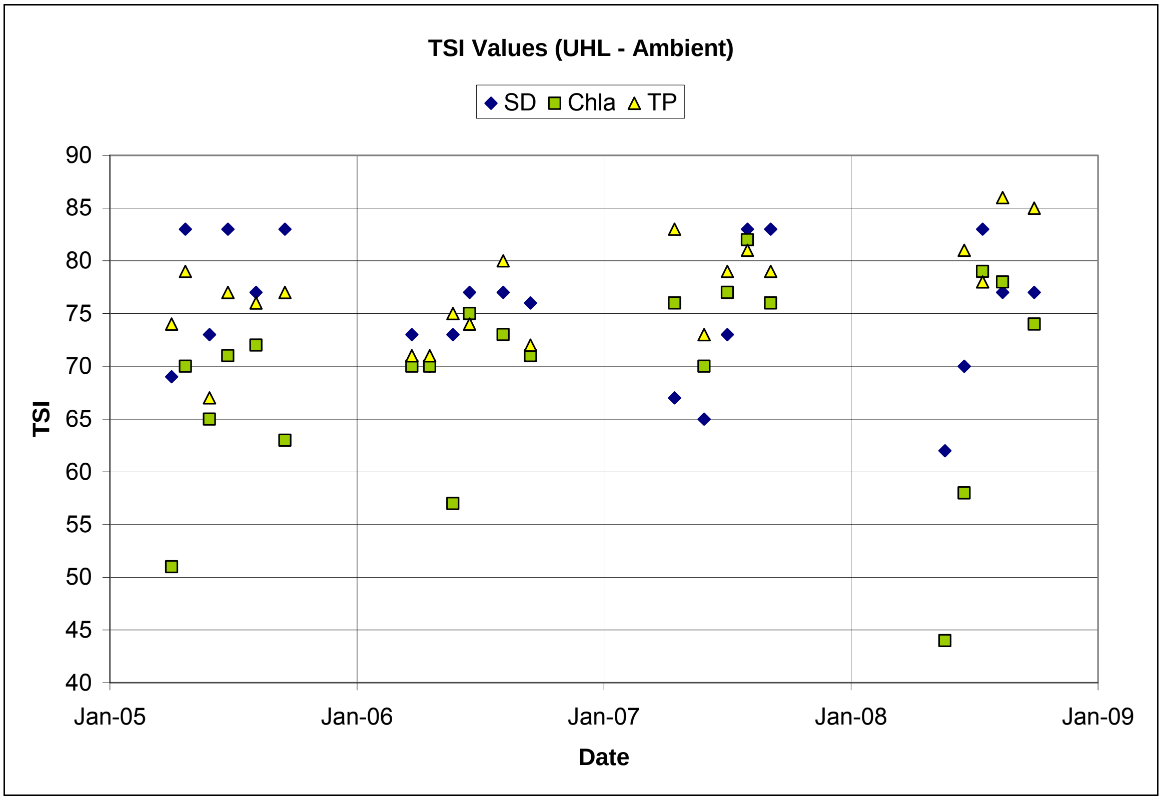

Figure 3-1. Black Hawk Lake TSI values (2005-2008 UHL data).

Using the mean observed values across all these data, the overall TSI values for TP, chlorophyll-a, and Secchi depth at the ambient monitoring location are 78, 72, and 74, respectively. This suggests that factors besides TP may be limiting (i.e., controlling) algal growth, since chlorophyll-a concentrations are lower than one would expect given the high TP concentrations. However, there are several occurrences of chlorophyll-a TSI values above 75, indicating that severe algal blooms do occur. TSI scores for all three parameters are high and confirm the hypereutrophic status of the lake.

The overall TN:TP ratio in Black Hawk Lake is 19.6. According to a study on blue-green algae dominance in lakes, ratios greater than 17 suggest a lake is phosphorus, rather than nitrogen limited (MPCA, 2005). Carlson states that phosphorus is limiting at TN:TP ratios greater than 10 (Carlson and Simpson, 1996). Additionally, the TN TSI is 79, higher than the TSI for TP. Table 3-1 reports TSI scores based on mean observations from the 2005-2008 UHL data. Table 3-2 describes the implications of TSI scores on attributes of lakes.

Table 3-1. TSI values in Black Hawk Lake (based on 2005-2008 averages).

	TSI (SD)	TSI (Chl)	TSI (TN)	TSI (TP)
Mean TSI Score	74	72	79	78

Table 3-2. Implications of TSI values on lake attributes.

TSI Value	Attributes	Primary Contact Recreation	Aquatic Life (Fisheries)
50-60	eutrophy: anoxic hypolimnia; macrophyte problems possible	[none]	Warm water fisheries only; [1]percid fishery; 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	[2]Centrarcid fishery
70-80	hyper-eutrophy (light limited). Dense algae and macrophytes	weeds, algal scums, and low transparency discourage swimming and boating	Cyprinid fishery (e.g., common carp and other rough fish)
>80	algal scums; few macrophytes	algal scums, and low transparency discourage swimming and boating	rough fish dominate; summer fish kills possible

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

As part of the TMDL monitoring conducted in 2007 and 2008, UHL collected water quality data concurrently at three locations in Black Hawk Lake; the west arm, the middle segment at the ambient data location, and in the large open bay on the east side of the lake. The goal of this monitoring was to assess spatial variability in water quality. Figure 3-2 shows the location of these monitoring sites and Figure 3-3 plots the TSI values.

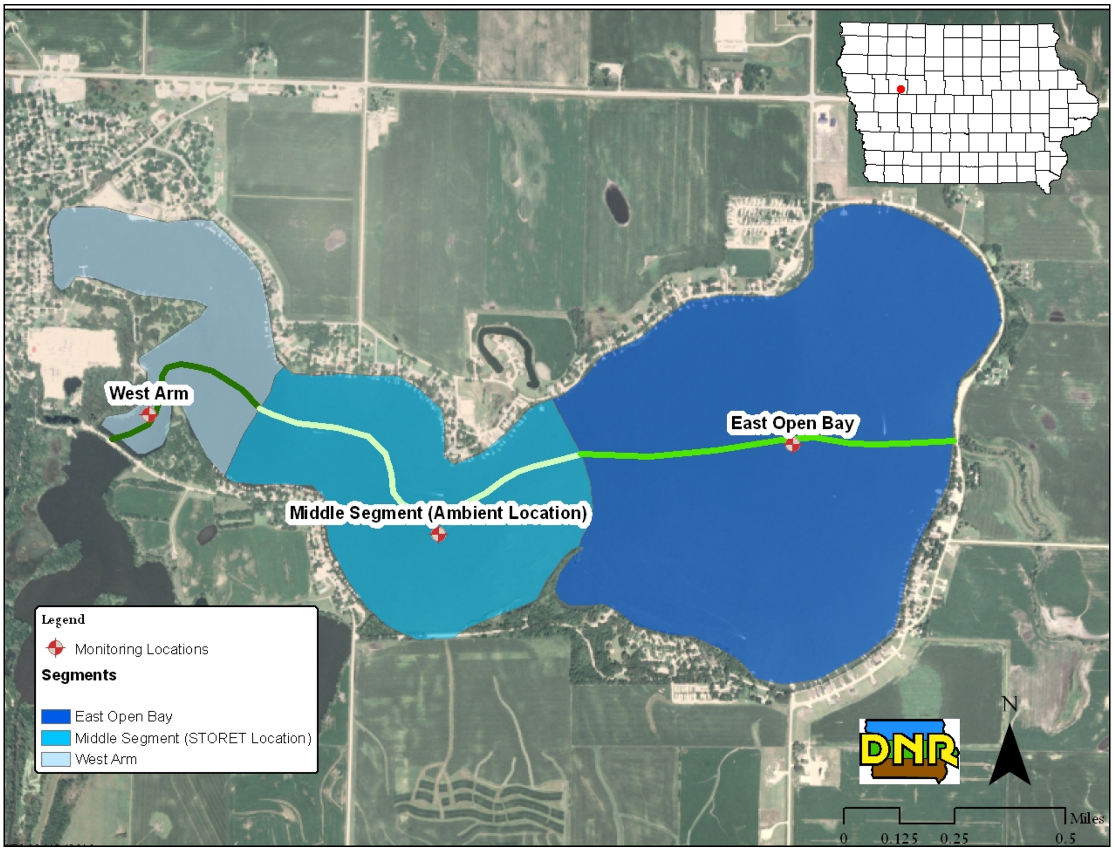

Figure 3-2. Monitoring locations for segmented data collected in 2007 and 2008.

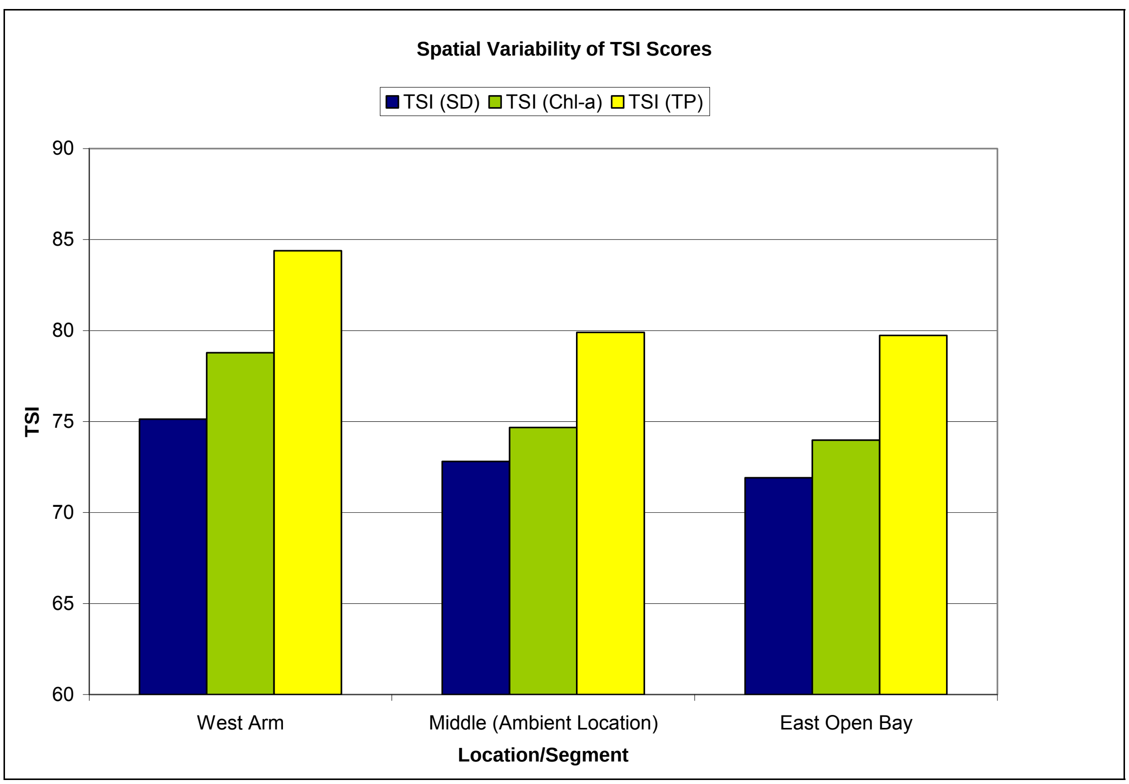

Figure 3-3. Mean TSI scores in each lake segment (2007 and 2008 data).

