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:

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

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

One purpose of this Water Quality Improvement Plan (WQIP) for 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)

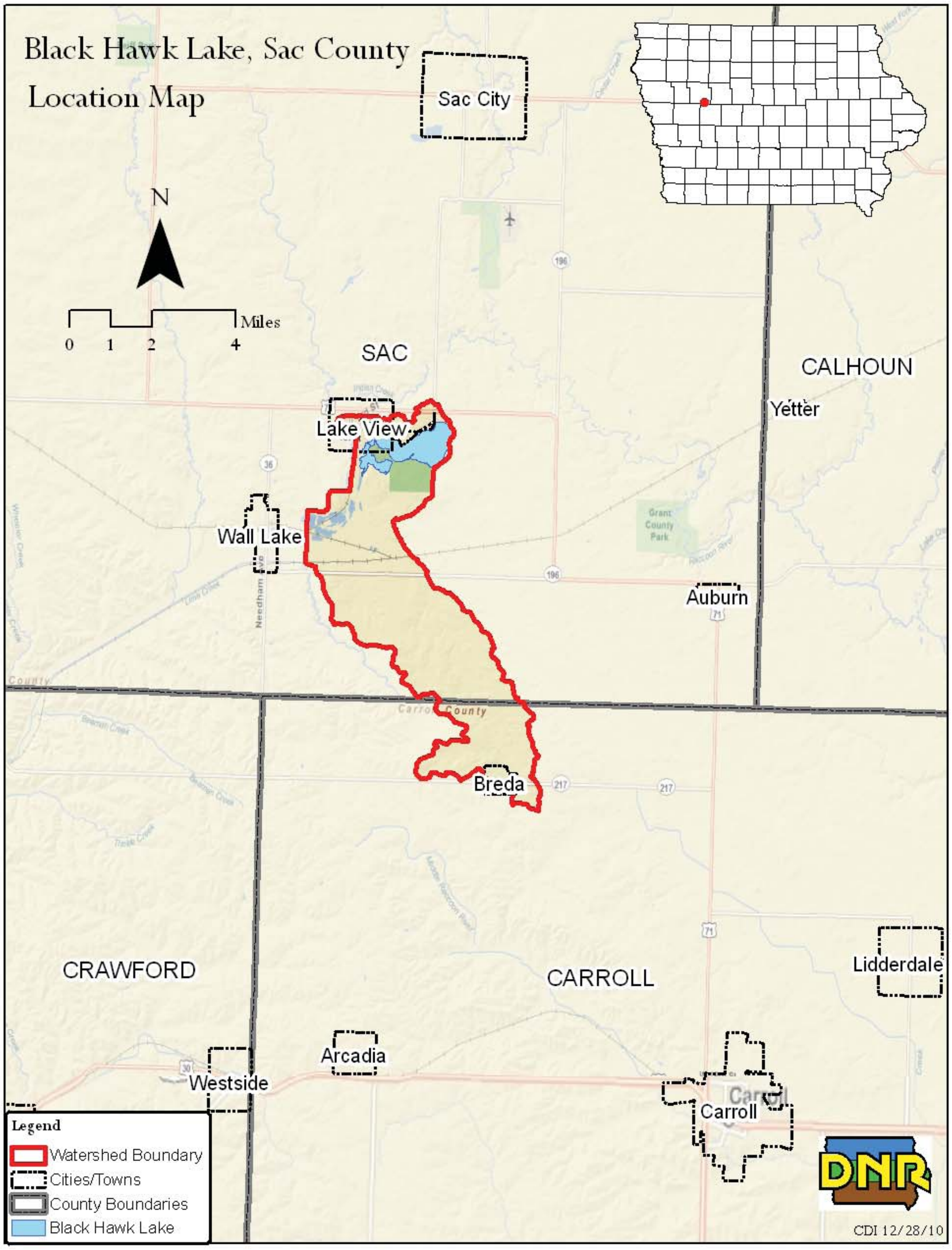


Figure 2-1. Watershed location map.

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)

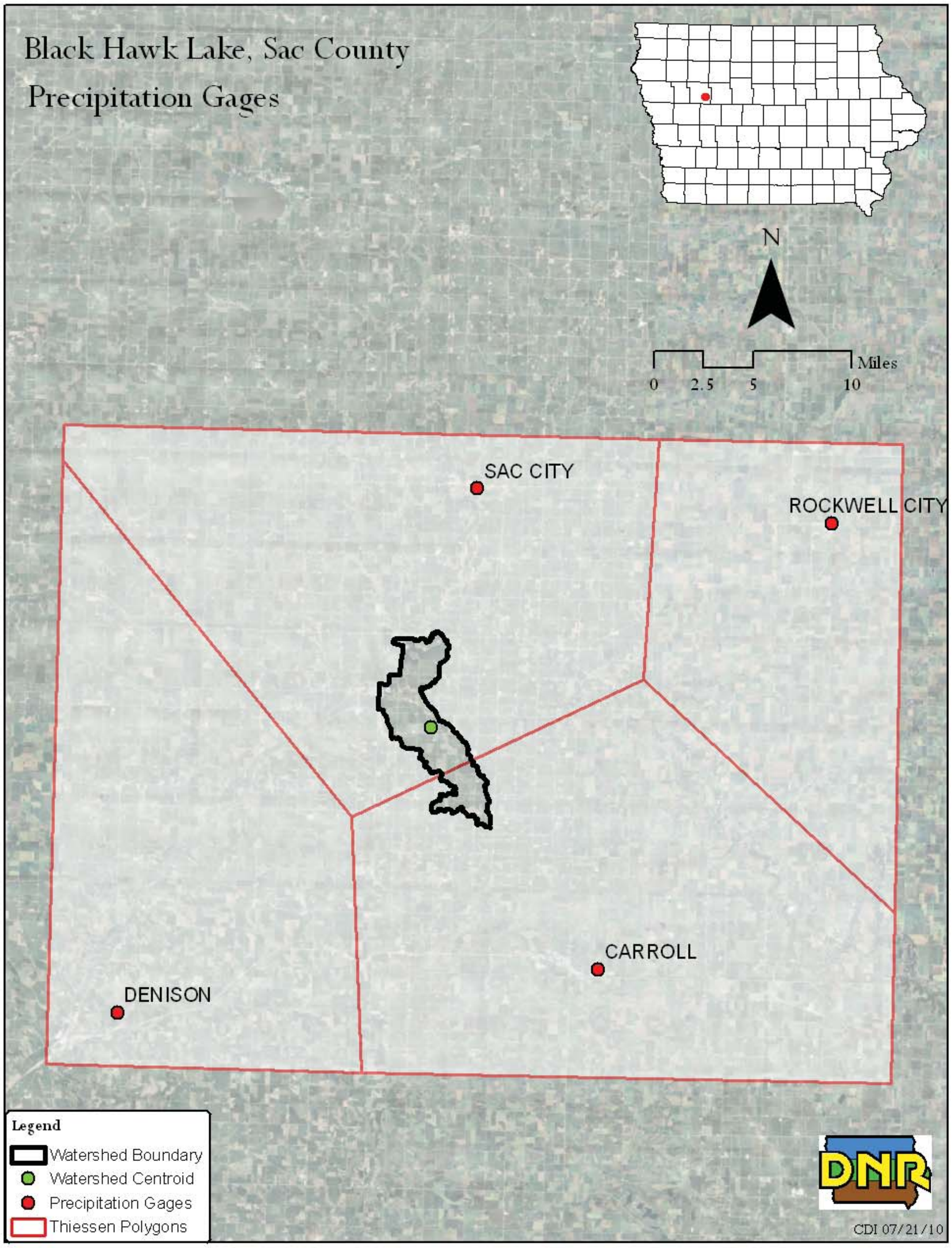


Figure 2-3. Map of nearby precipitation gages and Thiessen polygon.

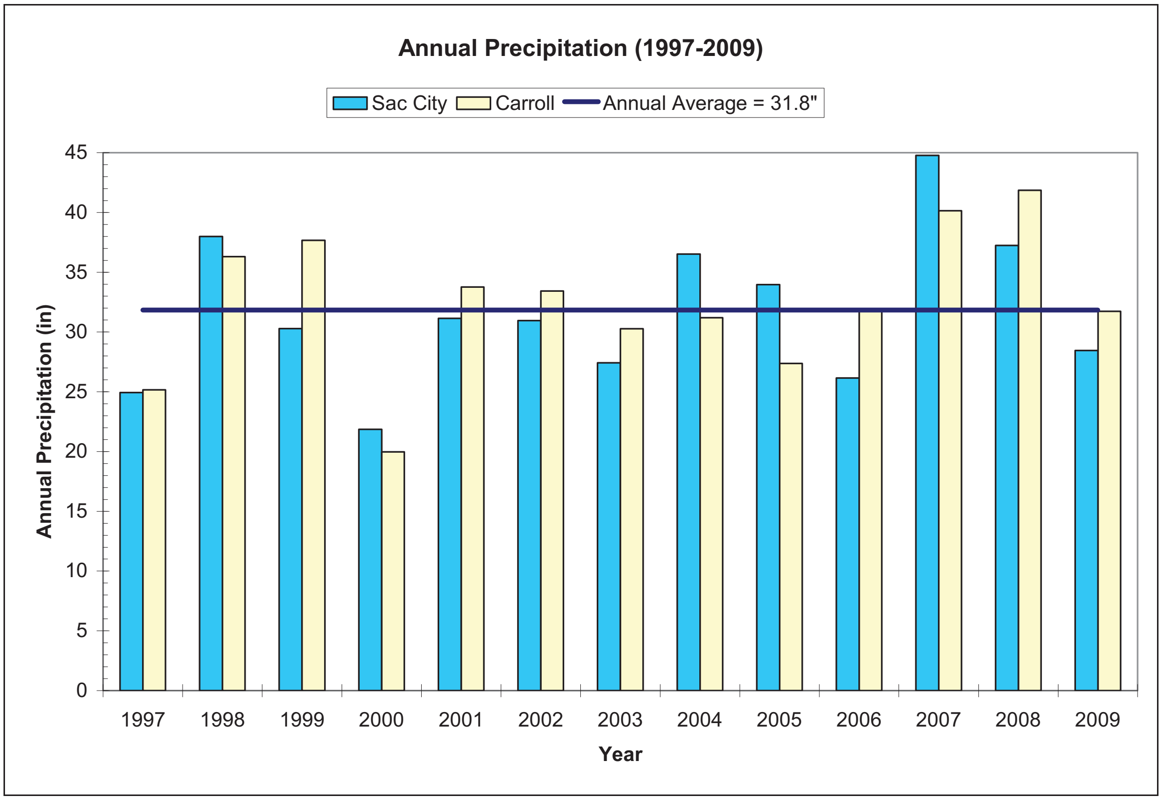


Figure 2-4. Annual water year precipitation at Sac City and Carroll, Iowa.

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)

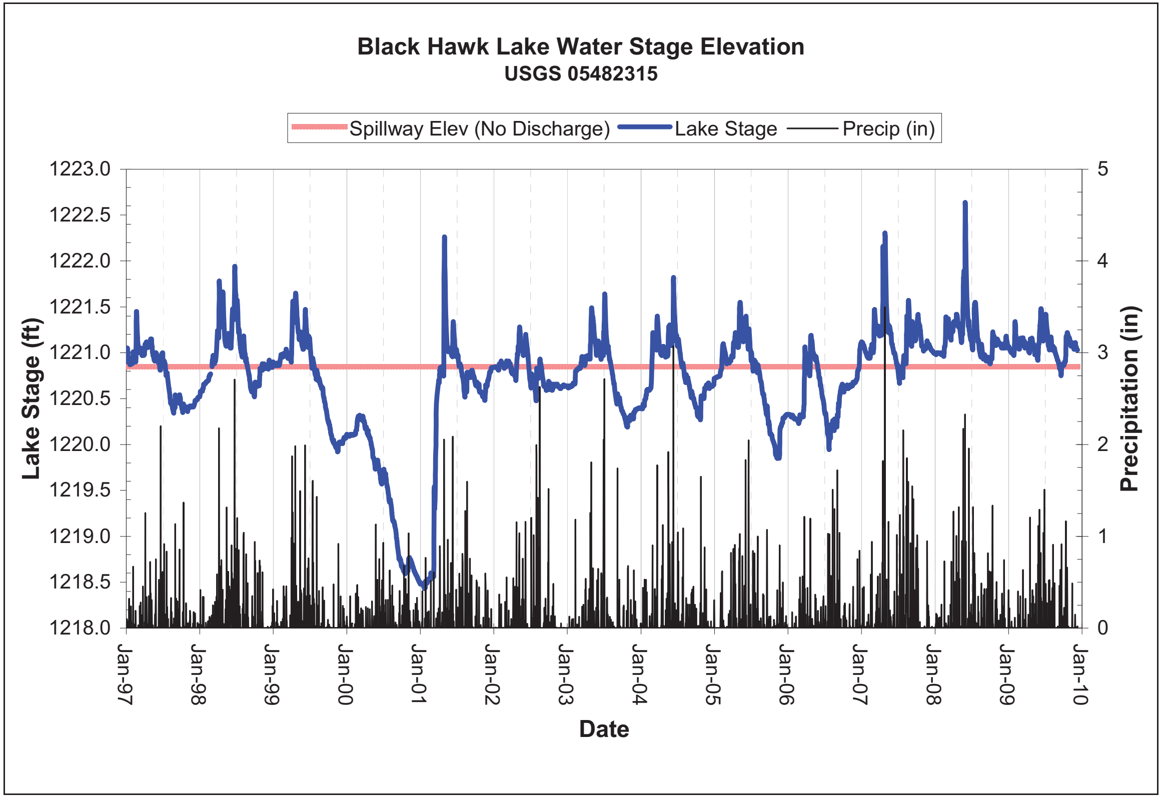


Figure 2-5. Daily lake stage and precipitation (1997-2009).

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.

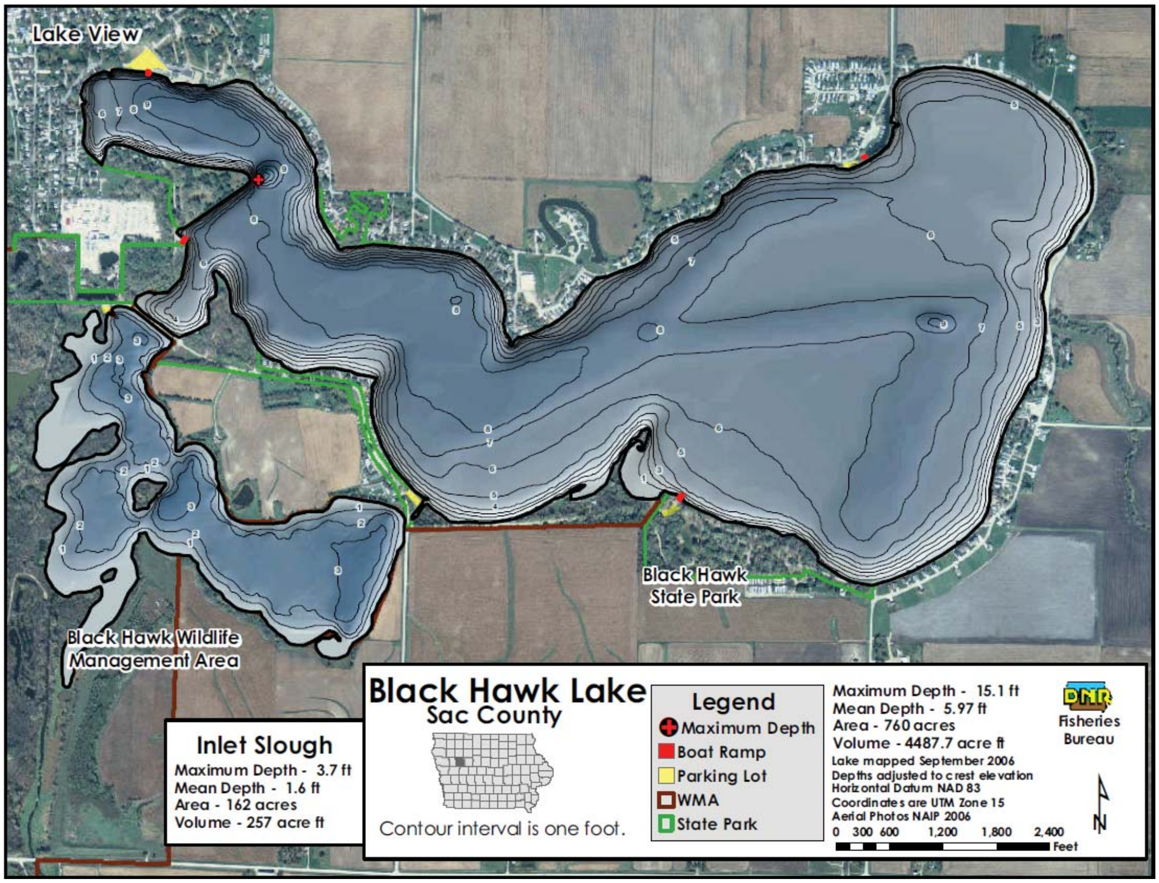


Figure 2-6. Aerial photograph and bathymetry of Black Hawk Lake.

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.

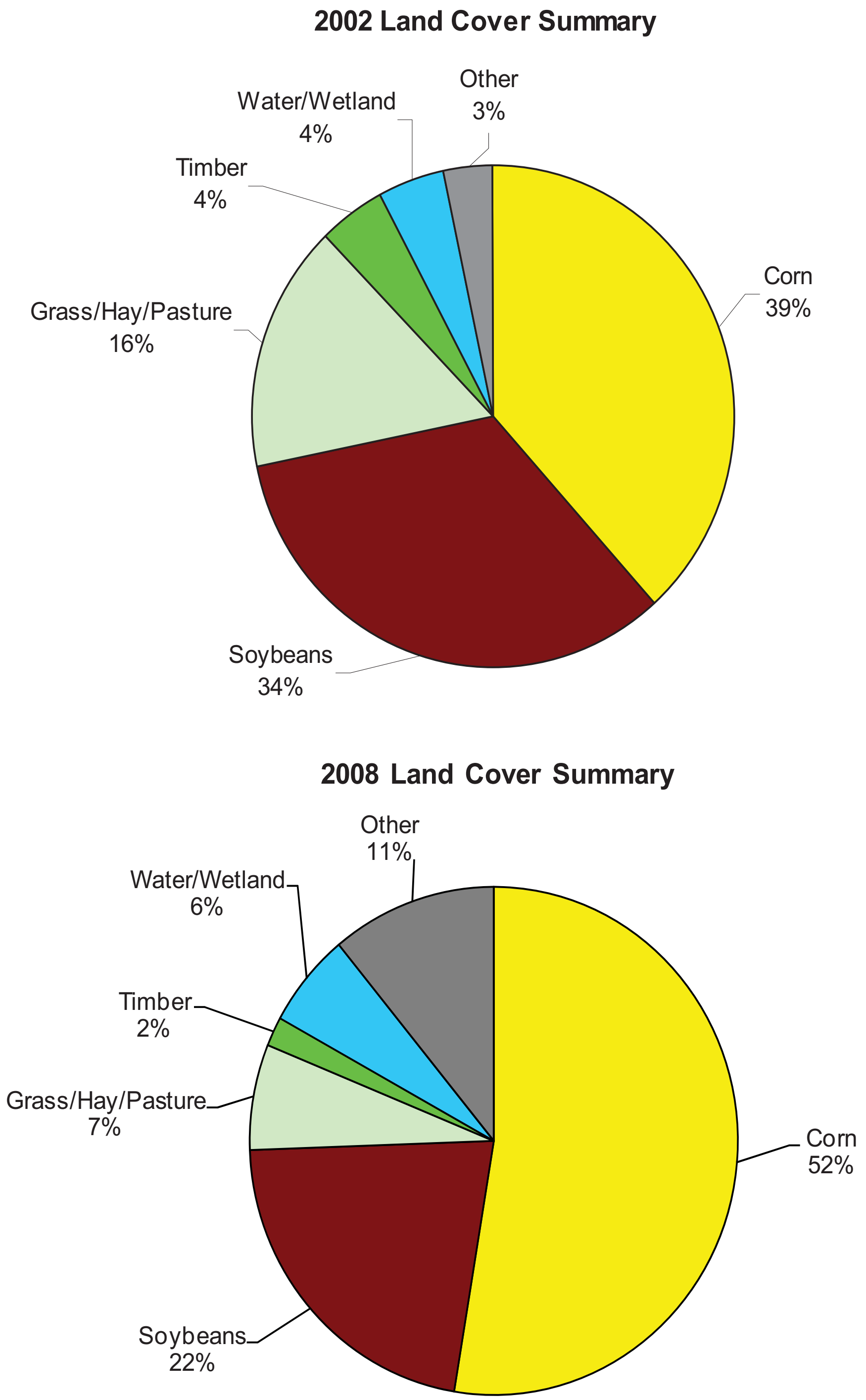


Figure 2-7. Comparison of land cover composition in 2002 and 2008.

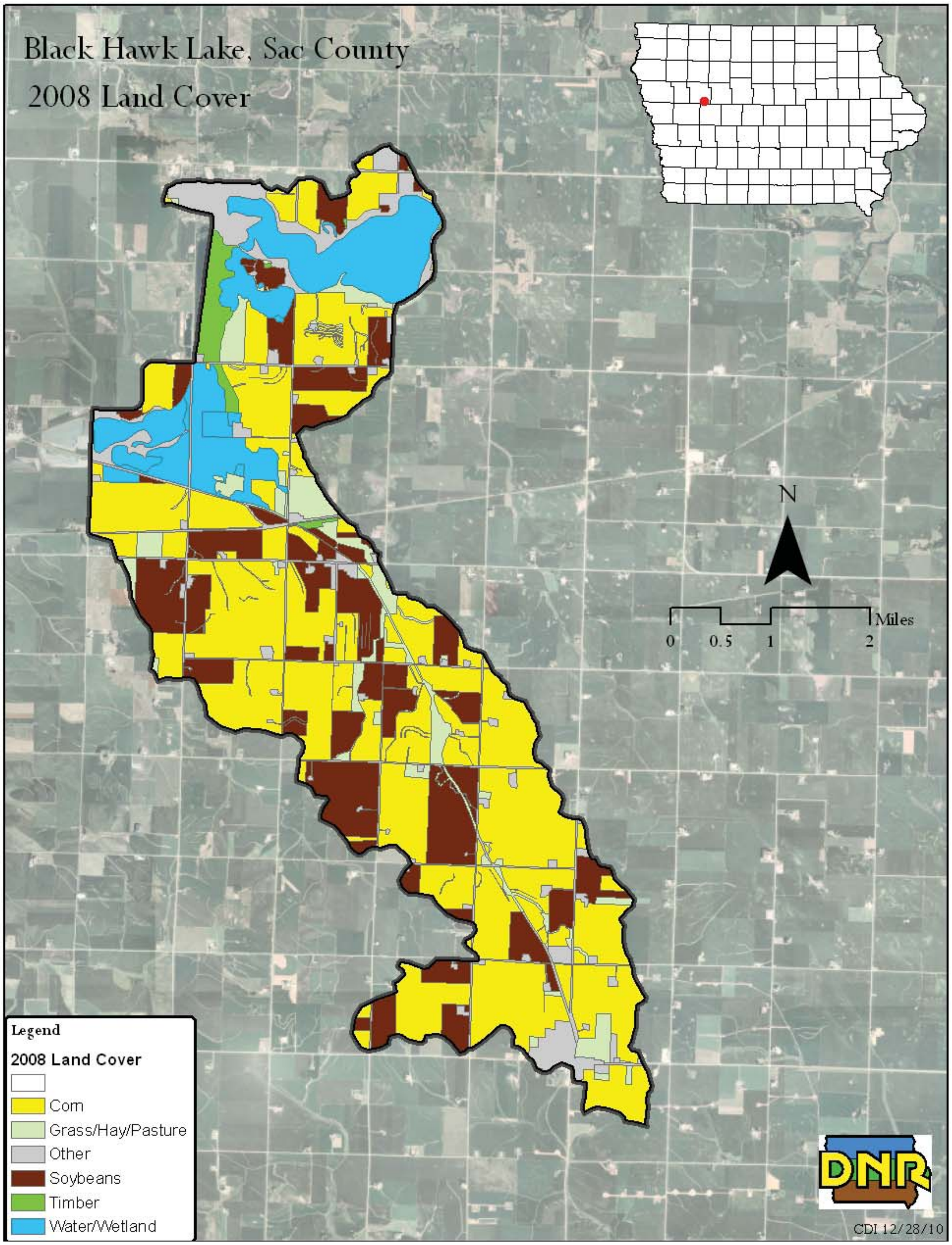


Figure 2-8. Black Hawk Lake watershed land cover (2008).

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.

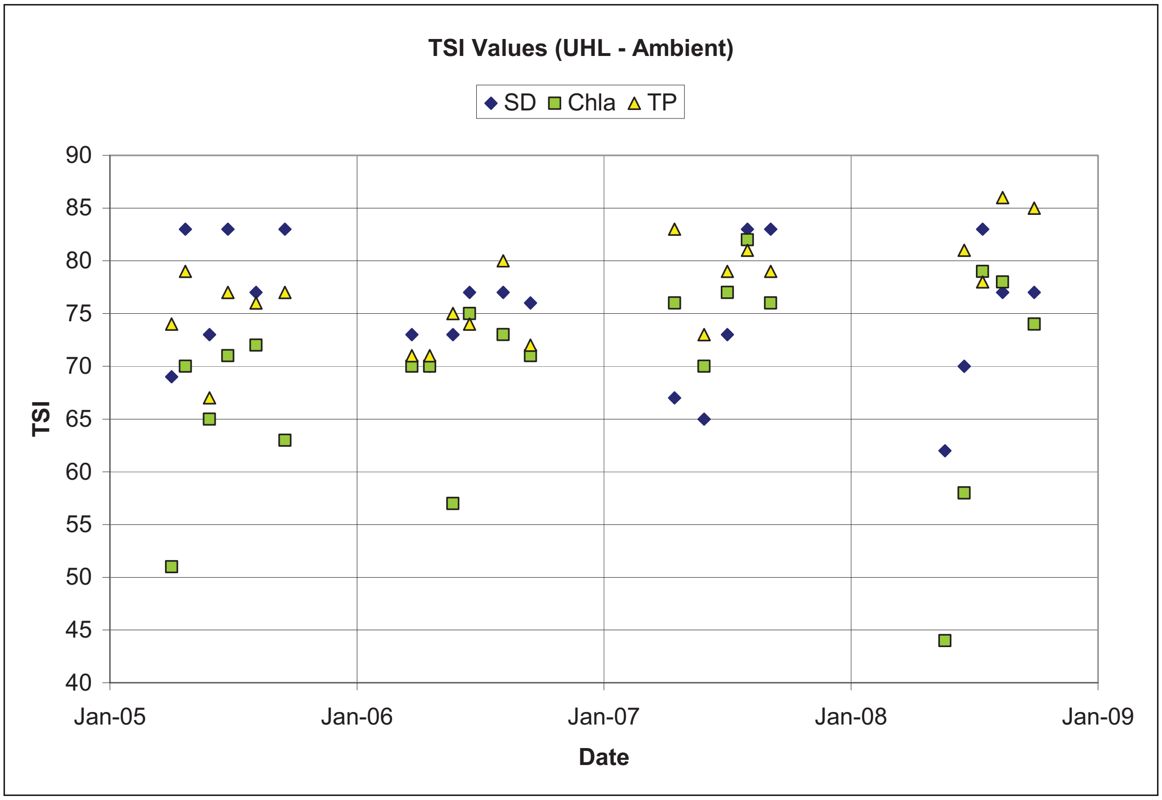


Figure 3-1. Black Hawk Lake TSI values (2005-2008 UHL data).

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.

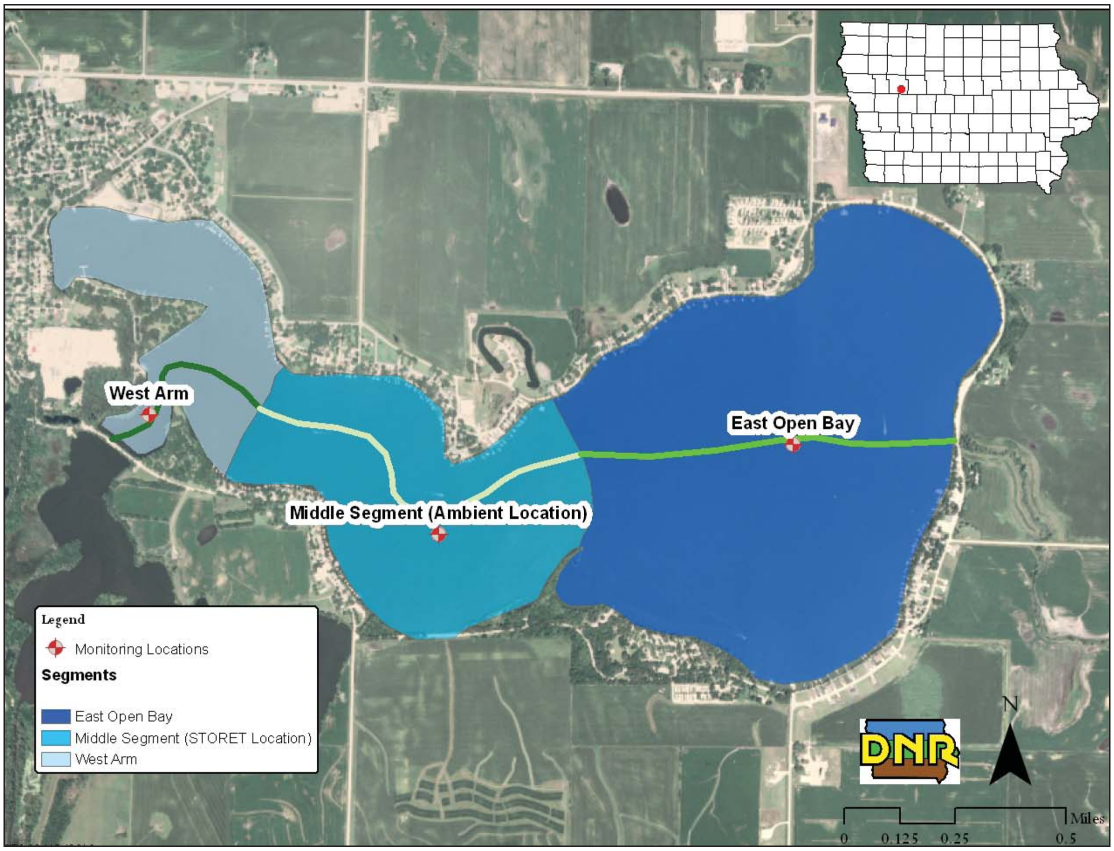


Figure 3-2. Monitoring locations for segmented data collected in 2007 and 2008.

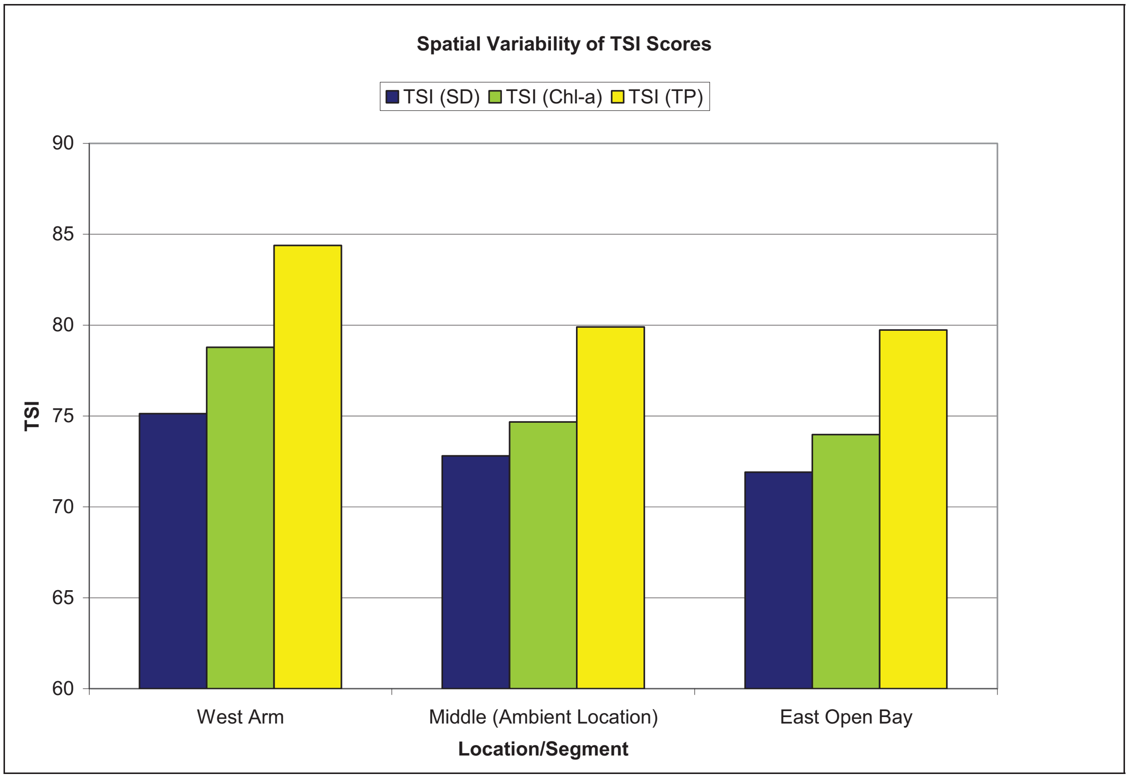


Figure 3-3. Mean TSI scores in each lake segment (2007 and 2008 data).

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.

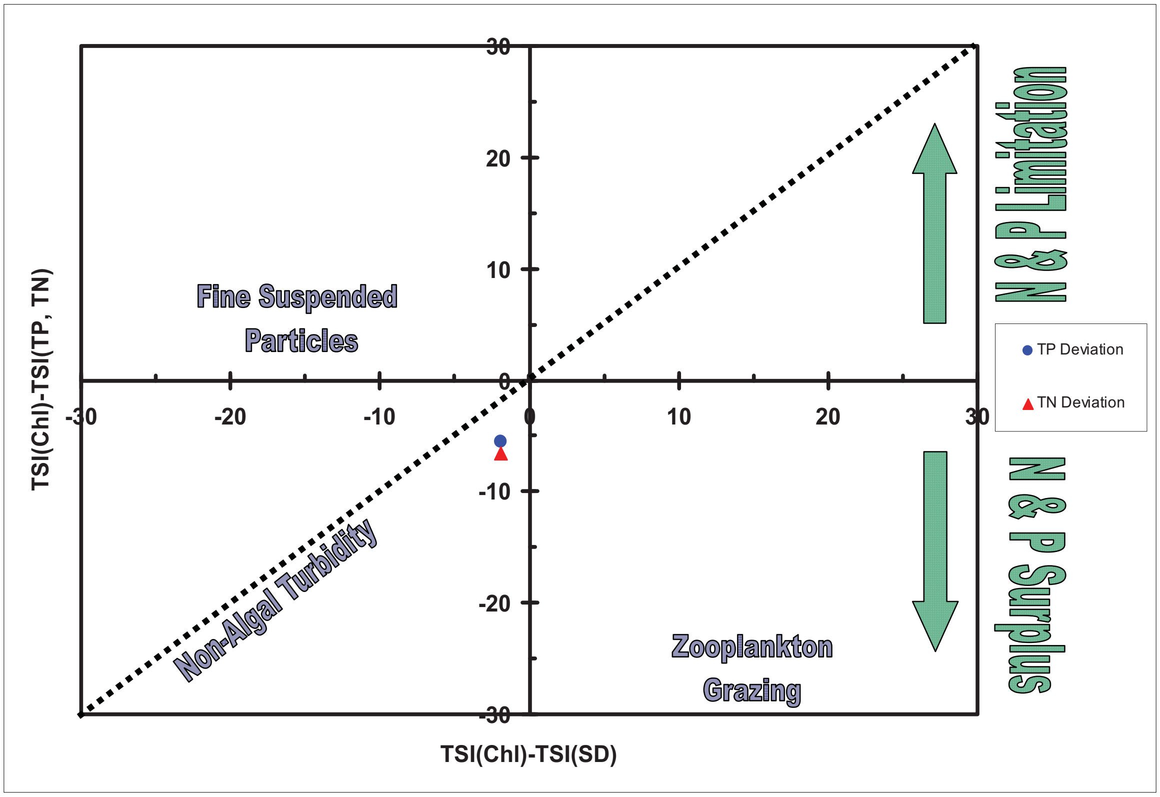


Figure 3-4. TSI deviations based on mean concentrations and Secchi depth.

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.

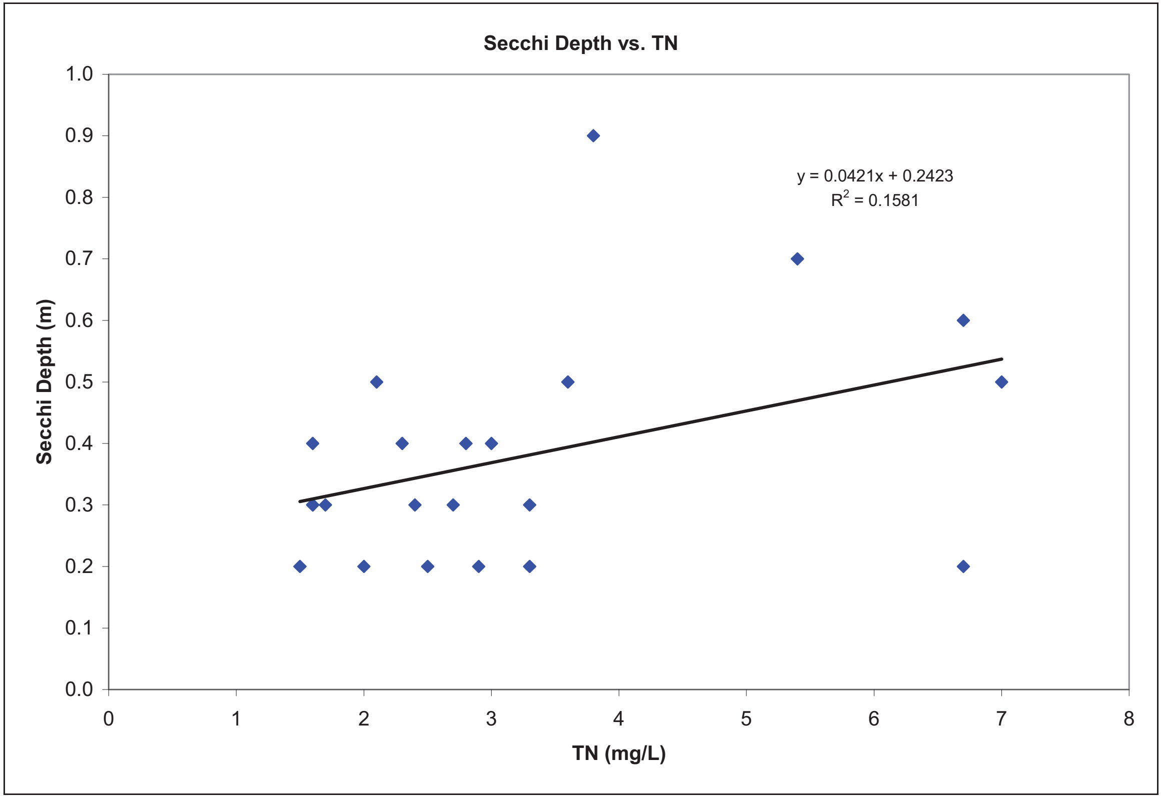


Figure 3-5. Secchi depth vs. total nitrogen (TN).