The spatially segmented data reveals several noteworthy trends in water quality. First, TP concentration is highest in the west arm of the Black Hawk Lake, where water enters the lake from the Provost Slough. TP levels decrease as the water travels through the lake towards the outlet, likely due to the settling of fine sediment particles that contain phosphorus. Resuspension of phosphorus in the inlet slough and shallow areas of the west arm may exacerbate TP levels in this segment of the lake. Second, both chlorophyll-a and Secchi depth TSIs follow the same pattern, but the drop in TSI is slightly less pronounced than for TP. Finally, TSI scores are highest for TP, followed by chlorophyll-a, and lowest for Secchi depth. This further suggests that algal growth is sometimes limited by factors other than phosphorus

Figure 3-4 illustrates a method for interpreting the meaning of the deviations between Carlson's TSI values for TP, Secchi depth, chlorophyll-a, and TN. Each quadrant of the chart indicates the potential factors that may limit algal growth in a lake. A detailed description of this approach is available in *A Coordinator's Guide to Volunteer Lake Monitoring Methods* (Carlson and Simpson, 1996). If the deviation between the chlorophyll-a TSI and TP TSI is less than zero (Chl TSI < TP TSI), the data point will fall below the X-axis. This suggests phosphorus may not be the limiting factor in algal growth. The X-axis, or zero line, is related to TN:TP ratios of greater than 33:1 (Carlson, 1992). Because phosphorus is thought to be the limiting nutrient at ratios greater than 10:1, deviations slightly below the X-axis do not necessarily indicate nitrogen limitation.

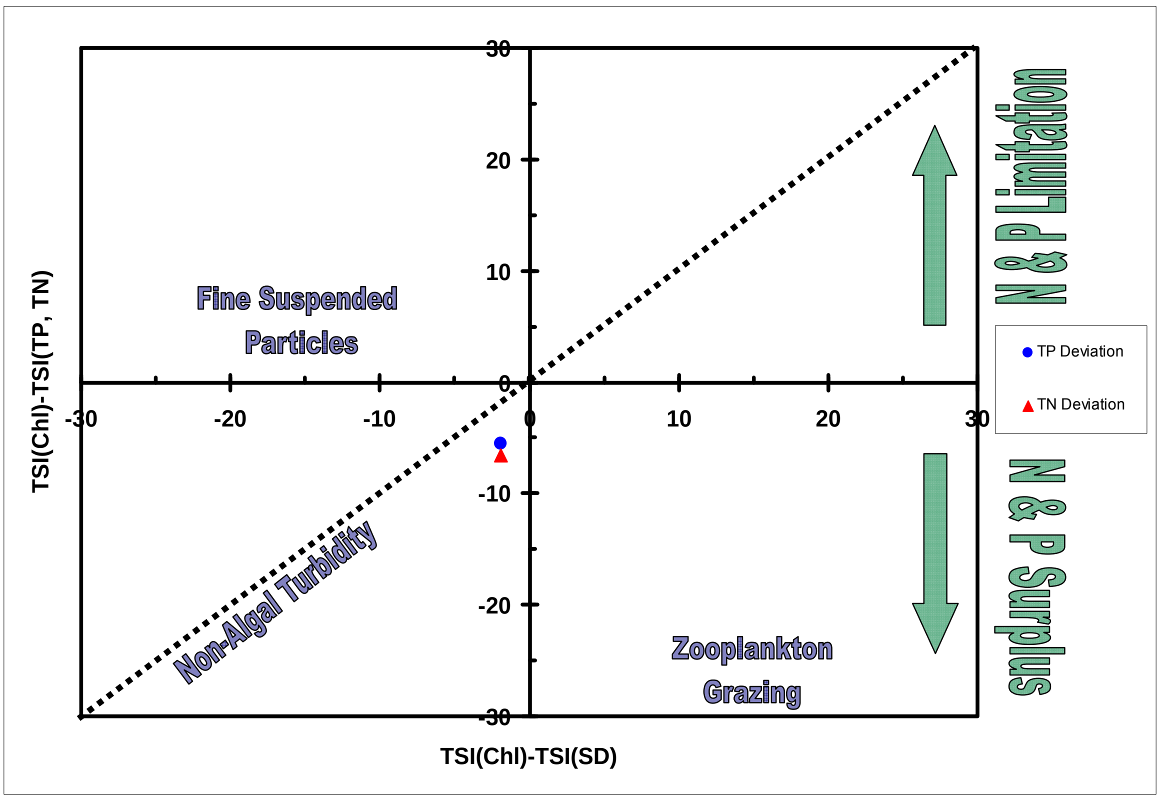

Figure 3-4. TSI deviations based on mean concentrations and Secchi depth.

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

The mean observed concentrations and Secchi depths in Black Hawk Lake, based on the 2005-2008 UHL data set, result in TSI deviations in the lower-left quadrant of Figure 3-4. Because the deviations are not extreme (i.e., the points lie near both the X and Y-axes), the importance of phosphorus in algal growth and transparency must be considered. TSI deviations suggest low Secchi depth readings would be observed even without the presence of non-algal turbidity.

Examination of the presence or lack of correlation between nutrients and indicators of water quality such as chlorophyll-a and Secchi depth provide further insight regarding probable causes of eutrophication. It is important to recognize that correlation is not equivalent to causation, but this does not render correlation useless. It is a valuable tool that should be used with other analyses to evaluate the relationship between water quality and nutrients. Figures 3-5 through 3-13 illustrate correlation, as expressed by linear regression, of a number of water quality parameters. Analysis of these figures reveals several important observations, discussed below.

Figure 3-5 and 3-6 reveal transparency, as measured by Secchi depth, is positively correlated with TN and negatively correlated with TP. Transparency improves with increasing TN levels and worsens with increasing TP. This supports the assumption that Black Hawk Lake is phosphorus, rather than nitrogen, limited. Figure 3-7 and 3-8 show that Secchi depth is also negatively correlated with inorganic suspended solids (ISS) and chlorophyll-a (Chl-a). These relationships are stronger than those between Secchi depth and nutrient levels, as indicated by higher R^2 values. The strong negative correlation with ISS indicates non-algal turbidity plays a potentially important role in eutrophication by limiting light penetration, which in turn limits algal growth. However, the relatively strong negative correlation between Secchi depth and chlorophyll-a confirms that algal blooms are also problematic.

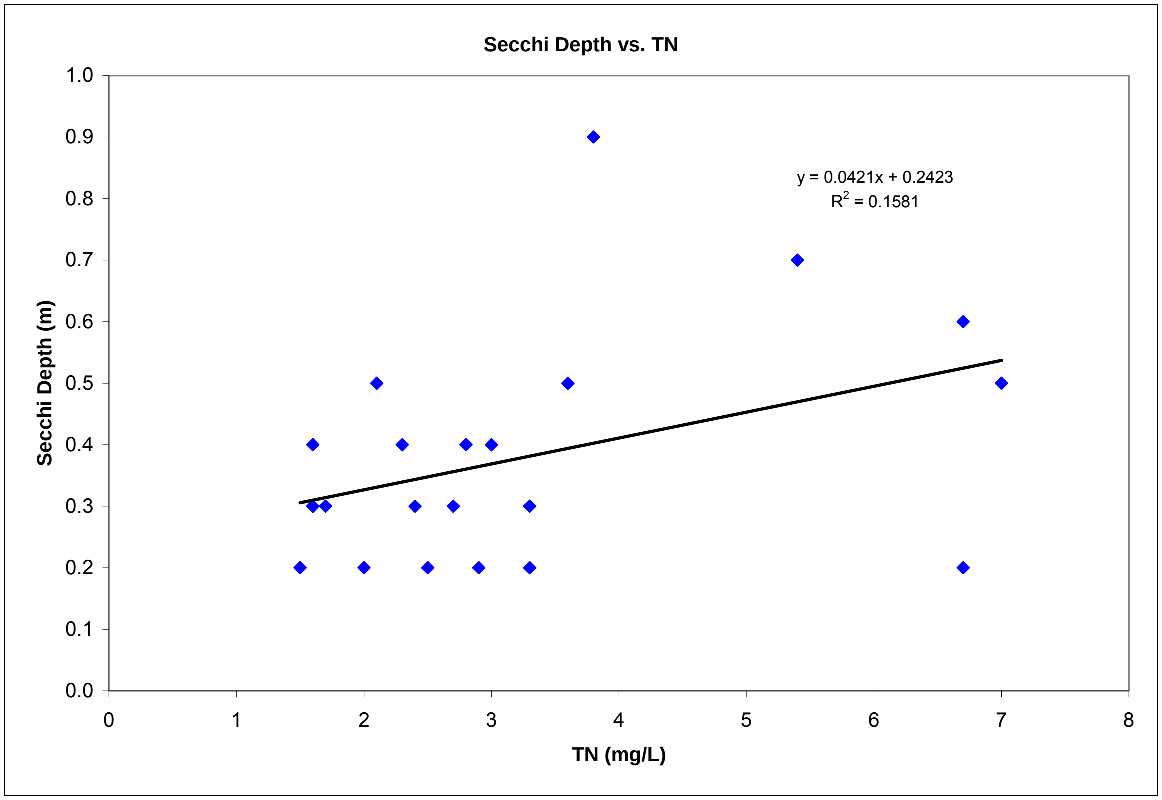

Figure 3-5. Secchi depth vs. total nitrogen (TN).

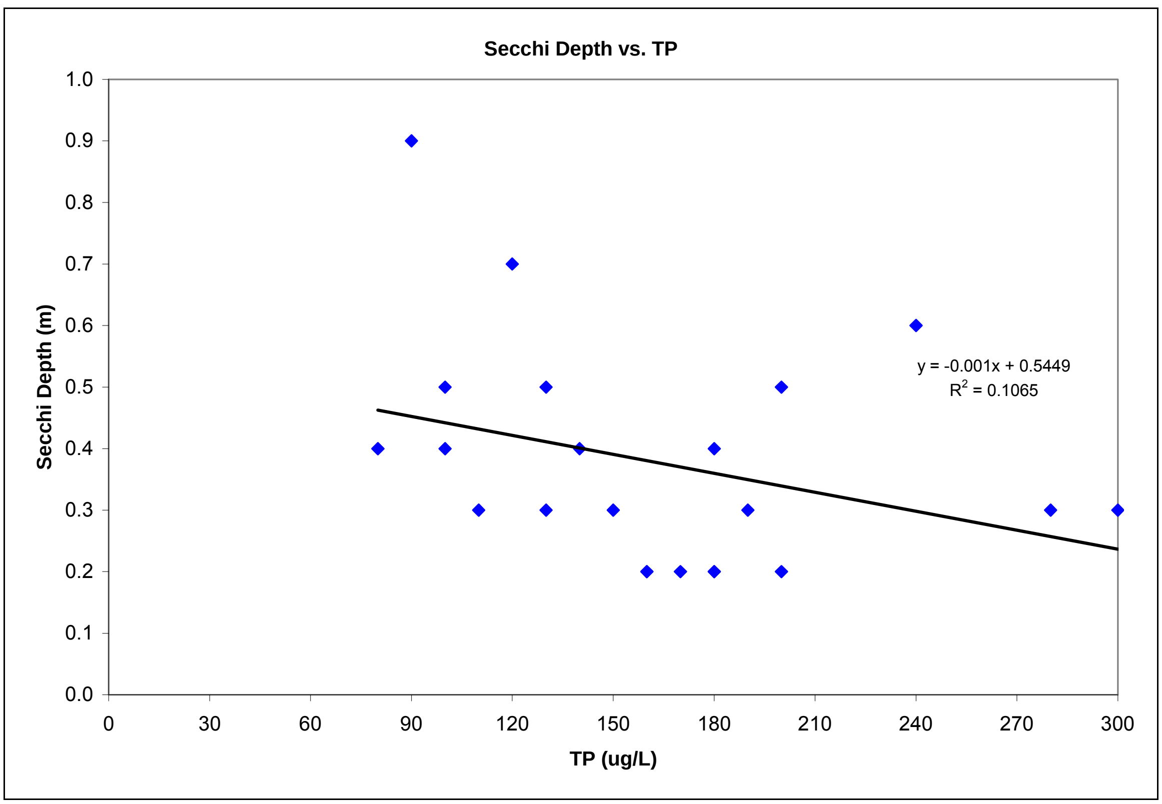

Figure 3-6. Secchi depth vs. total phosphorus (TP).

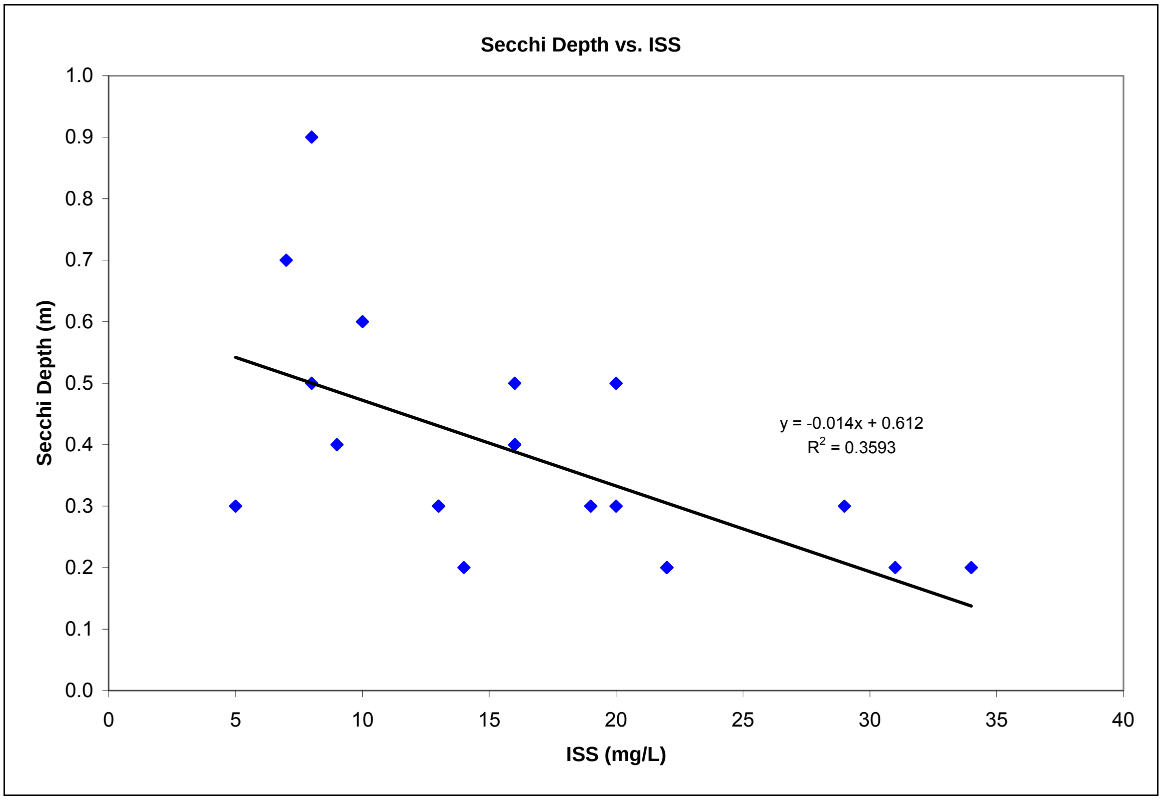

Figure 3-7. Secchi depth vs. inorganic suspended solids (ISS).

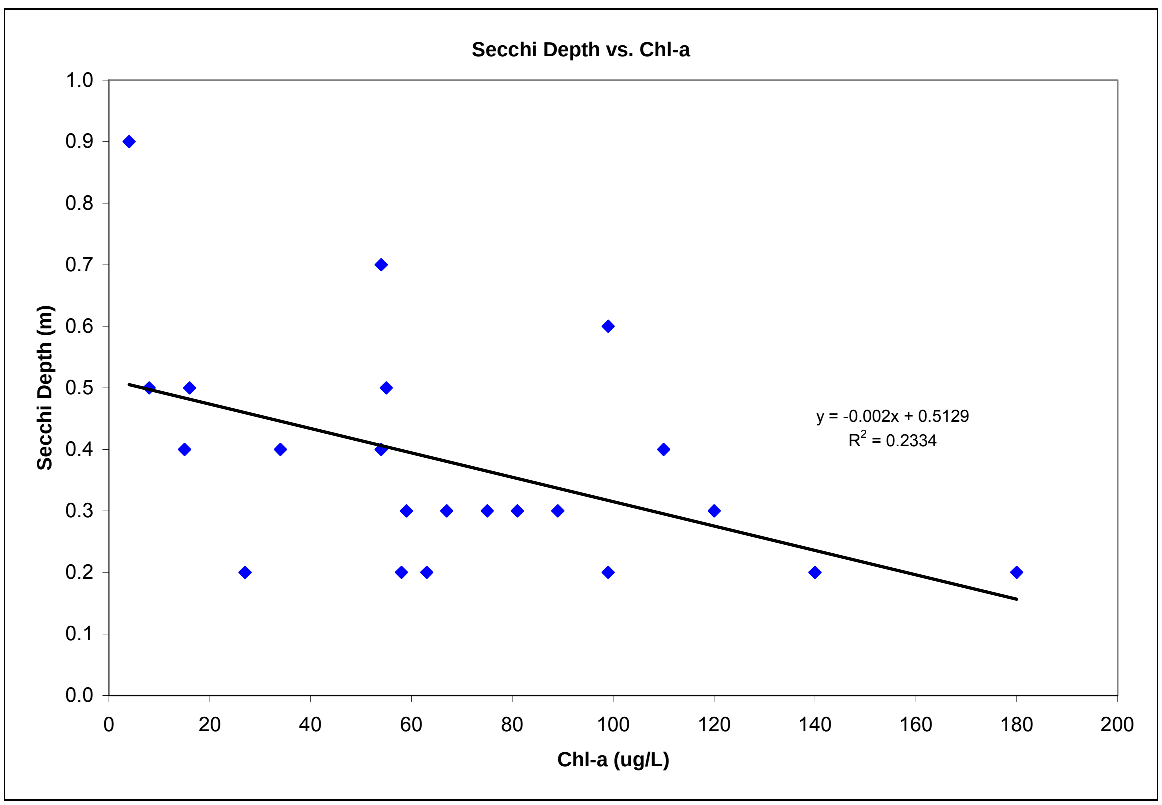

Figure 3-8. Secchi depth vs. chlorophyll-a (Chl-a).

Figures 3-9 and 3-10 show that ISS is weakly correlated with both TN and TP concentration. The correlation is weaker and negative for TN, which suggests that nitrogen reductions will be ineffective in reducing non-algal turbidity.

Figures 3-11 through 3-13 illustrate correlations between chlorophyll-a and three parameters: TP, TN, and the TN to TP ratio (TN:TP). Analysis of these figures reveals a relatively strong (compared to correlations between other consituents), positive relationship between chlorophyll-a and TP, a weak, negative correlation with TN, and a strong, negative correlation with TN:TP.