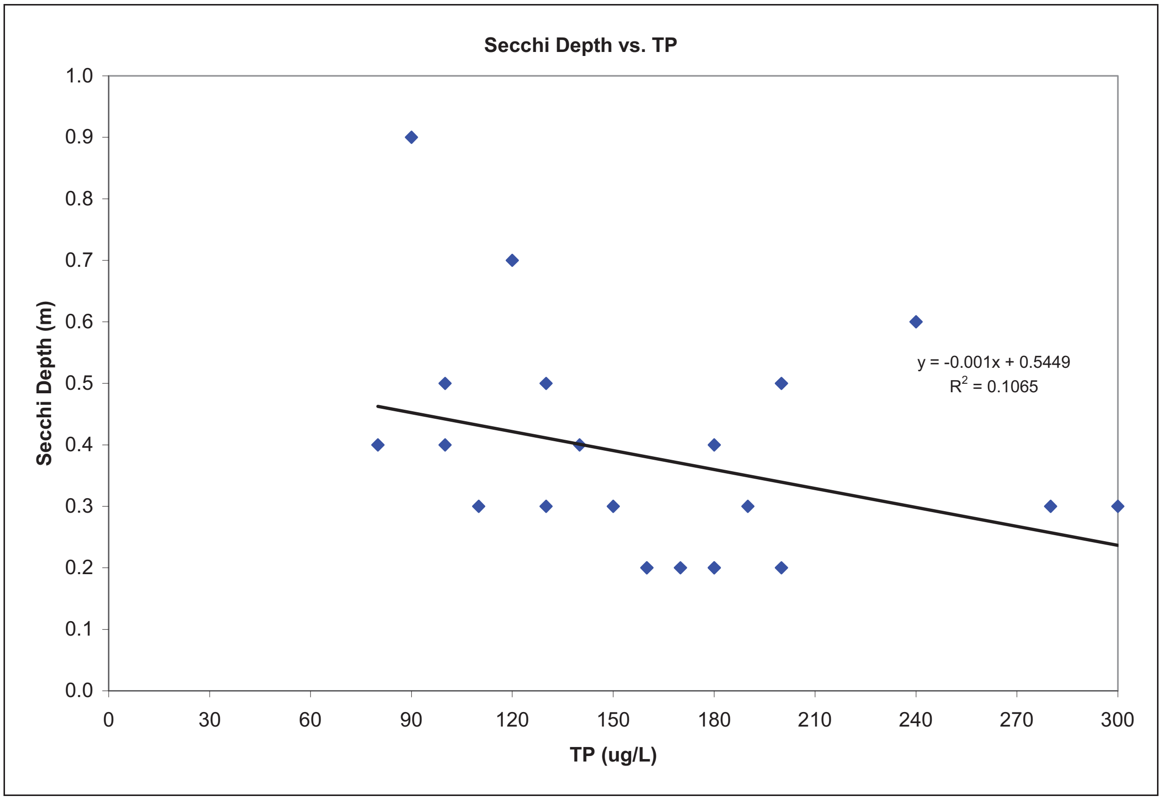


Figure 3-6. Secchi depth vs. total phosphorus (TP).

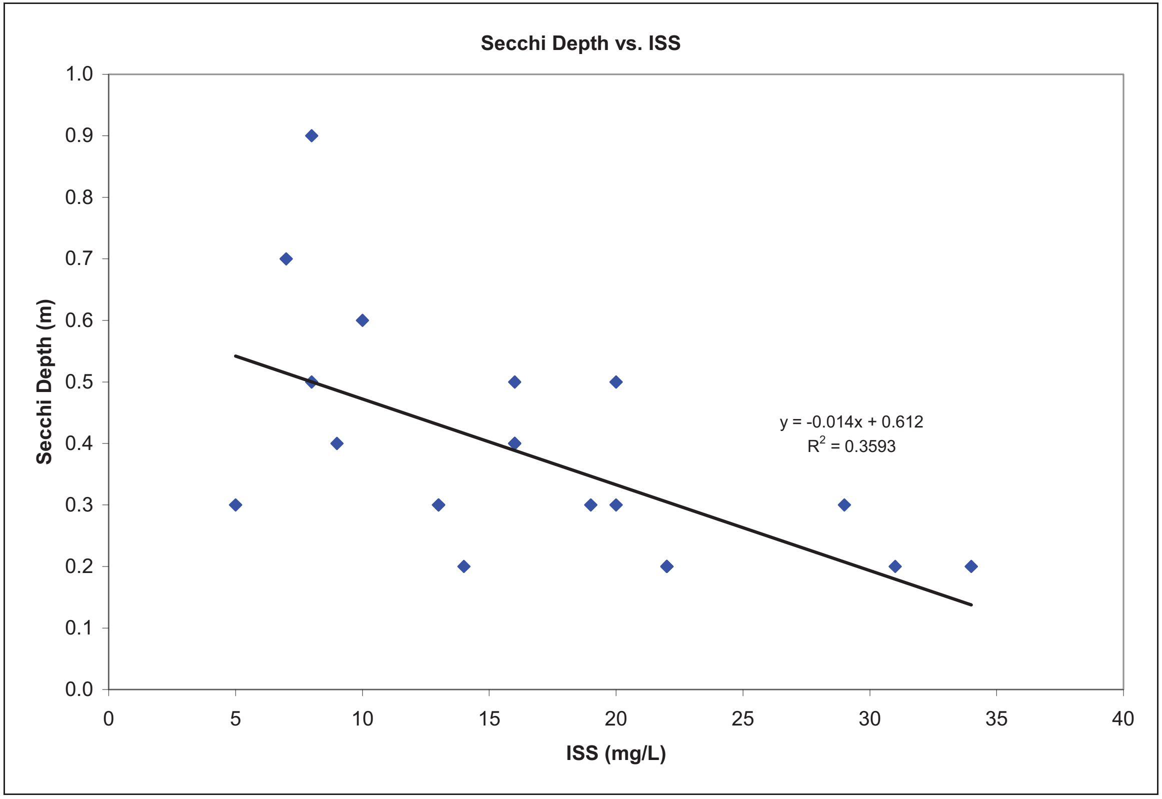


Figure 3-7. Secchi depth vs. inorganic suspended solids (ISS).

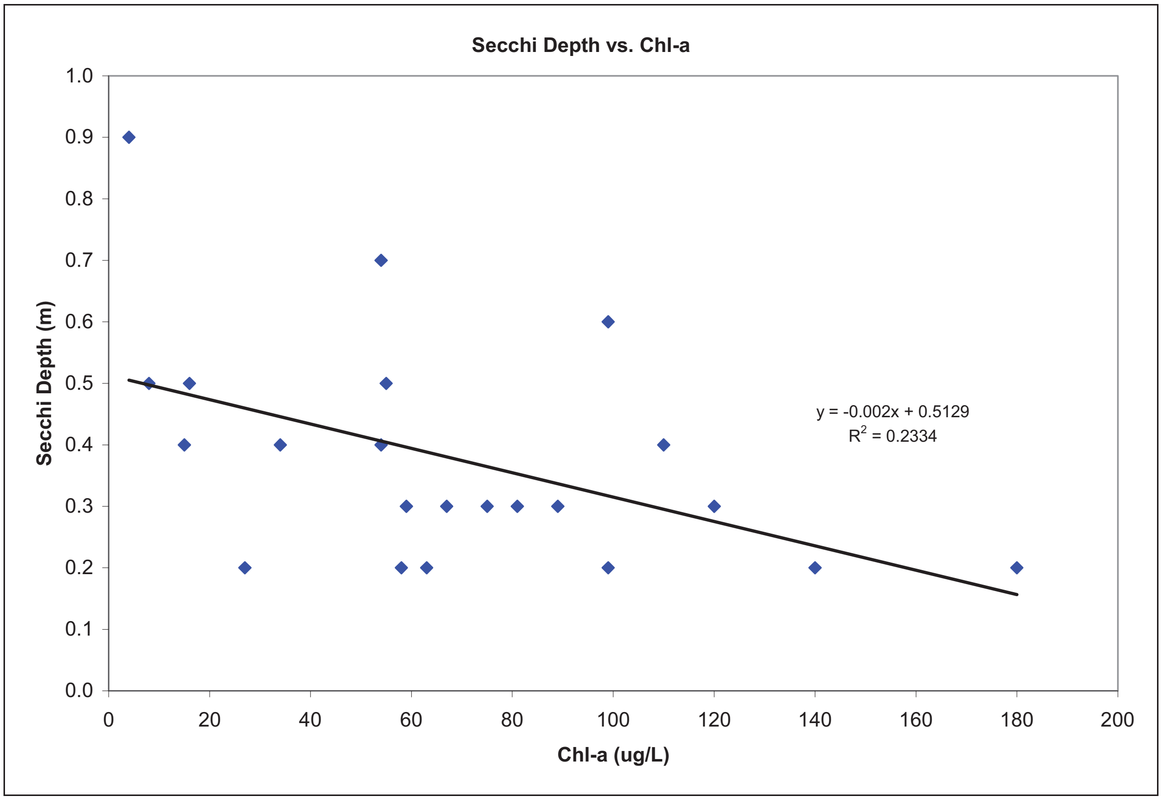


Figure 3-8. Secchi depth vs. chlorophyll-a (Chl-a).

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.

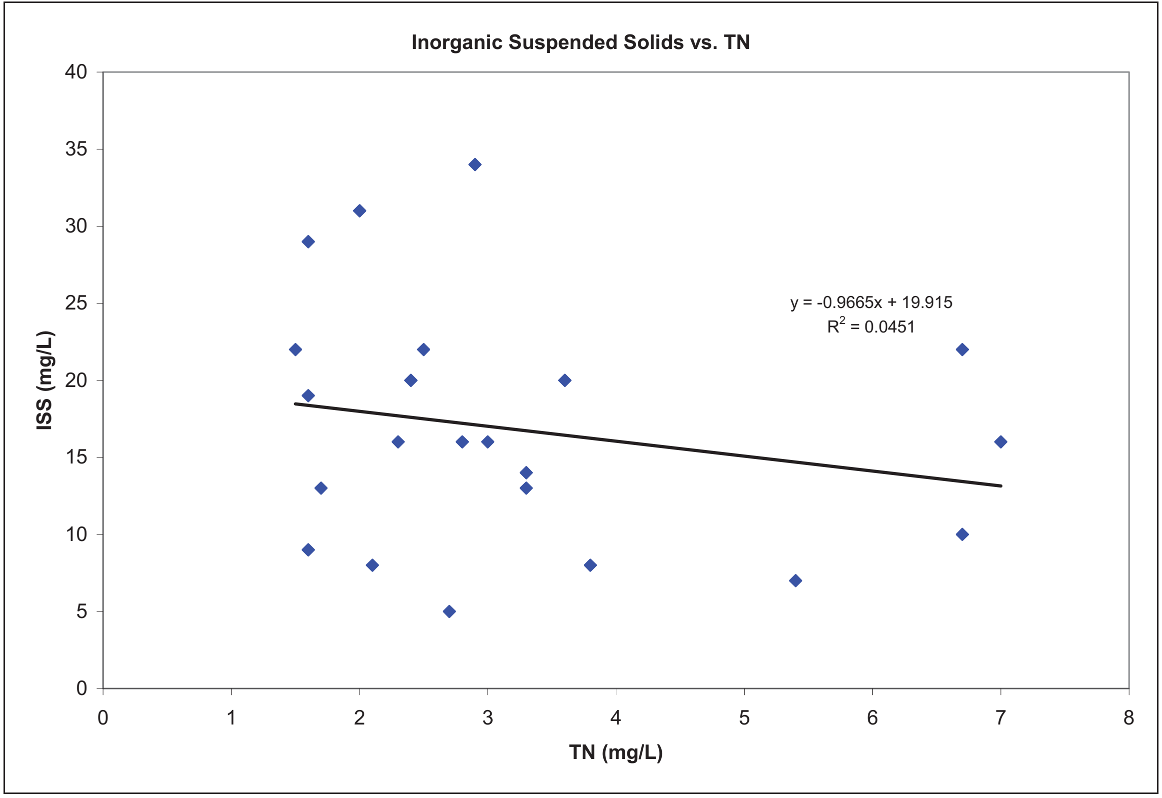


Figure 3-9. Inorganic suspended solids (ISS) vs. total nitrogen (TN).

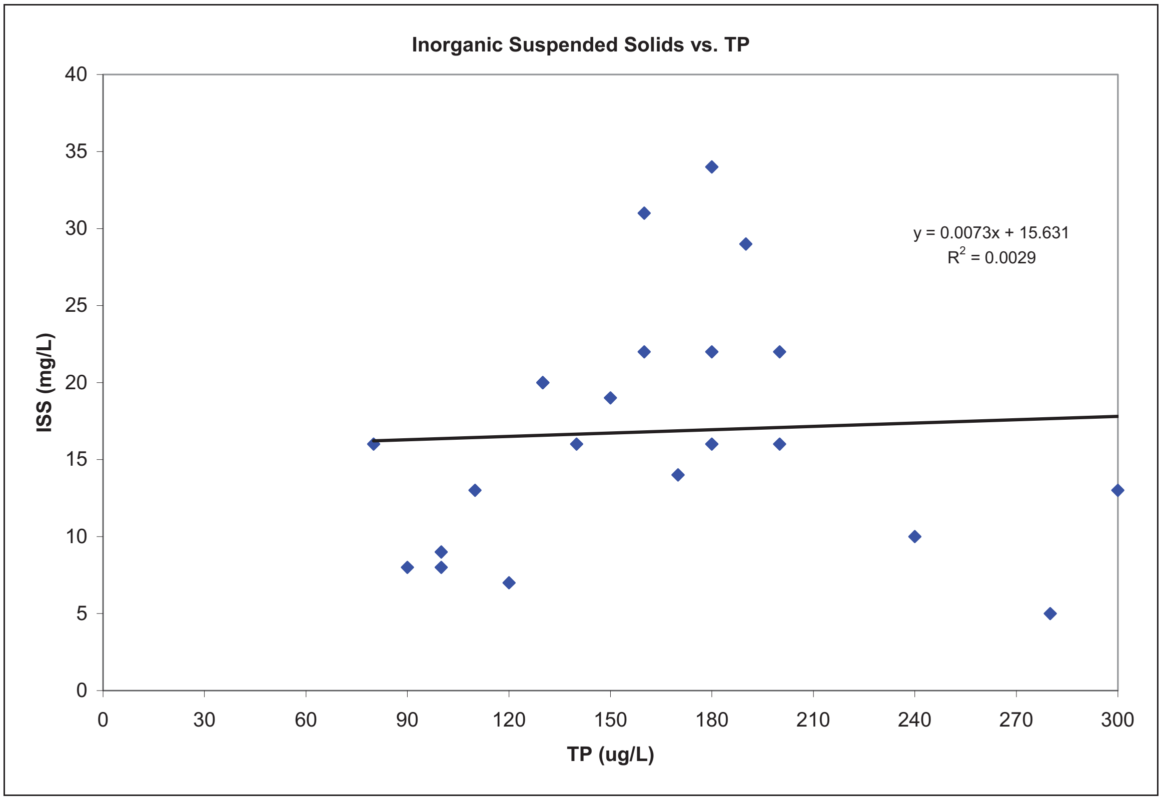


Figure 3-10. Inorganic suspended solids (ISS) vs. total phosphorus (TP).

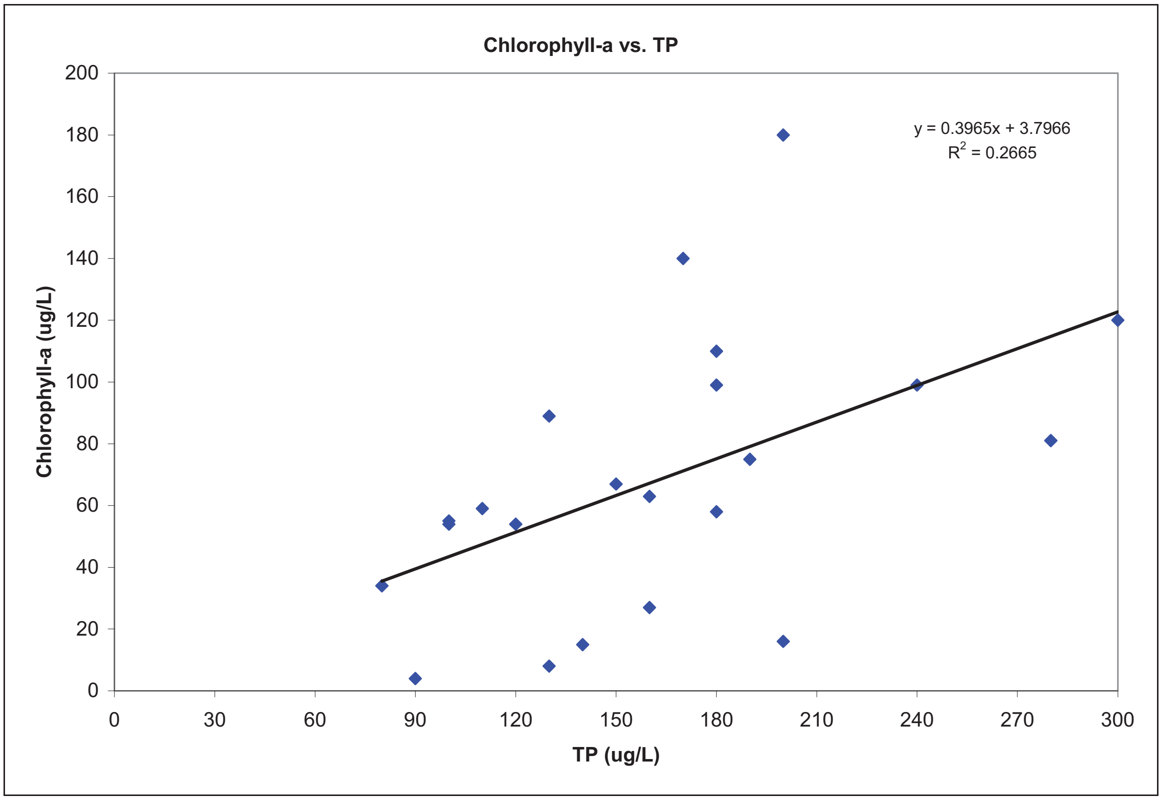


Figure 3-11. Chlorophyll-a vs. total phosphorus (TP).

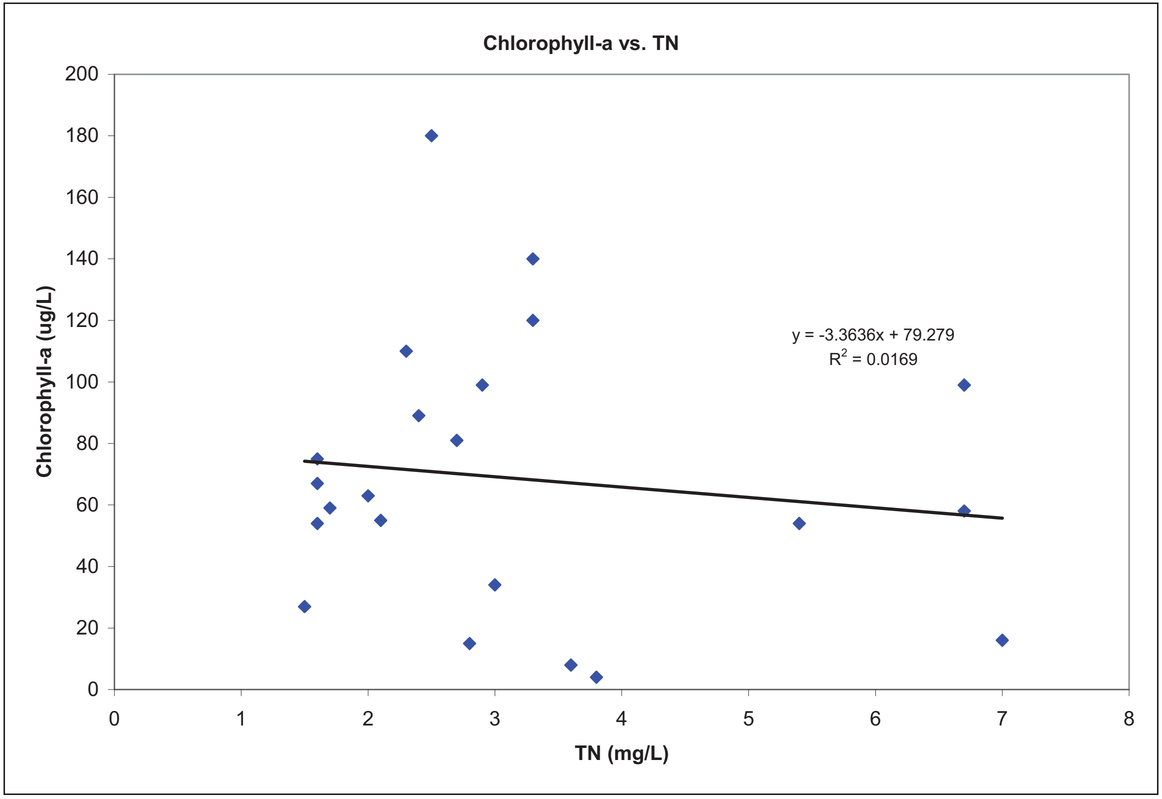


Figure 3-12. Chlorophyll-a vs. total nitrogen (TN).

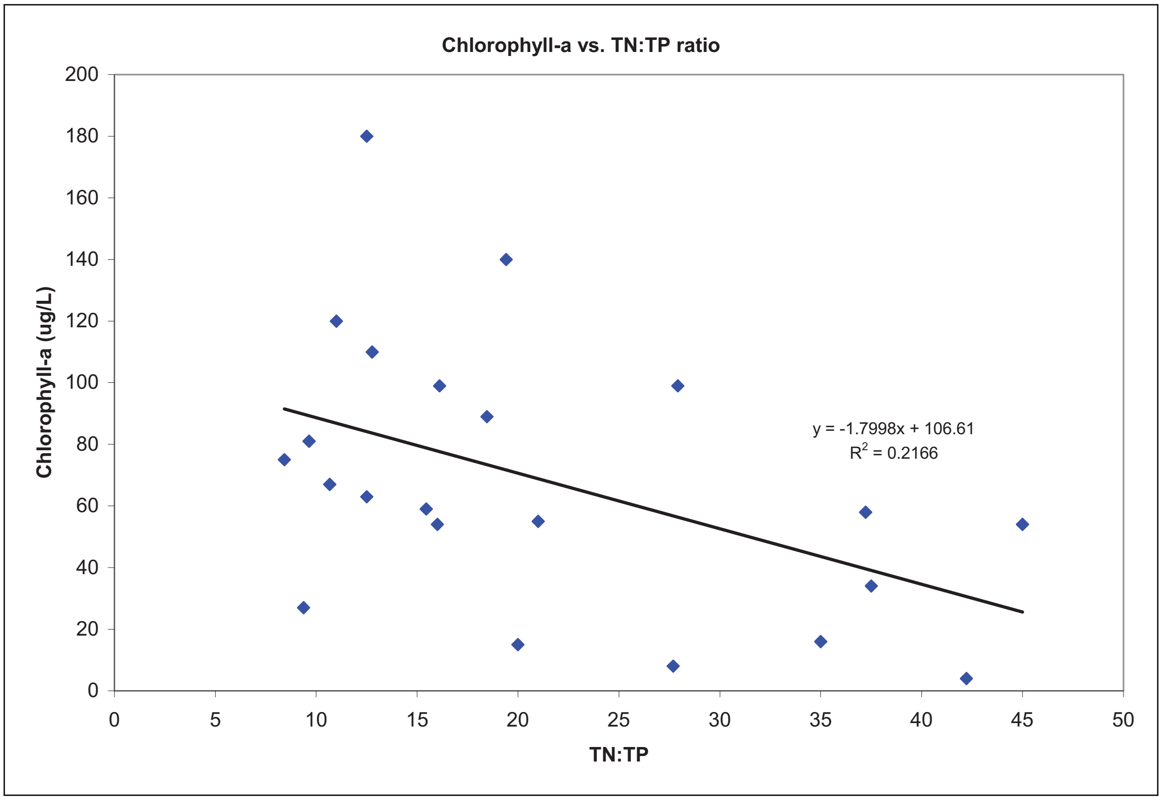


Figure 3-13. Chlorophyll-a vs. total nitrogen to total phosphorus ratio (TN:TP).

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.

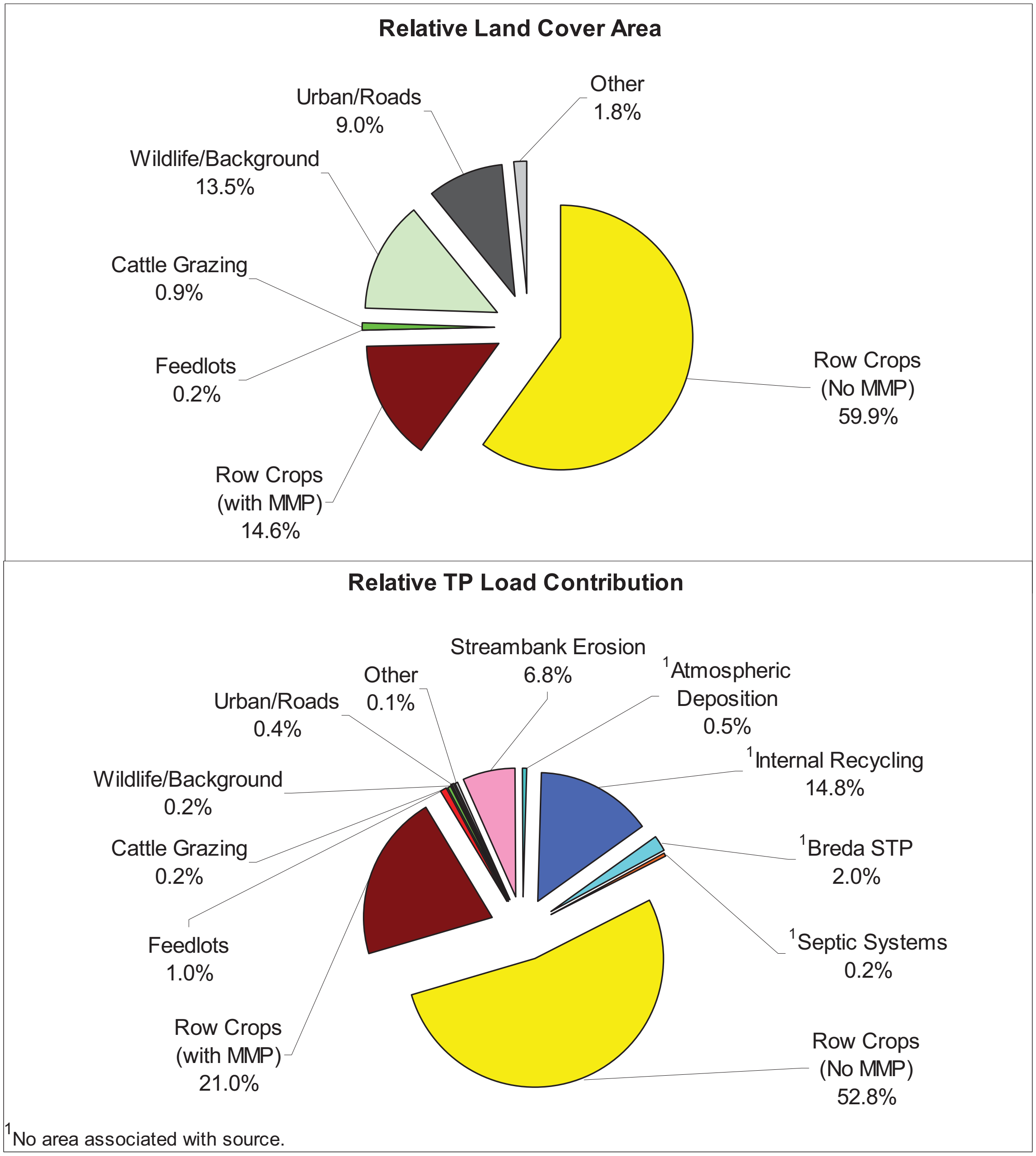
Table 3-4. Average growing season TP loads from each source (2001-08).

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.



[1] No area associated with source.

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.

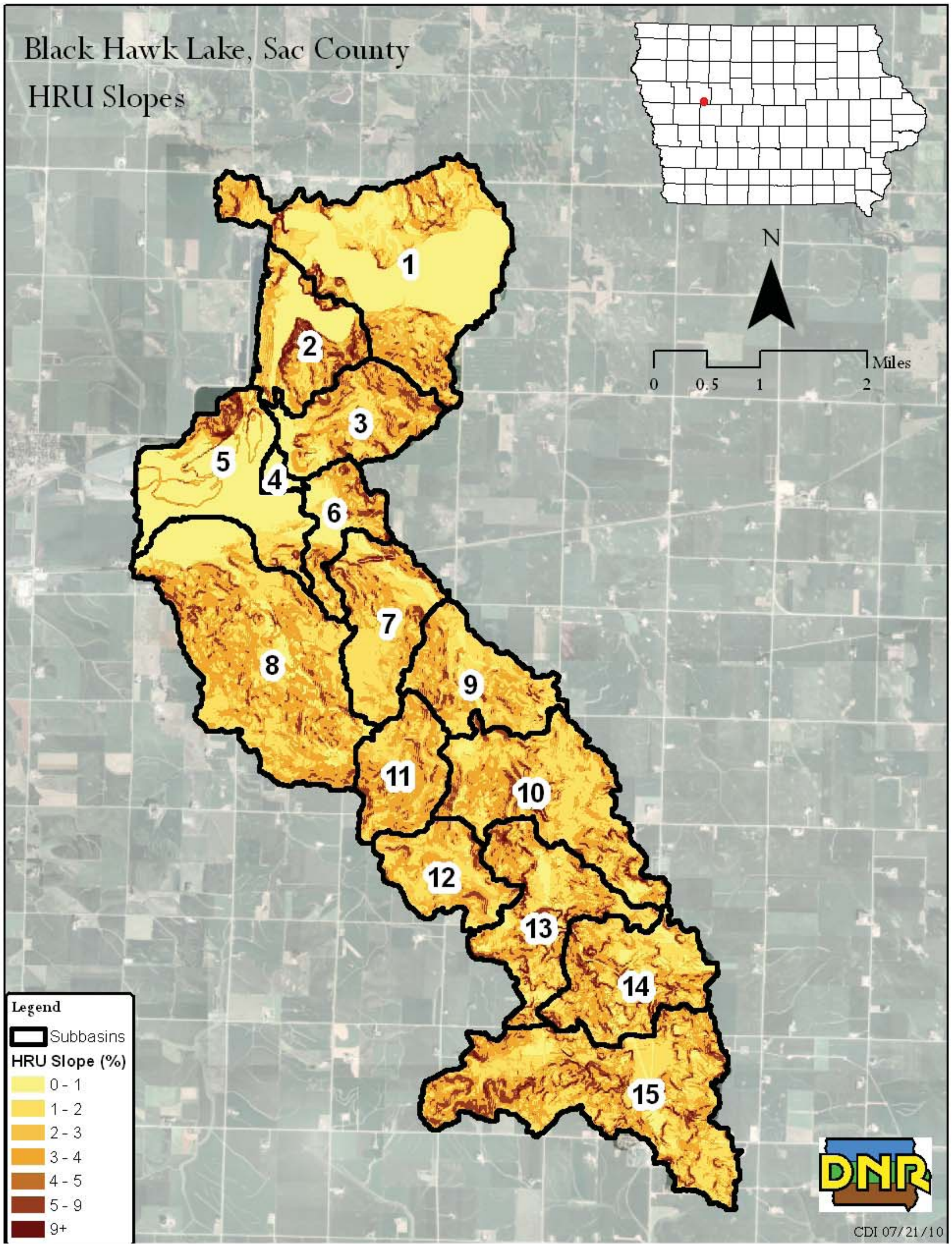


Figure 4-1. Average HRU slope in the Black Hawk Lake watershed.

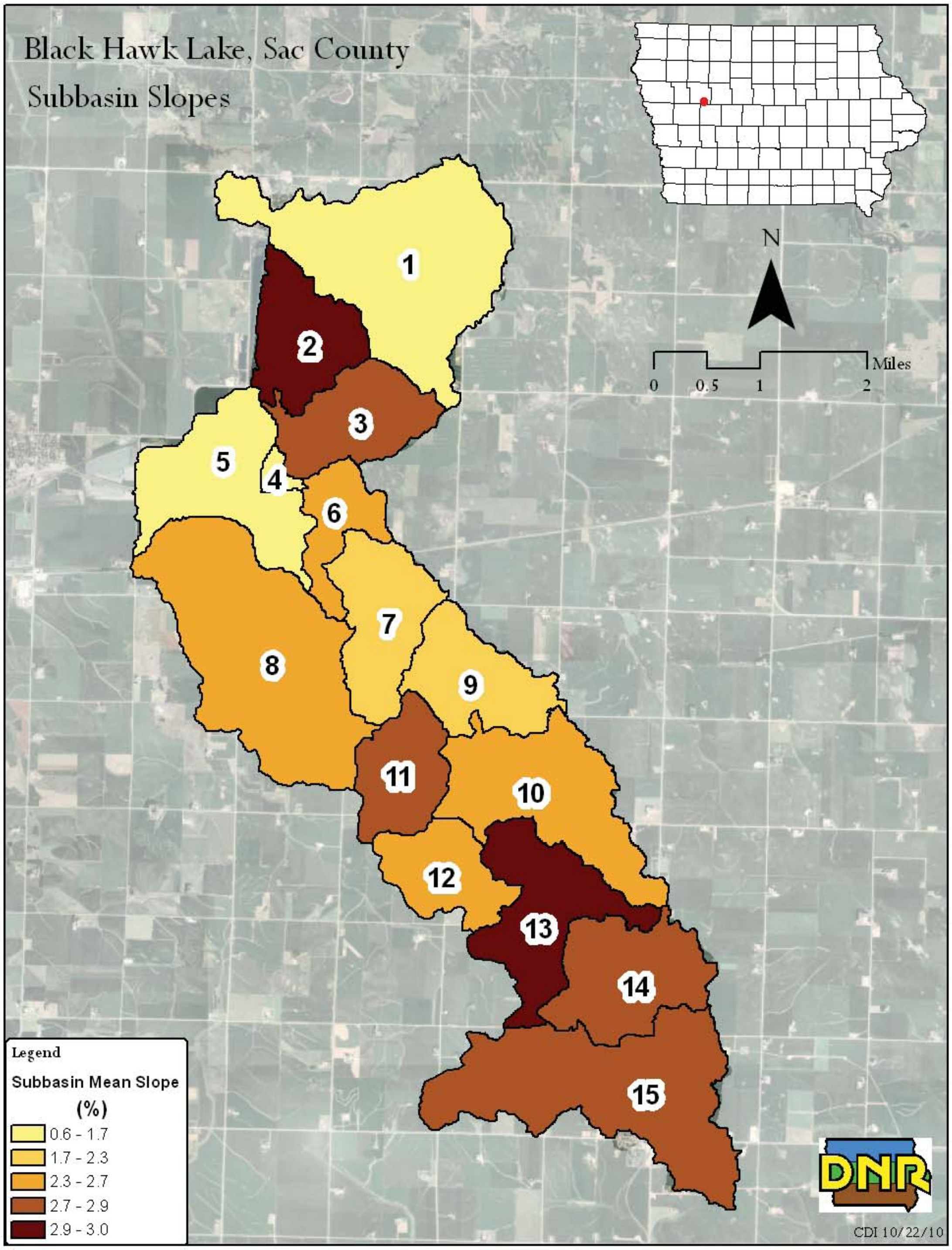


Figure 4-2. Average subbasin slope in the Black Hawk Lake watershed.

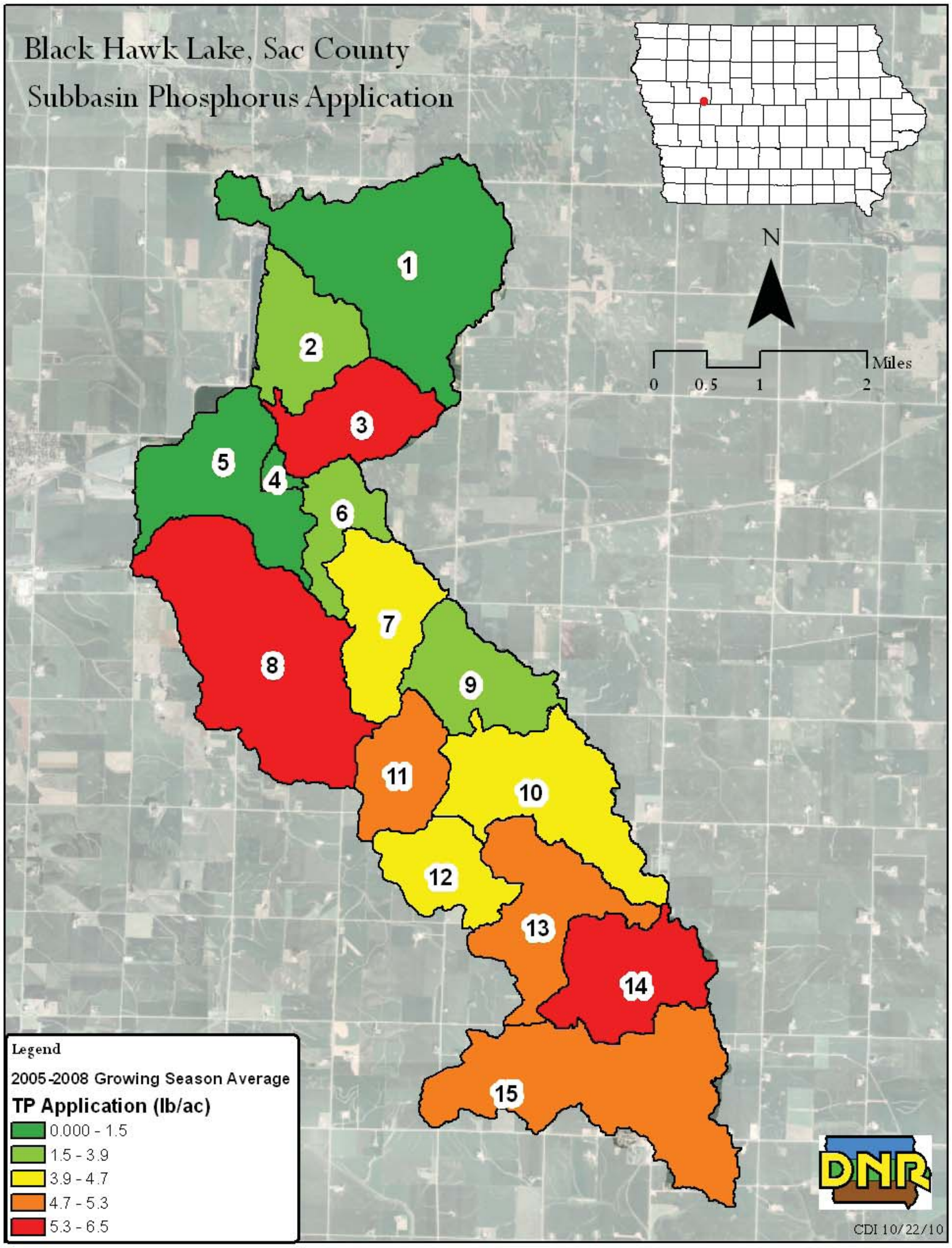


Figure 4-3. Subbasin average phosphorus application rates.