Although phosphorus may not be the sole limiting factor for algal growth at all times and under all conditions, it appears to play a larger role in limitation than nitrogen. The TN:TP ratio of 19.6, correlations between various eutrophication-related parameters, and the fact that the TP deviation lies above the TN deviation in Figure 3-4 all support this assertion. However, lakes are complex and dynamic systems, and these relationships vary spatially and temporally. It is likely that nitrogen limitation does play a role in algal growth and speciation under certain conditions, and this should be acknowledged when developing lake restoration plans, even though phosphorus more directly influences eutrophication in Black Hawk Lake.

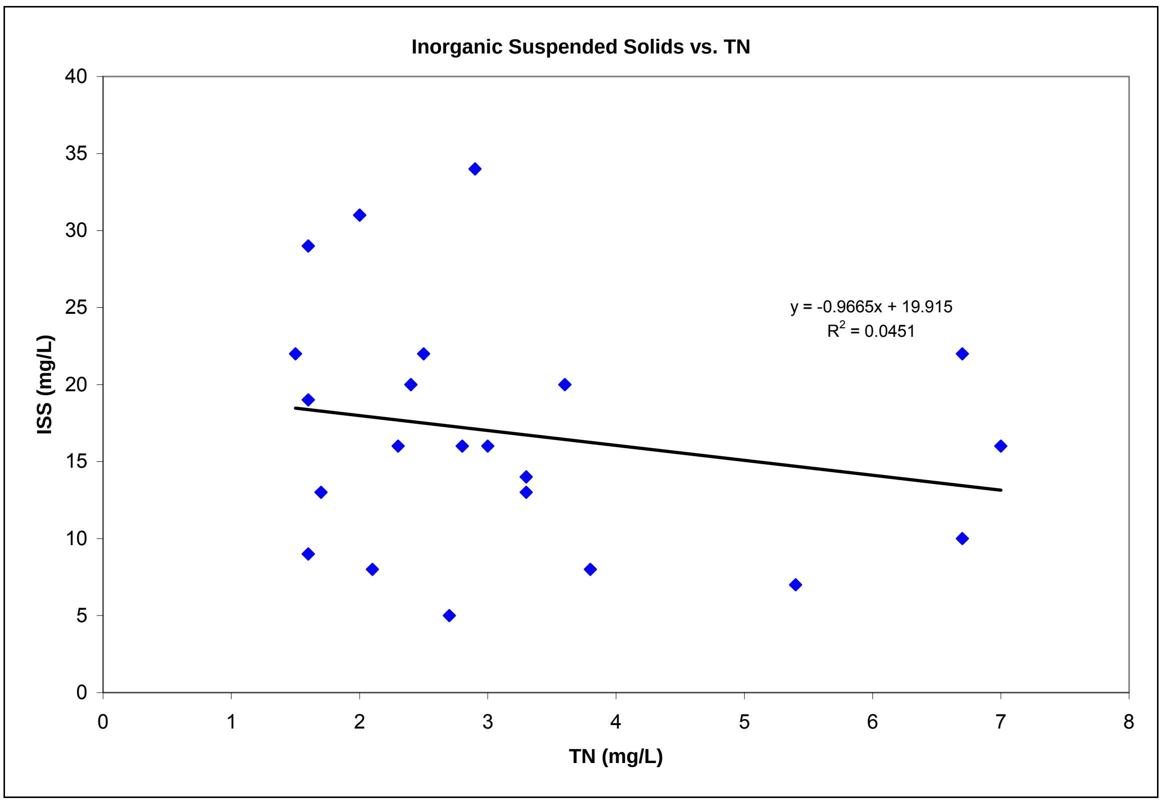

Figure 3-9. Inorganic suspended solids (ISS) vs. total nitrogen (TN).

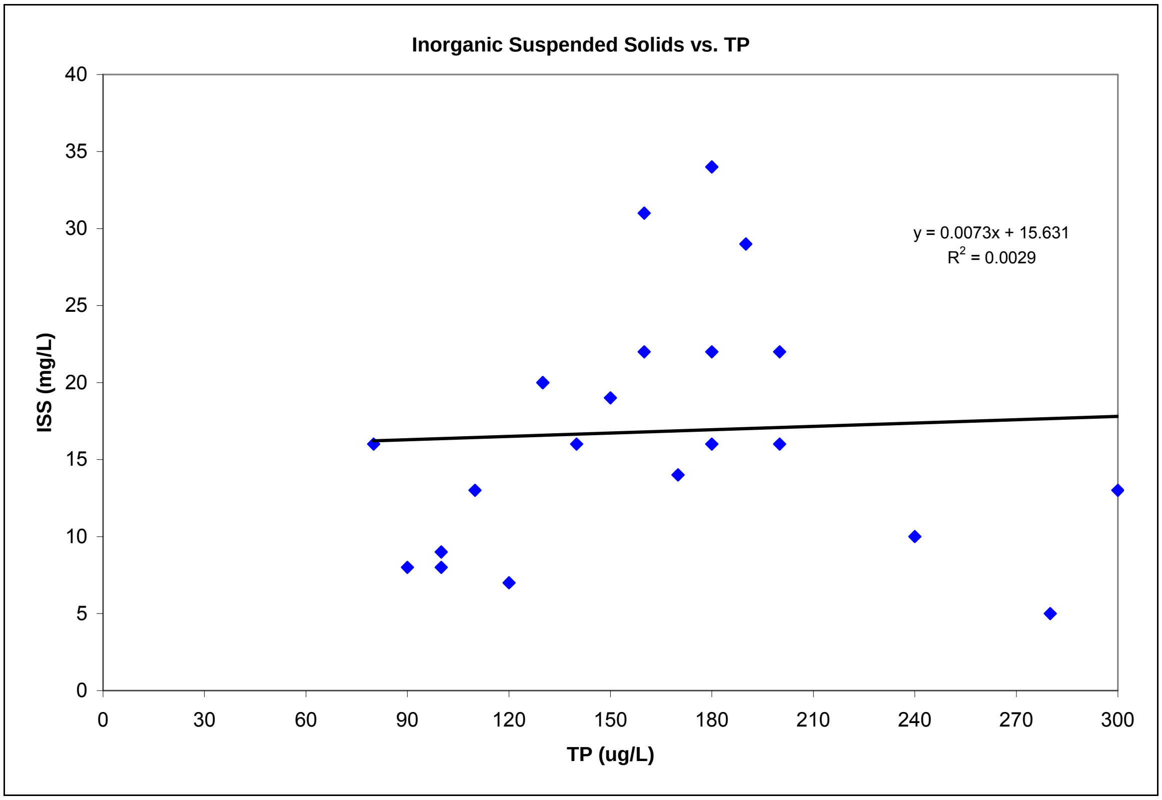

Figure 3-10. Inorganic suspended solids (ISS) vs. total phosphorus (TP).

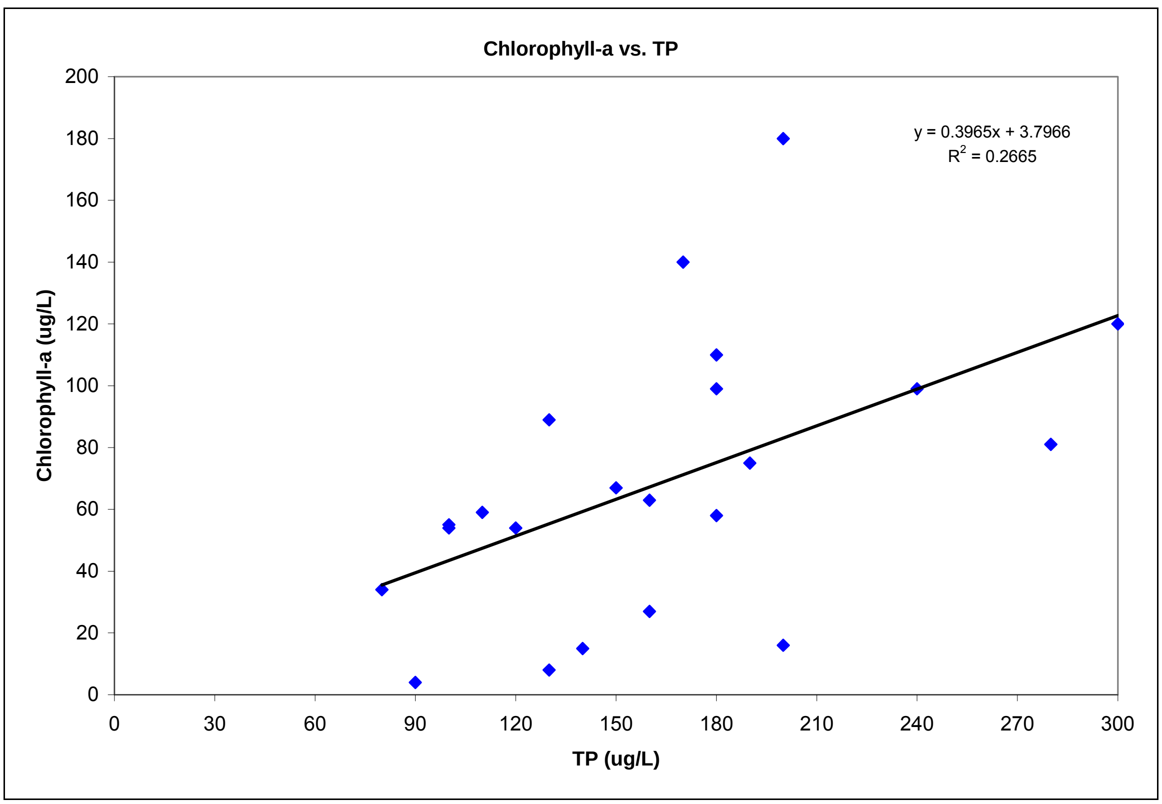

Figure 3-11. Chlorophyll-a vs. total phosphorus (TP).

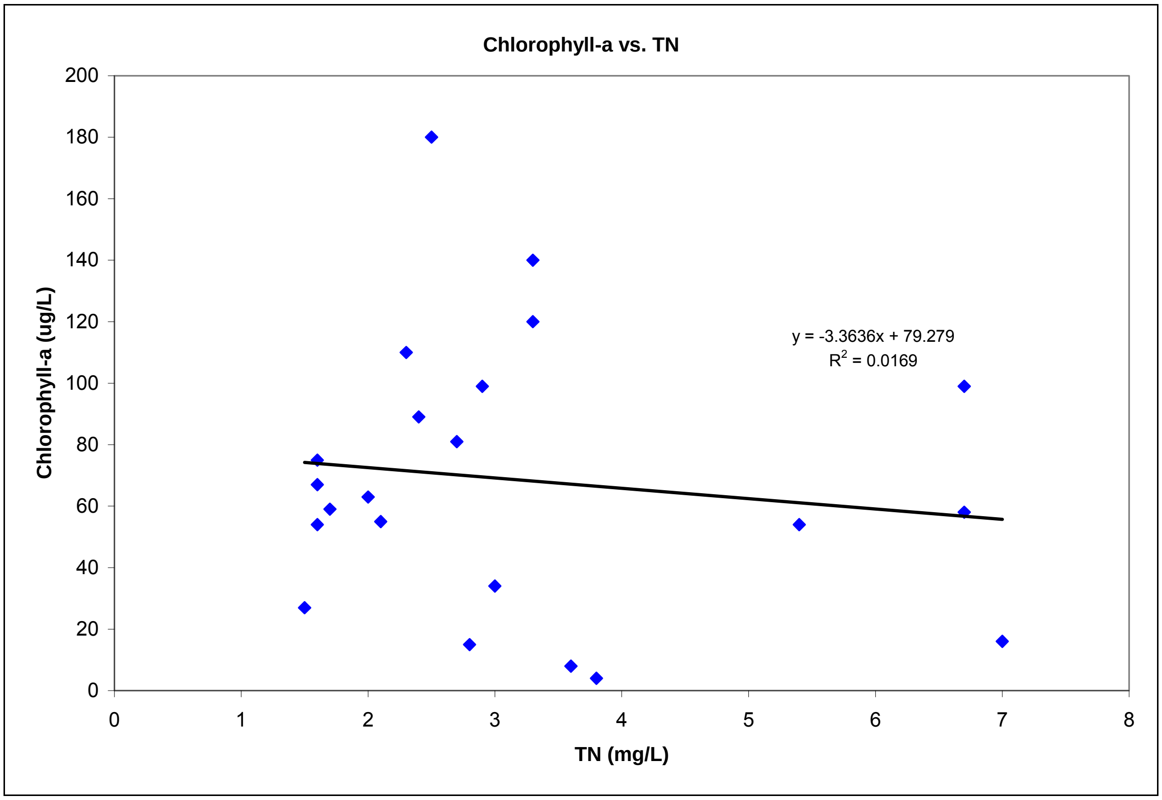

Figure 3-12. Chlorophyll-a vs. total nitrogen (TN).

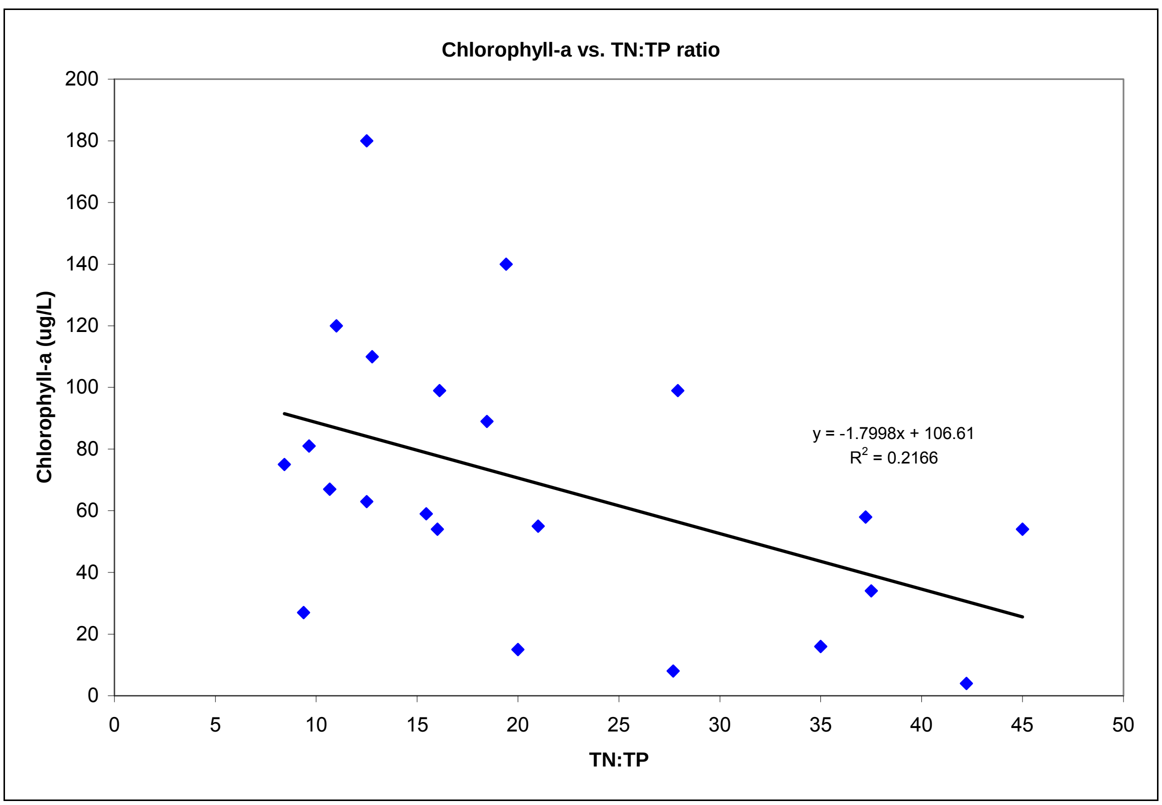

Figure 3-13. Chlorophyll-a vs. total nitrogen to total phosphorus ratio (TN:TP).

3.2. TMDL Target

General description of the pollutant

The 305(b) assessment and the data interpretation described in Section 3.1 reveal that both algae and non-algal turbidity are causing poor water clarity in Black Hawk Lake. Carlson's TSI methodology, the TN:TP ratio, and the regressions in Section 3.1 reveal that controlling phosphorus levels in Black Hawk Lake will have more impact on transparency than nitrogen reductions. Additionally, nitrogen reduction in lieu of phosphorus controls may tilt the TN:TP ratio higher, which could lead to conditions that increase risk of potentially dangerous blue-green algae called cyanobacteria (Smith, 1983).

Sediment reduction will also be important in improving water quality in Black Hawk Lake, since non-algal turbidity also reduces clarity. Reduction of phosphorus loads to the lake will result in decreased sediment loads, since much of the phosphorus transported to the lake is attached to sediment. Additionally, if only the non-algal turbidity were addressed, algal blooms would likely worsen due to increased light penetration. For these reasons, the TMDLs for both algae and non-algal turbidity are based on in-lake targets for chlorophyll-a, which will be achieved by reducing phosphorus loads to the lake. Table 3-3 reports the existing and target chlorophyll-a levels, as well as the existing TP and Secchi depth. A chlorophyll-a TSI target of 65 was selected, which is the threshold value where aesthetically objectionable conditions begin to occur, which violates the narrative WQS criterion.

Table 3-3. Existing and target chlorophyll-a and associated parameters.

Parameter	2005-08 TSI	[1]Target TSI	2005-08 Mean	[1]Target Mean	Improvement Needed
Secchi depth	74	--	0.38	--	--
Chlorophyll-a	72	65	69 ug/L	34 ug/L	51% decrease
Total Phosphorus	78	--	163 ug/L	--	--

[1]The in-lake target is for chlorophyll-a, which determines the target TP load.

Selection of environmental conditions

The critical period for the occurrence of high non-algal turbidity and algal blooms resulting from high phosphorus levels in the lake is the growing season (April through September). A combined watershed and in-lake modeling approach using SWAT and BATHTUB revealed that best agreement between predicted and observed in-lake eutrophication parameters was obtained when growing season output was utilized. Additionally, all in-lake water quality data was obtained during the growing season. Therefore, both existing and allowable TP loads to Black Hawk Lake are expressed as growing season averages. Phosphorus loads are also expressed as daily maximums to comply with EPA guidance.

Waterbody pollutant loading capacity (TMDL)

This TMDL for algae and non-algal turbidity establishes an in-lake target for chlorophyll-a and an associated target TP load using analysis of existing water quality data and Carlson's trophic state index methodology. The water quality target is aggressive and will require implementation of a comprehensive watershed management and lake restoration plan. If the target load for TP is achieved, narrative water quality criteria applicable to Black Hawk Lake should be attained.

The allowable in-lake chlorophyll-a target was translated to the TP loading capacity by performing water quality simulations using the BATHTUB model. BATHTUB is a steady-state water quality model that performs empirical eutrophication simulations in lakes and reservoirs (Walker, 1999). The BATHTUB model was calibrated to water quality data collected by ISU and UHL from 2001 through 2008 using watershed hydrology and sediment and nutrient loads predicted by the Soil and Water Assessment Tool (SWAT) model. SWAT input included local soil, land cover, and climate data, as well as detailed information regarding agricultural practices and other land management activities. The annual TP loading capacity of 9,366 pounds per growing season (lbs/season) was obtained by adjusting the tributary and internal TP loads in the BATHTUB model until the target chlorophyll-a concentration was attained. A detailed discussion of the parameterization and performance of the SWAT and BATHTUB models is provided in Appendices D through F.

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

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

As recommended by EPA, the loading capacity of Black Hawk Lake for TP is expressed as a daily maximum load, in addition to the seasonal loading capacity of 9,366 lbs/season obtained above. The annual average load is more applicable to the assessment of in-lake water quality and water quality improvement actions, while the daily maximum load expression satisfies the legal uncertainty addressed in the EPA memorandum.

The maximum daily load was estimated from the growing season average load using a statistical approach that is outlined in more detail in Appendix G. This approach uses a lognormal distribution to calculate the daily maximum from the long-term (e.g., seasonal) average load. The methodology for this approach is taken directly from a follow-up guidance document entitled *Options for Expressing Daily Loads in TMDLs* (EPA, 2007), and was issued shortly after the November 2006 memorandum cited previously. This methodology can also be found in EPA's 1991 *Technical Support Document for Water Quality Based Toxics Control*. Using the approach, the allowable maximum daily load (loading capacity) for TP in Black Hawk Lake is 219 lbs/day.