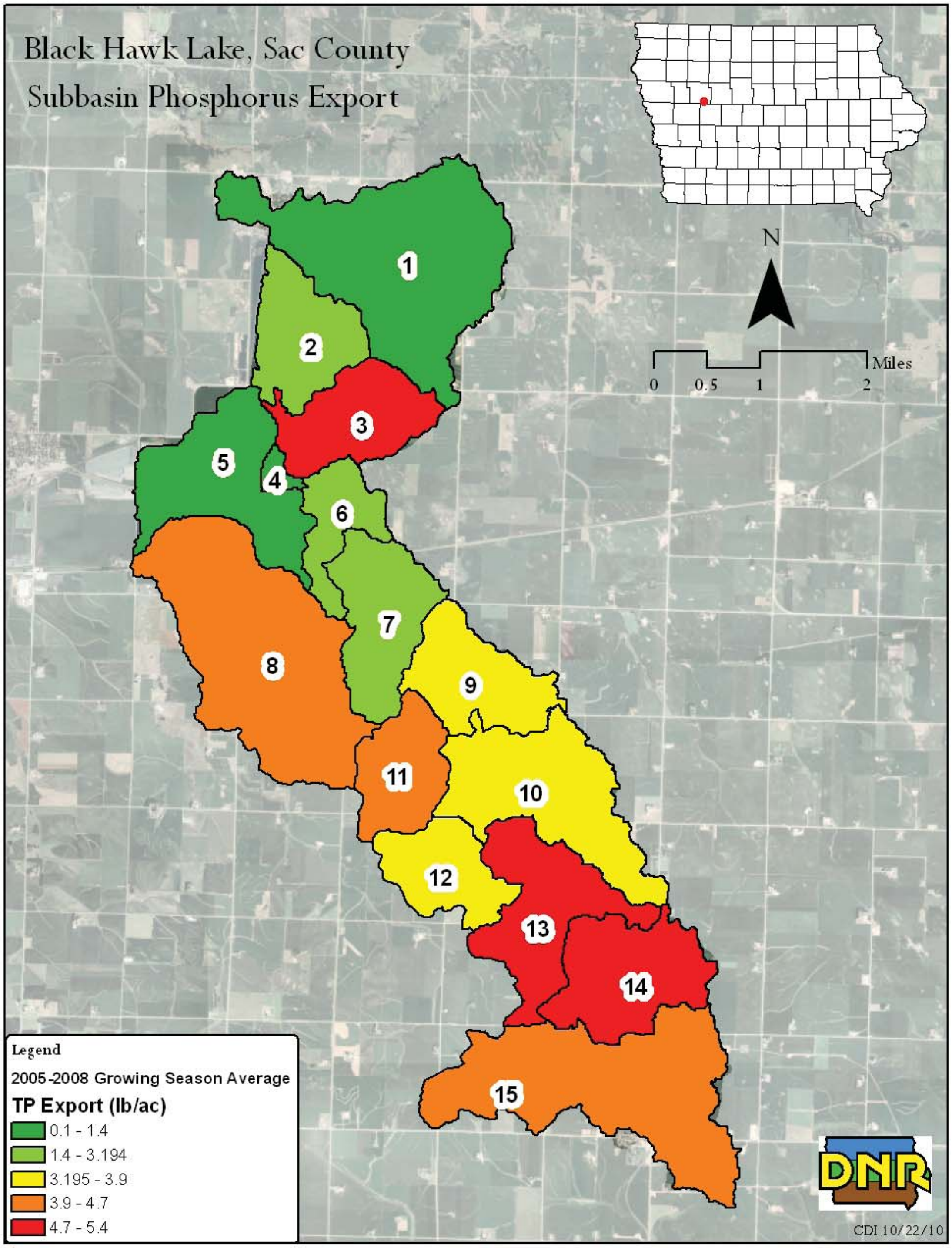


Figure 4-4. Phosphorus export rates (2005-2008 growing season averages).

Prioritization and location of erosion and phosphorus control practices should be guided by these figures because they reveal the areas contributing the most phosphorus. This will help ensure that BMP selection and placement maximizes phosphorus reductions. Highest priority should be given to areas that exhibit steep slopes, high phosphorus application rates, high phosphorus export rates, and do not currently have sediment or phosphorus BMPs in place. Figure 4-4 is critical for prioritizing the locations of BMPs because it illustrates phosphorus export from different areas of the watershed. However, the slope and application figures are also important, because they reveal whether topography (i.e., slope), nutrient inputs (fertilizer and manure), or the combination of both are driving phosphorus exports. Sediment and erosion control practices should be targeted to steeply sloped land in areas with high phosphorus export rates. Manure and fertilizer management alternatives should be considered in areas with gentle slopes but high phosphorus application rates. Areas with steep slopes and high nutrient application should be given highest priority for both sediment and erosion control and nutrient management. Reducing phosphorus loads to the point of meeting water quality standards will require widespread adoption of techniques that implement multiple BMPs in series. This is sometimes called a treatment-train approach, and can include both structural and non-structural BMPs.

Simulation of Agricultural BMPs using Watershed Model

To examine the impacts of watershed-scale BMPs on phosphorus export, a variety of hypothetical scenarios were simulated using the calibrated SWAT model developed for the Black Hawk Lake watershed. Practices were implemented at several spatial scales to investigate potential efficiencies gained by targeting practices. Table 4-2 reports the BMP scenarios, the implementation area, TP reduction percent, and the unit reduction (lbs/acre) associated with each scenario. This list is not all-inclusive or meant to limit the types of BMPs considered for implementation. Rather, it includes examples to help stakeholders and watershed planners develop their vision for the Black Hawk Lake watershed and to illustrate the importance of targeting and implementing multiple types of BMPs to reduce phosphorus export to the lake.

The Black Hawk Lake watershed model reveals that introducing perennial grasses, such as those planted on acres enrolled in the Conservation Reserve Program (CRP), has the potential to significantly reduce phosphorus export. On a per acre basis, this BMP is more effective than other BMPs evaluated. It is recognized that wide-scale implementation of this practice is not feasible. However, targeting marginal or highly erodible land can provide measurable water quality improvement with minimal loss of agricultural production. In the Black Hawk Lake watershed, converting row crops to CRP on lands with slopes greater than 5 percent could reduce TP export by over 12 percent, while targeting less than 7 percent of the land currently in row crop production.

Conservation tillage methods, such as no-till farming, also have the ability to reduce phosphorus loads significantly. Estimated TP reductions associated with no-till techniques range between 2.3 and 2.7 lbs of TP per acre. Data in Table 4-2 reveal that targeting the subbasins with the highest TP export (SWAT Subbasins 3, 13, and 14 in Figure 4-4) offers the most efficient reductions. A similar gain in efficiency is observed by targeting construction of terraces, grass waterways, and other soil and erosion protection measures. In order to achieve the phosphorus reductions required for attaining water quality goals, combining several practices, such as no-till and erosion protection measures, will be necessary.

Table 4-2. Potential BMP scenarios and associated TP reductions.

BMP/Scenario	BMP Location	Area (acres)	TP Reduction (%)	Unit Reduction (lbs/acre)
[1]Increase CRP areas (perennial grasses)	All row crops with slopes > 5%	742	12.1	8.2
[2]Conversion to no-till	Row crops in SWAT Subbasins 1-6 (north of railroad)	2,150	9.9	2.29
	Row crops in SWAT Subbasins 1-11 (north of 390th St.)	6,982	33.4	2.38
	Row crops in entire watershed	10,943	54.0	2.46
	Row crops in SWAT Subbasins 3, 13, and 14 (highest TP export subbasins)	2,448	13	2.65
[3]Construction of terraces, grass waterways, etc.	Row crops in SWAT Subbasins 1-6 (north of railroad)	2,150	3.5	0.82
	Row crops in SWAT Subbasins 1-11 (north of 390th St.)	6,982	11.8	0.84
	Row crops in entire watershed	10,943	18.9	0.86
	Row crops in SWAT Subbasins 3, 13, and 14 (highest TP export subbasins)	2,448	4.6	0.94
No-till and terraces/waterways	Row crops in entire watershed	10,943	59.3	2.70
	Row crops in SWAT Subbasins 3, 13, and 14 (highest TP export subbasins)	2,448	15.5	3.16
Reduce chemical phosphorus application by 30%	Row crops in entire watershed	10,943	13.2	0.60
Reduce manure phosphorus application by 30%	Row crops with manure management plans	2,096	4.0	0.96

[1] Simulated impact of CRP on less than 7 percent of land in row crop production.
[2] Simulated impact of no-till by reducing USLE C-factor from 0.25 to 0.07.
[3] Simulated impact of waterways, terraces, and other erosion control practices by reducing USLE P-factor from 1.0 to 0.7.

Reducing the amount of phosphorus applied via chemical or manure application would provide benefits to Black Hawk Lake. To quantify the benefits, a random application reduction of 30 percent was simulated using the watershed model. As Table 4-2 reports, reducing chemical fertilizer application on all row crops in the watershed (approximately 10,943 acres) by 30 percent would provide a 13.2 percent reduction in TP export. Reducing manure application by 30 percent on lands with manure management plans (approximately 2,096 acres) reduces TP export by only 4 percent. IDNR is neither mandating nor recommending that fertilizer application be reduced by 30 percent. Rather, these scenarios are presented to help the watershed planning group assess the potential impacts of various alternatives. Improved management of chemical and manure fertilizer is warranted, but could take several forms. Options include increased soil testing to minimize application without reducing yields, improved application equipment/methods, and strategic timing of application to minimize risk of nutrient loss from high rainfall runoff events.

There are many additional agricultural BMP scenarios not simulated for the purposes of this report. Other potential scenarios/alternatives should be investigated by the watershed planning group. Examples listed in Table 4-1 but not simulated by the watershed model include use of cover crops, implementation of vegetated riparian buffers, and construction and/or restoration of wetlands in strategic locations. IDNR is committed to providing the watershed planning group with additional technical assistance to evaluate potential benefits of agricultural BMPs most suitable to the Black Hawk Lake watershed.

In-Lake BMPs

Phosphorus recycled between the bottom sediment and water column of the lake is an important contributor of the TP load to Black Hawk Lake. The average growing season contribution of TP to the system from internal loading is estimated at 14.8 percent of the total load, second only in magnitude to TP loads from row crop production. The influence of internal loading on in-lake water quality is even greater than this average contribution would indicate. While much smaller than watershed loads on an annualized basis, internal loads can be the primary driver of eutrophication in dry years with little surface runoff. For example, in 2006, which was a dry year, the estimated internal TP load was 2.5 times greater than the total TP load from the watershed.

Even if all external TP load from the watershed could be eliminated, which is not feasible, it would take many years to observe significant water quality improvement in the lake due to sediment and attached phosphorus that have accumulated in the sediment at the bottom of the lake over many years. This sediment provides a potential source of TP to the water column that is released when sediments are resuspended by wind, power boating, and behavior of rough fish such as carp and buffalo. Rough fish stir up bottom sediment, which causes turbidity and phosphorus release to the water column, and prevent establishment of rooted aquatic plants, which would otherwise limit resuspension and provide a phosphorus sink. To achieve sustainable, measurable improvement in water clarity, and to meet the water quality goals established in this TMDL, the internal load must be reduced.

A brief description of potential in-lake restoration methods are included in Table 4-3, along with relative TP reductions. Actual reduction percentages of each alternative will vary and depend on a number of site-specific factors. It is virtually impossible to determine how much of the internal load is due to each of the contributing factors, and equally difficult to predict TP reductions associated with individual improvement strategies.

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

In-Lake BMPs	Comments	[1]Relative TP Reduction
Fisheries management	Moderate to high reductions in internal TP load are possible. The existing fish population must be manipulated to reduce problem fish such as common carp and buffalo. Full-scale restoration may not be possible without significant water level drawdown. If drawdown is not feasible, physical removal may be possible through commercial fishing incentive programs.	Med-High
Targeted dredging, sediment forebays, and flow re-direction in Provost Slough	Targeted dredging in Provost Slough would create pockets of deep-water habitat for predatory fish that would help keep down carp populations. Strategic dredging would also increase the sediment capacity of the slough, thereby reducing sediment loads to the larger, open water area of the lake. Sediment and nutrient capture in the slough could be enhanced by constructing submerged berms and/or jetties to create sediment forebays and re-direct inflow to the slough to the east to increase retention time. Sediment forebays could be located and constructed in a manner that would facilitate future sediment removal.	Med-High
In-Lake Dredging	Dredging is seldom cost-effective on a large scale and as a stand-alone measure; disposal of dredged material is often a challenge; dredging should be focused on areas of known sediment deposition or to create deep-water habitat as part of fisheries management.	Med
Shoreline stabilization (public areas)	Helps establish and sustain vegetation, which competes with algae for nutrients. Impacts of individual projects may be small, but cumulative effects of widespread stabilization projects can be significant.	Low-Med

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

Over the past decade, IDNR has gained valuable insight into the mechanisms that drive water quality and the quality of fisheries in Iowa's shallow lakes. Restoration of these ecosystems requires an adaptive management approach utilizing a combination of complimentary techniques. Previous lake restoration efforts have revealed that significant internal load reduction is achievable with a combination of fisheries management, creation of sediment forebays, shoreline stabilization and vegetation management, and dredging targeted to specific areas. Conceptual development of these alternatives is best accomplished within the context of a full-scale watershed management plan. Potential in-lake restoration techniques for Black Hawk Lake include:

- Construction of earthen structures (forebays, submerged berms, etc.) to re-direct flow and increase sediment capture in Provost Slough,
- retrofit or construct a new fish barrier between Provost Slough and the main body of the lake to cut-off common carp and buffalo from spawning habitat,
- shoreline stabilization to reduce erosion and establish and sustain aquatic plants,
- fisheries management to reduce common carp and buffalo populations,
- targeted dredging to remove sediment deposits and create deep-water predatory fish habitat to compliment fisheries management in Provost Slough and the main open water area of the lake.

Urban BMPs

Phosphorus loads to Black Hawk Lake generated from urban land uses account for a small portion of the overall load. However, areas of sediment deposition near stormwater outfalls to the lake have been observed. Several water quality BMPs for urban stormwater are relatively inexpensive and offer secondary benefits such as reduction of other pollutants, improved wildlife habitat, and aesthetic benefits. Additionally, implementation of urban BMPs in combination with public information and education programs can promote awareness among citizens and lake patrons that everyone plays a role in improving water quality. Although the area within the city limits of Lake View is a relatively small source of phosphorus, adoption of BMPs by homeowners can provide localized improvements in water quality near outfalls and give citizens a sense of ownership of water quality solutions.

A list of potential BMPs for urban areas and shoreline property owners is provided in Table 4-4. Some of these BMPs may not be feasible or practical for site-specific conditions. Local decision makers and property owners should evaluate all potential BMPs to select those most applicable to site-specific conditions.

Table 4-4. Potential BMPs for urban areas and shoreline properties.

BMP or Activity	[1]Potential TP Reduction
Dry Detention Basin	26%
Extended Wet Detention Basin	68%
Wetland Detention	44%
Grass Swales	25%
Infiltration Basin	65%
Bioretention Facility	80%
Vegetated Filter Strips	45%
Water Quality Inlets	9%
Weekly Street Sweeping	6%
Low Impact Development (LID) Techniques	20-80%
Pet Waste Programs (Public Information/Education)	Medium to High
No/Low Phosphorus Fertilizer Programs (Voluntary or Ordinance)	Medium to High
Shoreline buffer strips	Low to Medium
Shoreline stabilization/landscaping	Low to Medium

[1] Percent reductions taken from the EPA Region 5 STEPL model. Relative reductions from previous studies and various literature.

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 Black Hawk 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://www.iowadnr.com/water/standards/files/chapter61.pdf 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. Routine Monitoring for Water Quality Assessment

Future water quality data collection in Black Hawk Lake to assess water quality trends and compliance with water quality standards (WQS) is expected to include monitoring conducted as part of the IDNR Beach Monitoring Program and the IDNR Ambient Lake Monitoring Program. Unless there is local interest in collecting additional water quality data, these monitoring programs will comprise the vast majority of future sampling efforts.

The Beach Monitoring Program consists of routine *E. coli* monitoring at state park beaches and locally managed beaches throughout Iowa. The beaches are sampled at least two times per week from Memorial Day to Labor Day. The reported *E. coli* concentration for a particular sampling event is typically a composite sample average of nine sampling points collected at three approximate depths (ankle, knee, and chest) at three locations (e.g., left, middle, right) along the beach.

The Ambient Lake Monitoring Program was initiated in 2000 in order to better assess the water quality of Iowa lakes. Currently, 132 of Iowa's lakes are being sampled as part of this program, including Black Hawk 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.

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

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

5.2. Idealized Monitoring for Detailed Assessment and Planning

Data available from the IDNR/IGS Beach Monitoring Program and the IDNR Ambient Lake Monitoring Program will be used to assess general water quality trends and WQS violations/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.

The availability of existing IDNR staff and resources will not allow more detailed monitoring data to be collected as part of normal IDNR activities. 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 idealized monitoring plan by listing the components in order, starting with the highest priority recommendations. Proposed monitoring locations are illustrated in Figure 5-1.

Table 5-2. Recommended monitoring plan.

Parameter(s)	Intervals	Duration	[1]Location(s)
Routine grab sampling for flow, sediment, P, and N	Every 1-2 weeks	April through October	Lake inlet & outlet, 3 in-lake sites, and select tributary sites
Continuous flow	15-60 minute	April through October	Lake inlet & outlet
Continuous pH, DO, and temperature	15-60 minute	April through October	3 in-lake sites
Runoff event flow, sediment, P, and N	15-60 minute intervals during runoff	5 events between April and October	Lake inlet & outlet and select tributary sites
Wet and dry weather flow, sediment, P, and N	Hourly during wet and dry weather	10 to 14-day periods (multiple wet and dry weather periods)	Lake inlet & outlet and select tributary sites
Event or continuous tile drain flow, N, and P sampling	15-60 minute	10 to 14-day wet weather periods if continuous sampling is not feasible	Select tile drain sites
E. coli grab sampling	Every 1-2 weeks	March 15 to November 15	3 in-lake sites, lake inlet, and select tributary sites
[2] Microbial source tracking (MST)	Snapshots	At least two sampling events within recreation season. Consider one during high flow and one during low flow.	Beach, lake inlet, select tributary sites, select tile drain locations

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

[2] There are several MST approaches. Methodology should be researched and based on feasibility, cost, and advantage/disadvantages of each method. If budget does not allow for true MST methods, fluorometry or caffeine detection could be utilized in conjunction with *E. coli* sampling to detect human sources of wastewater.

Routine weekly or bi-weekly grab sampling with concurrent in-lake and tributary data would help identify long-term trends in water quality. Data collection should commence before BMPs are implemented in the watershed to establish baseline conditions. Selection of tributary sites should consider location of BMPs, location of historical data (for comparative purposes), landowner permission (if applicable), and logistical concerns such as site access and feasibility of equipment installation (if necessary). This data could form the foundation for assessment of water quality trends; however, more detailed information will be necessary to make any statements about water quality trends with certainty. Therefore, routine grab sampling should be viewed only as a starting point for assessing trends in water quality.

Continuous flow data at the inlet and outlet of the lake would improve the predictive ability and accuracy of modeling tools, such as those used to develop the TMDL for Black Hawk Lake. Reliable long-term flow data is also important because hydrology drives many important processes related to water quality, and a good hydrologic data set will be necessary to evaluate the success of BMPs such as reduced-tillage, sediment control structures, terraces and grass waterways, riparian buffers, and wetlands.

If funding is available, lake managers should consider deploying data loggers at multiple locations in Black Hawk Lake that 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.

Because water quality appears to be predominately driven by lands in row crop production, data collection efforts should attempt to answer questions about the relative importance of surface runoff, baseflow (i.e., dry weather flow), and flow from tile drains. Collection of flow, sediment, and nutrient data in tributaries and at tile outlets during multiple periods of dry and wet weather will facilitate assessment of these distinct pollutant pathways. Selection of tributary and tile drain sites must be based on the need to quantify specific potential pollutant sources, the location of proposed BMPs, land owner permission, and feasibility of equipment installation.

In addition to water clarity problems caused by algae and turbidity, high bacteria (*E. coli*) levels at the campground beach impair recreational use of the lake. Although the bacteria impairment is marginal and the implementation of phosphorus-reducing BMPs should result in attainment of the bacteria standards as well, stakeholders may want to collect additional *E. coli* data to supplement data IDNR collects as part of the Beach Monitoring Program. Additional *E. coli* grab samples, collected at the three in-lake sites and select tributary locations, would help answer questions regarding potential bacteria sources than cannot be answered using only data collected on the beach.

Conducting DNA source tracking or other methods of determining the source of *E. coli* at the swimming beach would help prioritize and target specific sources (e.g., septics, geese, or livestock) and optimize reduction efforts. Currently, source tracking is expensive and may not be cost effective. However, improvements in DNR tracking methods and related technology may make this more feasible in the near future. Other potential bacteria source assessment methods include the use of fluorometry to detect human-generated dyes and compounds, and testing for caffeine and/or pharmaceuticals that would indicate the presence of human waste and determine whether septics are a significant source of *E. coli*.

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

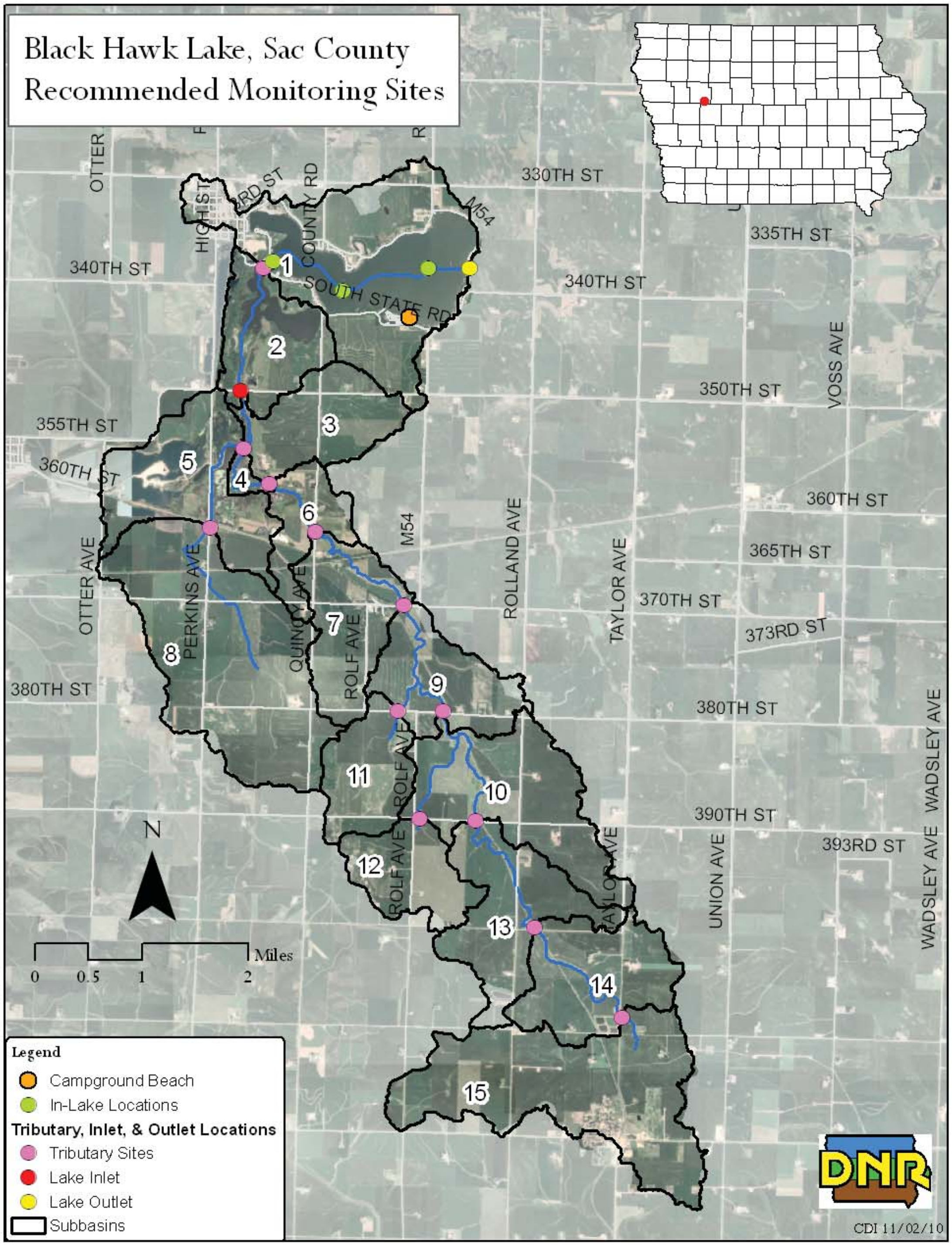


Figure 5-1. Recommended monitoring locations.

6. Public Participation

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

6.1. Public Meetings

March 26, 2009
In the early stages of TMDL development, a public meeting was held at Emmanuel Lutheran Church in Lake View, Iowa. The meeting was facilitated by the Iowa Department of Natural Resources (IDNR) in cooperation with the Limnology Laboratory at Iowa State University (ISU). ISU conducted a diagnostic feasibility study for Black Hawk Lake concurrent with TMDL development. IDNR and ISU collaborated to share data and public participation efforts.

The March 26 meeting focused on the diagnostic feasibility study; however, IDNR staff informed attendees of the TMDL process (goals, requirements, and timeline). Attendees were invited to ask questions and provide insight, and IDNR contact information was provided to attendees for future use. Approximately 60 individuals attended the meeting. Both urban and rural landowners and residents were well represented.

Key agency attendees included:

- IDNR – Black Hawk Lake State Park staff
- IDNR – Fisheries Bureau staff
- IDNR – Wildlife Bureau staff
- IDNR – Lakes Restoration program staff
- IDNR – Watershed Improvement Section (TMDL and 319 program staff)
- ISU Extension Office
- ISU Limnology Laboratory
- IDALS – Division of Soil Conservation (Basin Coordinator)
- Sac County Soil and Water Conservation District (SWCD)
- USDA-NRCS

March 22, 2010
Mid-way through the development of the Black Hawk Lake TMDL, a preliminary draft of the ISU/IDNR diagnostic feasibility study was presented to local stakeholders. The focus of the meeting was on the ISU study; however, an update regarding the TMDL was provided by IDNR staff. Meeting attendance was similar to attendance for the March 26, 2009 meeting. Discussion topics included:

- Results of diagnostic feasibility study (John Downing, ISU)

- Potential fishery restoration (Don Herrig, IDNR)
- Opportunities for landowner conservation measures (Kathy Koskovich, IDNR)
- Community-based watershed planning process (Ben Wallace, IDNR)

January 27, 2011
A public meeting to present the results of the TMDL study and discuss next steps for community-based watershed planning was held from 6:00 to 8:00 pm on January 27, 2011, in Lake View, Iowa. IDNR staff presented the findings of the TMDL to a group of over 50 people, most of which were citizens, residents, and land owners. The presentation included a summary of the water quality problem and related data analysis, the numeric TMDL, and the practical implications for the lake. Attendees were given the opportunity to ask questions and/or offer feedback, and were also encouraged to submit public comments before the end of the public comment period.

Key agency attendees included:
- IDNR – Black Hawk Lake State Park staff
- IDNR – Fisheries Bureau staff
- IDNR – Wildlife Bureau staff
- IDNR – Lakes Restoration program staff
- IDNR – Watershed Improvement Section (TMDL and 319 program staff)
- Sac County Soil and Water Conservation District (SWCD)
- USDA-NRCS

6.2. Written Comments

IDNR received no written or electronic comment(s) on the draft of the Black Hawk Lake TMDL.

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8. Appendices

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

303(d) list:	Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface waterbodies (creeks, rivers, wetlands, and lakes) that do not support their general and/or designated uses. Also called the state's "Impaired Waters List."
305(b) assessment:	Refers to section 305(b) of the Federal Clean Water Act, it is a comprehensive assessment of the state's public waterbodies' ability to support their general and designated uses. Those bodies of water which are found to be not supporting or only partially supporting their uses are placed on the 303(d) list.
319:	Refers to Section 319 of the Federal Clean Water Act, the Nonpoint Source Management Program. Under this amendment, States receive grant money from EPA to provide technical & financial assistance, education, & monitoring to implement local nonpoint source water quality projects.
AFO:	Animal Feeding Operation. A lot, yard, corral, building, or other area in which animals are confined and fed and maintained for 45 days or more in any 12-month period, and all structures used for the storage of manure from animals in the operation. Open feedlots and confinement feeding operations are considered to be separate animal feeding operations.
AU:	Animal Unit. A unit of measure used to compare manure production between animal types or varying sizes of the same animal. For example, one 1,000 pound steer constitutes one AU, while one mature hog weighing 200 pounds constitutes 0.2 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	A statistic that is a type of mean or average (different from

(GM):	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.
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.)

UHL:	University 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.
USDA:	United States Department of Agriculture
USGS:	United States Geologic Survey (United States Department of the Interior). Federal agency responsible for implementation and maintenance of discharge (flow) gauging stations on the nation’s waterbodies.
Watershed:	The land area that drains water (usually surface water) to a particular waterbody or outlet.
WLA:	Wasteload Allocation. The portion of a receiving waterbody's loading capacity that is allocated to one of its existing or future point sources of pollution (e.g., permitted waste treatment facilities).
WQS:	Water Quality Standards. Defined in Chapter 61 of Environmental Protection Commission [567] of the Iowa Administrative Code, they are the specific criteria by which water quality is gauged in Iowa.
WWTF:	Wastewater Treatment Facility. General term for a facility that treats municipal, industrial, or agricultural wastewater for discharge to public waters according to the conditions of the facility’s NPDES permit. Used interchangeably with wastewater treatment plant (WWTP).
Zooplankton:	Collective term for all animal plankton suspended in the water column which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

Scientific Notation

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

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

Here are some examples of scientific notation.

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

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

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

Introduction

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

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

General Use Segments

A general use segment waterbody is one that does not maintain perennial (year-round) flow of water or pools of water in most years (i.e. ephemeral or intermittent waterways). In other words, stream channels or basins that consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use waterbody, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

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

Designated Use Segments

Designated use segments are waterbodies that maintain flow throughout the year, or at least hold pools of water that are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are thirteen different designated use classes (Table B-1) that may apply, and a waterbody may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

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

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

Designated use classes are determined based on a Use Attainability Analysis, or UAA. This is a procedure in which the waterbody is thoroughly scrutinized, using existing knowledge, historical documents, and visual evidence of existing uses, in order to determine what its designated use(s) should be. This can be a challenging endeavor, and as such, conservative judgment is applied to ensure that any potential uses of a waterbody are allowed for. Changes to a waterbody's designated uses may only occur based on a new UAA, which depending on resources and personnel, can be quite time consuming.

It is relevant to note that on March 22, 2006, a revised edition of Iowa's water quality standards became effective which significantly changed the use designations of the state's surface waters. Essentially, the changes that were made consisted of implementing a "top down" approach to use designations, meaning that all waterbodies should receive the highest degree of protection applicable until a UAA could be performed to ensure that a particular waterbody did not warrant elevated protection. For more information about Iowa's water quality standards and UAAs, contact the Iowa DNR's Water Quality Bureau.

Appendix C --- Water Quality Data

The following include a portion of the sampling data from the Iowa State University (ISU) Iowa Lakes Information System and the Iowa Department of Natural Resources and University Hygienic Laboratory (IDNR/UHL) Ambient Lake Monitoring Program.

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

Date	Secchi (m)	Chl-a (ug/L)	TP (ug/L)	TN (mg/L)	ISS (mg/L)	VSS (mg/L)	TSS (mg/L)	TSI (SD)	TSI (Chl)	TSI (TP)
[2]6/12/00	0.2	74.3	[4]--	2.7	62.3	23.6	85.9	82	73	90
[2]7/11/00	0.3	99.0	[4]--	2.8	35.4	21.4	56.8	78	76	95
[2]8/3/00	0.2	64.6	[4]--	1.7	21.3	16.6	37.8	86	71	94
[2]5/14/01	0.6	--	23.4	4.7	0.5	0.5	0.5	67	[4]--	50
[2]6/11/01	0.3	--	202.3	3.0	18.8	5.8	24.6	75	[4]--	81
[2]7/16/01	0.4	9.2	380.3	1.8	18.0	15.4	33.4	73	52	90
[2]5/20/02	1.1	3.9	100.8	2.4	14.4	3.4	17.8	59	44	71
[2]6/17/02	1.5	19.3	[4]--	1.9	5.7	2.7	8.3	54	60	[4]--
[2]7/22/02	0.2	68.0	285.3	1.5	48.6	7.9	56.4	83	72	86
[2]5/19/03	1.4	12.9	59.7	2.8	6.6	4.4	11.0	55	56	63
[2]6/16/03	0.3	31.3	118.1	2.7	3.4	6.8	10.2	77	64	73
[2]7/21/03	0.3	24.4	162.1	2.4	35.7	14.1	49.7	76	62	78
[2]5/17/04	0.4	9.3	110.0	1.9	14.5	7.8	22.3	72	52	72
[2]6/14/04	0.6	67.6	95.6	1.8	27.1	0.5	27.6	67	72	70
[2]7/19/04	0.3	65.2	145.0	1.5	16.9	10.9	27.9	75	72	76
[2]5/23/05	0.5	159.2	90.8	4.4	18.0	12.0	30.0	70	80	69
[2]6/20/05	0.4	59.3	107.6	3.6	14.0	13.0	27.0	72	71	72
[2]7/27/05	0.2	127.5	179.7	1.6	40.7	22.7	63.3	83	78	79
[3]4/28/05	0.5	8	130	3.6	20	8	28	69	51	71
[3]5/18/05	0.2	58	180	6.7	22	9	31	83	70	79
[3]6/22/05	0.4	34	80	3.0	16	8	22	73	65	67
[3]7/19/05	0.2	63	160	2.0	31	18	49	83	71	77
[3]8/29/05	0.3	67	150	1.6	19	16	35	77	72	76
[3]10/10/05	0.2	27	160	1.5	22	17	39	83	63	77
[2]5/22/06	0.4	54.5	78.7	1.9	6.8	11.2	18.0	73	70	67
[2]6/19/06	0.2	22.5	127.7	2.8	24.5	9.0	33.5	81	61	74
[2]7/24/06	0.3	56.4	169.7	1.7	38.7	20.0	58.7	77	70	78
[3]4/13/06	0.4	54	100	1.6	9	12	21	73	70	71
[3]5/9/06	0.5	55	100	2.1	8	9	17	70	70	71
[3]6/12/06	0.4	15	140	2.8	16	8	24	73	57	75
[3]7/6/06	0.3	89	130	2.4	20	13	32	77	75	74
[3]8/24/06	0.3	75	190	1.6	29	17	46	77	73	80
[3]10/3/06	0.3	59	110	1.7	13	15	27	76	71	72
[2]5/21/07	0.6	9.2	19.0	0.7	15.6	7.2	22.8	69	52	47
[2]6/18/07	0.4	66.3	129.8	5.2	11.5	10.5	22.0	73	72	74
[2]7/26/07	0.3	103.9	139.3	0.7	18.0	25.2	43.2	79	76	75
[3]5/1/07	0.6	99	240	6.7	10	12	22	67	76	83
[3]6/13/07	0.7	54	120	5.4	7	9	16	65	70	73
[3]7/17/07	0.4	110	180	2.3	16	25	40	73	77	79
[3]8/15/07	0.2	180	200	2.5	22	26	48	83	82	81
[3]9/18/07	0.2	99	180	2.9	34	22	54	83	76	79
[3]5/29/08	0.9	4	90	3.8	8	4	12	62	44	169
[3]6/26/08	0.5	16	200	7.0	16	9	25	70	58	81

Table C-1 (continued)

Date	Secchi (m)	Chl-a (ug/L)	TP (ug/L)	TN (mg/L)	ISS (mg/L)	VSS (mg/L)	TSS (mg/L)	TSI (SD)	TSI (Chl)	TSI (TP)
[3]7/23/08	0.2	140	170	3.3	14	22	36	83	79	78
[3]8/21/08	0.3	120	300	3.3	13	50	63	77	78	86
[3]10/6/08	0.3	81	280	2.7	5	37	42	77	74	85
[3]6/1/09	0.4	29	209.6	3.6	19.5	11.1	30.5	73	64	81
[3]7/6/09	0.4	21	243.8	2.5	25.3	18.0	43.3	73	60	83
[3]8/3/09	0.3	65	381.3	3.1	6.8	26.0	32.8	77	72	90
Mean	**0.42**	**60.2**	**158.9**	**2.8**	**19.2**	**14.2**	**33.1**	**72**	**71**	**77**
Median	**0.30**	**59.0**	**145.0**	**2.7**	**16.9**	**12.0**	**30.5**	**77**	**71**	**76**
St Dev	**0.28**	**42.3**	**78.8**	**1.4**	**12.1**	**9.3**	**16.7**	**--**	**--**	**--**
CV	**0.66**	**0.70**	**0.50**	**0.51**	**0.63**	**0.66**	**0.50**	**--**	**--**	**--**

[1] Ambient monitoring location = STORET ID 22810002
[2] ISU data
[3] UHL data
[4] Dashes (--) indicate no data was reported

Table C-2. UHL water quality sampling data (west arm of lake[1]).