Decision criteria for water quality standards attainment

The narrative criteria in the water quality standards require that Black Hawk 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/maintaining a chlorophyll-a TSI of no greater than 65, which corresponds to a chlorophyll-a concentration of less than 34 ug/L.

3.3. Pollution Source Assessment

Existing load.

Long-term simulations (1997-2009) of hydrology and pollutant loading were developed using the Soil and Water Assessment Tool (SWAT) model. SWAT has been applied internationally to simulate watershed processes in agriculturally dominated watersheds, and has been utilized extensively in the United States for research and TMDL development. Model description and parameterization are described in detail in Appendix D.

Using SWAT, the growing season (April through September) average TP load to Black Hawk Lake, including watershed, internal, and atmospheric loading was estimated to be 42,620 lbs per season, or an average of 234 lbs/day, from 2001 through 2008. This period was selected for several reasons: the growing season is the critical season for algal blooms and poor water clarity, water quality data were collected by ISU and UHL during the 2001-08 growing seasons, and best agreement between observed and simulated in-lake water quality were achieved in this period. In addition, the impaired designated use, primary contact recreation, is most applicable to this period. The existing daily maximum load is 996 lbs/day. For consistency, the existing maximum daily load was estimated from the seasonal average load (SWAT output) using the same statistical approach described for the loading capacity.

Departure from load capacity

The target TP load, also referred to as the load capacity, for Black Hawk Lake is 9,366 lbs/season and 219 lbs/day (maximum daily load). To meet the target loads, a reduction of 78.0 percent of the TP load is required. This is an aggressive goal, and will require implementation of a comprehensive package of BMPs and other water quality improvement activities in the watershed. The implementation plan included in Section 4 describes potential BMPs, potential TP reductions, and a table of sample BMP scenarios.

Identification of pollutant sources

The existing TP load to Black Hawk Lake is primarily from nonpoint sources of pollution, but includes one point source operating under a National Pollution Discharge Elimination System (NPDES) permit. Table 3-4 reports estimated TP loads to the lake from all known sources during the growing seasons (April to September) of 2001-2008.

Table 3-4. Average growing season TP loads from each source (2001-08).

Source	Descriptions and Assumptions	[1]TP Load (lb/season)	Percent (%)
Row Crops	Corn and soybeans	31,459	73.8
Internal Recycling	Phosphorus recycled from lake bottom	6,299	14.8
Streambank Erosion	Phosphorus-bound sediment from unstable stream banks	2,888	6.8
Breda STP	Municipal sewage treatment plant	847	2.0
Feedlots	Runoff from open feedlots	418	1.0
Atmospheric Deposition	Wet and dry deposition from the atmosphere	204	0.5
Urban/Roads	Stormwater from Lake View, runoff from roads, etc.	192	0.4
Septic systems	Private on-site wastewater treatment systems	104	0.2
Cattle Grazing	Direct deposition of cattle manure in streams and pasture runoff	75	0.2
Wildlife/Background	Runoff from wildlife grass and timber areas; direct deposition by wildlife and geese	79	0.2
Other	All other minor sources	55	0.1
Total		42,620	100.0

[1]Loads in table are estimated loads transported to the lake from each source. Loads contributed to the network are greater than loads reported in the table.

Figure 3-14 illustrates the relative contributions of generalized phosphorus sources, compared with the percentage of the watershed area they comprise. The predominant source of phosphorus in the watershed is land in row crop production. Soil erosion results in phosphorus-laden sediment being washed into tributaries to Black Hawk Lake. Phosphorus levels in sediment and runoff are increased by the application of chemical and organic fertilizers, such as di-ammonium phosphate and swine manure. Runoff from row crops also carries soluble phosphorus into the stream network. Row crops comprise approximately 75 percent of the land use in the watershed and contribute an estimated 74 percent of the TP load. Approximately 20 percent of row crops in the watershed receive manure application, according to manure management plan (MMP) records. SWAT simulations revealed that the 20 percent of row crops receiving manure application account for over 28 percent of the total TP load from row crops.

Internal recycling of phosphorus in the lake, sometimes referred to as internal loading, comprised 14.8 percent of the average TP load in the 2001-2008 growing seasons. However, internal recycling may be more critical than this contribution suggests. In dry years, the internal load can drive algal blooms in the absence of significant phosphorus loads from watershed runoff. Precipitation data indicates that 2006 was the driest year on record between 2001 and 2009, and the estimated internal load in 2006 was two and one-half times greater than the simulated load from all watershed sources. The average chlorophyll-a TSI during the 2006 growing season was 70, lower than most other years but still classified as hypereutrophic. The relative magnitude of average internal loads is decreased due to extremely large external loads in wet years, but in-lake water quality will not improve significantly without reducing both internal and external sources of phosphorus.

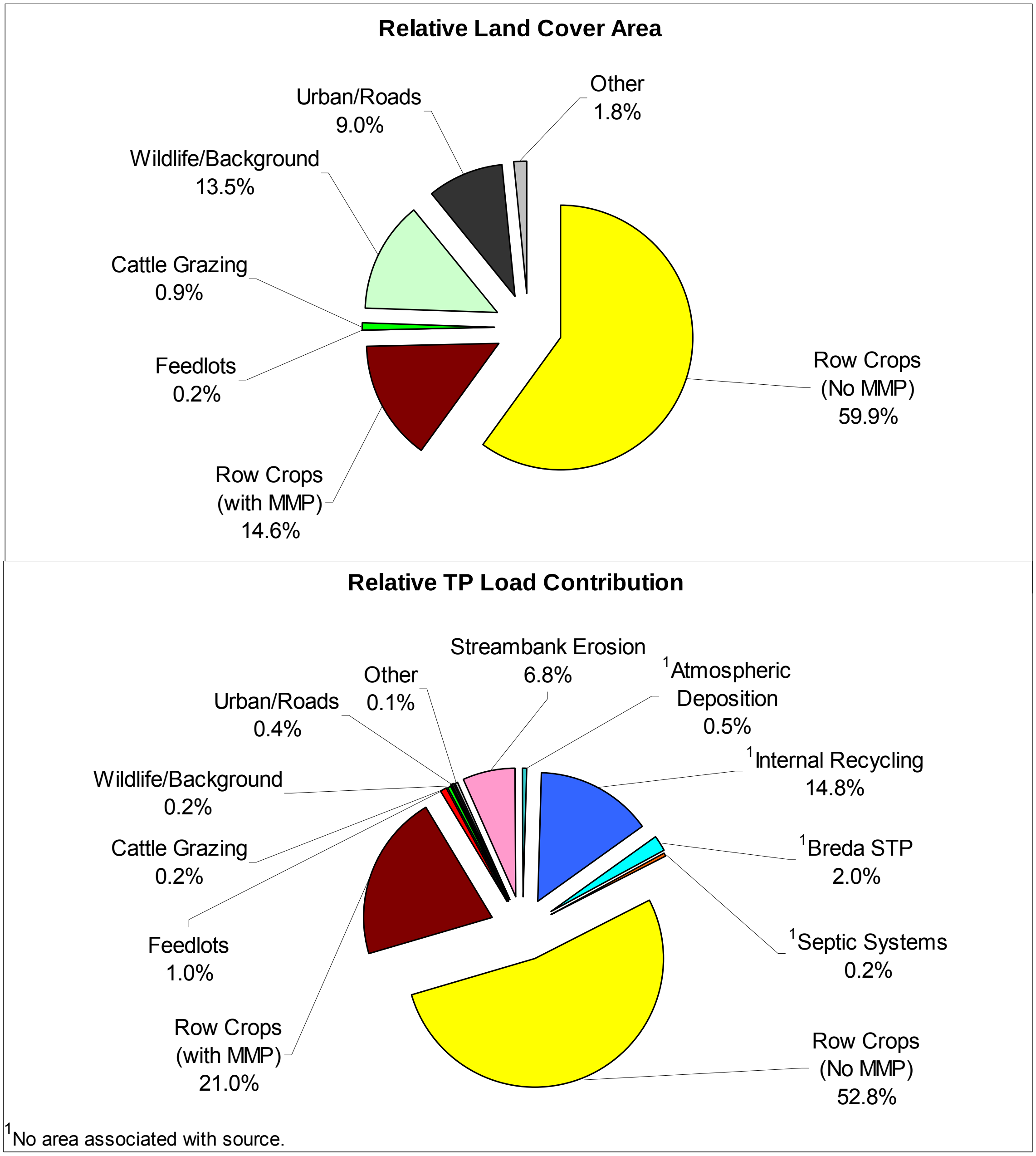

Figure 3-14. Percent of watershed area and TP load by source.

Streambank erosion (also called channel erosion) is temporally and spatially variable and inherently difficult to quantify. The SWAT model simulates streambank erosion and deposition, but quantifies only sediment, not phosphorus associated with channel sediment. One problem arising from this limitation is that the affects of sediment deposition on phosphorus transport are ignored. To calculate TP loads to Black Hawk

Lake resulting from streambank erosion, SWAT-predicted channel erosion, in metric tons (mtons), was multiplied by the 2001-2008 watershed-wide growing season-average sediment phosphorus concentration of 1,074 mg TP per kg sediment. This concentration was obtained from the simulated average sediment and phosphorus yields from the subbasins to the stream, and therefore considers phosphorus enrichment of sediment as it is delivered to the stream network. The inherent assumption is that streambank soil has the same phosphorus concentration as sediment that is washed from the land surface. The simulated 2001-2008 growing season average TP load to the lake (from streambank erosion) is 2,888 lb-TP/season, 6.8 percent of the TP load to Black Hawk Lake. A more detailed discussion of channel erosion methodology is discussed in Appendix D. Comparison of predicted and measured channel erosion is provided in Appendix E.

Phosphorus discharged from the Breda Sewage Treatment Plant (STP) is estimated at two percent of the total load, the fourth largest TP source behind row crop agriculture, internal loading, and streambank erosion. Other relatively insignificant sources, each comprising less than one percent of the total load, include natural background sources such as wildlife and atmospheric deposition, livestock grazing, privately owned on-site wastewater treatment systems (e.g., septic systems), and runoff from roads and urban land uses in the City of Lake View. Although overall loads from the urban area are relatively small due to the small urban area in the watershed, localized impacts on water quality (e.g., near outfalls) could be significant and should be considered when developing a watershed management plan. Assumptions and calculations used to estimate individual source contributions are discussed in detail in Appendix D.

Allowance for increases in pollutant loads

There is no allowance for increased TP loading included as part of this TMDL. A majority of the watershed is in agricultural row crop production, and is likely to remain in cropland in the future. Black Hawk State Park, which is adjacent to the lake, is unlikely to undergo significant land use changes. There are no incorporated unsewered communities in the watershed; therefore, it is unlikely that a future WLA would be needed for a new point source discharge. There may be an increase in residential development in the watershed in the future, but areas of Lake View that drain to the lake are already developed. Any transition from agriculture to residential land use would change the nature and the source of loading, but not the total LA as set forth in the TMDL.

3.4. Pollutant Allocation

Wasteload allocation

The Breda STP is located approximately 7 miles south of Black Hawk Lake and is the only permitted point source discharger in the watershed. The treatment facility is a four-cell controlled-discharge lagoon that typically discharges for 2-3 week periods in the spring and fall of each year. Existing phosphorus loads from the Breda facility were estimated using daily discharge records and an assumed effluent concentration of 3.6 mg/L TP. This concentration is based on the findings of two independent studies of TP in wastewater effluent (IDNR, 2007 and MPCA, 2000). The MPCA study found that TP in lagoon effluent ranges from 1 to 3 mg/L, with mean and median TP concentrations both equal to 2.0 mg/L (MPCA, 2000). The median effluent concentration from mechanical plants in the MPCA study was 4.0 mg/L. IDNR sampled ortho-phosphorus concentrations (PO_4) from 100 wastewater treatment facilities (WWTFs) across the State of Iowa, 16 of which were waste stabilization lagoons. The median outfall composite sample concentration (including all types of systems) was 3.6 mg/L PO_4 (IDNR, 2007). The data indicated that concentrations in lagoon effluent were lower than most other types of systems. Due to a limited number of controlled discharge lagoons in the study, the statewide WWTF median concentration of 3.6 mg/L PO_4 was assumed to represent the Breda STP effluent total phosphorus (TP) concentration. This is reasonable, and likely a conservative assumption, given the collective findings of the MPCA and IDNR studies.

The estimated load contributed by the Breda STP is two percent of the overall TP load to Black Hawk Lake. However, because no observed phosphorus data are available for the Breda facility, there is uncertainty associated with this allocation. The WLA is based on the best estimate of the existing effluent concentration of 3.6 mg/L and actual discharge (flow) records. Lagoon effluent concentrations above 3.6 mg/L may be indicative of conditions that require additional phosphorus reduction measures at the facility. This TMDL sets the WLA ceiling for the Breda STP at 936 lbs-TP/season, with a maximum daily WLA of 37 lb/day.

Load allocation

Nonpoint sources to Black Hawk Lake include loads from agricultural land uses, internal recycling in the lake, and natural/background sources in the watershed, including wildlife and atmospheric deposition. It is seldom feasible or economical to achieve large load reductions from natural/background sources. However, changes in agricultural land management, implementation of structural best management practices (BMPs), and in-lake restoration techniques can reduce phosphorus loads and improve water quality in Black Hawk Lake.

Table 3-5 shows a potential load allocation scheme for the Black Hawk Lake watershed that would meet the overall TMDL phosphorus target. The seasonal LA is 7,493 lbs/season, with a maximum daily LA of 160 lbs/day. Individual reductions shown in Table 3-5 are not required, but are provided as an example of how the overall reduction may be accomplished.

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. This equates to 937 lbs/season in the seasonal average expression, and 22 lbs/day in the daily maximum expression.

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

TP Source	Existing Load (lb/season)	LA (lb/season)	Load Reduction (%)
Row Crops	31,459	5,505	82.5
Internal Recycling	6,299	1,071	83.0
Streambank Erosion	2,888	505	82.5
Feedlots	418	21	95.0
Atmospheric Deposition	204	204	0.0
Urban/Roads	192	34	82.5
Septic systems	104	4	96.0
Cattle Grazing	75	15	80.0
Wildlife/Background	79	79	0.0
Other	55	55	0.0
Total	**41,773**	**7,493**	**82.1%**

Reasonable Assurance
Under current EPA guidance, TMDLs that allocate loads to both point sources (WLAs) and nonpoint sources (LAs) must demonstrate reasonable assurance that implementation and pollutant reductions will occur. For point sources, reasonable assurance is provided through NPDES permits. Permits include operation requirements and compliance schedules that are developed based on water quality protection. For nonpoint sources, allocations and proposed implementation activities must satisfy four criteria:

- They must apply to the pollutant of concern
- They will be implemented expeditiously
- They will be accomplished through effective programs
- They will be supported by adequate water quality funding

Nonpoint source measures developed in the Black Hawk Lake TMDL satisfy all four criteria. First, LAs developed in this section and implementation activities described in Section 4 of the report apply directly to the pollutant of concern (phosphorus). Second, the implementation plan sets forth an approximate timeline for implementation activities. Additionally, there is an active local watershed group that is already pursuing detailed watershed planning and implementation activities in parallel with TMDL development. Third, IDNR has set forth detailed requirements for watershed planning and implementation to ensure that watershed management plans and Section 319 applications meet EPA requirements. Examples of these requirements include a monitoring program to track progress towards water quality improvement, a phased and prioritized schedule of activities, and a plan that targets the impairment appropriately. Finally, ongoing monetary support is available for implementation in a variety of forms, including Section 319 grants, IDNR Lake Restoration funds, Watershed Improvement Review Board (WIRB) grants, the Water Protection Fund (WPF), and the Watershed Protection Fund (WSPF). WIRB funds were authorized in Chapter 466A of the Iowa Code and are administered by the WIRB board. WPF and WSPF funds are appropriated from the Iowa State Legislature and are administered by the IDALS Division of Soil Conservation (DSC).

3.5. TMDL Summary

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

TMDL = LC = Σ WLA + Σ LA + MOS

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

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

Expressed as the maximum growing season average, which is helpful for water quality assessment and watershed management:

TMDL = LC = Σ WLA (936 lbs-TP/season) + Σ LA (7,493 lbs-TP/season) + MOS (937 lbs-TP/season) = **9,366 lbs-TP/season**

Expressed as the maximum daily load:

TMDL = LC = Σ WLA (37 lbs-TP/day) + Σ LA (160 lbs-TP/day) + MOS (22 lbs-TP/day) = **219 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 (IDNR) recognizes that technical guidance and support are critical to achieving the goals outlined in this Water Quality Improvement Plan (WQIP). Therefore, this 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 represent a package of potential tools that will help achieve water quality goals if appropriately utilized. It is up to land managers, citizens, and local conservation professionals to determine which practices are most applicable to the Black Hawk Lake watershed and how best to implement them.

4.1. General Approach & Timeline

Collaboration and action by residents, landowners, lake patrons, and local agencies will be required in order to improve water quality in Black Hawk Lake to 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 Black Hawk Lake will have 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 BMPs and land management changes in the watershed. Because Black Hawk Lake lies within Black Hawk State Park, IDNR has a heightened interest in implementing BMPs within the park boundaries and lake. This large and diverse group of stakeholders provides the opportunity for an effective network of partnerships.

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

Timeline
Development of a comprehensive watershed management plan is underway and will be completed in 2011. Implementation of watershed BMPs should begin in 2012, and could take three to seven years, or longer, depending on funding availability, willingness of landowner participation, and time needed for design and construction of any structural BMPs. Realization and documentation of significant water quality benefits may take 10

years or longer, depending on weather patterns, amount of water quality data collected, and the successful location, design, construction, and maintenance of BMPs. A monitoring plan, based on the one outlined in Section 5, should be implemented immediately to establish baseline conditions. Monitoring efforts should continue throughout implementation of BMPs and beyond. Watershed planners should establish phased goals and milestones, verify achievement of goals with monitoring, and use monitoring data to guide future implementation efforts to continue progress towards WQS attainment.

4.2. Best Management Practices

No stand-alone BMP will be able to sufficiently reduce pollutant loads to Black Hawk Lake. Rather, a comprehensive package of BMPs will be required to address poor water transparency that has caused "aesthetically objectionable conditions" and impaired primary contact recreation. The majority of the phosphorus and sediment that enter the lake is from agricultural land uses, specifically land in row crop production. Although small on an annual average basis, internal recycling can be a significant source of phosphorus and drive algal blooms, particularly in dry years. Because the drainage area in urban land use is very small, urban pollution is a relatively small source of phosphorus. However, poor water quality and sediment deposition has been observed at urban stormwater outfalls to the lake, so urban contributions should not be ignored by watershed planners. Therefore, potential BMPs are grouped into three components: agricultural, in-lake, and urban. Tables 4-1 through 4-4 identify potential BMPs in each of these groups. These lists are not all-inclusive, and further investigation may reveal some alternatives are more or less feasible and applicable to site-specific conditions than others. Development of a detailed watershed management plan will be helpful in selecting, locating, and implementing the most effective and comprehensive package of BMPs practicable, and will maximize opportunities for future technical and funding assistance.

Agricultural BMPs

Many agricultural BMPs are designed to reduce erosion and/or capture sediment before it reaches a stream or lake. Because a large portion of TP is adsorbed to sediment, BMPs that reduce erosion and sediment transport will also reduce TP loads. Water quality improvement alternatives implemented in row crop areas should include structural BMPs such as sediment control structures, terraces, grass waterways, and wetlands restoration. Nonstructural conservation practices such as cross-slope farming, no-till and strip-till farming, diversified crop rotation methods, utilization of riparian buffers, and planting winter cover crops. To obtain reductions in TP load necessary to meet water quality targets, these practices should be focused where they are needed most (i.e., in areas with the highest potential to contribute sediment and phosphorus loads to the lake).