Date	Secchi (m)	Chl-a (ug/L)	TP (ug/L)	TN (mg/L)	ISS (mg/L)	VSS (mg/L)	TSS (mg/L)	TSI (SD)	TSI (Chl)	TSI (TP)
6/13/07	0.5	120	160	6.9	17	16	32	70	78	77
7/17/07	0.3	120	290	2.9	20	30	50	77	78	86
8/15/07	0.3	150	230	2.9	17	21	38	77	80	83
5/29/08	0.5	130	200	8.6	16	15	31	70	78	81
6/26/08	0.4	150	240	9.9	27	22	49	73	80	83
7/23/08	0.2	240	320	4.1	26	38	64	83	84	87
8/21/08	0.4	120	300	3.3	19	37	55	73	78	86
10/6/08	0.2	57	350	3.2	52	50	100	83	70	89
Mean	**0.35**	**135.9**	**261.3**	**5.2**	**24.3**	**28.6**	**52.4**	**75**	**79**	**84**
Median	**0.35**	**125.0**	**265.0**	**3.7**	**19.5**	**26.0**	**49.5**	**75**	**78**	**85**
St Dev	**0.12**	**51.1**	**64.5**	**2.8**	**11.9**	**12.3**	**22.4**	**--**	**--**	**--**
CV	**0.34**	**0.38**	**0.25**	**0.54**	**0.49**	**0.43**	**0.43**	**--**	**--**	**--**

[1] West arm location = STORET ID 22810003

Table C-3. UHL water quality sampling data (east open bay[1]).

Date	Secchi (m)	Chl-a (ug/L)	TP (ug/L)	TN (mg/L)	ISS (mg/L)	VSS (mg/L)	TSS (mg/L)	TSI (SD)	TSI (Chl)	TSI (TP)
6/13/07	0.8	49	80	6.5	6	10	16	63	69	67
7/17/07	0.3	110	190	2.6	24	27	50	77	77	80
8/15/07	0.2	180	220	2.7	19	27	46	83	82	82
5/29/08	0.9	5	120	3.7	11	5	15	62	46	73
6/30/08	0.4	25	190	5.6	24	13	37	73	62	80
7/23/08	0.3	97	160	3.2	12	17	29	77	75	77
8/21/08	0.3	120	280	3.4	14	53	67	77	78	85
10/6/08	0.3	80	270	2.7	10	40	50	77	74	85
Mean	**0.44**	**83.3**	**188.8**	**3.8**	**15.0**	**24.0**	**38.8**	**72**	**74**	**80**
Median	**0.30**	**88.5**	**190.0**	**3.3**	**13.0**	**22.0**	**41.5**	**77**	**75**	**80**
St Dev	**0.26**	**56.5**	**69.0**	**1.5**	**6.7**	**16.2**	**18.1**	**--**	**--**	**--**
CV	**0.60**	**0.68**	**0.37**	**0.38**	**0.44**	**0.68**	**0.47**	**--**	**--**	**--**

[1] East open bay location = STORET ID 22810004

Table C-4. UHL Hydrolab profiles (west arm of lake[1]).

Date	Depth (m)	Temp (°C)	pH	Spec Cond (mS/cm)	TDS (g/L)	DO (% Sat)	DO (mg/L)	Turbidity (NTU)
5/29/08	0	16.36	8.21	0.53	0.3	105.2	10.28	40.5
	0.5	16.31	8.23	0.53	0.3	105.3	10.31	44.7
	1.0	16.12	8.22	0.55	0.4	104.7	10.29	53.4
	1.3	16.02	8.21	0.56	0.4	104.9	10.34	66.2
6/26/08	0.5	24.68	7.94	0.44	0.3	143.4	11.89	67.3
	1.0	24.46	7.93	0.44	0.3	138.6	11.55	90.1
7/23/08	0	27.51	8.78	0.31	0.2	125.0	9.86	108
	0.5	27.46	8.77	0.31	0.2	120.1	9.50	107
	1	27.25	8.74	0.32	0.2	114.2	9.05	111
8/21/08	0.1	25.01	8.51	0.33	0.2	73.7	6.08	103
	0.5	25.09	8.61	0.33	0.2	62.3	5.13	104
	1.0	25.09	8.63	0.33	0.2	59.6	4.91	109
10/6/08	0.1	17.78	8.76	0.36	0.2	80.6	7.65	101
	0.5	17.73	8.73	0.36	0.2	74.2	7.07	96
	1.0	**17.47**	**8.69**	**0.36**	**0.2**	**65.5**	**6.26**	**100**

[1] West arm location = STORET ID 22810003

Table C-5. UHL Hydrolab profiles (ambient monitoring location[1]).

Date	Depth (m)	Temp (°C)	pH	Spec Cond (mS/cm)	TDS (g/L)	DO (% Sat)	DO (mg/L)	Turbidity (NTU)
5/29/08	0	16.42	8.19	0.48	0.3	84.0	8.20	19.4
	0.5	16.42	8.17	0.48	0.3	82.7	8.08	19.9
	1.0	16.43	8.16	0.48	0.3	82.8	8.09	19.5
	1.5	16.43	8.16	0.48	0.3	82.4	8.05	20.3
	2.0	16.42	8.16	0.48	0.3	82.7	8.07	20.0
6/26/08	0.5	24.84	7.70	0.46	0.3	81.8	6.76	35.7
	1.0	24.83	7.76	0.46	0.3	81.5	6.75	34.0
	1.5	24.83	7.81	0.46	0.3	81.4	6.74	33.6
	2.0	24.82	7.85	0.46	0.3	81.9	6.78	35.4
	2.2	24.81	7.85	0.46	0.3	82.1	6.80	35.6
	[2]--	24.83	7.87	0.46	0.3	82.5	6.81	29.2
7/23/08	0	26.63	8.74	0.31	0.2	84.9	6.79	61.0
	0.5	26.63	8.73	0.31	0.2	85.5	6.85	61.7
	1.0	26.63	8.73	0.31	0.2	83.4	6.69	62.5
	1.5	26.61	8.73	0.31	0.2	82.1	6.59	62.7
	2.0	26.61	8.73	0.31	0.2	81.2	6.52	63.0
8/21/08	0.1	24.39	9.28	0.29	0.2	84.0	7.01	113
	0.5	24.41	9.29	0.29	0.2	81.2	6.77	113
	1.5	24.41	9.30	0.29	0.2	80.5	6.72	112
10/6/08	0.1	17.40	8.96	0.34	0.2	105.3	10.07	75.7
	0.5	17.34	9.00	0.34	0.2	100.6	9.65	72.6
	1.0	17.32	9.01	0.34	0.2	99.7	9.56	73.2
	2.0	**17.27**	**9.01**	**0.34**	**0.2**	**97.8**	**9.39**	**73.0**

[1] Ambient monitoring location = STORET ID 22810002

Table C-6. UHL Hydrolab profiles (east open bay location[1]).

Date	Depth (m)	Temp (°C)	pH	Spec Cond (mS/cm)	TDS (g/L)	DO (% Sat)	DO (mg/L)	Turbidity (NTU)
5/29/08	0	16.47	8.13	0.48	0.3	84.7	8.27	27.7
	0.5	16.48	8.16	0.48	0.3	82.4	8.04	23.4
	1.0	16.48	8.16	0.48	0.3	81.4	7.94	21.7
	1.5	16.47	8.16	0.48	0.3	81.2	7.92	21.9
	2.0	16.47	8.15	0.48	0.3	80.5	7.85	22.8
6/26/08	0.1	22.36	8.00	0.46	0.3	100.3	8.70	54.5
	0.5	22.36	8.04	0.46	0.3	102.2	8.87	54.0
	1.0	22.19	8.05	0.46	0.3	101.4	8.82	54.5
	1.5	21.5	8.05	0.46	0.3	96.8	8.53	57.7
	2.1	21.22	8.05	0.46	0.3	92.0	8.16	80.3
	2.2	21.22	8.05	0.46	0.3	91.5	8.11	5999
7/23/08	0	25.81	8.54	0.31	0.2	61.6	5.01	54.6
	0.5	25.80	8.54	0.31	0.2	62.2	5.06	53.8
	1	25.80	8.53	0.31	0.2	61.5	5.00	53.4
	1.5	25.80	8.53	0.31	0.2	60.9	4.96	55.1
	2.0	25.79	8.53	0.31	0.2	59.7	4.85	56.9
8/21/08	0	24.46	9.29	0.28	0.2	83.3	6.94	118.0
	0.5	24.47	9.30	0.28	0.2	80.7	6.72	118.0
	1.5	24.47	9.31	0.28	0.2	78.9	6.57	116.0
10/6/08	0.1	17.45	9.10	0.33	0.2	104.1	9.98	86.7
	0.5	17.42	9.13	0.33	0.2	101.8	9.75	85.1
	1.0	17.41	9.14	0.33	0.2	100.8	9.65	85.4
	2.0	**17.39**	**9.07**	**0.33**	**0.2**	**96.0**	**9.15**	**5999**

[1] West arm location = STORET ID 22810004

Appendix D --- Watershed Model Development

Watershed and in-lake water quality modeling were used in conjunction with observed flow and water quality data to develop the Total Maximum Daily Load (TMDL) for algae and turbidity impairments to Black Hawk Lake in Sac County, Iowa. The Soil & Water Assessment Tool (SWAT2005), version 2.3.4, was applied to the watershed to simulate hydrology and pollutant loading. In-lake water quality simulations were performed using BATHTUB 6.1, an empirical lake and reservoir eutrophication model. The integrated watershed and in-lake modeling approach allows the holistic analysis of hydrology and water quality in Black Hawk Lake and its watershed, including Carnarvon Creek and several tributaries. This section of the Water Quality Improvement Plan (WQIP) discusses development of the SWAT model for Black Hawk Lake. Development of the BATHTUB model is discussed in Appendix F.

D.1. SWAT Model Description

SWAT is a watershed-scale hydrology and water quality model developed by the U.S. Department of Agriculture – Agricultural Research Service (USDA-ARS). SWAT is a long-term continuous-simulation model that operates on a daily time step, and was developed to assess the impacts of land use and management practices on hydrology and water quality (Gassman et al., 2007; Schilling et al., 2008). SWAT is capable of simulating a variety of pollutants, including sediment, nutrients, pesticides, and bacteria. Primary physical inputs include spatial coverage of soil types and land uses. Climatic data includes daily precipitation, temperature, solar radiation, relative humidity, and wind speed. Land management considerations that affect hydrology and water quality, such as crop rotation, tillage practices, best management practices, manure application, tile drainage characteristics, livestock grazing, and point source pollution loads, are also important model inputs.

Watersheds are delineated into subbasins based on a desired area threshold. Subbasins are further divided into hydrologic response units (HRUs) that consist of homogeneous soil, land use, and slope characteristics (Gassman et al., 2007; Schilling et al., 2008). Because each HRU represents the portion of a subbasin with the same soil, land use, and slope classification, HRUs are not spatially contiguous. An overall water balance is simulated for each HRU and flows are summarized at the subbasin level before being routed through the stream system. Pollutant loadings or concentrations can also be calculated for each HRU and summed at the subbasin level before being routed through the watershed. There is a long history of the use of SWAT for hydrologic and water quality simulations (Gassman et al., 2007), and its utilization for the development of TMDLs is increasingly popular (Borah et al., 2006).

D.2. Meteorological Input

Precipitation and Temperature Data
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). IEM also provides daily NEXRAD data, which estimates the spatial distribution of rainfall data using radar rather than rainfall observed and recorded on the earth's surface. Daily changes in lake stage were correlated to daily precipitation from each of the individual stations and NEXRAD, and to areal average daily precipitation calculated using the Thiessen polygon method. The Thiessen polygon method results in an area-weighted precipitation data set utilizing the Sac City and Carroll stations. The method eliminates the more distant Denison and Rockwell City stations. This method provided the strongest correlation to daily change in lake stage when compared to individual stations and the NEXRAD data. Therefore, the Thiessen approach was used to develop input precipitation data for the SWAT model.

The Thiessen polygon precipitation data from 1994-2009 was converted to millimeters (mm) and imported to SWAT during model development. Similarly, the Thiessen polygon method was applied to temperature data at the Sac City and Carroll NWS COOP stations to develop a daily record of maximum and minimum temperature (degrees Celsius) for SWAT input. A summary of weather station and precipitation data is provided in Section 2.1.

Solar Radiation, Wind Speed, and Relative Humidity
SWAT2005 allows the user to simulate solar radiation, wind speed, and relative humidity input, or import data from nearby weather stations. Oftentimes, daily solar radiation, wind speed, and humidity data near the watershed of interest are not available. Simulated input is generated through algorithms within the SWAT model that draw from historical weather data stored in the SWAT database and precipitation and temperature inputs. The SWAT model used in this TMDL relied on simulated input data for solar radiation, wind speed, and relative humidity, which is consistent with previous SWAT applications in Iowa.

D.3. Hydrologic Response Unit (HRU) Input

Topography
The Black Hawk Lake watershed boundary was delineated in the ArcSWAT 2.3.4 Interface for SWAT2005 using a 10-meter resolution digital elevation model (DEM) developed by the Iowa Department of Natural Resources (IDNR). Topographical input has two primary purposes. First, it provides a basis for watershed and subbasin delineation. Second, it allows calculation of average slope for each HRU, which is an important input for hydrologic and water quality simulation.

During the delineation process, a drainage area threshold of 176 hectares (435 acres) was entered to define the minimum subbasin size. This value was obtained through an iterative process and selected in order to provide a manageable number of subbasins. Subbasin outlets were added manually as part of the delineation process to establish outlets at key locations. Fourteen outlets were added manually at locations where flow and water quality data had been collected (including the lake outfall location) and another outlet was added to help define the confluence of two adjoining segments of the drainage system. Placement of outlets at these locations allows comparison of simulated and observed data. Manual outlet definition was also helpful to ensure that the range of subbasin areas was within an order of magnitude, as recommended by SWAT model developers (R. Srinivasan, March 16, 2009, personal communication).

The delineation resulted in a total watershed area of 5,740 hectares (14,184 acres) consisting of 15 subbasins. One subbasin (Subbasin 4) has a drainage area of approximately 27 hectares, which deviates more than one order of magnitude from the maximum. However, this subbasin was defined in order to simulate the impacts of a wetland/marsh, and the small subbasin area was required to accurately reflect the drainage network. The other 14 subbasins have areas ranging from 166 to 822 hectares (410 to 2,039 acres), well within the recommended order of magnitude. The delineation is illustrated in Figure D-1.

Land Use

Land use inputs for the SWAT model are based on windshield surveys conducted by IDNR in 2008 and 2009. Land uses observed during the 2008 survey were assumed to represent land cover in even years of SWAT simulations, whereas land uses observed in 2009 are simulated in odd years. The land use surveys were also used to incorporate crop rotation into the watershed model. Twenty distinct land uses were identified in the watershed during the surveys. These land uses are generalized and illustrated in Figure 2-6 of Section 2.2.

During SWAT model development, a filter was applied to land uses during HRU definition. The land use filter eliminates land uses that comprise less than five percent of each subbasin, and reapportions these small areas to the remaining (unfiltered) land uses in each subbasin. The filtration process reduces the number of resulting HRUs, which significantly reduces model run time and increases model efficiency. Pastureland and feedlots were exempted from the land use filter to ensure that no areas with these potentially important sources of manure were eliminated from the simulations. Table D-1 reports the even-year land use breakdown used for HRU definition (after filtering).

Odd-year land use is based on the 2009 windshield survey and would have similar areas as even years, but with less corn and more soybeans due to corn-soybean crop rotations. This is the land use information that the SWAT model utilizes for hydrologic and water quality simulations. Differences between this land use distribution and the generalized distribution reported in Table 2-5 and Figure 2-6 are due to the exclusion of the lake and inlet slough areas from the land uses in Section 2, small differences in the watershed boundary (and subsequent area) due to automatic delineation in ArcSWAT, and the filtering process during SWAT model development.

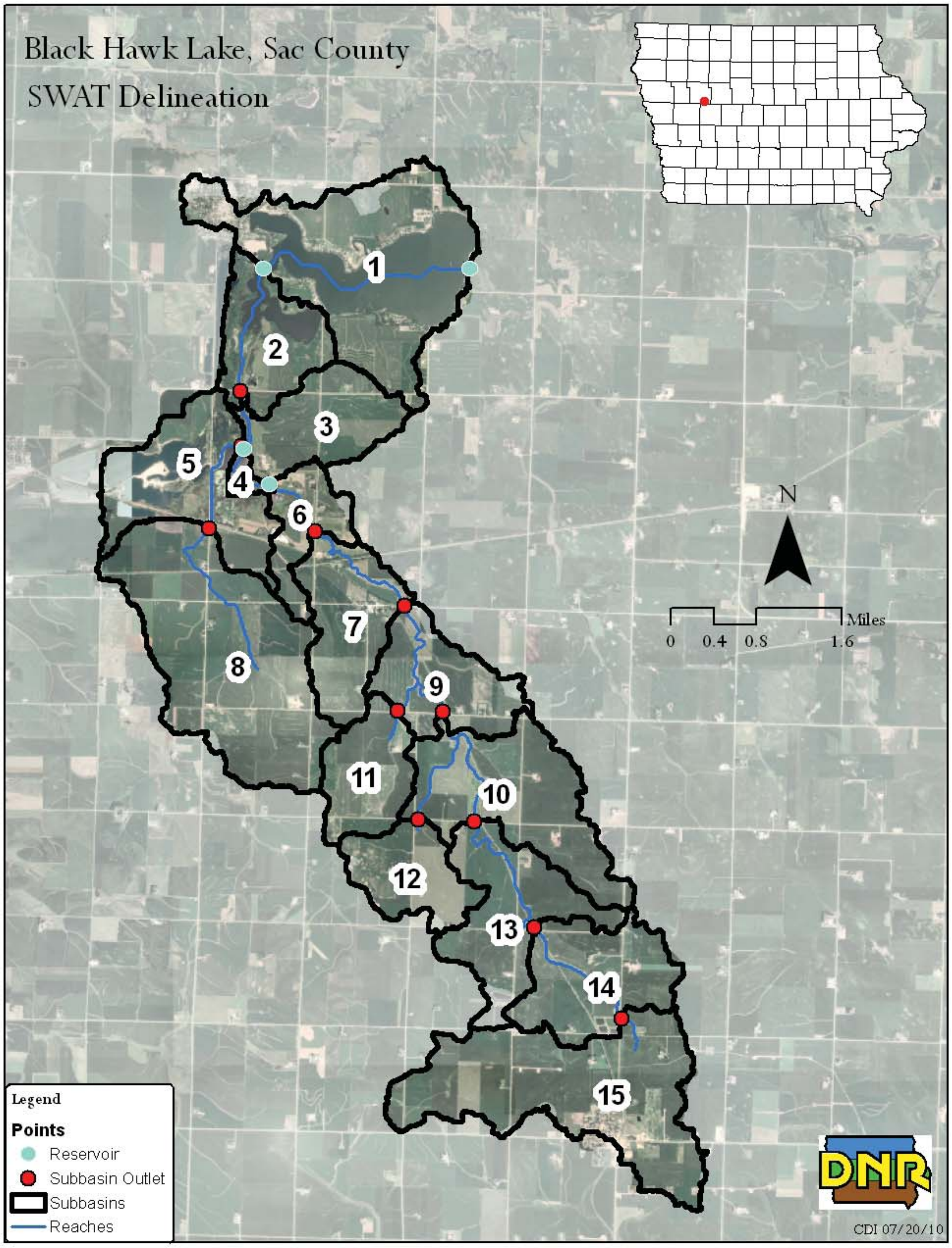

Figure D-1. SWAT delineation.

Table D-1. Land use classifications in Black Hawk Lake SWAT model.

2008 Land Use	SWAT Classification	Watershed Area (%)
Corn	Corn (CORN)	54.4
Soybeans	Soybean (SOYB)	22.7
Water	Water (WATR)	9.0
Urban/Residential	Residential-Medium Density (URMD)	4.4
Wetland	Wetlands-Mixed (WETL)	3.4
Grassland	Smooth Bromegrass (BROS)	2.7
Timber	Forest-Mixed (FRST)	1.3
Pasture	Pasture (PAST)	0.9
Quarry	Industrial (UIDU)	0.5
Roads/ROW	Transportation (UTRN)	0.4
Hay/Alfalfa	Alfalfa (ALFA)	0.2
CAFO (Feedlots)	Agricultural Land-Generic (AGRL)	0.1

Soils

SWAT model development utilized the Soil Survey Geographic (SSURGO) soils coverage for Sac and Carroll Counties, developed by the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS). Soils data are discussed in more detail in Section 2.2. The SSURGO data was filtered during HRU definition so that soils comprising less than 10 percent of a land use in a given subbasin would be eliminated, and the corresponding area would be reapportioned to the remaining soils (soils comprising greater than 10 percent of the land use in a subbasin). The soil groups comprising the largest areas of the watershed (after filtration), and their respective hydrologic soil group (HSG), are reported in Table D-2. A substantial majority of the watershed is classified as HSG B, which NRCS describes as soils having a moderate infiltration rate when thoroughly wet, a moderately fine to moderately coarse texture, and a moderate rate of water transmission. SWAT uses the soil HSG in conjunction with land cover to assign NRCS runoff curve numbers (CNs).

Table D-2. Predominant soils with hydrologic soil group.

Soil Name	Watershed Area (%)	Hydrologic Soil Group (HSG)
Clarion	43.2	B
Nicollet	15.6	B
Webster	11.3	B/D
Coland	6.2	B/D
Marshall	2.6	B
All others	21.1	B and B/D

Slopes

During the watershed delineation process, ArcSWAT creates a slope grid using the input DEM. To complete the definition of HRUs, the SWAT user must define the desired slope classifications. For the Black Hawk Lake SWAT model, four slope classifications were defined in accordance with classifications found in the NRCS soil surveys. A 10 percent filter was applied to the slopes during HRU definition. A map of mean slope for each HRU in the Black Hawk Lake SWAT model is provided in Figure D-2. The breakdown of slope classes is reported in Table D-3. A map of the average subbasin slope is shown in Figure D-3.

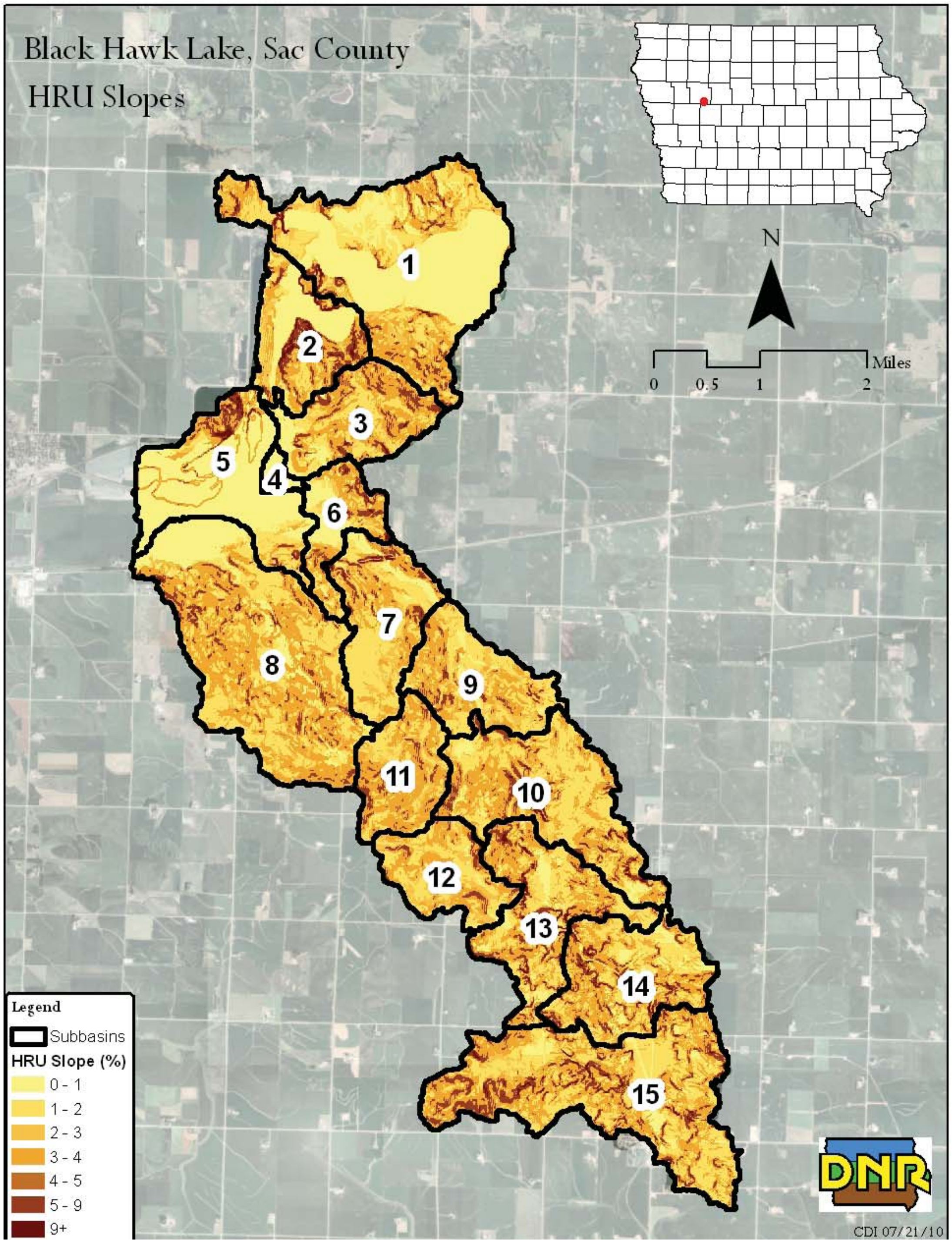

Figure D-2. Average HRU slope in the Black Hawk Lake SWAT model.

Table D-3. Slope classifications in Black Hawk Lake SWAT model.

Slope (%)	Description	Watershed Area (%)
0-2	Level and nearly level	50.9
2-5	Gently sloping	42.9
5-9	Moderately sloping	5.9
>9	Strongly sloping to very steep	0.3

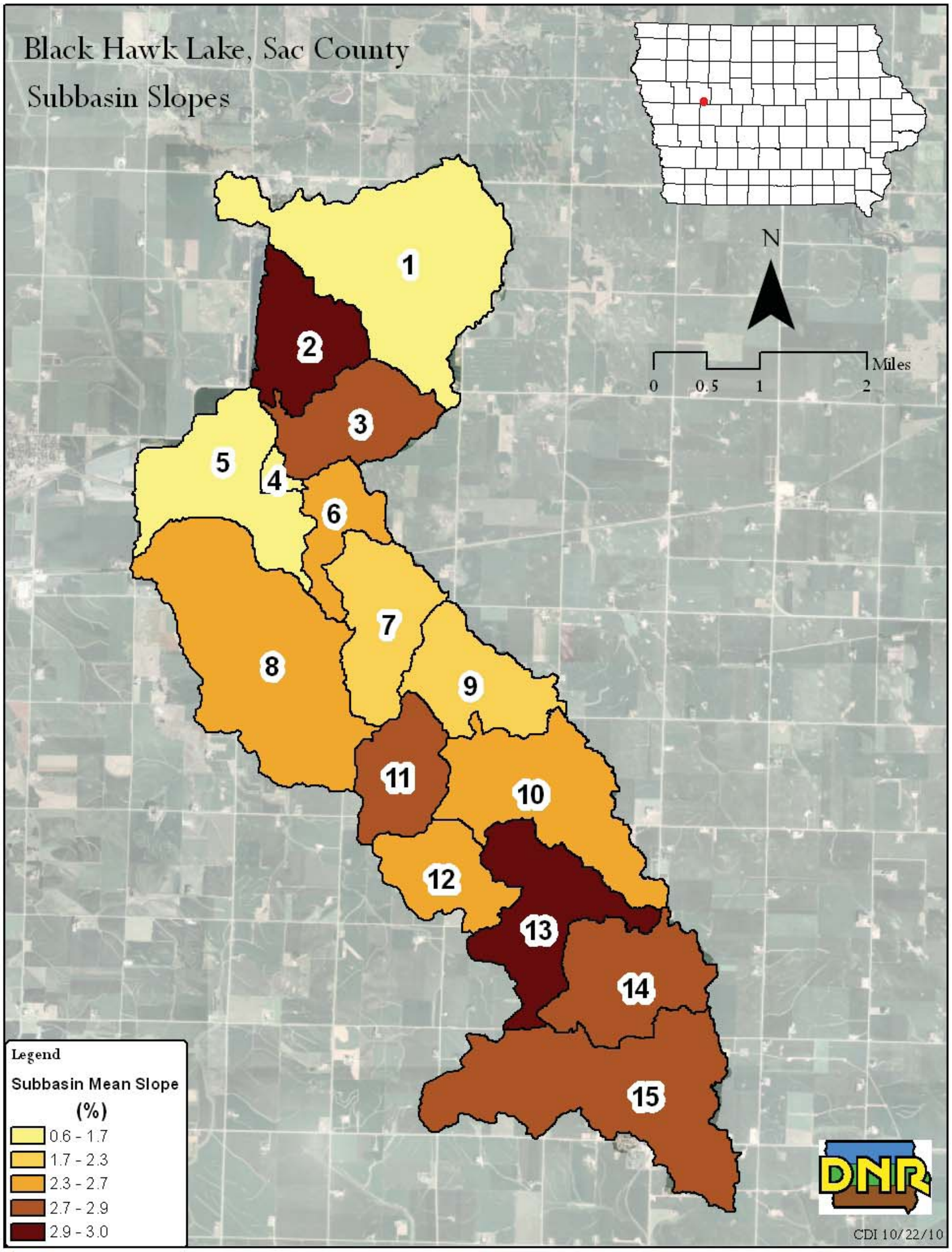

Figure D-3. Average subbasin slope in the Black Hawk Lake SWAT model.

The HRU definition process resulted in 382 unique combinations of land use, soil, and slope. Hydrologic and water quality computations are performed in SWAT for each HRU, summed for each subbasin, then routed through the watershed and ultimately to the watershed outlet.

D.4. Channel Routing

SWAT allows the user to choose between two methods for routing flows through the stream channel. The default option is the Variable Storage Method, and the alternative method is the Muskingum Method. Hydrologic output was not highly sensitive to routing methodology; therefore, the more simple default Variable Storage Method was used.

SWAT assumes that each reach has a trapezoidal shape with side slopes of 2:1 (run:rise). Default channel widths and depths are calculated during the automatic delineation process based on empirical relationships between drainage area and channel geometry. Because LiDAR data were available for the entire watershed, channel geometry was updated by cutting cross-sections using a DEM built from LiDAR data. Channel inputs are entered in the RTE data, which is found in the Subbasin Data menu of the ArcSWAT interface. SWAT channel geometry is shown in Table D-4. The table includes default geometry, LiDAR-derived changes to width and depth, and Manning's roughness coefficients. Manning's coefficients were updated based on channel cover observed in each reach and suggested values in the SWAT user documentation.

Table D-4. Default and adjusted SWAT channel characteristics.

Subbasin	Default			LiDAR-derived		
	Width (m) CH_W2	Depth (m) CH_D	Manning's CH_N2	Width (m) CH_W2	Depth (m) CH_D	Manning's CH_N2
1	14.7	0.66	0.014	14.7	0.66	0.08
2	13.4	0.62	0.014	12.5	0.95	0.08
3	12.9	0.60	0.014	10.7	0.30	0.08
4	10.2	0.52	0.014	7.0	0.70	0.08
5	5.8	0.35	0.014	11.0	1.30	0.08
6	10.2	0.52	0.014	8.3	1.13	0.08
7	9.9	0.50	0.014	10.7	1.50	0.035
8	4.6	0.30	0.014	9.0	1.40	0.08
9	9.2	0.48	0.014	11.3	1.37	0.035
10	8.1	0.44	0.014	5.0	0.70	0.035
11	2.1	0.18	0.014	8.0	1.00	0.08
12	2.1	0.18	0.014	4.0	0.18	0.08
13	6.4	0.38	0.014	8.1	1.36	0.035
14	5.4	0.34	0.014	7.1	1.33	0.035
15	4.2	0.29	0.014	10.0	1.50	0.08

Overall, SWAT default widths appeared to be reasonable; however, default depths were increased by an average factor of two. Most previous applications of the SWAT model in the State of Iowa have not incorporated adjustments to default channel geometry. Although the model was not fully calibrated at the time the channel geometry was modified, it was instructive to examine the impacts the changes had on hydrology. The flow distribution before and after updating RTE parameters is reported in Table D-5. Overall, the LiDAR derived channel geometry resulted in slightly lower flows in Reach 03, which is near the downstream end of the watershed but upstream of the inlet to Black Hawk Lake. Given that the largest changes were fractions of a cubic foot per second (cfs), it does not appear the detailed modifications to channel geometry are warranted for hydrologic simulation using SWAT.

Table D-5. Impacts of RTE parameter edits on flow in Reach 03 (350th St.).

Flow Percentile	Default Geometry Flow (cfs)	Adjusted Geometry Flow (cfs)	Percent Difference (%)
Minimum	0.22	0.22	-0.8
5th	0.54	0.54	0.8
10th	0.68	0.68	0.1
20th	0.99	1.00	1.1
1st quartile	1.12	1.13	0.7
30th	1.28	1.29	1.1
40th	1.64	1.67	1.8
Median	2.11	2.15	1.8
60th	2.72	2.76	1.2
70th	3.66	3.72	1.5
2nd quartile	4.46	4.53	1.5
80th	5.77	5.83	1.2
90th	16.11	16.16	0.3
95th	36.23	36.16	-0.2
Maximum	52.2	52.1	-0.1

D.5. Reservoir Input

Four reservoir outlets were added during the ArcSWAT watershed delineation process. Reservoir nodes allow the user to simulate the effects of lakes and reservoirs on watershed hydrology and water quality. Although a reservoir outlet was included at the Provost Slough inlet, the State Marsh, and the Duck Unlimited (DU) Pond, these reservoirs were not activated in the SWAT model. The inlet slough and main body of the lake are hydraulically connected, and the combined storage was incorporated in the reservoir outlet that represents the entire lake in Subbasin 1. The State Marsh and DU Pond are not designed or operated as flood control systems and have little effect on daily average flows. Inclusion of reservoir nodes at these locations allows for future investigation of potential impacts on water quality.

Table D-6 lists the location, Subbasin ID, and Reservoir ID of each reservoir included in the SWAT model. Required input parameters for hydrologic simulation of reservoirs in SWAT using the simulated target release method include the surface area at the principal spillway crest elevation (RES_PSA), the storage volume at the principal spillway crest (RES_PVOL), the surface area and volume at the emergency spillway crest elevation (RES_ESA and RES_EVOL, respectively), the targeted monthly storage volume (STARG), and the number of days required to reach target storage (NTARGR). For

Black Hawk Lake, the DU Pond, and the State Marsh, input parameters were obtained from design plans and available elevation data (i.e., a DEM) in GIS.

Table D-6. Reservoirs outlets in SWAT.

Location/Feature	Subbasin ID	Reservoir ID	Outflow Calculation Method
Ducks Unlimited (DU) Pond	6	1	Not simulated
State Marsh	4	2	Not simulated
Provost Slough	2	3	Not simulated
Black Hawk Lake	1	4	Simulated Target Release

The target storage (STARG) was set to the principal spillway volume. STARG can vary monthly, but is constant for Black Hawk Lake. The number of days required to reach the target storage (NDTARGR) was initially derived by comparing time series discharge curves based on outlet structure geometry with the time series discharge produced by the simulated target release method. This required iteratively adjusting the NDTARGR values until the target release method curve most closely matched the rating curve based on the Iowa State University Diagnostic Feasibility Study data described in Section E.1. Table D-7 reports the input variables for each reservoir simulated in SWAT. Note that NDTARGR was adjusted during calibration (See Section E.1).

Table D-7. SWAT Reservoir simulation parameters for Black Hawk Lake.

Input Parameters	Parameter Description	Units	Black Hawk Lake (Res 4/Sub 1)
RES_PSA	Surface area of lake at principle spillway elevation	ha	376.37
RES_PVOL	Volume of lake at principal spillway elevation	10^4 m^3	635.768
RES_ESA	Surface area of lake at emergency spillway elevation	ha	430.51
RES_EVOL	Volume of lake at emergency spillway elevation	10^4 m^3	961.591
NDTARGR	Number of days to reach target storage	days	5
RES_K	Hydraulic conductivity (seepage) of reservoir bottom	mm/hr	0
STARG	Monthly target storage	10^4 m^3	635.768

D.6. Management Operations

Tile Drainage

Like most land in agricultural production in the Des Moines Lobe ecoregion, Black Hawk Lake watershed is heavily tile drained. Tile drainage was added to the SWAT model based on three criteria: land use, soil type, and slope. HRUs that have a corn or soybean land use, slopes less than or equal to 5 percent, and soil types known to require tile drainage for row crop production were assigned tile drainage characteristics. Using these criteria, approximately 68 percent, or 9,655 acres of the 14,184-acre watershed simulated in SWAT, are row crops with tile drains. Tile drainage is incorporated into SWAT using three parameters, described in Table D-8.

Table D-8. SWAT tile drain parameters for the Black Hawk Lake watershed.

Description	SWAT Variable	Value
Depth to subsurface drain	DDRAIN	900 mm
Time required to drain to field capacity	TDRAIN	48 hr
Drainage tile lag time (hr)	GDRAIN	24 hr

Input values in Table D-8 are consistent with calibrated SWAT model development for the Raccoon River Basin (Jha et al., 2006; IDNR, 2008). The DDRAIN parameter was decreased from 1,200 mm in the Raccoon River SWAT model to 900 mm for Black Hawk Lake to account for the smaller watershed size, local topography, and high groundwater table. Figure D-4 highlights HRUs that are assumed to have tile drainage.

Crop Rotation

Land uses were assigned in the SWAT model using the land use coverages developed from the windshield surveys conducted in the fall of 2008 and 2009. The surveys revealed that corn and soybean rotation is most common, but there are also significant amounts of continuous corn. HRUs described as corn in the 2008 survey and soybeans in the 2009 survey were modeled as corn in even years of the simulation period and soybeans in odd years. Similarly, areas described as soybeans in 2008 were designated as soybeans in even years and corn in odd years. Some HRUs were assigned continuous corn rotations based on the observance of corn in both 2008 and 2009 surveys. This may bias flow and water quality predictions to current (2008-2009) conditions, but this is appropriate given the goals of the TMDL and implementation plan.

Tillage

The 2009 watershed assessment delineated tillage practices in row crop areas at the field scale. The vast majority (approximately 95 percent) of row crops in the watershed are conventional tillage. Therefore, conservation tillage practices, such as mulch and no till, are not reflected in the existing conditions SWAT model, and all Universal Soil Loss Equation (USLE) P-factors are set to 1.0. However, the impacts of conservation tillage are evaluated as part of the Implementation Plan in Section 4. To assess the effects of tillage practices in SWAT, HRUs that implement improved tillage are assigned lower CNs and lower USLE C-factors. Table D-9 reports the SWAT 4-digit crop code, C-Factors, and relative change in CN associated with each tillage practice. C-Factors for each tillage practice are consistent with the NRCS District Conservationist's recommendations for the watershed. Changes in CN are relative to a baseline CN associated with conventional tillage, and are consistent with differences in CNs reported for row crops with and without crop residue in the NRCS Technical Release 55 (TR-55).

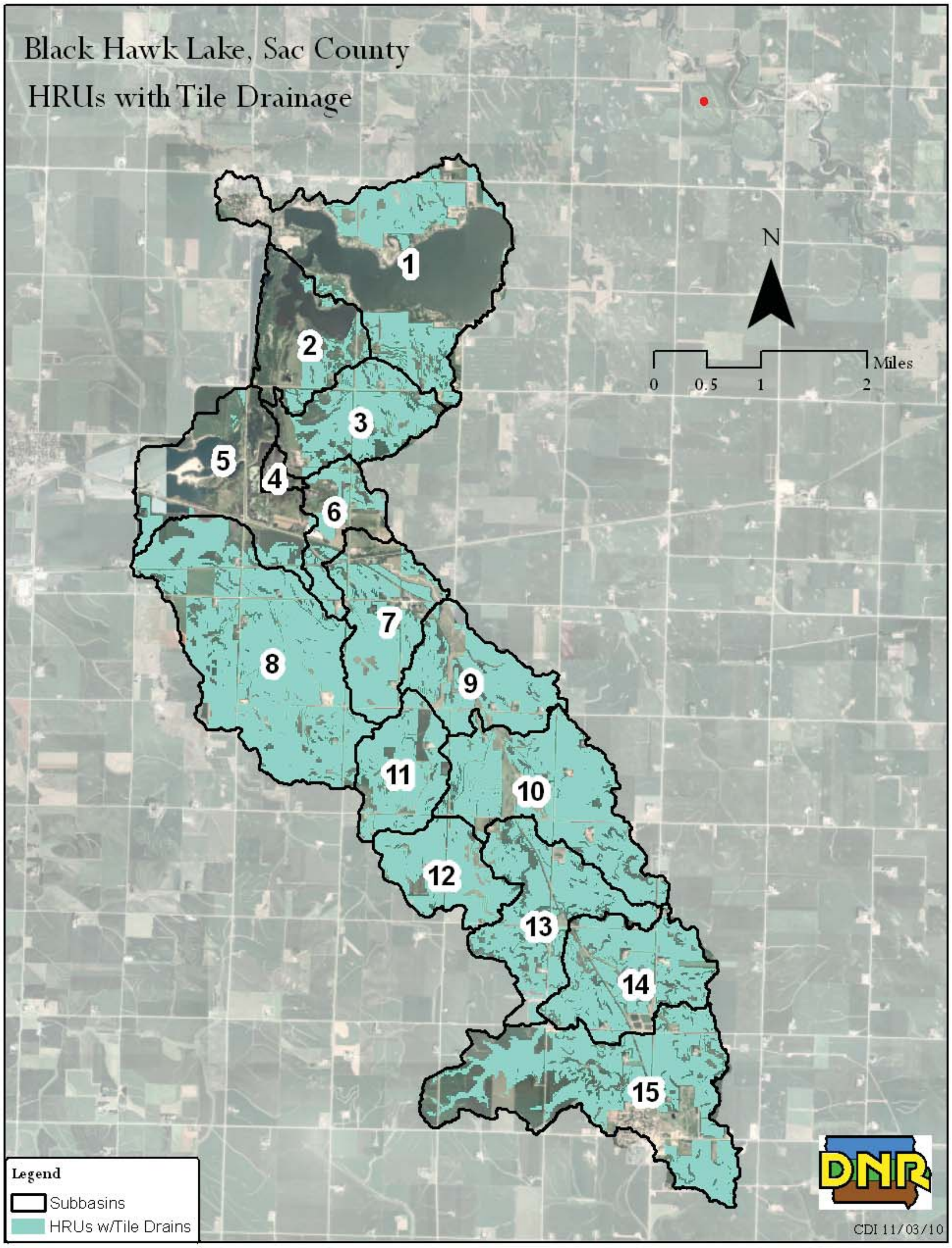

Figure D-4. HRUs with tile drainage in the Black Hawk Lake SWAT model.

Table D-9. SWAT C-Factors and CNs for corn and bean of tillage practices.

4-digit Crop Code	Description	USLE C-Factor	Change in CN
COCT	Conventional-till CORN	0.25	0
CORN	Mulch-till CORN	0.14	-2
CONT	No-till CORN	0.07	-4
SOCT	Conventional-till SOYB	0.25	0
SOYB	Mulch-till SOYB	0.14	-2
SONT	No-till SOYB	0.07	-4

Fertilizer Application

Nitrogen and phosphorus fertilizers were applied to row crops at rates and times consistent with previous SWAT applications for TMDL development in Iowa. Anhydrous ammonia was applied to all corn ground in the fall after the previous year's crop was harvested. Di-ammonium phosphate fertilizer (SWAT fertilizer ID 18-46-00) was applied to all soybean ground in the spring prior to planting. Table D-10 shows the rates and timing of fertilizer applications in the Black Hawk Lake SWAT model. Fertilizer application is required to support crop growth in SWAT – without adequate crop growth, the accuracy of hydrologic output from SWAT is compromised. Additionally, fertilizer application is an important component of nutrient export to the lake.

Table D-10. Fertilizer application in the Black Hawk Lake SWAT model.

Fertilizer Type	Application Rate	Timing
Di-ammonium phosphate	175 kg/ha (156 lbs/ac)	Spring – prior to planting soybeans
Anhydrous ammonia	170 kg/ha (152 lbs/ac)	Fall – prior to spring corn planting

Manure Application

Manure was applied to corn in the SWAT model as specified by available manure management plans (MMPs). IDNR requires MMPs for all confinements with greater than 500 animal units (AUs) and all open feedlots with over 1,000 AUs. Several animal feeding operations (AFOs) in or near the Black Hawk Lake watershed have MMPs on file with IDNR. Manure application (location, volume, and timing) reported in the MMPs was input to the SWAT model. The areas of application fields reported in the MMPs were assigned to equivalent HRU areas in each SWAT subbasin. This provides spatial accuracy to the subbasin level, but not to field level. All manure is applied as hog manure according to the "Swine-Fresh Manure" classification in the SWAT2005 database.

The MMPs report application rates in gallons per acre (gal/acre) of liquid manure, and the manure nutrient content varies across different MMPs. SWAT assumes that manure is applied on a dry basis and has default manure nutrient concentrations in the Swine-Fresh Manure option. To simplify manure application inputs to SWAT, MMP application amounts were converted to a dry basis (kg/ha), and manure was applied in SWAT to reflect nitrogen application amounts equivalent to those estimated in each

MMP. This eliminated the need to develop a separate manure type for each MMP, which would provide little increase in accuracy but a large increase in model development time.

Annual liquid application rates ranged from approximately 3,100 to 7,100 gal/acre, and manure is applied to approximately 1,650 acres a year (1,950 acres in even years, 1,350 in odd years. Annual dry application rates are between 4,270 and 5,428 kg/ha/year. The simulated applications were spread over a period of 4-6 days in the spring and/or fall, depending on the information included in the MMP. Resulting daily application rates range from 409 to 499 kg/ha/day. For example, HRU 000020020 receives 423 kg/had/day of swine manure on April 1-5 in years of corn production and on October 1-5 in years of soybean production.

Livestock Grazing

The number of grazing livestock (beef cattle) was estimated by multiplying the number of acres of pasture by a typical grazing density of 0.5 head of cattle per acre of pastureland (Dr. James Russell, ISU Extension, February 10, 2010, personal communication). This equates to 63 head of cattle grazing on approximately 126 acres of pasture in the watershed. Manure production rates, nutrient content, and bacteria concentrations for beef cattle were obtained from ASAE standards (ASAE, 2003). Manure deposition rates, in kilograms per hectare per day (kg/ha/day), were entered for all pasture HRUs in each SWAT subbasin. Grazing was simulated from April 15 through November 15 of each year. Table D-11 shows beef cattle grazing inputs used in SWAT.

Table D-11. SWAT model inputs – livestock grazing.

Livestock Type	Beef Cattle
Manure type (MANURE_ID)	Beef – Fresh Manure
No. Grazing days (GRZ_DAYS)	214
Start Date	April 15
End Date	November 15
[1] Manure Production	2.44 kg/head/day
[2]Manure Deposition (MANURE_KG)	3.02 kg/ha/day

[1] Dry manure production calculated from wet production rates reported by ASAE (2003) and manure moisture contents reported by USDA (1992).

[2] Manure deposition = dry manure production times number of head of cattle divided by area of grazed pasture in watershed.

Open Feedlots

There are a number of animal feeding operations in the Black Hawk Lake watershed. Sources of nutrients and bacteria include application of manure from confined feeding operations and grazing, as discussed previously, and small open feedlots that result in runoff containing manure. Open feedlots with less than 100 animal units (AUs) are required to “settle solids,” but are not required to store runoff for a prolonged period. For this reason, small open feedlots in the Black Hawk Lake watershed are assumed to have the potential to generate runoff with high levels of phosphorus. This process is simulated in SWAT by using the grazing function to deposit manure on known feedlot areas. Manure production and characteristics cited previously for beef cattle are utilized, and feedlot densities were estimated using a combination of anecdotal data, field observations, and/or aerial photography. Manure deposition in feedlots is simulated for HRUs representative of feedlot areas in each applicable subbasin. As with manure application, this results in spatial accuracy to the subbasin level, but not to individual HRUs.

Wildlife "Grazing"

The estimated deer density in Sac County, based on road kill rates, is approximately two deer per square mile (Willie Suchy, IDNR, June 18, 2009, personal communication). The countywide deer density was increased by 50 percent for modeling purposes for two reasons. First, to account for manure deposition from furbearing wildlife such as raccoons, beavers, opossums, etc. Second, to account for the fact that wildlife management areas surround the lake, which likely provide habitat for a more dense population of wildlife than the Sac County average. The resulting wildlife density is reasonable when compared to the results of spotlight and road kill surveys in the Trends in Wildlife Populations and Harvest 2008 (IDNR, 2009).

Wildlife was assumed to reside in HRUs with ungrazed grass (BROS) and forest (FRST) land covers. It is almost certain that wildlife are also present in row crop, pasture, and other land cover types; however, this assumption will not affect the overall pollutant contributions from wildlife and will help separate these contributions for development of source inventories. The assumed wildlife density in forest and grass areas is 74 deer per square mile (deer/mi^2). The overall wildlife density equates to 3 deer/mi^2, which is 50 percent more than the countywide average as explained above. Manure production from wildlife "grazing" was entered in SWAT using a manure production rate of 1.74 kg/ha/day for all forest and grass HRUs. Veal is the most reasonable approximation of deer manure available in the SWAT database, so wildlife manure nutrient levels reflect those of veal. Wildlife grazing and subsequent manure deposition is assumed to occur 365 days a year.

Urban stormwater

There is a relatively small amount of urban land use in the Black Hawk Lake watershed. For modeling purposes, urban land cover includes roadways (UTRN), industrial land use (UIDU), and residential (URMD). Combined, these land covers comprise less than 5 percent of the total watershed area. The City of Lake View does not meet the criteria for requiring a municipal separate storm sewer (MS4) permit; therefore, urban runoff is not considered a point source from a regulatory standpoint. Nutrient contributions are simulated using a buildup/washoff algorithm within the SWAT model. Inputs include default values associated with each land use in the SWAT model.

D.7. Point Source Input

The only permitted point source discharger in the watershed is the City of Breda wastewater lagoon, discussed below. Due to input formatting requirements of SWAT, several continuous, in-stream sources were modeled as point sources even though they are technically nonpoint sources. These include failing septic systems and direct deposition in streams by livestock and wildlife.

NPDES Facilities
The only NPDES-permitted discharger in the Black Hawk Lake watershed is a four-cell controlled discharge lagoon operated by the City of Breda in Carroll County, Iowa. This facility discharges to Carnarvon Creek at the southern end of the watershed, typically twice a year for several weeks at a time. Discharge records from 2004 through 2009 were obtained from IDNR Field Office 4 in Atlantic. These records include daily flow for each discharge period, but pollutant concentration data is limited. Total suspended solids (TSS) concentrations collected from the lagoon during discharge were used in conjunction with daily flows to estimate the daily TSS load from the Breda lagoon.

Nitrogen loads to the lagoon were estimated using a per capita loading rate of 0.027 pounds of total Kjeldahl nitrogen (TKN) per person per day (lbs/person/day), per the EPA Nitrogen control manure (EPA, 1993). In most untreated domestic wastewater, nitrate/nitrate concentrations are neglible, therefore influent TKN approximates influent total nitrogen (TN). The resulting daily TN load to the lagoon is 5.8 kg per day (kg/day). Potential removal/reduction of nitrogen in the lagoon is ignored, and nitrogen builds up in the lagoon between discharge periods. Effluent TN is calculated using the observed daily flows and the nitrogen load that accumulated in the lagoon since the last discharge period. Effluent nitrogen is assumed to be 50 percent organic nitrogen and 50 percent ammonia nitrogen (EPA, 2000a). The resulting daily organic and ammonia nitrogen loads are input to SWAT using a point source input table.

An effluent total phosphorus (TP) concentration of 3.6 milligrams per liter (mg/L) was assumed for the Breda lagoon, based on studies of municipal wastewater treatment facilities (WWTFs) in Minnesota (MPCA, 2000) and Iowa (IDNR, 2007). Effluent phosphorus loads were calculated using daily flow records and the assumed discharge concentration. Effluent TP is assumed to be 80 percent orthophosphate (mineral P) and 20 percent organic P, based on several studies of phosphorus in WWTF effluent (MPCA, 2004; EPA, 2000a). Daily discharges and mineral and organic phosphorus loads were entered into a point source input table. This table is imported to SWAT during model development.

Septic Systems
A GIS coverage of rural residences and other residences suspected to have private onsite wastewater treatment systems (e.g., septic systems) was developed using aerial photography and anecdotal data from various state, county, and local agencies. The Carroll County Environmental Health Department estimates that county wide, up to 70 percent of non-registered systems and 30 percent of registered systems may dump into agricultural tile drains that flow directly to streams. Based on the number of onsite systems in the Black Hawk Lake watershed, this equates to an onsite system “failure” rate of just over 60 percent. The Sac County sanitarian estimated that as many as half (50 percent) of onsite systems likely discharge to agricultural tiles.

Nutrient loads were calculated using the daily per capita flow (70 gal/person/day), assumed total nitrogen (TN) concentration of 45 mg/L and TP concentration of 7 mg/L (EPA, 2000b), and the same ratio of organic and mineral forms assumed for the Breda wastewater lagoon described previously. Septic system nutrient contributions were input to SWAT using daily point source discharge tables for each subbasin.

In-Stream Deposition by Livestock

The number of grazing livestock in the watershed was estimated using the area of grazed pasture and a grazing density of 0.5 cows/acre (described in Section D.5). All grazing livestock were assumed to have direct stream access, since no stream exclusion practices (e.g., fencing) were observed during watershed reconnaissance efforts. Livestock with direct access were assumed to defecate in streams a portion of the time during the grazing season, May 15 to October 15. The amount of time cattle spend in streams varies monthly, as shown in Table D-12. The percent of time cattle spend in streams is highest during hot weather periods.

Iowa State University Extension has researched cattle behavior and found that even during the hottest weather, cattle spend a maximum of about 13 percent of the time (approximately 3 hours a day) within 100 feet of the stream and a maximum of 5 percent of the time in the stream itself (Dr. Jim Russell, Department of Animal Science, ISU-Extension, September 8, 2009, personal communication). During SWAT model development, it was assumed that approximately 75 percent of all manure deposited within this 100-foot corridor is effectively delivered directly into the stream. This is equivalent to a maximum of 10 percent direct stream access time in July and August (13 percent in corridor times 75 percent "effective" deposition equals 10 percent direct deposition).

Table D-12. Assumptions regarding direct deposition by livestock.

Month	Time in Streams (%)	Average Time in Streams (hours/day)
January	0	0
February	0	0
March	0	0
April	0	0
May	3	0.7
June	6	1.4
July	10	2.4
August	10	2.4
September	6	1.4
October	3	0.7
November	0	0
December	0	0

Direct deposition was calculated in the EPA BIT spreadsheet by multiplying the fraction of time spent in streams by ASAE defecation rates and manure nutrient concentrations (ASAE, 2003). Inputs were entered into SWAT via the daily point source discharge tables on a subwatershed basis.

In-Stream Deposition by Wildlife
The SWAT model also simulates in-stream deposition from wildlife. TMDLs developed in Virginia have estimated that deer directly deposit waste into streams less than 1 percent of the time, whereas furbearers directly deposit between 2 and 25 percent of the time (VDEQ et al., 2006). Deer and furbearers in the Black Hawk Lake watershed were assumed to directly deposit 0.5 and 10 percent of their waste to streams, respectively. This results in an overall wildlife in-stream deposition rate of approximately 2 percent when adjusted for relative waste production of deer versus furbearers. Unlike livestock, wildlife was assumed to access the stream year round, and time spent in streams does not vary from month to month.

Nutrient loads from wildlife deposition in streams was estimated in the BIT model by multiplying time spent in streams by the same nutrient concentrations used for wildlife "grazing", as documented in Section D.5. Wildlife contributions were tabulated and entered into SWAT using the daily point source input table for each subbasin.

In-Lake Deposition by Waterfowl
Pollutant contributions from waterfowl included nutrients and bacteria contained in feces deposited in and near the lake by Canada geese. Estimates for amount of goose droppings and nutrient content of goose feces were provided by IDNR waterfowl biologists (Guy Zenner, IDNR, April 24, 2009, personal communication). Estimates consider the changes in the goose population throughout the year due to migratory patterns, nesting season, and number of resident geese. Calculations also consider the amount of time geese spend on land versus in the lake. There is a notable population of coots (another type of waterfowl) at the lake during certain times of the year, but according to IDNR waterfowl biologists, coots do most of their feeding on the lake, hence, they result in very little net nutrient contribution to the system. Nutrient contributions from waterfowl are reported in Table D-13, and were incorporated into SWAT using a monthly point source input file.

Table D-13. Geese population and pollutant contributions.

Month	Population	Nitrogen (kg/day)	Phosphorus (kg/day)
January	2,100	2.11	0.66
February	1,500	1.68	0.52
March	2,316	2.19	0.68
April	366	0.32	0.10
May	154	0.07	0.02
June	106	0.05	0.01
July	106	0.05	0.01
August	106	0.04	0.01
September	406	0.36	0.11
October	845	0.71	0.22
November	3,089	2.49	0.78
December	3,083	2.93	0.91

D.8. References

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Appendix E --- Watershed Model Calibration

E.1. Hydrologic Calibration

The Black Hawk Lake watershed SWAT model was calibrated and validated by comparing simulated hydrology to several sources of monitored and/or previously available data. The primary source of calibration/validation data is an in-lake water stage recorder maintained and operated by the USGS. USGS has utilized this gage, theoretical equations, and manually measured flow to construct a rating curve that predicts outflow from Black Hawk Lake based on the recorded stage (USGS, 2009).

In addition to the USGS stage recorder, Iowa State University (ISU) conducted flow and water quality monitoring as part of a lake diagnostic feasibility study (DFS). Data collection for the DFS commenced in July of 2008, was discontinued in November of 2008 due to ice formation, and was completed between March and July of 2009. ISU developed rating curves for two locations in the tributary stream, Carnarvon Creek, using continuous stage measurements and approximately a dozen manually measured flows throughout the study period. A series of manual flow measurements were made just downstream of the lake outlet structure as well. The monitoring period in the tributaries is too short for use in thorough calibration analysis, but it was helpful in evaluating hydrologic simulations on a daily basis, and for refining the calibration of lake outflow.

Black Hawk Lake Discharge

The discharge rating curve provided by USGS for Black Hawk Lake was developed as part of a study on the characterization of the hydrologic relationship between Black Hawk Lake and the Raccoon River (USGS, 2009). The USGS gage is located on the west end of the lake, over 1.5 miles from the outfall structure that discharges to the east. Because of this long fetch between the gage and outlet structure, it is possible that moderate winds could occasionally lead to a seiche effect, thereby causing the gage to record a water surface elevation that is slightly different from the elevation present at the outlet structure. Additionally, USGS only collected one manual flow to verify the accuracy of the proposed rating curve. Because of these potential sources of error, USGS does not recommend use of the rating curve to estimate the actual discharge on a specific date. Rather, the rating curve should be used to estimate flows over a longer period (e.g., monthly average flows) and to assess the lake’s response to precipitation (Dan Christiansen, USGS, April 14, 2010 personal communication). The USGS study that documents development of the rating curve acknowledges that “…discharges at 05482316 Black Hawk Lake at Outlet at Lake View, Iowa, that are determined from the rating table and lake levels measured at 05482315 Black Hawk Lake at Lake View, Iowa, must be rated poor.” (USGS, 2009). Figure E-1 shows the location of the USGS gage relative to the lake outlet structure.

Figure E-1: USGS lake gage (blue marker) and the outlet channel (red marker). Source: USGS, 2009

Because of the uncertainty associated with the USGS rating curve, calibration of lake outflow from the SWAT model used in this Water Quality Improvement Plan (WQIP) is based on the rating curve developed by the Iowa Department of Natural Resources (IDNR) using 12 measured discharges obtained by ISU during the DFS in 2008-09. Table E-1 reports the lake discharge values measured by ISU and the corresponding lake stage reported by the USGS water level recorder (USGS 05482316). Figure E-2 illustrates the correlation between flow and stage.

Table E-1. Observed discharge (ISU DFS) and lake stage (USGS 05482316).

Date	Stage (ft)	Discharge (cfs)
07/28/2008	8.05	108.0
08/26/2008	7.45	2.1
09/22/2008	7.43	2.0
10/30/2008	7.68	24.1
11/19/2008	7.63	22.0
12/08/2008	7.55	7.9
03/17/2009	7.61	21.0
04/06/2009	7.58	19.5
05/13/2009	7.60	15.0
06/11/2009	7.60	20.2
07/08/2009	7.80	53.2
09/10/2009	7.43	2.3

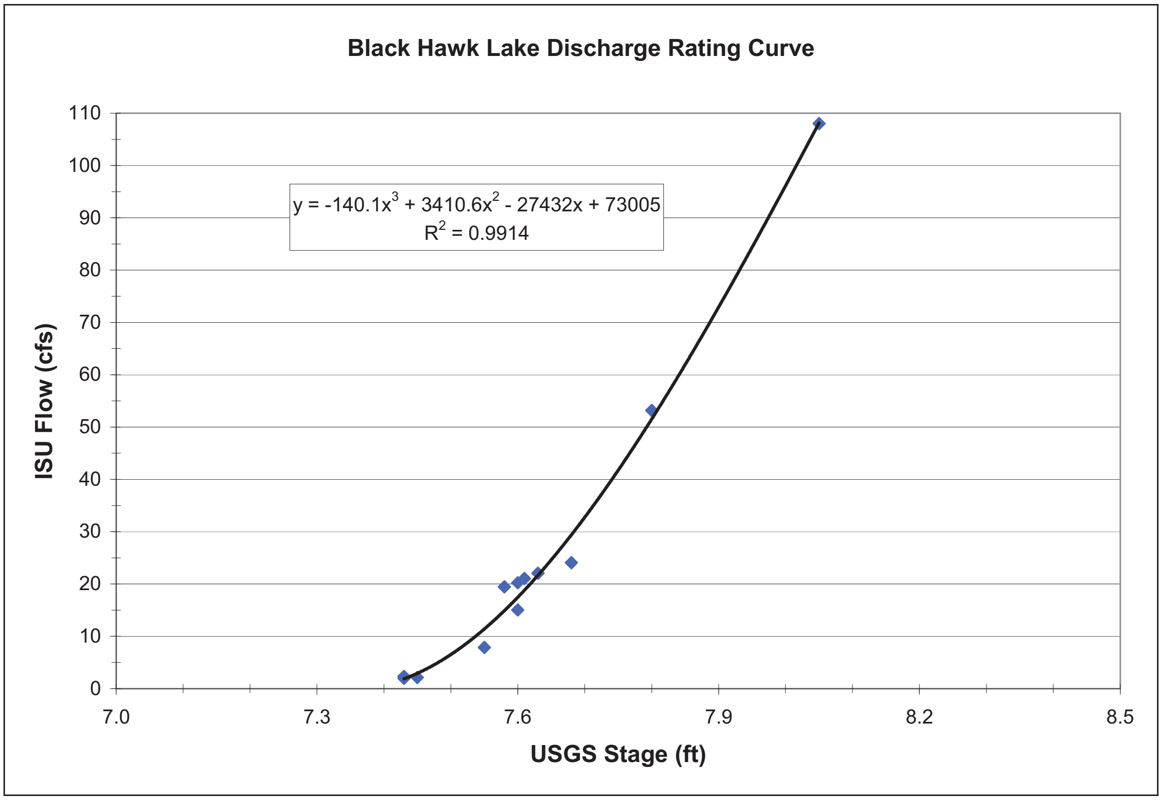

Figure E-2. Rating curve used for calibration of Black Hawk Lake discharge.

The polynomial regression has an R^2 value of 0.99. The equation can be rewritten as follows:

$$Q = -140.1h^3 + 3{,}410.6h^2 - 27{,}432h + 73{,}005$$

Where: Q = the average daily discharge (cfs) from the lake
h = the lake stage (ft) relative to the gage datum.

Calibration Parameters

Calibration of SWAT involved iterative adjustment of hydrologic parameters until graphical and/or statistical comparison of observed and simulated data revealed sufficient agreement. Initial values for all hydrologic parameters were obtained from previously existing SWAT models developed and calibrated in the Raccoon River Basin. These include a SWAT model application for TMDL development on the Raccoon River (IDNR, 2008) and a working paper produced by the Center for Agriculture and Rural Development CARD) and ISU (Jha et al, 2006). Final values for parameters that were adjusted during calibration of the Black Hawk Lake model are reported in Table E-2.

Table E-2. Summary of hydrologic calibration parameters in SWAT model.

Parameter	Input Description	Calibrated Value
Curve Number	Corn (COCT) – Soil Group B	67
	Soybeans (SOCT) – Soil Group B	68
	Pasture (PAST) – Soil Group B	64
	Grassland (BROS) – Soil Group B	59
	Forest (FRST) – Soil Group B	60
	Industrial (UIDU) – Soil Group B	66
	Residential (URMD) – Soil Group B	66
	Transportation (UTRN) – Soil Group B	66
NDTARGR	Number of days to reach target storage	5
IPET	Potential Evapotranspiration Method	Hargreaves
ESCO	Soil Evaporation Compensation	0.95 (default)
EPCO	Plant Uptake Compensation Factor	1.0 (default)
ICN	Daily curve number calculation method	Plant ET
CNCOEF	Plant ET curve number coefficient	0.7
SURLAG	Surface Runoff Lag	1 day
IRTE	Channel Routing Method	Variable Storage
NPERCO	Nitrogen percolation coefficient	0.2 (default)
PPERCO	Phosphorus percolation coefficient	10 (default)
GW_DELAY	Groundwater Delay	10 days
ALPH_BF	Alpha Base Flow Factor	0.9 days
GW_REVAP	Groundwater revap coefficient	0.02 (default)
REVAPMN	Threshold Revap Depth	30 mm
RCHRG_DP	Deep aquifer percolation fraction	0.05 (default)
GWQMN	Threshold depth required for return flow	0 mm (default)
DEP_IMP	Depth to impervious layer	2,400 mm

Average Annual Water Balance

The average annual water balance for the entire simulation period (1997-2009) was evaluated to ensure that the SWAT model was accounting for each of the hydrologic components. Water balance components reported in Table E-3 are all simulated values, except for precipitation, which is observed. Baseflow, as reported in Table E-3 is the summation of lateral flow, groundwater flow, and tile flow.

Table E-3. Average annual water balance components.

Component	(mm)	(in)
Precipitation	809.5	31.9
Surface runoff	70.32	2.8
Lateral flow	5.27	0.2
Groundwater flow	48.66	1.9
Tile flow	53.68	2.1
Evapotranspiration	649.9	25.6

Calibration Statistics

Evaluation of model performance followed guidelines developed by researchers at the United States Department of Agriculture-Agricultural Research Service (USDA-ARS), which actively supports and updates the SWAT model. The guidelines included a thorough literature review of SWAT model application and performance, and recommended use of two quantitative statistics during calibration/validation, in addition to graphical techniques (Moriasi et al., 2007). The statistics include the Nash-Sutcliffe efficiency (NSE) and percent bias (PBIAS). Graphical techniques included hydrograph analysis and percent exceedance probability curves (also called flow duration curves).

The NSE, like the slope and R^2 statistics, indicates how well the plot of simulated versus observed data fits the 1:1 line (Nash and Sutcliffe, 1970). The PBIAS statistic quantifies the tendency of the model to over or underestimate observed data. The optimal PBIAS value is zero, with low absolute values representing accurate model simulation. Positive values indicate underestimation bias, and negative values indicate overestimation bias. Table E-4 reports general performance ratings for the recommended statistics for use with monthly flow data. Statistical results are expected to be better for annual data and worse for daily data.

The most appropriate observed data set available for hydrologic model calibration and assessment was obtained from the rating curve developed by IDNR using observed lake stage (USGS) and measured lake discharges (ISU) previously described. Note that this flow data is not truly “observed”, but calculated from a rating curve based on observed stage. It is likely that the rating curve introduces some uncertainty and error to the data due to human error and natural variation in flow measurements used to construct the curve. The seiche affect, described previously, is another potential source of error in the observed data. Monthly flows calculated from the rating curve are more reliable, and hence more appropriate for model assessment, than daily estimates.

Table E-4. Performance ratings for recommended statistics.

[1]Performance Rating	NSE	PBIAS (%)
Very good	0.75 < NSE ≤ 1.00	PBIAS ≤ ±10
Good	0.65 < NSE ≤ 0.75	±10 < PBIAS ≤ ±15
Satisfactory	0.50 < NSE ≤ 0.65	±15 < PBIAS ≤ ±25
Unsatisfactory	NSE ≤ 0.50	PBIAS ≥ ±25

[1] Suggested SWAT statistics and ratings for monthly flow (Moriasi et al., 2007)

Average Annual Flow

The first step in model calibration involved comparing SWAT outputs to observed flows from the lake. Due to the limited years of available data, annual flows were not split into calibration and validation years. Figure E-3 illustrates simulated and observed annual flows for the entire simulation period (1997-2009).

Figure E-4 shows the regression analysis of annual discharge from the lake, which yielded an R^2 of 0.78. The NSE (0.73) and PBIAS (-9.54) are also reported on Figure E-4. The statistics indicate reasonable agreement between predicted and observed output. One would expect slightly better annual statistics compared with those based on monthly flow. However, statistics improve with larger data sets, and only 13 years of flow data are available for Black Hawk Lake. Subsequent analysis of monthly data suggests that the Black Hawk Lake SWAT model performs at least as well on a monthly basis.

Analysis of annual flow data reveals that the hydrology model is providing reasonable predictions of annual flow at the Black Hawk Lake outlet. The model overestimates annual flow in 1997 and between 1999 and 2006, and underestimates flow in all other years. Overall, results suggest a fair match between observed and simulated annual flows. For the 13-year simulation period, the simulated average annual discharge (8.3 inches) was reasonably close to the observed (rating curve) value (7.6 inches), a difference of 8.7 percent. There are years in which the simulated and observed outflows vary by a large amount. This is likely due to complexities related to modeling reservoirs, extended periods of non-discharge from the reservoir, and SWAT's limitations in simulating reservoir storage and outflow.

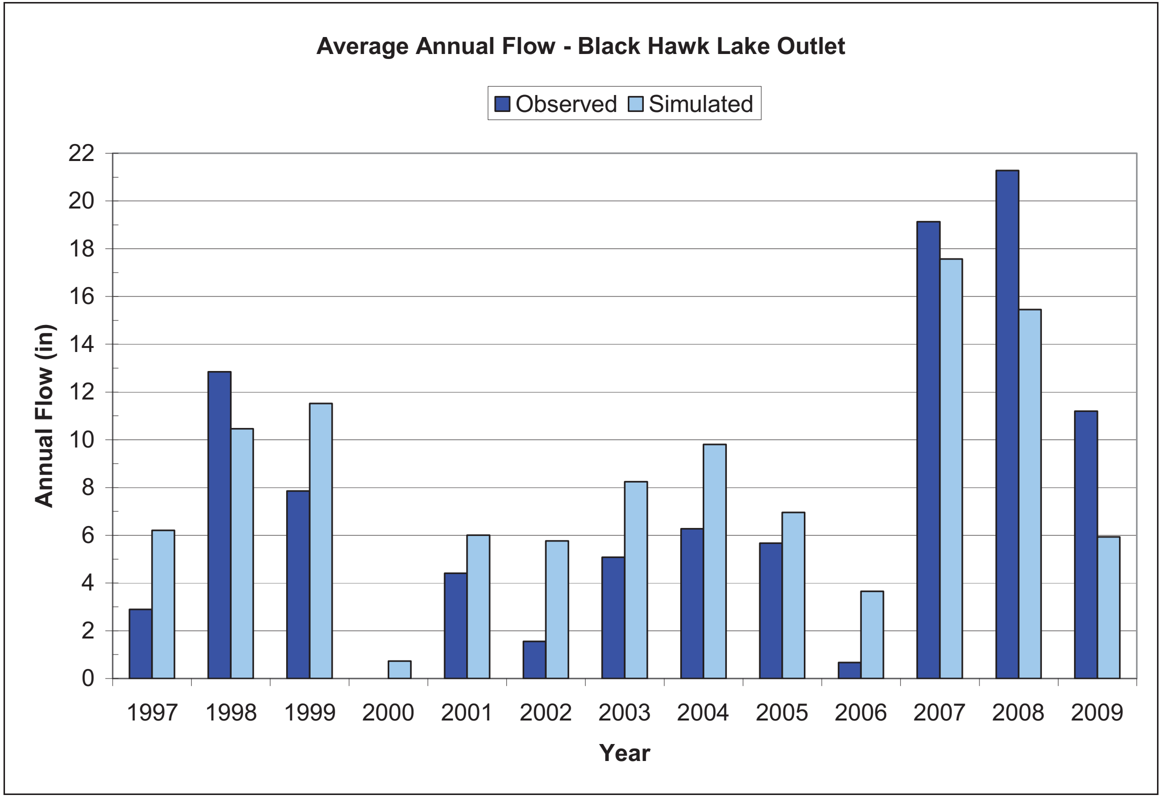

Figure E-3. Simulated and observed (rating curve) annual flow.

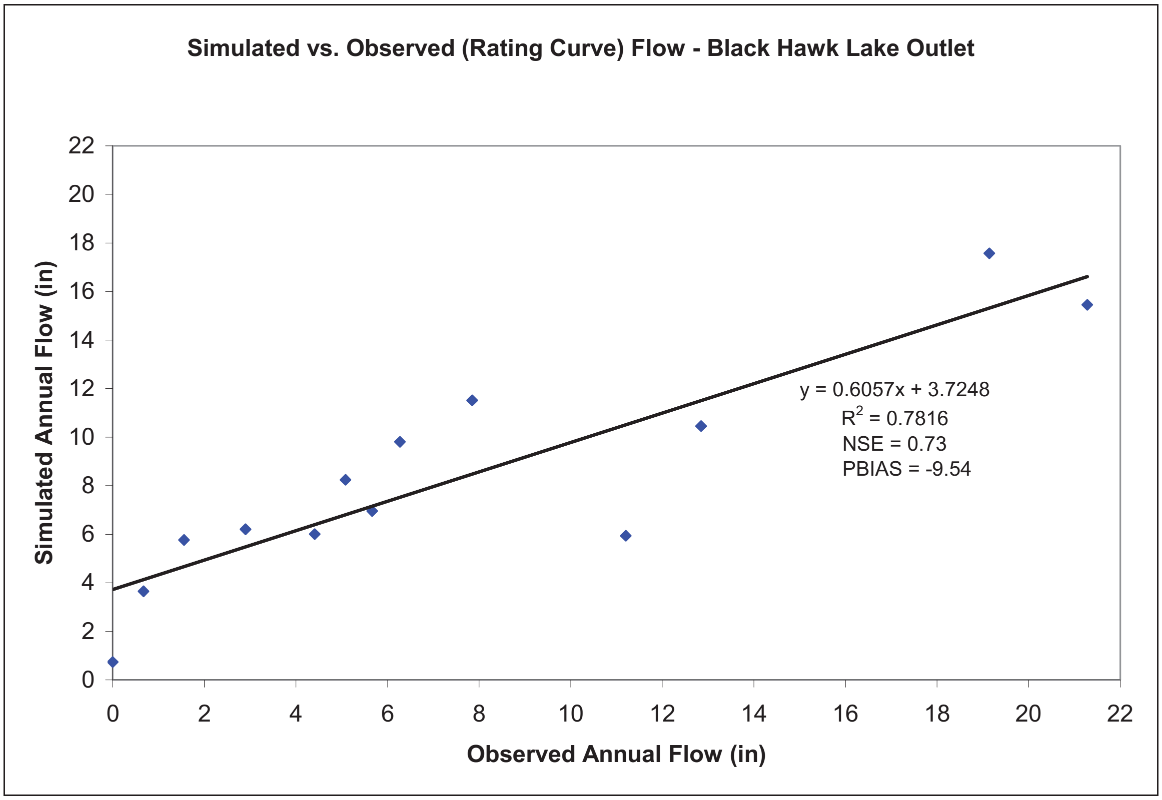

Figure E-4. Regression of simulated and observed (rating curve) annual flow.

Monthly Average Flow
A continuous time series of simulated and observed monthly average flow, in cubic feet per second (cfs), is plotted for the entire simulation period (1997-2009) in Figure E-5. This excludes the three-year spin-up period of 1994-1996. There are instances where high and low flows are not perfectly simulated, but overall agreement appears to be reasonably good. Excellent agreement is observed in years 2003, 2005, 2007, and 2008. The poorest agreement is observed 1997, 2001, and 2006, which were all relatively low-flow years.