Management of livestock manure and synthetic fertilizer is another agricultural BMP that would reduce phosphorus loads to the lake. Incorporation of applied manure and fertilizer into the soil by knife injection equipment reduces phosphorus levels, as well as nitrogen and bacteria levels, in runoff from application areas. Strategic timing of manure and fertilizer application and avoiding over-application may have even greater benefits to water quality. Application of manure on frozen ground should be avoided, as should application prior to periods of anticipated heavy rainfall.

Table 4-1. Potential agricultural BMPs for water quality improvement.

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%
Terraces	50%
[2]Grass Waterways	--
[2]Sediment Control Structures	--
Pasture/Grassland Management:	
Livestock Exclusion from Streams	75%
Rotational Grazing vs. Constant Intensive Grazing	25%
Seasonal Grazing vs. Constant Intensive Grazing	50%
Phosphorus Nutrient Application Techniques	
[3]Deep Tillage Incorporation vs. Surface Broadcast	-15%
[3]Shallow Tillage Incorporation vs. Surface Broadcast	-10%
Knife/Injection Incorporation vs. Surface Broadcast	35%
Phosphorus Nutrient Application Timing and Rates:	
Spring vs. Fall Application	30%
Soil-Test P Rate vs. Over-Application Rates	40%
Application: 1-month prior to runoff event vs. 1-day	30%
Riparian Buffers	45%
[4]Wetlands	20%

[1]Adopted from USDA-ARS (2004). Actual reduction percentages may vary widely across sites and runoff events.
[2]No reductions reported by USDA-ARS for grass waterways or sediment structures
[3]Note: Tillage incorporation can increase TP in runoff.
[4]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.

Targeting Agricultural BMPs

Proper location of BMPs is as important as selection of BMP types. Figure 4-1 illustrates small areas composed of unique combinations of land use, soil, and slope, called hydrologic response units (HRUs), that are most prone to high erosion rates due to steep slopes. Figure 4-2 also shows slope information, but slopes have been aggregated to subbasin averages. Figure 4-3 highlights the subbasins that have the largest amounts of phosphorus applied to the soil by fertilizer and/or manure application. Subbasins with the lowest amount of phosphorus introduced to the land are green, whereas red indicates very high levels of phosphorus application. Finally, Figure 4-4 illustrates the amount of phosphorus exported to the stream network from each subbasin. Note that this includes surface runoff, tile flow, and groundwater, but does not include continuous in-stream sources (e.g., wastewater treatment systems, septics, etc.). Green subbasins indicate low phosphorus export and red subbasins export large amounts of phosphorus.

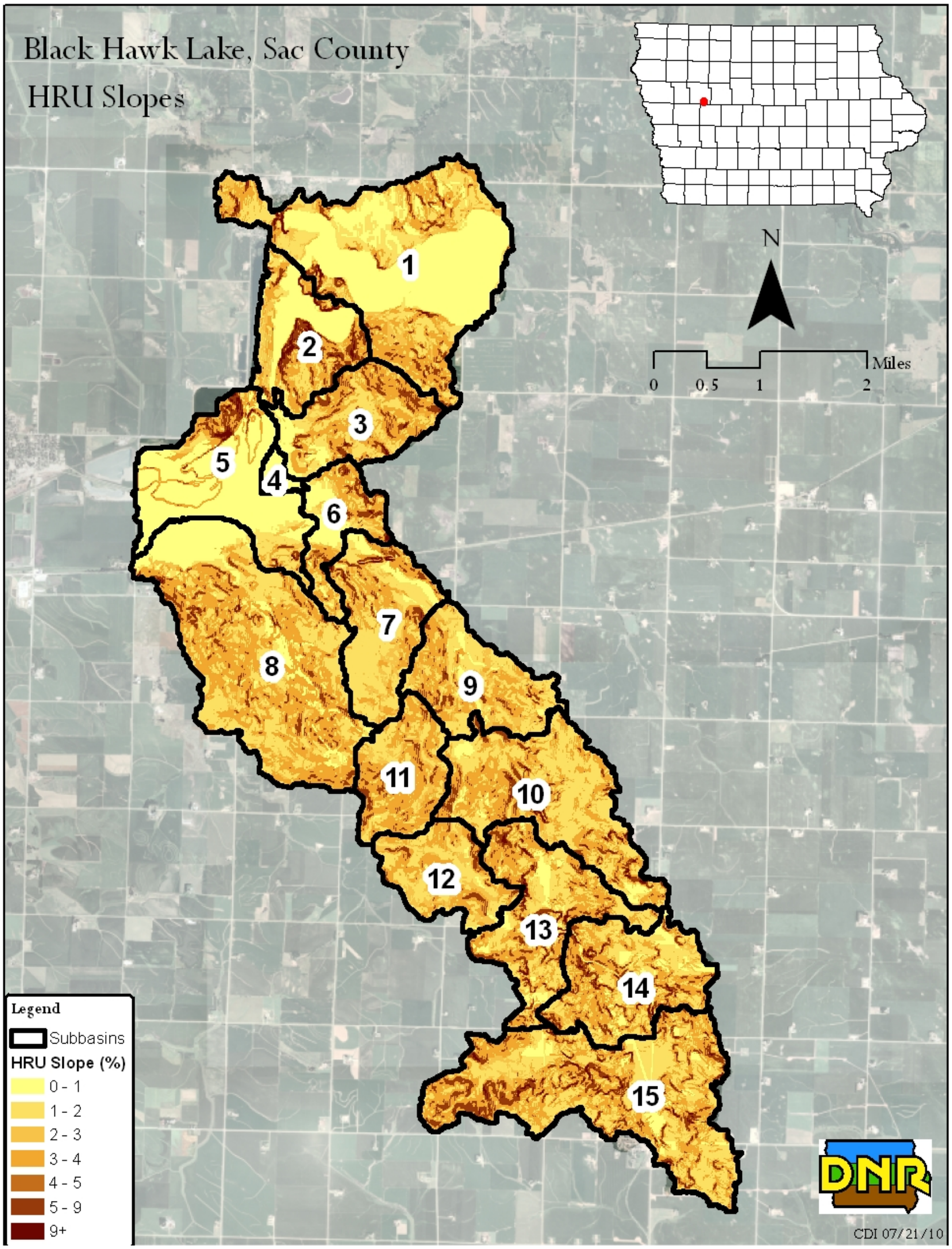

Figure 4-1. Average HRU slope in the Black Hawk Lake watershed.

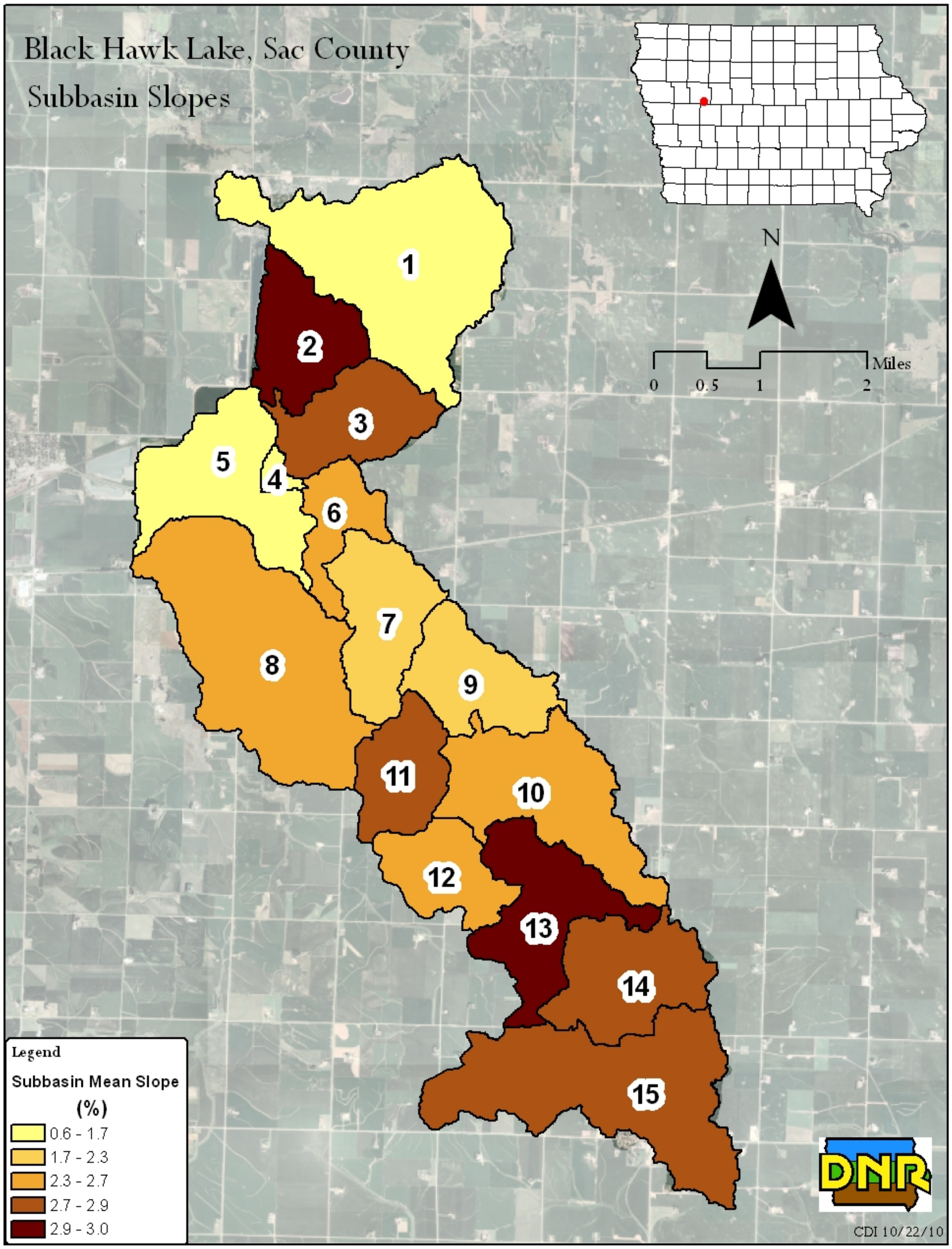

Figure 4-2. Average subbasin slope in the Black Hawk Lake watershed.