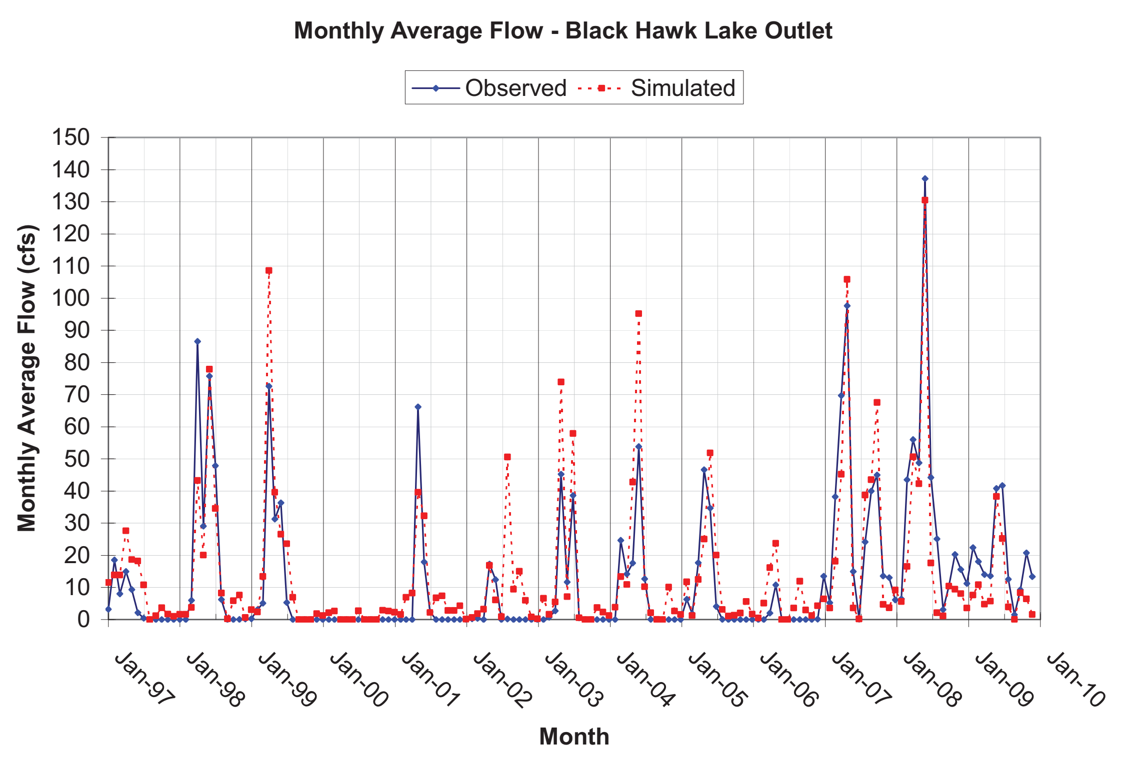

Figure E-5. Monthly average flows from Black Hawk Lake (1997-2009).

Figure E-6 shows the average flows summarized by month for the entire simulation period. The model tends to overestimate flows between June and October, but underestimates flow in March and April. However, agreement is good in April, May, July, November, December, January, and February.

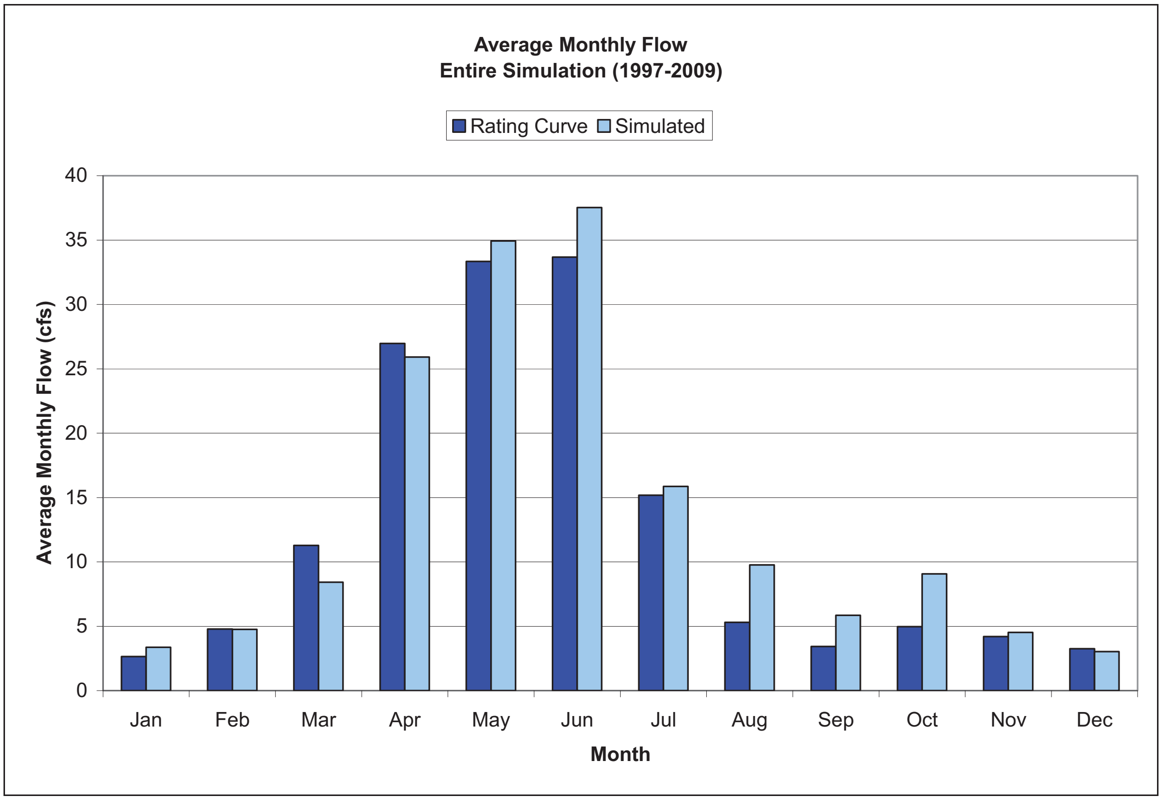

Figure E-6. Average monthly flows for each month (1997-2009).

It should be noted that both calibration and validation periods utilize the same spin-up period (1994-1996); however, output was retrieved for both periods from the same model run. In other words, the effective spin-up period for the calibration period includes the validation years. This is common practice in SWAT model application, and allows initialization of calibration and validation periods using previous real-world meteorological conditions.

Linear regression analysis was performed on the data for the calibration period (2002-2009) and validation period (1997-2001). In addition to linear regression, the NSE and PBIAS statistics were also calculated for comparison of simulated and observed monthly average flows. Figures E-7 and E-8 illustrate the linear regressions for calibration and validation, respectively. Table E-5 reports the model performance statistics for the calibration and validation of monthly discharge from the lake.

The calibration R^2 value is 0.74, which is acceptable according to recommendations made in modeling literature. The slope of the linear regression is 0.91. The calibration NSE of 0.71 is rated “good” and the PBIAS of -3.24 is considered “very good” according to guidance issued by developers of the SWAT model (Moriasi et al., 2007).

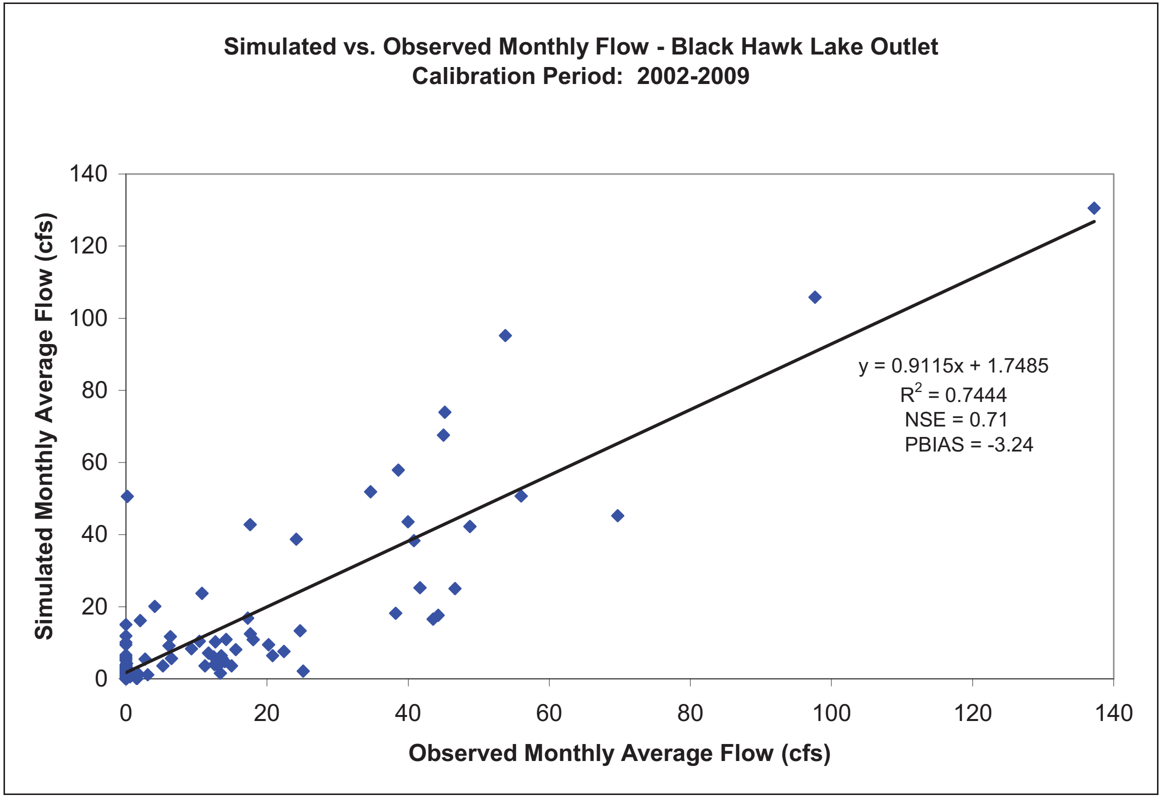

Figure E-7. Linear regression of monthly average flow (calibration).

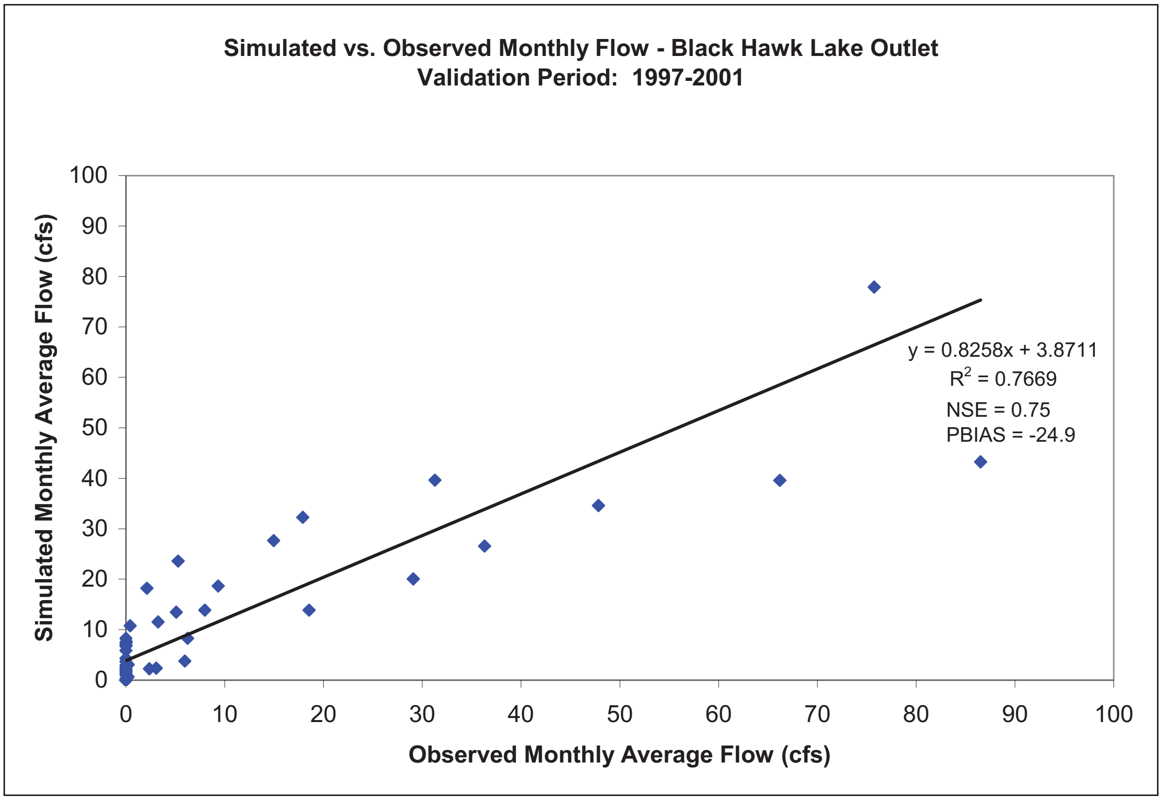

Figure E-8. Linear regression of monthly average flow (validation).

Table E-5. Monthly flow statistics (and suggested ratings[1]).

	Regression Slope	R^2	NSE	PBIAS
Calibration (2002-09)	0.91	0.74	0.71 (Good[1])	-3.24 (Very Good[1])
Validation (1997-2001)	0.83	0.77	0.75 (Very Good[1])	-24.9 (Satisfactory[1])

[1] Moriasi et al., 2007

Linear regression yielded a validation R^2 of 0.77 and a slope of 0.83. The validation NSE is 0.75 (very good) and PBIAS is -24.9 (satisfactory). The negative PBIAS value indicates that in general, the model tends to overestimate flows predicted by the rating curve. Examination of the regression equation provides greater temporal resolution and reveals that SWAT tends to overestimate smaller, more frequent flows and underestimate larger, infrequent flows. Overall, the statistics obtained during calibration and validation analysis suggest that the model provides reasonable estimates of monthly average flow from Black Hawk Lake.

Monthly Average Runoff and Baseflow

If data is available, SWAT model calibration should include analysis of runoff and base flow. Because no stream gage was available for the main tributary to Black Hawk Lake (Carnarvon Creek), no direct calibration of runoff and base flow was performed using SWAT model output. However, simulated base flow percentage was compared to the results of two previously calibrated SWAT models developed for the Raccoon River basin and for a stream with base flow estimates developed by USGS. Table E-6 lists the baseflow percentages from other sources, and describes the source of the data.

Table E-6. Percentage of total flow comprised of base flow.

Waterbody/ Location	USGS Gage	Drainage Area (mi^2)	Period of Record	Source	Baseflow (%)
Raccoon River @ Van Meter	05484500	3,441	1981-2003	Jha et al., 2006	58
North Raccoon River @ Sac City	05482300	700	1958-2005	IDNR, 2008	69.1
North Raccoon @ Jefferson	05482500	1,619	1940-2005	IDNR, 2008	68.2
Middle Raccoon @ Bayard	05483450	375	1979-2005	IDNR, 2008	69.7
Walnut Creek @ Des Moines	05484800	78	1971-2005	IDNR, 2008	57.3
Hazelbrush Creek near Maple River	05483343	9.2	1990-1994	USGS NHDPlus	57.3
Carnarvon Creek @ Black Hawk Lake	**--**	**22.2**	**1997-2009**	**SWAT Model (Current TMDL)**	**60.5**

The USGS gage on the North Raccoon at Sac City is the closest in proximity to Black Hawk Lake, and is only 4.5 miles northeast of the water elevation gage at the lake. However, it has a much larger drainage area than the Black Hawk Lake watershed, and a higher estimated base flow (69.1 percent). The gage on Hazelbrush Creek is the next closest, lying 12.5 miles directly south of the gage on Black Hawk Lake. This gage has a similar drainage area as Black Hawk Lake, and an estimated base flow portion of 57.3 percent. The SWAT-simulated base flow portion of the total flow to Black Hawk Lake (60.5 percent) lies well within the range of values from previous baseflow estimations listed in Table E-6 (57.3 to 69.1 percent). This indicates the model simulates base flow reasonably well.

Daily Tributary Flow
Some limited flow data was collected by ISU as part of the 2008-2009 Diagnostic Feasibility Study upstream of Black Hawk Lake. An ISCO automated sampler with bubbler attachment was deployed by the University of Iowa Hygienic Lab (UHL) on Carnarvon Creek at 350th Street, about a half mile upstream of Provost Slough. Two separate deployments were made (July 28 to November 18, 2008, and March 17 to June 30, 2009) because of ice during winter conditions. UHL discontinued deployment on June 30, 2009, due to the end of their contract with IDNR. ISU continued the 2009 deployment through September 10, 2009. Eleven manual flow measurements were made at this site (Site 03 in the ISU DFS) between July 2008 and September 2009. During the deployment periods, continuous stage was measured at 15-minute intervals, which were condensed to daily average stage. ISU developed a flow rating curve for Site 03 in 2008 based on observed flow and stage for data collected. UHL calculated flow using a similar method based on the 2009 data. UHL staff noted that correlations between stage and flow were weak in 2008, but correlation was better in 2009 (Travis Morarend, December 22, 2008, and Jim Luzier, August 6, 2009, personal communications).

The location of Site 03 (and other tributary sites monitored by ISU) is shown in Figure E-9. Monitoring at other sites consisted primarily of grab samples for water quality parameters. The data collection period of the ISU monitoring was too short to provide adequate data for detailed calibration statistics. Additionally, field observation indicated that backwater from the lake frequently affects water stage at Site 03. The backwater effect introduces some error and uncertainty to the accuracy of the rating curve by “clouding” the correlation of flow and stage. This issue appeared to be more problematic in 2008 than 2009. Nonetheless, analysis of daily flow at Site 03 was helpful in making general assessments of the hydrologic response of the SWAT model.

Figure E-10 illustrates the linear regression of simulated and rating curve daily flows for the 2008 and 2009 data collection periods. The R^2 value of 0.30 is much lower than for monthly data, as expected. The low slope of 0.43 suggests that overall, the SWAT model is under-predicting daily flow at 350th Street. Backwater’s negative influence on the accuracy of the rating curve is likely the primary reason for this under-prediction. Increases in stage may falsely suggest increases in flow under backwater conditions, which would cause the rating curve to over-estimate flow.

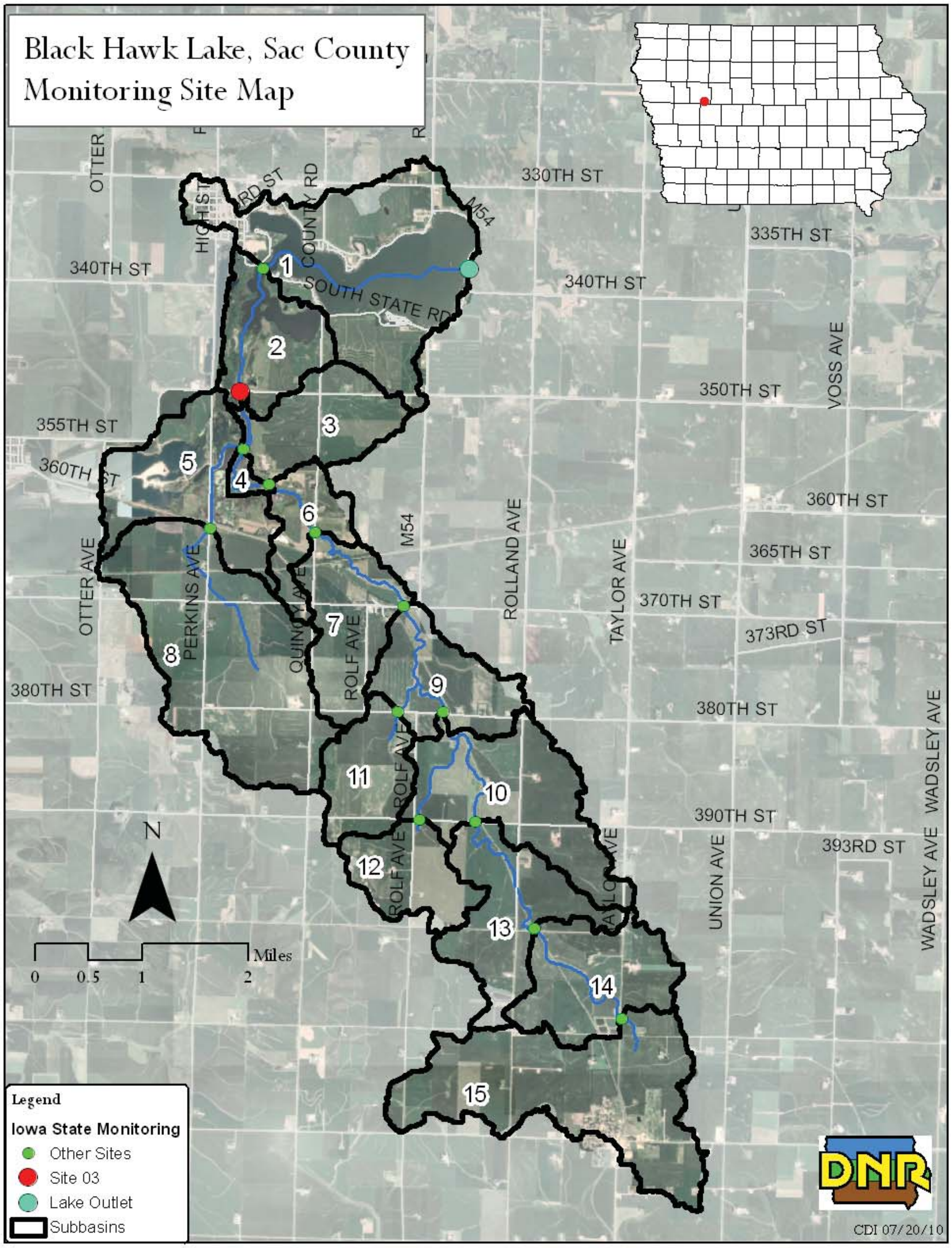

Figure E-9. Iowa State University monitoring sites.

The statistics are more favorable using only the 2009 data. This is best explained by the observation that the correlation of flow and stage was better in 2009 than 2008. Figure E-11 illustrates the regression of 2009 data and the improved R^2 (0.63) and slope (0.92).

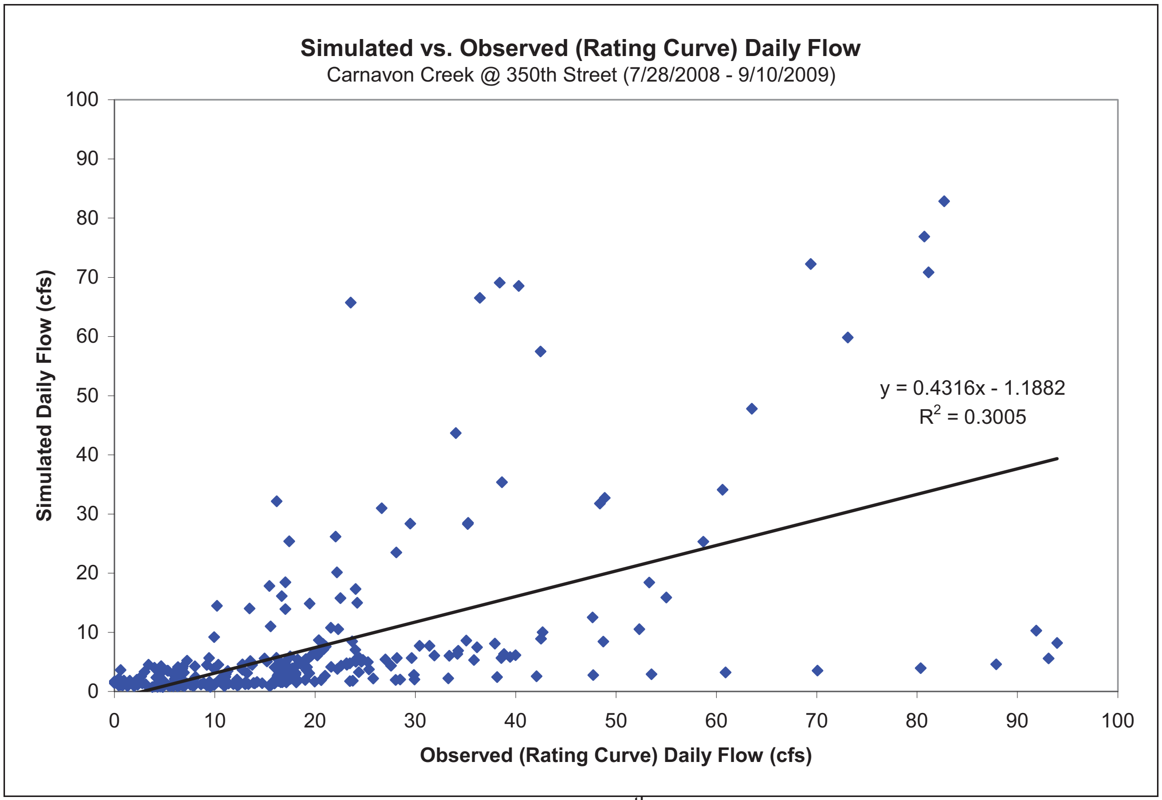

Figure E-10. Regression of daily flow at 350th Street (2008 and 2009).

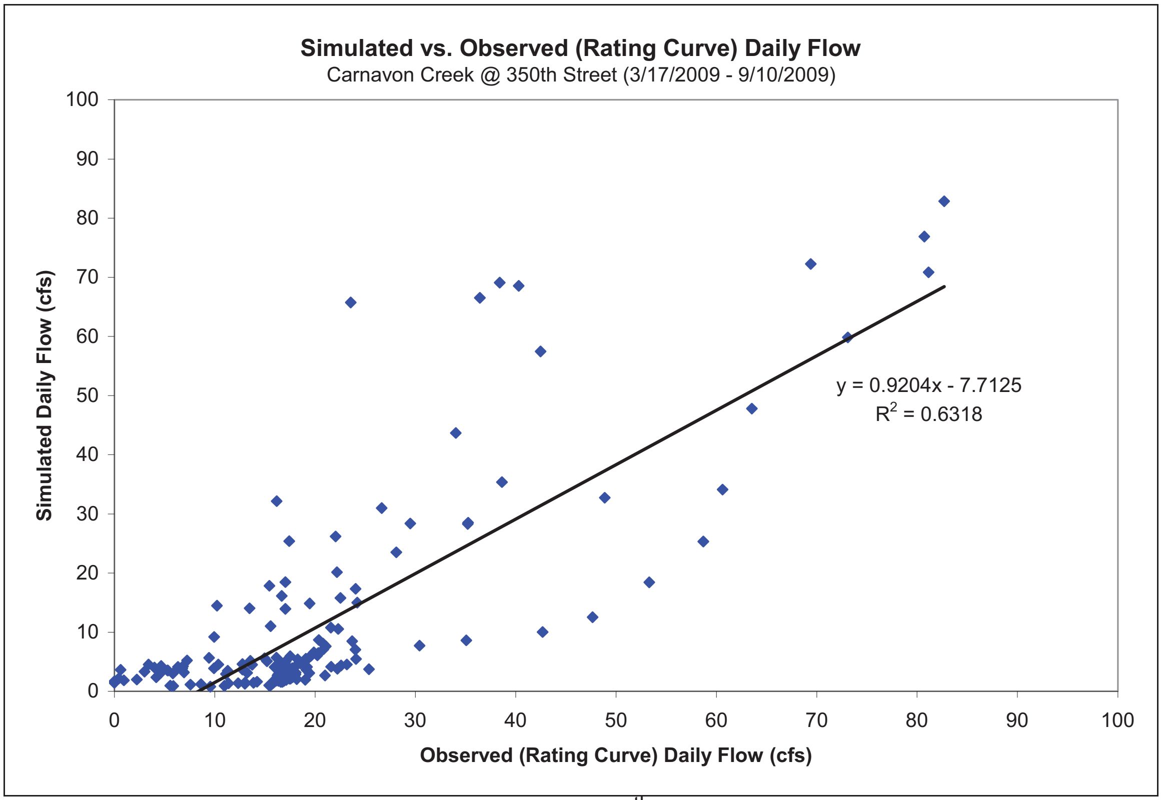

Figure E-11. Regression of daily flow at 350th Street (2009 data only).

Daily flow at 350th Street was used to improve model performance in the calibration process. Results may not indicate extremely reliable prediction of daily flow, but performance on a monthly scale is of more importance in development of the TMDLs for Black Hawk Lake because lake eutrophication is driven by cumulative nutrient loads rather than individual (i.e., daily) events. Daily calibration at Site 03 was used as a tool for model improvement, not final assessment of model performance.

Daily Lake Outflow

Observed daily flow from the reservoir, calculated using the rating curve, was also used to adjust calibration parameters and assess model performance. Average daily flows from the lake are plotted in Figures E-12 through E-19. Each plot includes one year of the calibration period (2002-2009).

SWAT greatly overestimates flow in the latter half of 2002 (Figure E-12), most likely due to heavy localized rainfall at the precipitation gages in Carroll and Sac City that did not occur in the Black Hawk Lake watershed. Simulated flows match observed flows well in 2003 (Figure E-13), although SWAT simulates continuous low flows from January to March and August to September, when the rating curve data suggests that the water level is below the lake outfall during these periods. Model and rating curve agreement is fair in 2004 and 2005 (Figures E-14 and E-15), but poor for 2006 (Figure E-16), wherein SWAT consistently overestimates discharge from the lake. Agreement is good in 2007 (Figure E-17) and 2008 (Figure E-18). The time series plot for 2009 (Figure E-19) shows that SWAT mimics the pattern of daily flows well, but consistently underestimates magnitude of flow.

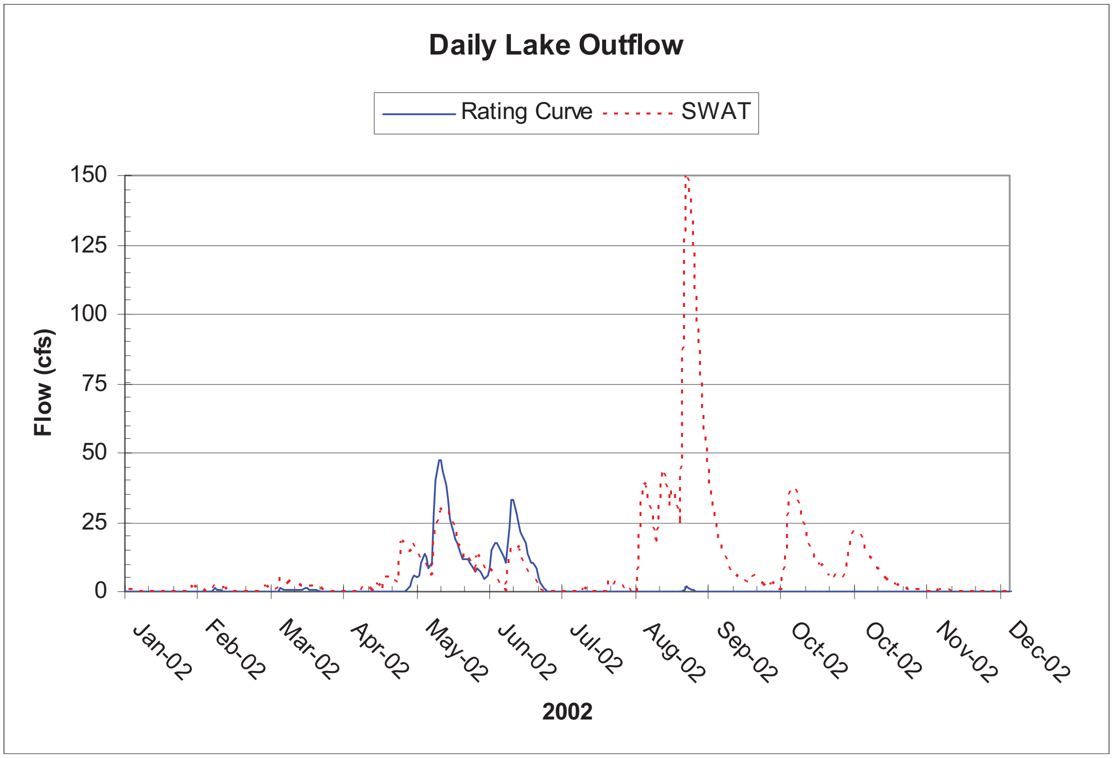

Figure E-12. Daily simulated and observed (rating curve) flow from lake (2002).

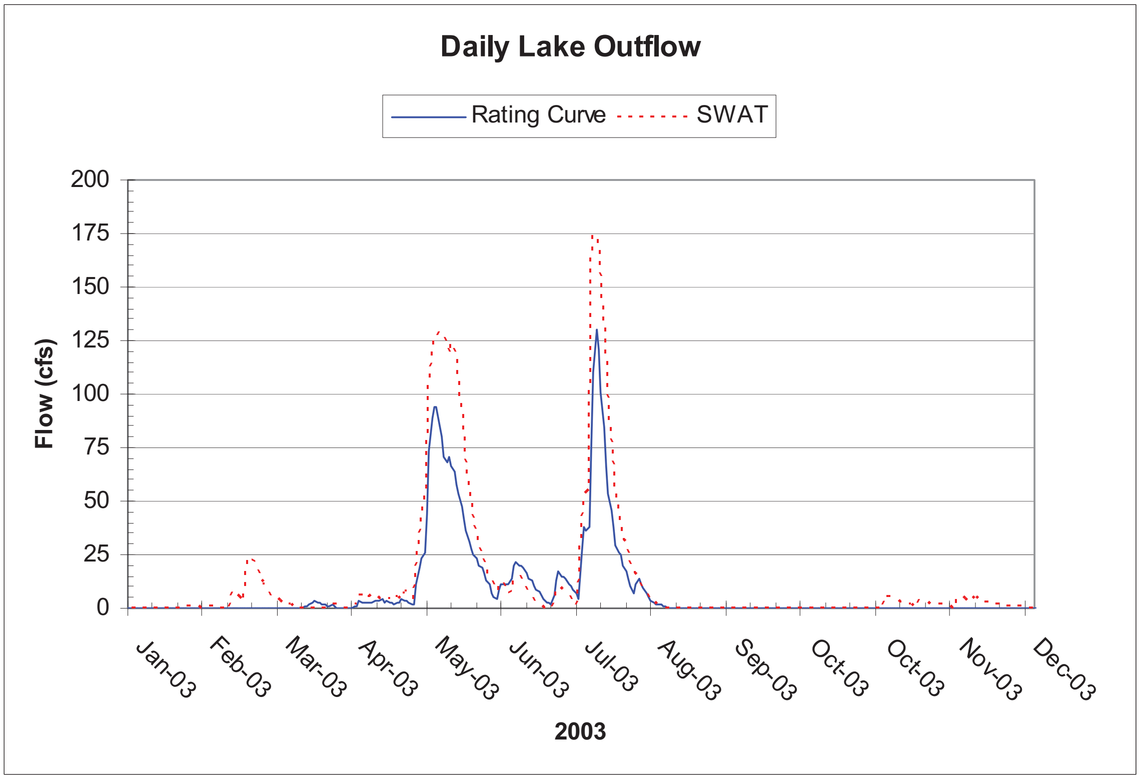

Figure E-13. Daily simulated and observed (rating curve) flow from lake (2003).

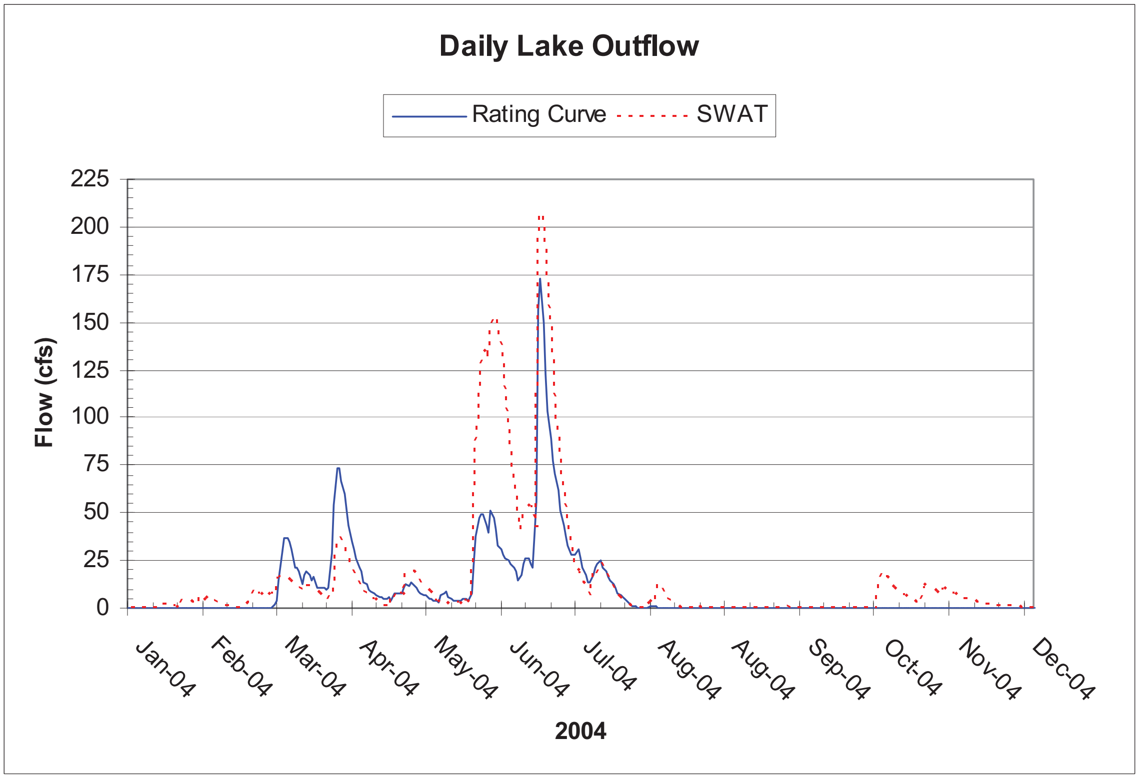

Figure E-14. Daily simulated and observed (rating curve) flow from lake (2004).

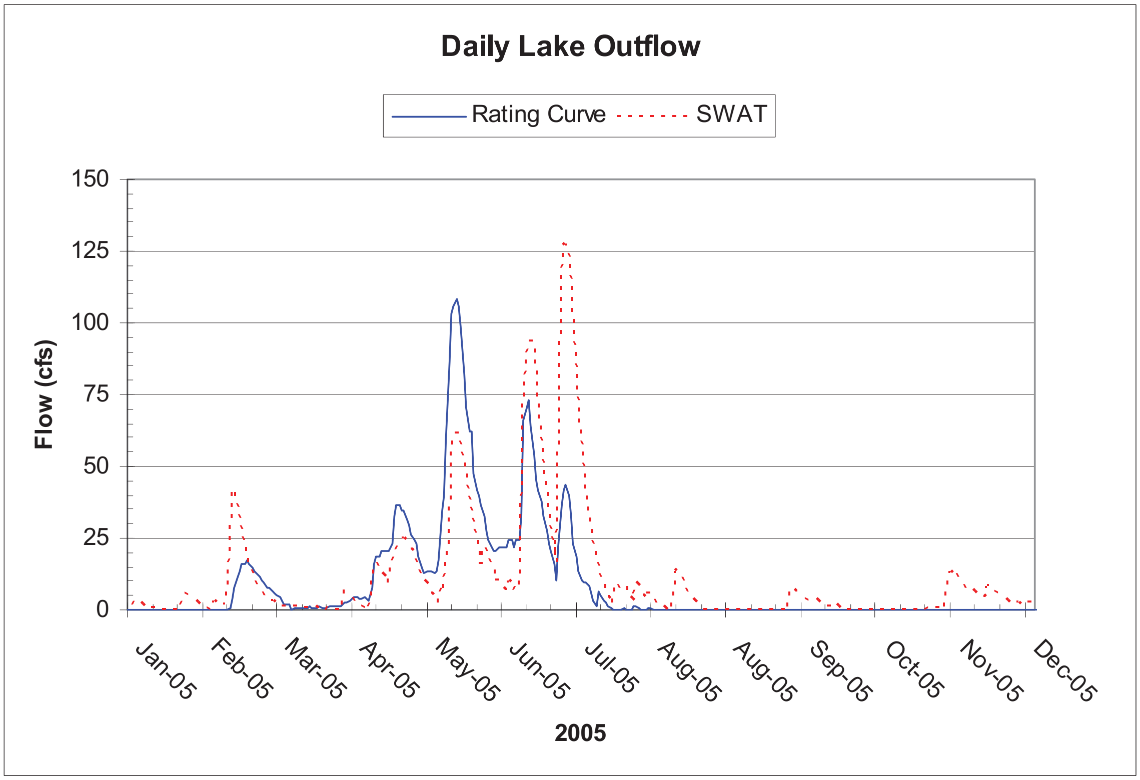

Figure E-15. Daily simulated and observed (rating curve) flow from lake (2005).

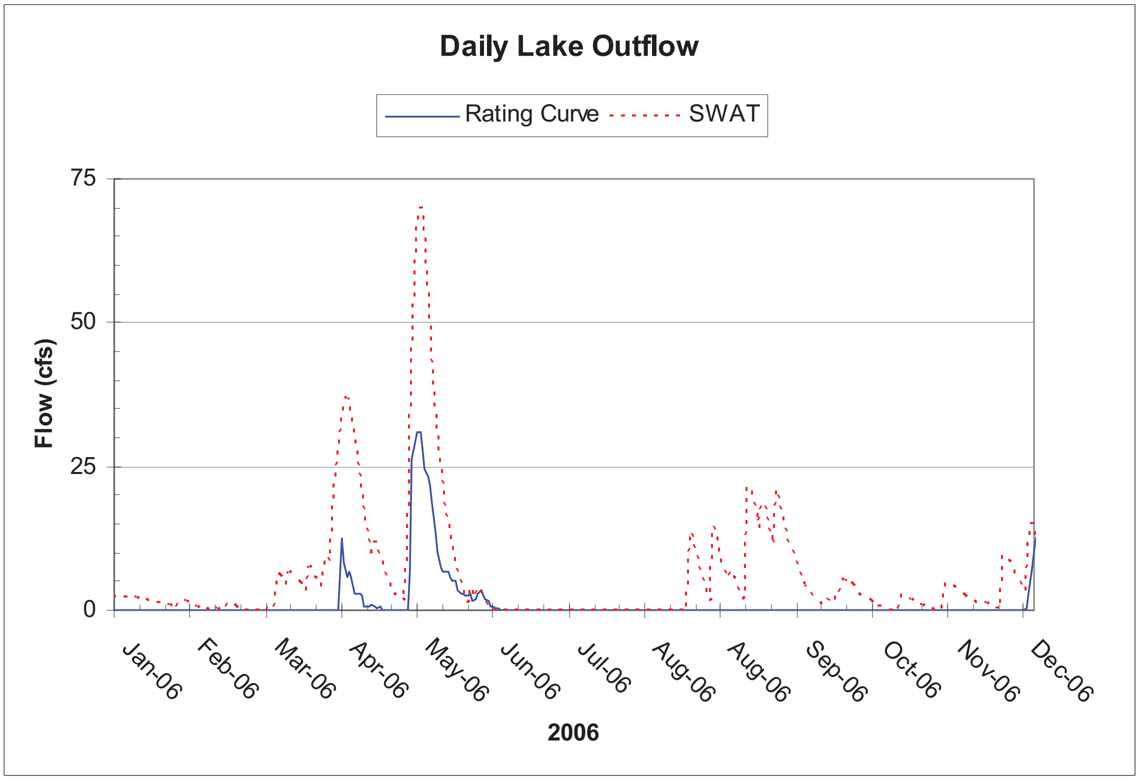

Figure E-16. Daily simulated and observed (rating curve) flow from lake (2006).

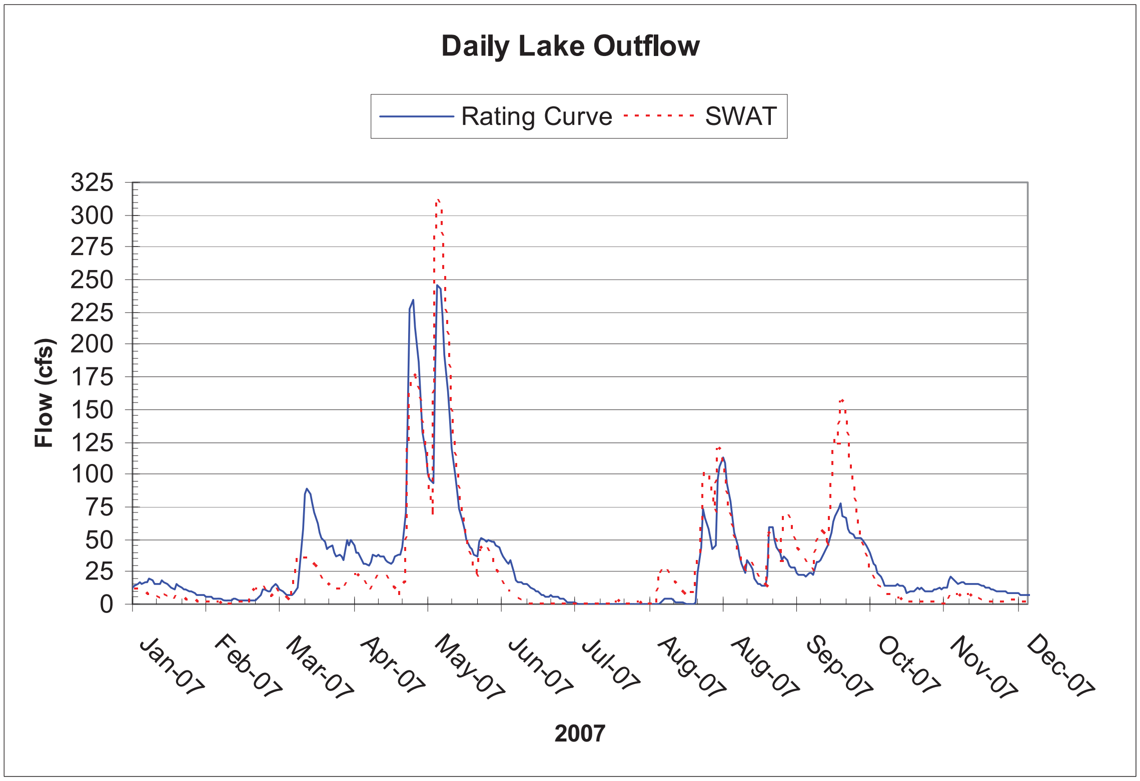

Figure E-17. Daily simulated and observed (rating curve) flow from lake (2007).

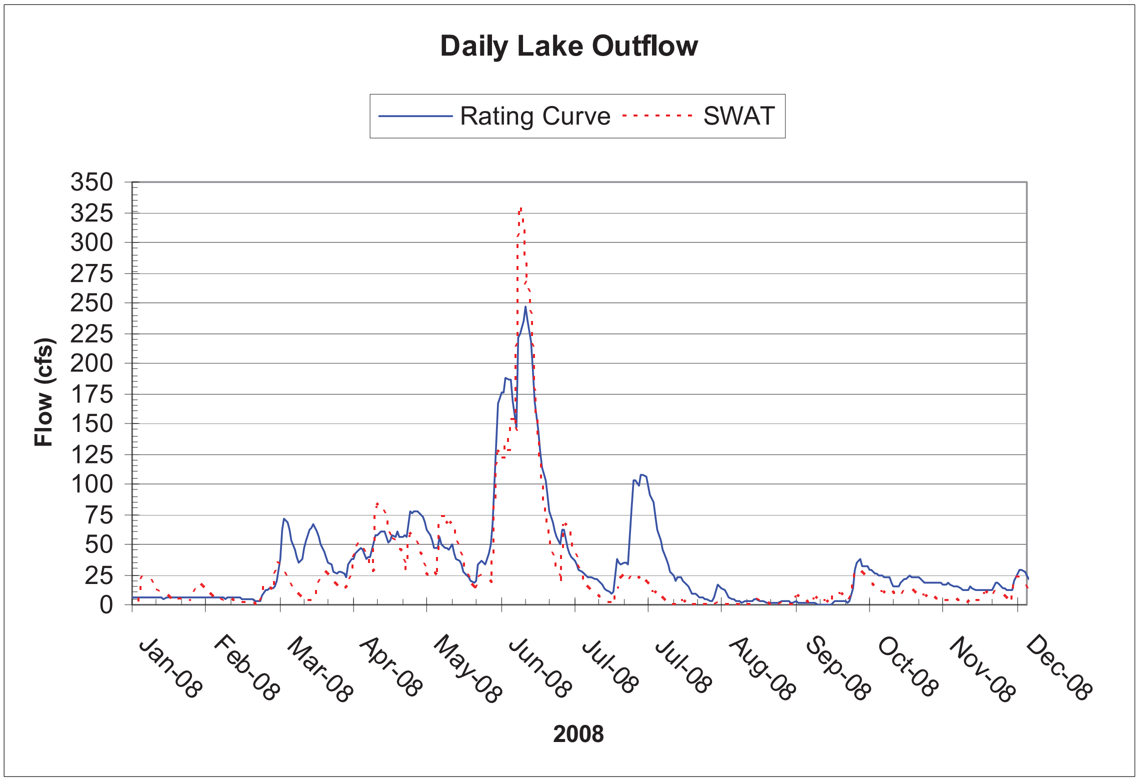

Figure E-18. Daily simulated and observed (rating curve) flow from lake (2008).

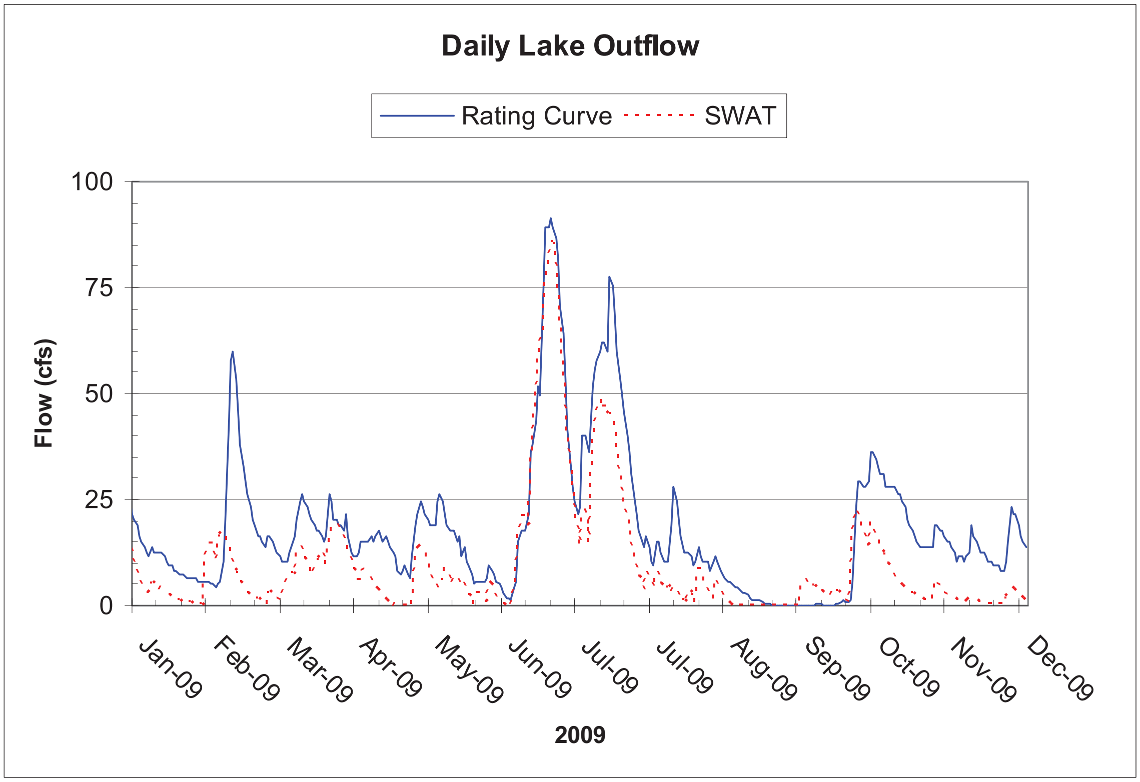

Figure E-19. Daily simulated and observed (rating curve) flow from lake (2009).

Figure E-20 illustrates the linear regression of simulated daily flow at the lake outlet. The R^2 of 0.70 indicates excellent agreement between the model and the rating curve daily flows. The slope of the regression is near 1.0 (0.94), indicating that the model is not significantly biased towards over or underestimate of observed flows in the calibration period. Further examination of the regression equation reveals that SWAT tends to overestimate flows under 19 cfs and underestimate flows greater than 19 cfs. The PBIAS value of -3.30 reveals that SWAT tends to slightly overestimate flow. The NSE of 0.61 is also quite good for a daily time-step. If all days for which the rating curve outflow equals zero (i.e., days when no water flows over the outfall structure) are removed from the data, the R^2, slope, NSE, and PBIAS become 0.69, 0.98, 0.56, and 6.99, respectively. All values remain well within a reasonable range per literature recommendations.

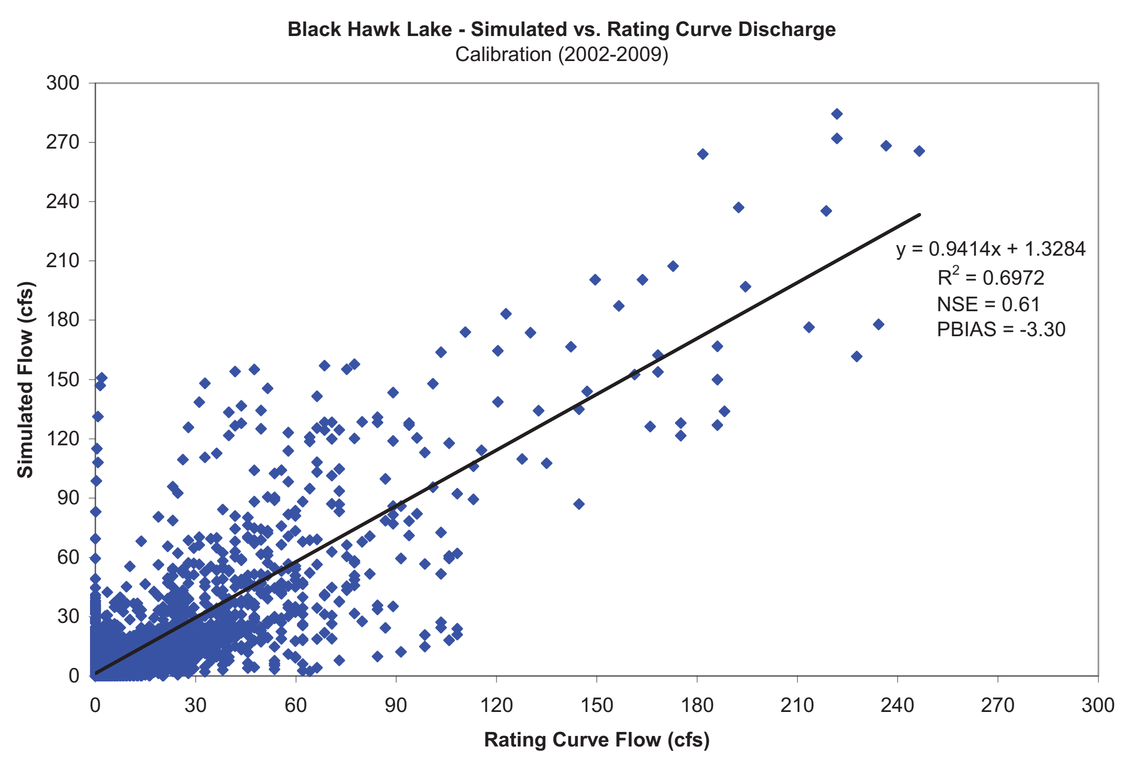

Figure E-20. Regression of daily flow from Black Hawk Lake (calibration period).

Time series daily flows for the validation period (1997-2001) are shown in Figures E-21 through E-25. Figure E-21 shows relatively poor agreement between simulated and rating curve-predicted flows in 1997, especially in July, where it appears that the precipitation gages received much more rainfall than the Black Hawk Lake watershed. Agreement appears to be fair to good in 1998 and 1999 (Figure E-22 and E-23). There was no flow out of Black Hawk Lake in 2000 according to rating curve calculations; however, SWAT predicted periods of low flow in January-February and November-December (Figure E-24). Agreement was poor in 2001, in which the model under-predicted flow in May, performed well in June, and predicted low flows throughout the rest of the year, while the rating curve predicted no flow out of the lake (Figure E-25).

Figure E-26 illustrates the linear regression of daily flows for the validation period. The R^2 of 0.62 suggests acceptable agreement between the model and the rating curve during the validation period. The slope of the regression is 0.70. The negative PBIAS of -25.5 indicates that the model tends to overestimate flows predicted by the rating curve. Further examination of the regression equation provides greater temporal resolution and reveals the model overestimates flows under 16 cfs and underestimates flows over 16 cfs. The NSE of 0.61 is good for a daily time interval, but the R^2 value is inflated due to zero-flow days when the water level is below the outfall structure. If all of the days with rating curve predictions of 0.0 cfs are removed from the data, the R^2, slope, NSE, and PBIAS become 0.55, 0.63, 0.53, and -7.42, respectively. All values are still well within a reasonable range per literature recommendations, and the PBIAS improves significantly.

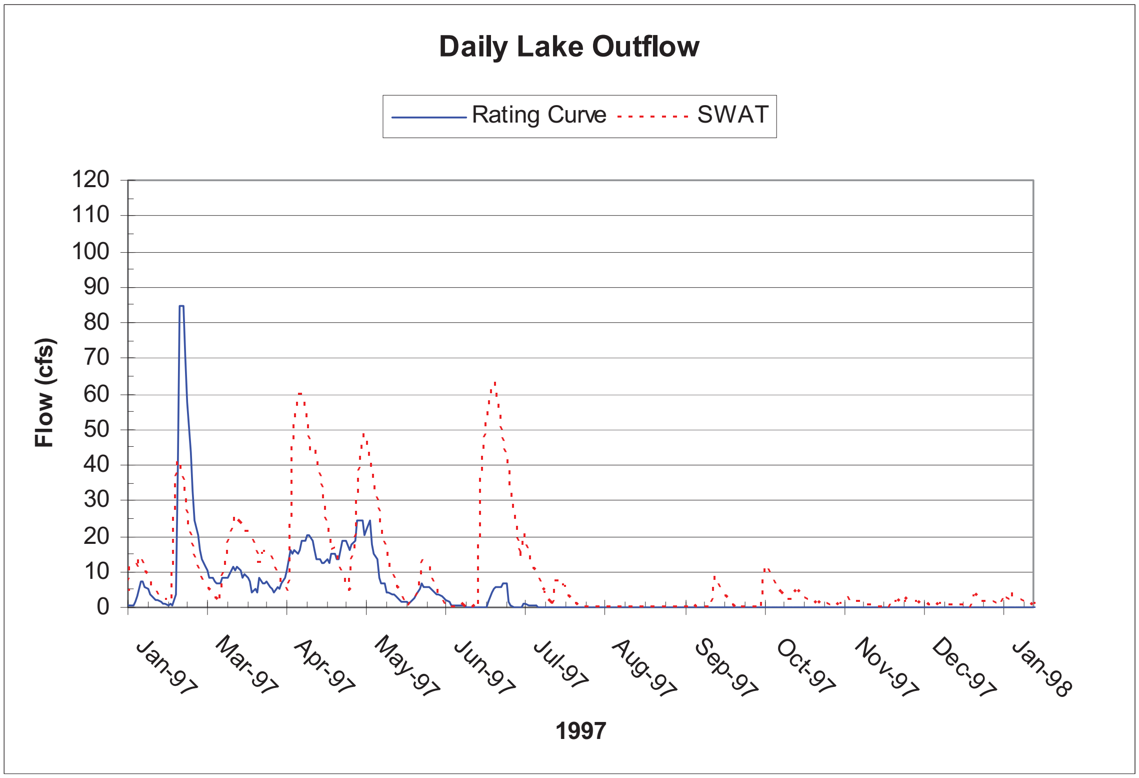

Figure E-21. Daily simulated and observed (rating curve) flow from lake (1997).

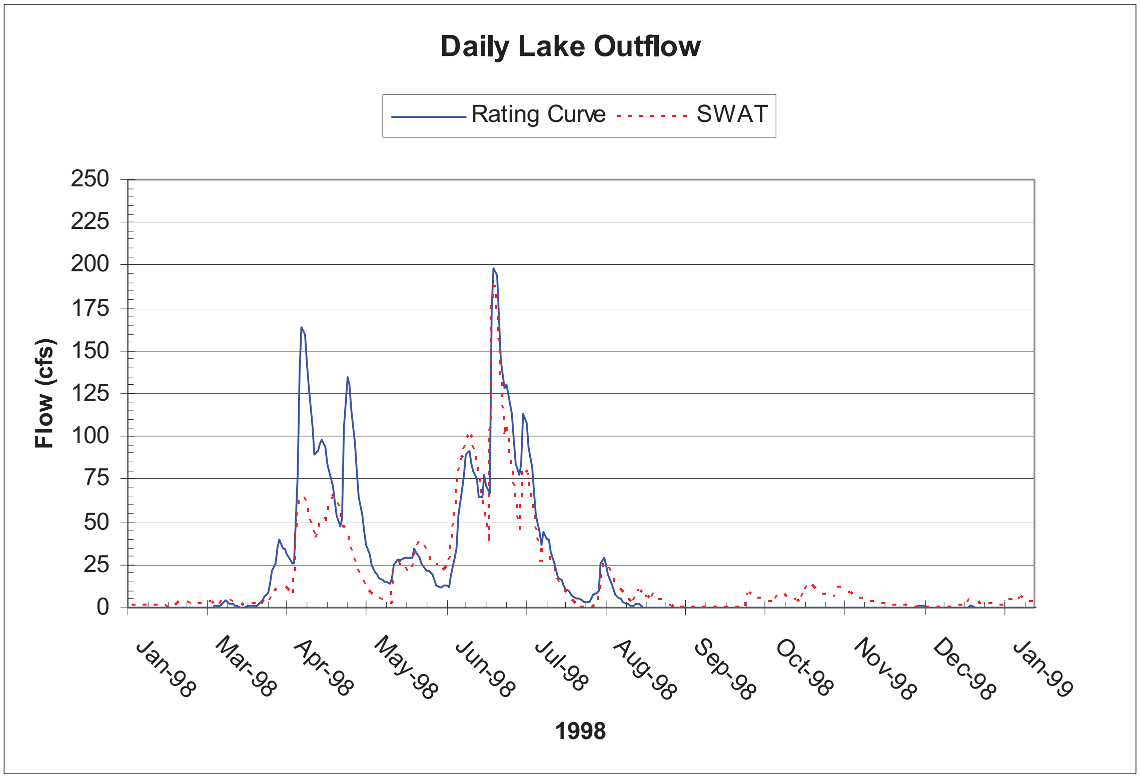

Figure E-22. Daily simulated and observed (rating curve) flow from lake (1998).

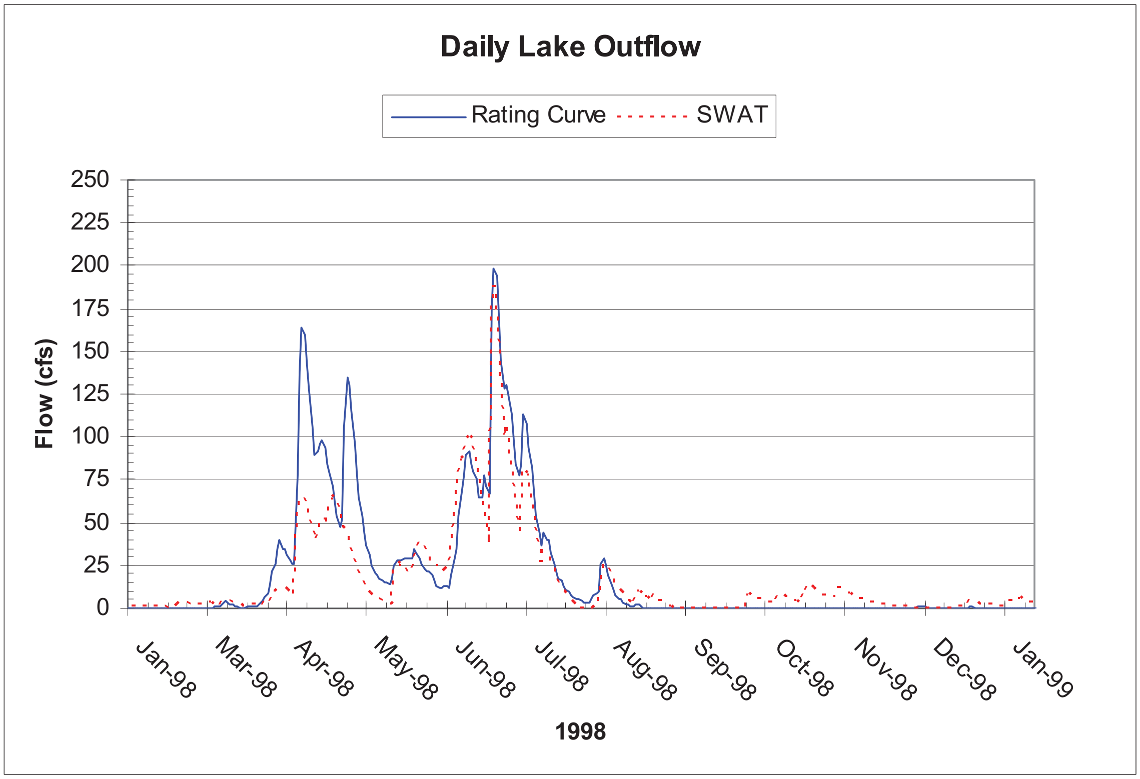

Figure E-23. Daily simulated and observed (rating curve) flow from lake (1999).

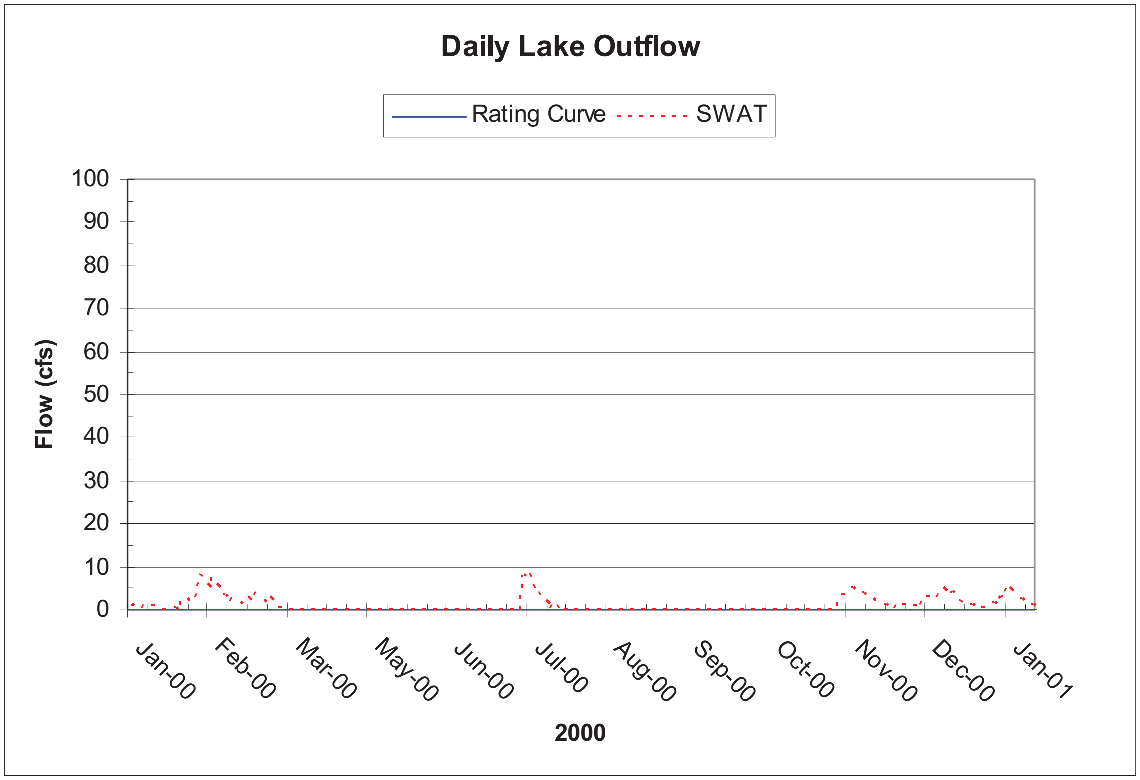

Figure E-24. Daily simulated and observed (rating curve) flow from lake (2000).

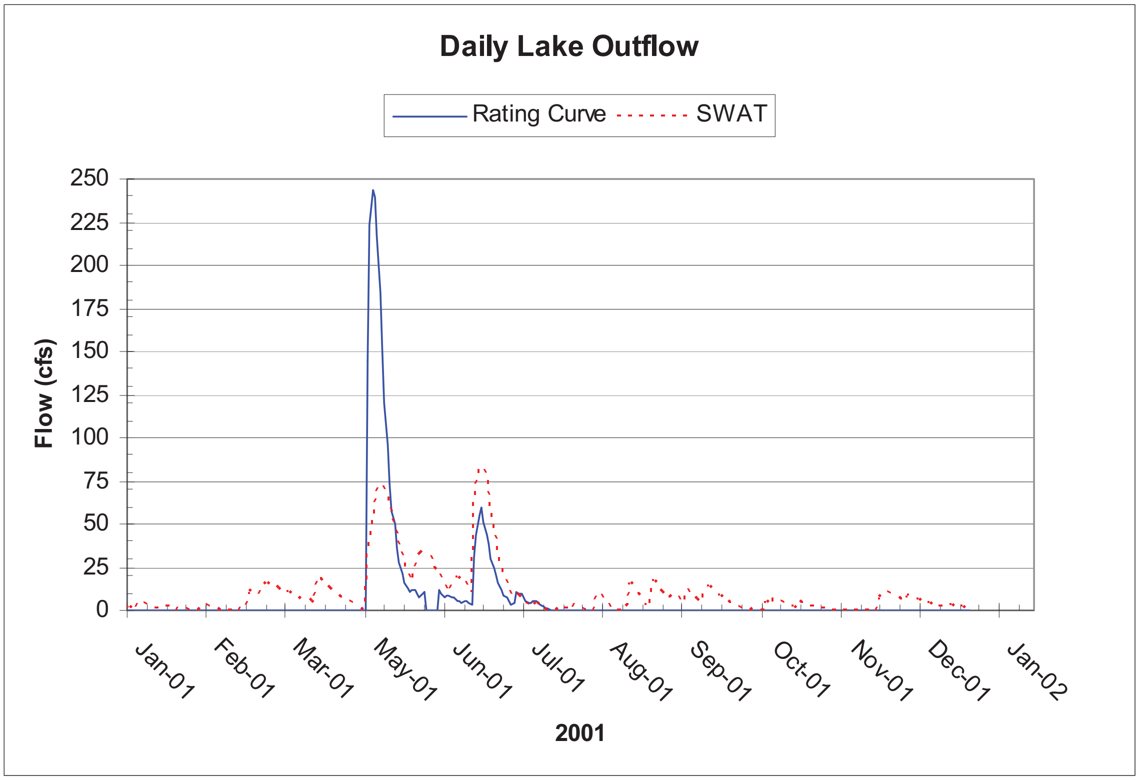

Figure E-25. Daily simulated and observed (rating curve) flow from lake (2001).

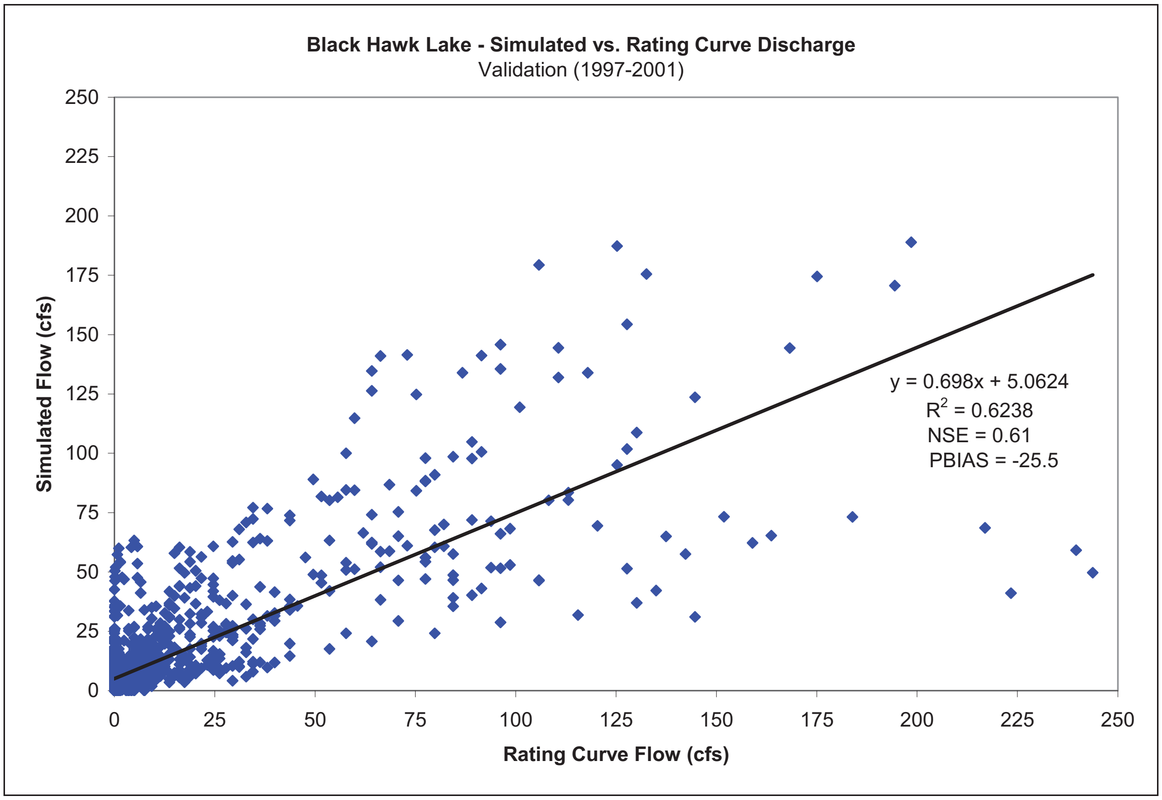

Figure E-26. Regression of daily flow from Black Hawk Lake (validation period).

Calibration and validation statistics for daily flow from Black Hawk Lake are summarized in Table E-7. All statistical results rate satisfactory to very good according to recommendations by Moriasi et al., (2007) for monthly flow. Lower ratings would be expected for daily statistics. These results indicate adequate model performance in terms of hydrologic simulation, especially in light of the fact that monthly flows (and resulting monthly pollutant loads) were used in the development of TMDLs for Black Hawk Lake.

Table E-7. Calibration/validation statistics for daily flow from lake.

	Regression Slope	R^2	NSE	PBIAS
Calibration (2002-09)	0.94	0.70	0.61	-3.30
Validation (1997-2001)	0.70	0.62	0.61	-25.5

Flow Duration Curves

Flow duration curves (FDCs) provide an illustration of how well the model simulates the frequency of observed daily flows throughout the calibration and validation periods (Van Liew et al., 2003). FDCs were not used to develop numeric targets for the Black Hawk Lake TMDLs; however, because they are a measure of model performance, they were used in the calibration process. Figure E-27 illustrates the simulated FDC compared with the FDC predicted by the lake stage and rating curve.

The model simulates the highest 30 percent of flows from Black Hawk with a high degree of accuracy. At the 5 percent duration interval (95th percentile), SWAT-predicted flow exceeds the rating curve flow by 1.9 percent. At the 25 percent duration (75th percentile), SWAT underestimates rating curve flow by only 3.1 percent. However, the rating curve predicts that outflow from the lake is zero approximately half the time, whereas SWAT predicts that low flows are present approximately 78 percent of the time. Adjustment of calibration parameters indicated that this discrepancy is likely related to the manner in which SWAT simulates storage in reservoirs and not problems with hydrologic simulation of inflows to the lake.

Errors resulting from the rating curve described previously may also contribute to the discrepancy at low flows. The two FDCs in Figure E-27 diverge at outflows lower than 9 cfs. The rating curve predicts that a stage of 0.18 feet (2.16 inches) results in a lake discharge of 9 cfs. Wave action, seiche effects, and other factors could result in discharges on days when the rating curve predicts no outflow. If only non-zero flows predicted by the rating curve are included in the FDC analysis, the agreement becomes substantially better. Figure E-28 shows the simulated and rating curve FDCs for all non-zero flow days (i.e., rating curve flows less than 0.0 cfs). The modified FDC reveals excellent agreement for beyond the 92 percent duration interval. Because the bulk of pollutant transport to the lake occurs during periods of runoff (i.e., high flow), the low flow discrepancies are not critical to TMDL development for Black Hawk Lake.

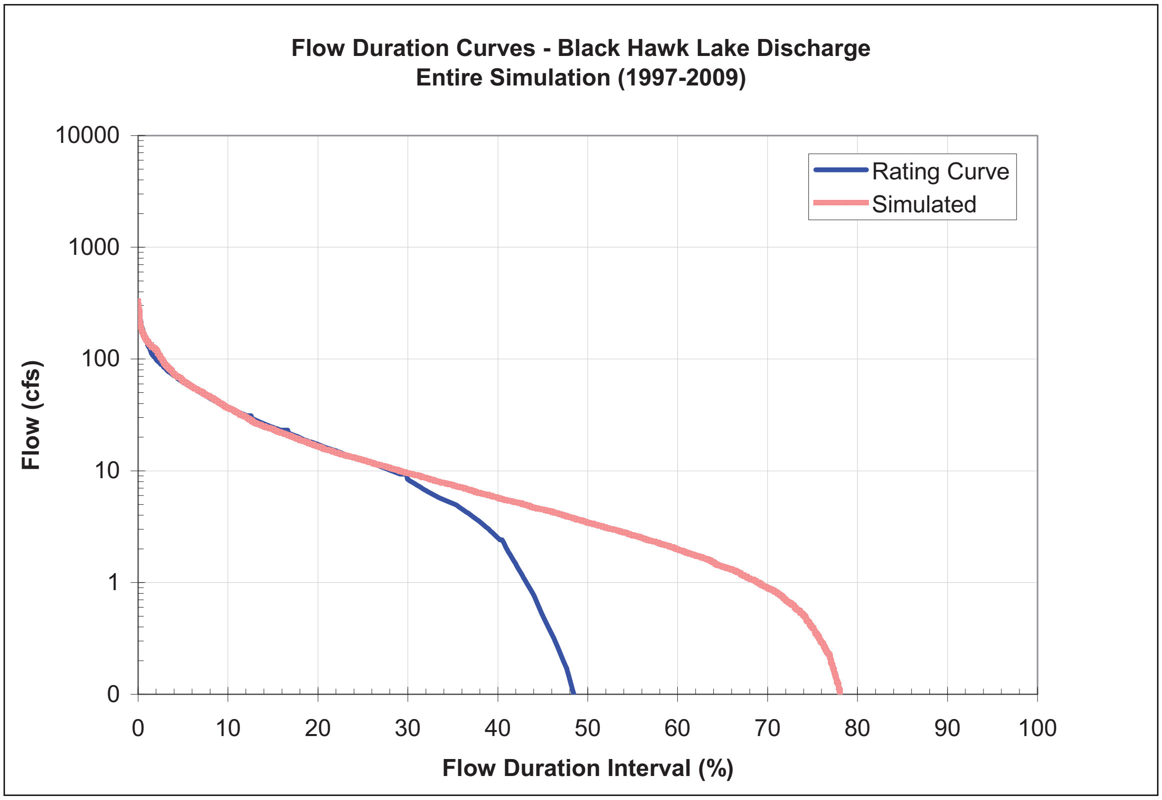

Figure E-27. FDCs of daily flow at lake outlet (1997-2009).

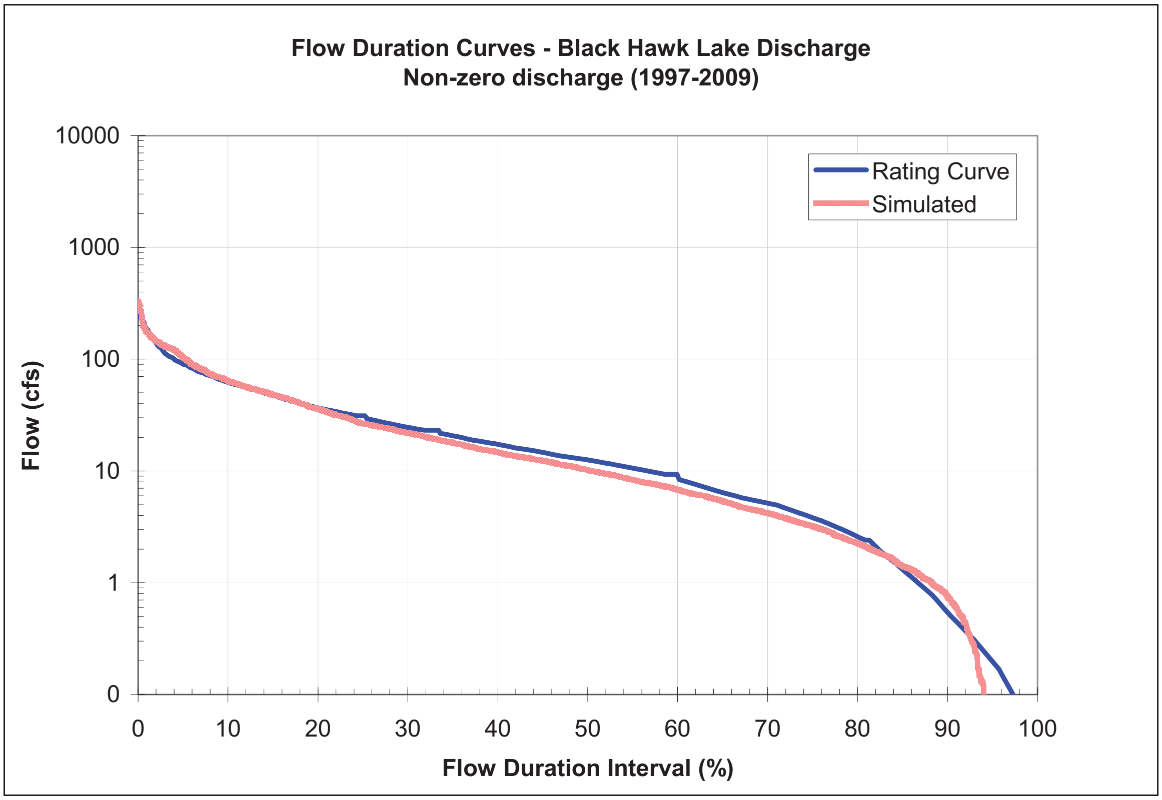

Figure E-28. FDCs of daily flow for all non-zero observed flow days (1997-2001).

E.2. Sediment

Evaluation and improvement of model performance with respect to sediment loading to Black Hawk Lake was based on several general comparisons. The frequency and amount of observed sediment data was inadequate for detailed and robust statistical calibration. However, several alternative estimates of sediment are available for comparison with model data, including the ISU Diagnostic Feasibility Study, NRCS methodology, and other state and local data. Parameters used in assessment of sediment output included:

- Simulated sheet and rill erosion vs. generally accepted ecoregion erosion rates
- Simulated streambank erosion vs. previous IDNR estimates using NRCS methodology
- Simulated sediment loads vs. sediment loads predicted by the ISU DFS
- Simulated sediment delivery ratio vs. generally accepted ecoregion-specific delivery ratio
- Simulated sediment concentration vs. observed total suspended solids (TSS) concentrations measured via monthly sampling in the ISU DFS.

Sheet and Rill Erosion
The Watershed Improvement Section of IDNR regularly assists locally led watershed groups in the development of stream and watershed assessments to facilitate soil and water quality conservation efforts. Watershed assessments include estimates of sheet and rill erosion using the Revised Universal Soil Loss Equation (RUSLE) method. Sheet and rill erosion is represented in the SWAT model as sediment yield, in metric tons per hectare per year (mtons/ha/yr). SWAT utilizes the Modified Universal Soil Loss Equation (MUSLE) method to predict sheet and rill erosion. The RUSLE method necessitates the development of a sediment delivery ratio to predict sediment transport, since RUSLE predicts erosion as a function of rainfall energy. MUSLE, and hence, the SWAT model, does not require the user to derive a sediment delivery ratio because sediment detachment and transport in MUSLE is a function of runoff, rather than rainfall.

The non-runoff parameters in the MUSLE equation are K, C, P, LS, and CFRG

Where: K = USLE soil erodibility factor
C = USLE cover and management factor
P = USLE practice factor
LS = USLE topographic factor
CFRG = coarse fragment factor

K and CFRG are determined by the soil coverage (SSURGO) and are not adjusted in SWAT model development or calibration. LS is determined by topographic data during watershed delineation process using the ArcSWAT interface. Typically, only the C and P factors are adjusted by the user. For simulation of existing conditions, which are represented in the calibration/validation scenarios, all HRUs have a P-factor of 1.0. This factor may be adjusted for future scenarios to aid with selection and placement of potential BMPs. The C-factor is dependent on land use and varies regionally. C-factors used in the Black Hawk Lake SWAT are discussed in Section D-6 and listed in Table D-9.

Table E-8 compares sheet and rill erosion rates estimated by IDNR for several watersheds in northwest Iowa to sediment yield predicted by SWAT for the Black Hawk Lake watershed.

Table E-8. Comparison of watershed sheet and rill erosion rates.

Watershed	County	Ecoregion	Area (acres)	Distance (miles)	Erosion (tons/acre)
Storm Lake	Buena Vista	Northwest Iowa Plains	14,719	23	1.9
Littlefield Lake	Audubon	Southern Iowa Drift Plains	2,500	51	1.8
Briggs Woods Lake	Hamilton	Des Moines Lobe	7,210	62	1.6
Lost Island Lake	Palo Alto	Des Moines Lobe	6,270	60	2.2
Silver Lake	Dickinson	Des Moines Lobe	17,019	80	1.6
Brushy Creek Lake	Webster	Des Moines Lobe	56,930	52	0.8
Little Clear Lake	Pocahontas	Des Moines Lobe	365	29	1.7
Marrowbone Creek	Carroll	Des Moines Lobe	8,916	17	2.4
[1]Black Hawk Lake	**Sac**	**[3]Transition**	**--**	**--**	**1.1**
[2]Black Hawk Lake	**Sac**	**[3]Transition**	**--**	**--**	**2.8**

[1] Annual average of entire simulation period (1997-2009)
[2] Simulated sheet and rill erosion in heavy rainfall year (2008)
[3] The Black Hawk Lake watershed is primarily in the Des Moines Lobe ecoregion, but intersects the transition between the Des Moines Lobe, Iowa Southern Drift Plains, and Northwest Iowa Plains ecoregions.

The Black Hawk Lake SWAT model predicts sheet and rill erosion rates that are similar to rates predicted by IDNR for other lakes in the region. The 1997-2009 simulated annual average rate was 1.1 tons/acre, near the low end of the range observed in other watersheds (0.8 to 2.4 tons/acre). In 2008, SWAT predicted an erosion rate of 2.8 tons/acre, slightly above the range predicted for nearby watersheds. This is explained by the occurrence of multiple high intensity rainfall events in the spring of 2008, and is not unreasonable given the highly erosive weather patterns that year.

Streambank Erosion

SWAT simulates channel erosion in addition to upland sheet and rill erosion. It is beyond the scope of this document to describe the channel erosion methodology in detail, which is readily available in the SWAT2005 documentation. SWAT allows the user to choose whether the model simulates channel degradation throughout the simulation. This option was made active in the Black Hawk Lake SWAT model. Channel (i.e., streambank) erosion parameters that were adjusted in the Black Hawk Lake SWAT model are reported in Table E-9.

Table E-9. Streambank/channel erosion parameters.

Parameter	Input Description (Allowable Range)	Calibrated Value
SPCON	Linear coefficient in sediment transport equation (0.0001 ≤ 0.01)	0.002
SPEXP	Exponential coefficient in sediment transport equation (1.0 ≤ 2.0)	1.1
CH_COV	Channel cover factor (0.0 ≤ 1.0)	Varies by reach
CH_EROD	Channel erodibility factor (0.0 ≤ 1.0)	Varies by reach

Channel cover factor and channel erodibility vary by reach because field reconnaissance revealed channel vegetation and conditions are not uniform throughout the watershed. Table E-10 reports the reach specific values for CH_COV and CH_EROD. These inputs are based on the 2009 stream assessment data for Carnarvon Creek. These data are reported in Figures E-29 and E-30. Figure E-29 illustrates the varying degrees of vegetative cover, and Figure E-30 shows areas of existing streambank erosion.

Table E-10. Channel cover and erodibility factors.

Subbasin/Reach	Channel Cover (CH_COV)	Channel Erodibility (CH_EROD)
1	0.5	0.3
2	0.6	0.4
3	0.6	0.4
4	0.5	0.3
5	0.5	0.3
6	0.5	0.3
7	0.9	0.6
8	0.5	0.3
9	1.0	0.6
10	0.7	0.3
11	0.5	0.3
12	0.5	0.3
13	1.0	0.6
14	1.0	0.6
15	0.5	0.3

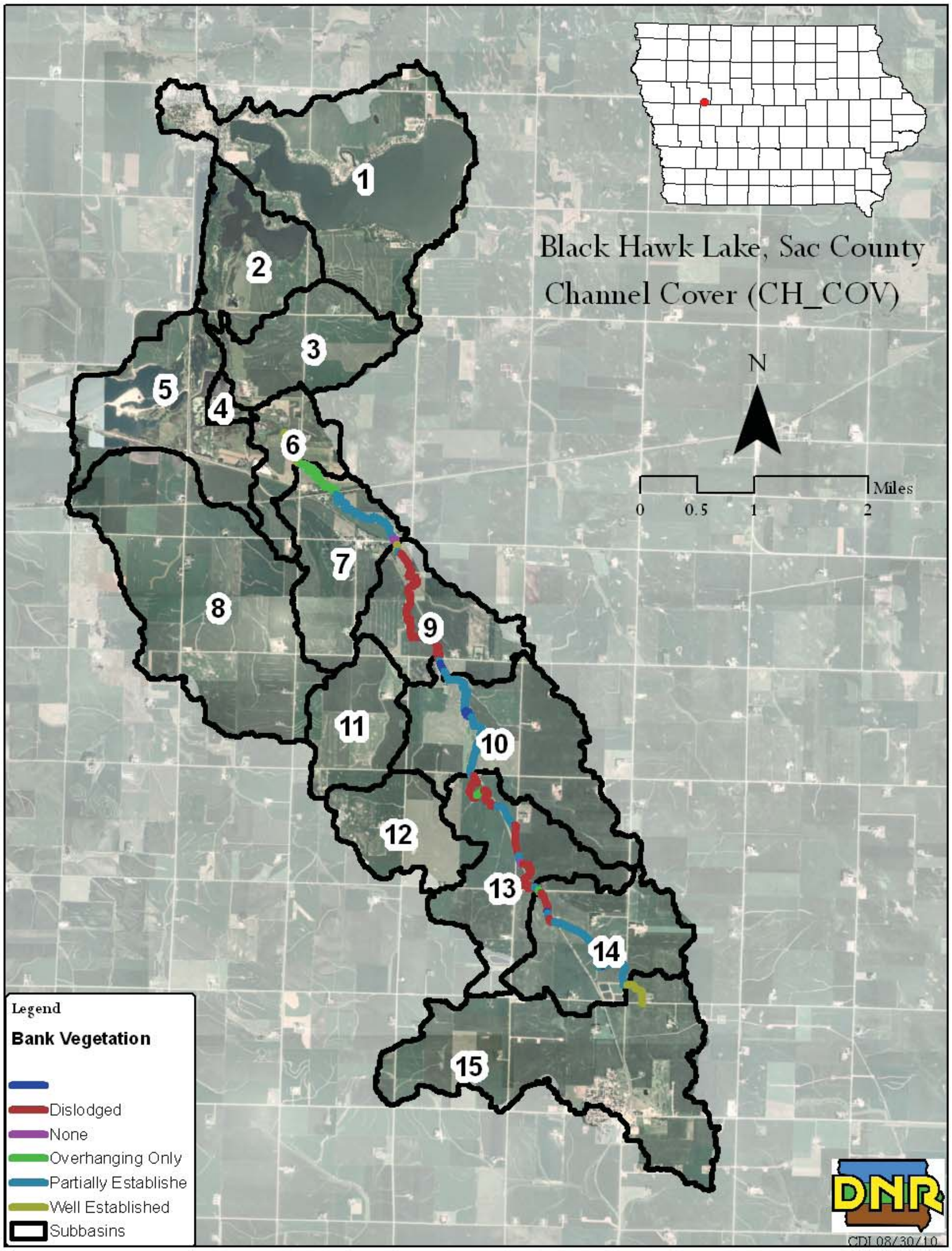

Figure E-29. Channel vegetation per 2009 stream assessment.

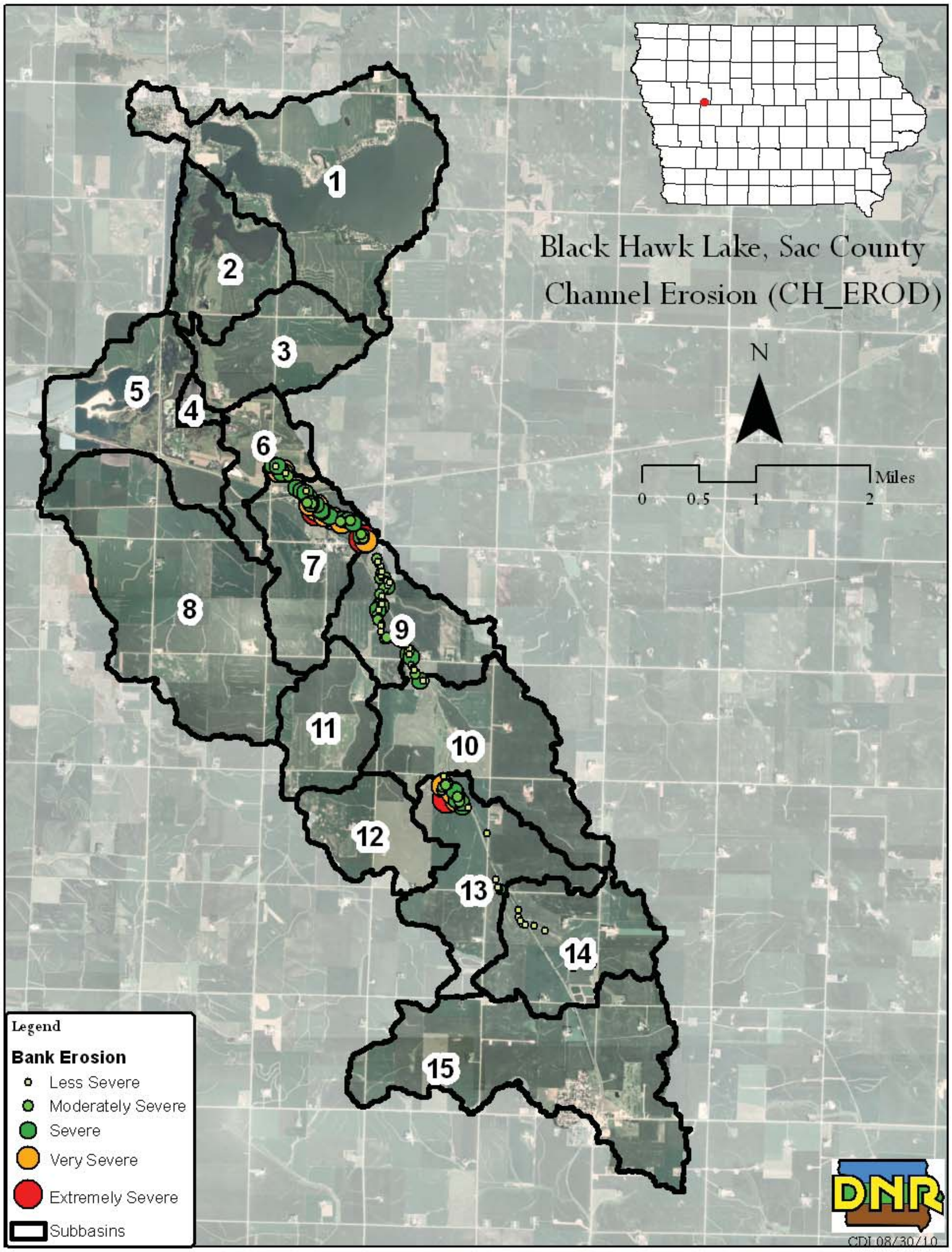

Figure E-30. Channel erosion per 2009 stream assessment.

Examination of SWAT output reveals that some reaches act as channel erosion sources, while other reaches act as sinks and accumulate sediment as it is transported through Carnarvon Creek. Existing channel erosion was estimated as part of the 2009 stream assessment using the "Erosion and Sediment Delivery" methodology developed by the state geologist for Iowa NRCS (Natural Resources conservation Field Office Technical

Guide, Section 1, Erosion Prediction; IA-198 “Erosion and Sediment Delivery”, Schneider, March 27, 1998). Total streambank erosion predicted using this method, based on 2009 conditions was 945 tons per year (tons/yr). In some cases, channel erosion may accumulate in stream reaches rather than being directly transported to the watershed outlet. Even if transport is delayed and inefficient, bank erosion does contribute to the overall sediment load and should be considered. Note that channel erosion is highly variable both temporally and spatially, and erosion rates are expected to vary from year to year.

The SWAT model estimate for channel erosion in 2009 is 943 metric tons per year, or 1,039 English tons/yr. This exceeds the NRCS method estimate by 10 percent. The comparison of the stream assessment estimate and SWAT output is reported in Table E-11. This analysis indicates that the model appears to provide a reasonable simulation of channel erosion, although this process is highly variable and a large degree of uncertainty is inherent with any attempt to quantify channel erosion.

Table E-11. Streambank/channel erosion estimates (2009).

Estimation Method	Channel Erosion (mtons/yr)	Channel Erosion (tons/yr)
Black Hawk Lake SWAT model	943	1,039
NRCS Technical Guide	857	945

Total Sediment Load

SWAT aggregates upland sheet and rill erosion in individual HRUs to the subbasin level, simulates channel erosion as previously discussed, and routes sediment through the reach network to generate a total sediment load out of the watershed. This total sediment load is assumed to enter Black Hawk Lake, and is a key driver of in-lake water quality.

ISU estimated annual sediment load to the lake between July 2008 and 2009 (IDNR and ISU, 2010). Because the heavy rainfall and highly erosive storm events of 2008 occurred before ISU began their study, 2009 is the best period of comparison between study data and SWAT output. The SWAT model simulated a total sediment load of 630 metric tons (694 tons) to the lake in 2009, compared to 781 mtons/yr (861 tons/yr) estimated by ISU. The SWAT estimate is approximately 19 percent lower than the ISU prediction. Sediment transport, like sheet and rill erosion, is highly variable and difficult to quantify. Comparison of ISU predictions and SWAT indicate the Black Hawk Lake SWAT model’s ability to provide reasonable estimates of sediment load, but detailed and robust calibration is not possible due to lack of observed sediment data. Predicted sediment loads are reported in Table E-12 for several simulation periods.

Table E-12. Total sediment load estimates.

Estimation Method	Period	Sediment Load (tons/yr)
Black Hawk Lake SWAT model	1997-2009 2008 2009	1,405 3,003 694
ISU Diagnostic Feasibility	[1]2009	861

[1] The ISU data is based on monthly flow and TSS measurements between July 2008 and July 2009.

Sediment Delivery Ratio

The total sediment load to the lake can be compared with upland and channel erosion to examine the effective sediment delivery ratio of sediment transport in the SWAT model. The effective sediment delivery ratio should be reasonably close to ratios estimated by the NRCS field guidance, which is used in conjunction with RUSLE methodology. Table E-13 reports the effective sediment delivery ratios for 2008, 2009, and 1997-2009 simulation periods. These ratios were calculated by summing total sheet and rill erosion plus channel erosion divided by the total sediment load out of the downstream reach. Table E-13 also reports expected sediment delivery ratios calculated using the NRCS technical guidance. The NRCS ratios are dependent on drainage area and the ecoregion in which the watershed resides. Estimates for the Des Moines Lobe and the Plains regions are included because the watershed is located in a transition area between these ecoregions.

Table E-13. Sediment delivery ratios.

Estimation Method	Period/Ecoregion	SDR (%)
Black Hawk Lake SWAT model	1997-2009 2008 2009	8.4 7.1 13.9
NRCS Technical Guidance	Des Moines Lobe S. Drift/NW IA Plains	3.9 24.4

Similar to previous sediment simulation performance metrics, analysis of sediment delivery ratios suggests that the model provides reasonable estimates of sediment loads to Black Hawk Lake. While a robust calibration is not possible, this quantitative analysis supports the use of the SWAT model to predict existing sediment loads and assess potential impacts of BMP implementation, as discussed in Section 4.

In-Stream Sediment Concentration

SWAT also simulates and reports suspended sediment concentrations in the stream reach, in addition to sediment yields and loads. As with other sediment-related parameters, lack of observed data prevents detailed and robust calibration. However, monthly grab samples were collected at several sites in Carnarvon Creek between July 2008 and 2009. Refer to Figure E-9 for a map of ISU monitoring locations. Monthly grab sample concentrations were averaged and compared with average concentrations in the SWAT output to test model performance. In addition to limited observed data, other factors add uncertainty and potential error in comparison of observed and simulated sediment data. SWAT simulates suspended sediment concentration, which is not numerically equivalent to total suspended solids (TSS), the parameter most commonly used to quantify sediment concentration in lab analysis. More research is necessary to fully address this problem. Nonetheless, comparison of SWAT sediment concentrations with observed TSS values provides insight to model performance.

Figure E-31 illustrates observed and simulated sediment concentrations in each SWAT reach/subbasin for the ISU study period and 2009 simulation period. Reach 1 is the downstream-most reach and Reach 15 is at the upstream end of the watershed. Note that there is no observed data in Reach 01, 04, 05, or 06. Also note that observed data is reported as TSS, whereas SWAT output is suspended sediment (both in mg/L).

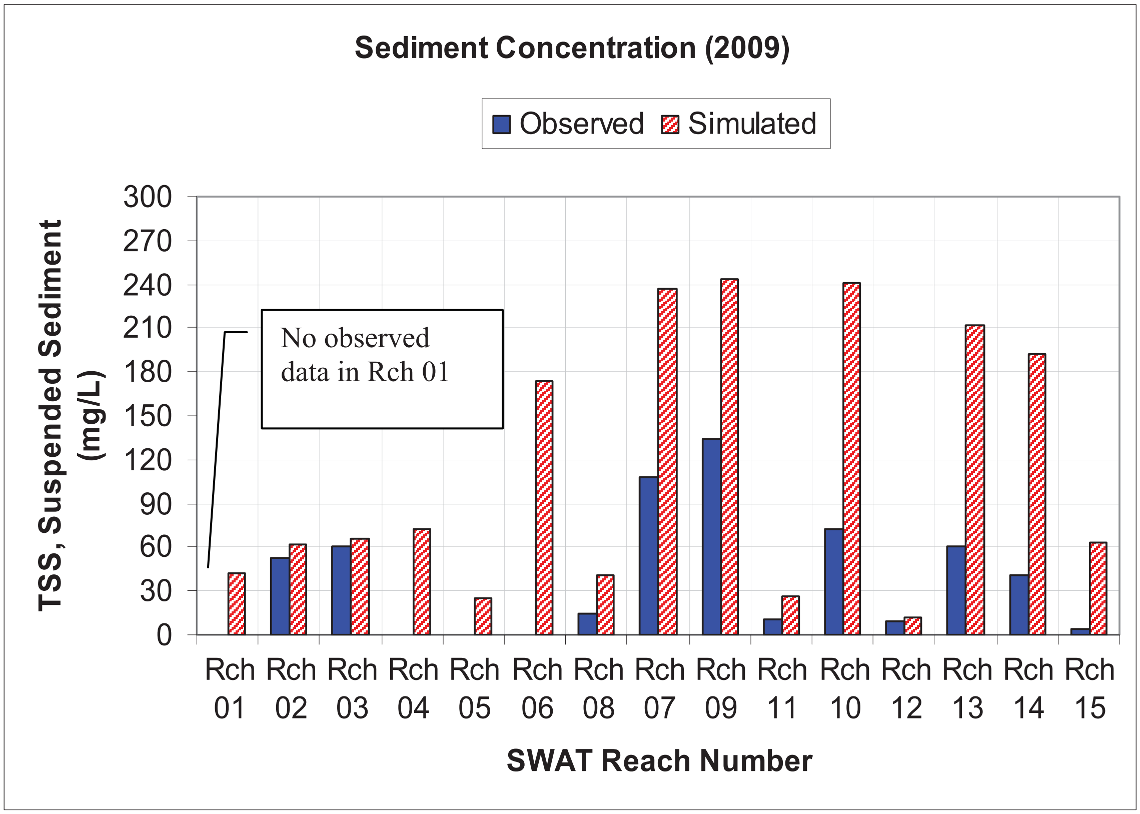

Figure E-31. Average in-stream sediment concentrations (2009).

Analysis of Figure E-31 reveals good agreement between observed and simulated concentration near the downstream end of the watershed (Reaches 02 and 03), which represents the water entering the Provost Slough and Black Hawk Lake. In the upper end, SWAT tends to overestimate in-stream sediment concentration (Reaches 10, 13, and 14), but trends are similar. The highest concentrations in the SWAT output are present in reaches that exhibit the highest observed concentrations. In-stream concentration is not critical in the development of the Black Hawk Lake TMDL because sediment and associated phosphorus loads to the lake are the key drivers of in-lake water quality.

However, evaluation of sediment concentration suggests that the model provides reasonable spatial representation of sediment levels in the Black Hawk Lake watershed.

E.3. Nutrients

Availability of observed data for the evaluation and improvement of model performance with respect to nutrient loading to Black Hawk Lake was even more limited than sediment related data. ISU estimated nitrogen and phosphorus loads to Black Hawk Lake as part of the 2009 DFS. Therefore, the following parameters were compared:

- Simulated total phosphorus (TP) loads vs. TP loads predicted by the ISU DFS
- Simulated total nitrogen (TN) loads vs. TN loads predicted by the ISU DFS
- Simulated TP export vs. estimated TP exports for other tile-drained watersheds in the Midwest

Table E-14 reports TP and TN loads to Black Hawk Lake predicted by the SWAT model used in this study and the results of the Diagnostic Feasibility Study developed by ISU (IDNR and ISU, 2010). Although nitrogen results were analyzed, the algal impairment in Black Hawk Lake is attributed to phosphorus. The difference in TP loads between the DFS and TMDL is not insignificant. However, given that the estimates are based on different methods of analysis (i.e., modeling vs. monitoring and flux calculations) with slight differences in time span (July 2008 to July 2009 for DFS vs. Calendar year 2009 for SWAT) the comparison is reasonable.

Table E-14. Nitrogen and phosphorus loading comparison.

Source	**TP (kg/yr)**	**TN (kg/yr)**
Black Hawk Lake SWAT model	[1]4,666	[1]67,315
ISU Diagnostic Feasibility	3,611	71,517
Difference	**29.2 %**	**5.9%**

[1]Loads simulated for 2009

Table E-15 compares the annual average and median TP export simulated by the Black Hawk Lake SWAT model with study results in other tile-drained watersheds in the Midwest. TP export in the Black Hawk Lake watershed is at the upper end of the range of literature values and closely matches TP export in the Skunk River. Because the SWAT model predicted nutrient loads of similar magnitude to estimates developed in the ISU study, and TP export is within the range of exports in similar watersheds, IDNR has determined the SWAT model to be adequate for estimation of phosphorus loads to Black Hawk Lake for development of TMDLs and implementation planning.

Table E-15. Comparison of TP exports in tile-drained watersheds.

Watershed/Location	Source	TP Export (lb/ac)
East Central Illinois	Royer et al., 2006	0.1-1.9
South Fork Iowa River	Tomer et al., 2008	0.4-0.6
Skunk River at Augusta, IA	USGS, 2001	2.5
Iowa River at Wapello, IA	USGS, 2001	0.88
Lake Geode, Henry Co.	IDNR (Previous TMDL)	1.38
Silver Lake, Dickinson Co.	IDNR (Previous TMDL)	0.7
Other Study Average	**4 studies above**	[1]**1.4**
Black Hawk Lake	**SWAT Model (Current TMDL)**	[2]**2.1**
Black Hawk Lake	**SWAT Model (Current TMDL)**	[3]**1.6**
Black Hawk Lake	**SWAT Model (Current TMDL)**	[4]**2.5**

[1] Average annual TP export (1997-2009)
[2] Median annual TP export (1997-2009)
[3] Average growing season TP export (2001-2008)
[4] Average annual TP export: Skunk River, Iowa River, Lake Geode, and Silver Lake

E.4. References

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Appendix F --- BATHTUB Model Methodology

A combination of modeling software packages were used to develop the Total Maximum Daily Load (TMDL) for Black Hawk Lake. Watershed hydrology and pollutant loading was simulated using the Soil & Water Assessment Tool (SWAT2005), version 2.3.4. SWAT model development was described in detail in Appendix D of this Water Quality Improvement Plan (WQIP). SWAT model performance/calibration was discussed in Appendix E.

In-lake water quality simulations were performed using BATHTUB 6.1, 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 Black Hawk Lake and its watershed.

F.1. BATHTUB Model Description

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

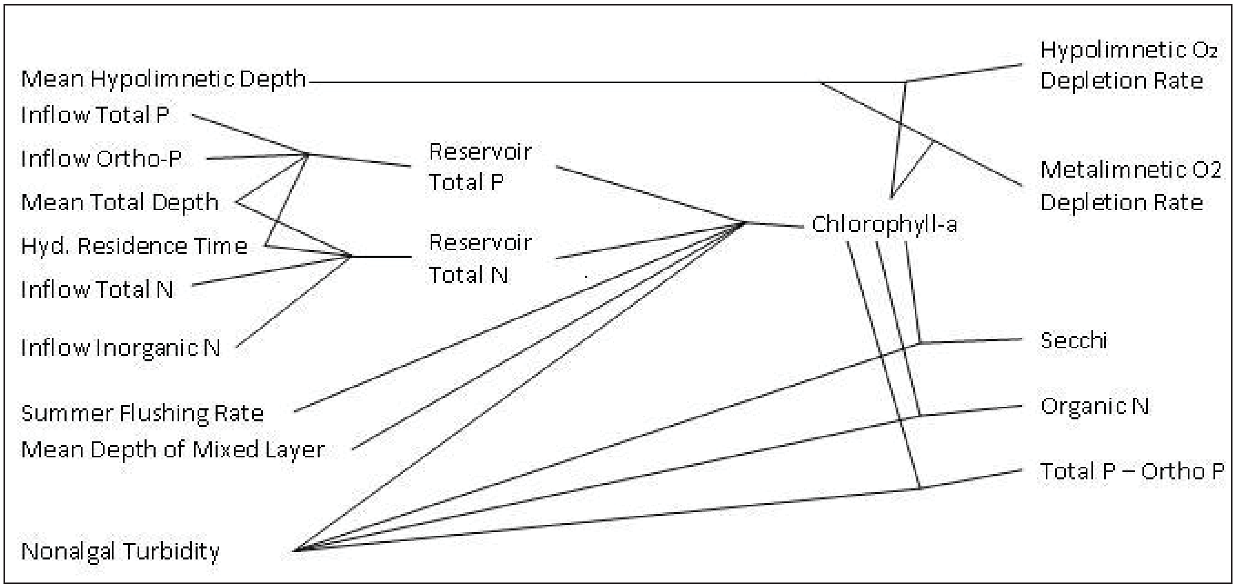

Figure F-1. Eutrophication control pathways in BATHTUB (Walker, 1999).

F.2. Model Parameterization

BATHTUB includes several data input menus/modules to describe lake characteristics and set up water quality simulations. Data menus utilized to develop the BATHTUB model for Black Hawk 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 Black Hawk Lake BATHTUB model and report input parameters for each menu.

Model Selections

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

Table F-1 reports the models selected for each parameter used to simulate eutrophication response in Black Hawk Lake. Preference was given to Models 1 and 2 during evaluation of model performance and calibration of the Black Hawk Lake model. Final selection of model type was based on applicability to lake characteristics, availability of data, and agreement between predicted and observed data. Although calibration by the BATHTUB user is possible, the underlying data used to derive empirical relationships included some calibration during creation of the BATHTUB model (Walker, 1999). For Black Hawk Lake, the calibration method is irrelevant, since all calibration factors were left as 1.0 because of good agreement between observed and simulated data. Model performance is discussed in more detail in Appendix F.3.

Table F-1. Model selections for Black Hawk Lake.

Parameter	Model No.	Model Description
Total Phosphorus	02	2nd order, decay
Total Nitrogen	00	Not computed *
Chlorophyll-a	02	P, Light, T *
Transparency	01	vs. Chl-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 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. The BATHTUB user documentation provides guidance for determining averaging period based on nutrient residence times. According to the user manual, seasonal averaging periods are appropriate for reservoirs with phosphorus residence times less than 0.2 years (Walker, 1999). This holds true for Black Hawk Lake in nearly every scenario (i.e., simulation year) that was evaluated. In fact, phosphorus residence times predicted by BATHTUB, considering input hydrology and TP loads from SWAT, are well below this threshold in most years. Additionally, model output provided better agreement with in-lake water quality when an averaging period of 6 months was utilized, when compared with a full year. Therefore a seasonal averaging period of 0.5 years (April to September) was utilized to quantify existing loads and in-lake water quality, and to develop TMDL targets.

Precipitation, evapotranspiration, and change in storage vary with each simulation period. Monthly (April through September) precipitation and evapotranspiration data were obtained from the SWAT model for each simulation period. These data were summarized and converted to BATHTUB units (meters) and entered in the global data menu. The change in storage was calculated from the simulated reservoir volume in SWAT at the beginning and end of each growing season. Note that change in storage over a growing season is often negative due to high evapotranspiration and low flow in the summer months.

Atmospheric deposition rates were obtained from a regional study (Anderson and Downing, 2006). Nutrient deposition is assumed to be in inorganic form and deposition rates are assumed constant from year to year.

Global input data for Black Hawk Lake is reported in Table F-2. The precipitation and evaporation totals shown are growing season averages for 2005-2008. Individual growing seasons between 2001 and 2008 were also simulated with distinct precipitation and evaporation inputs for each season.

Table F-2. Global variables data for the Black Hawk Lake BATHTUB model.

Parameter	Measured or Simulated Data	BATHTUB Input
Averaging Period	April – September	0.5 years
[1]Precipitation	660 mm	0.660 m
[1]Evaporation	555 mm	0.550 m
[2]Increase in Storage	-402,500 m^3	-0.131 m
[3]Atmospheric Loads:		
TP	0.3 kg/ha-yr	30 mg/m^2-yr
TN	7.7 kg/ha-yr	770.3 mg/m^2-yr

[1] Growing season averages for 2005-2008. Taken from monthly SWAT output.
[2] Change in lake volume from beginning to end of simulation period.
[3] From Anderson and Downing, 2006. Assumed all deposition is inorganic form.

Segment Data
Lake morphometry, observed water quality, calibration factors, and internal loads are all included in the segment data menu of the BATHTUB model. Separate inputs can be made for each segment of the lake or reservoir system that the user wishes to simulate. In lakes with simple morphometry and one primary tributary, simulation of the entire lake as one segment is often acceptable. This configuration is described as a "single reservoir, spatially averaged" in the BATHTUB user guidance. Assessment and calibration of model performance for Black Hawk Lake is based primarily on the single reservoir, spatially averaged configuration. Morphometric data for the spatially averaged configuration are listed in Table F-3.

Table F-3. Segment morphometry for the spatially averaged configuration.

Parameter	Measured or Monitored Data	BATHTUB Input
Lake Surface Area	760 acres	3.08 km^2
Mean Depth	5.97 feet	1.82 m
[1]Reservoir Length	3,532 meters	3.53 km
Mixed Layer Depth	5.97 feet	1.82 m
[2]Hypolimnetic Depth	14 feet	4.27 m

[1] Estimated using GIS
[2] Not applicable – lake stratifies only rarely and for short durations

The single reservoir, spatially averaged configuration was used to confirm nutrient loading and develop TMDL targets for Black Hawk Lake. However, the lake was divided into three segments to examine intra-lake variability, which provides insight for lake management. This configuration is described as "single reservoir, segmented" in the BATHTUB user guidance. The segments are illustrated in Figure F-2, as are monitoring locations for each segment. Morphometric data for the segmented configuration is reported in Table F-4. Division of the lake into segments was based on the locations of observed water quality data. The Middle Segment includes the ambient lake monitoring location (STORET ID 22810002). Hypolimnetic depth is included in Table F-4, but is not relevant to model output because the lake stratifies only in rare occurrences, and for short durations.

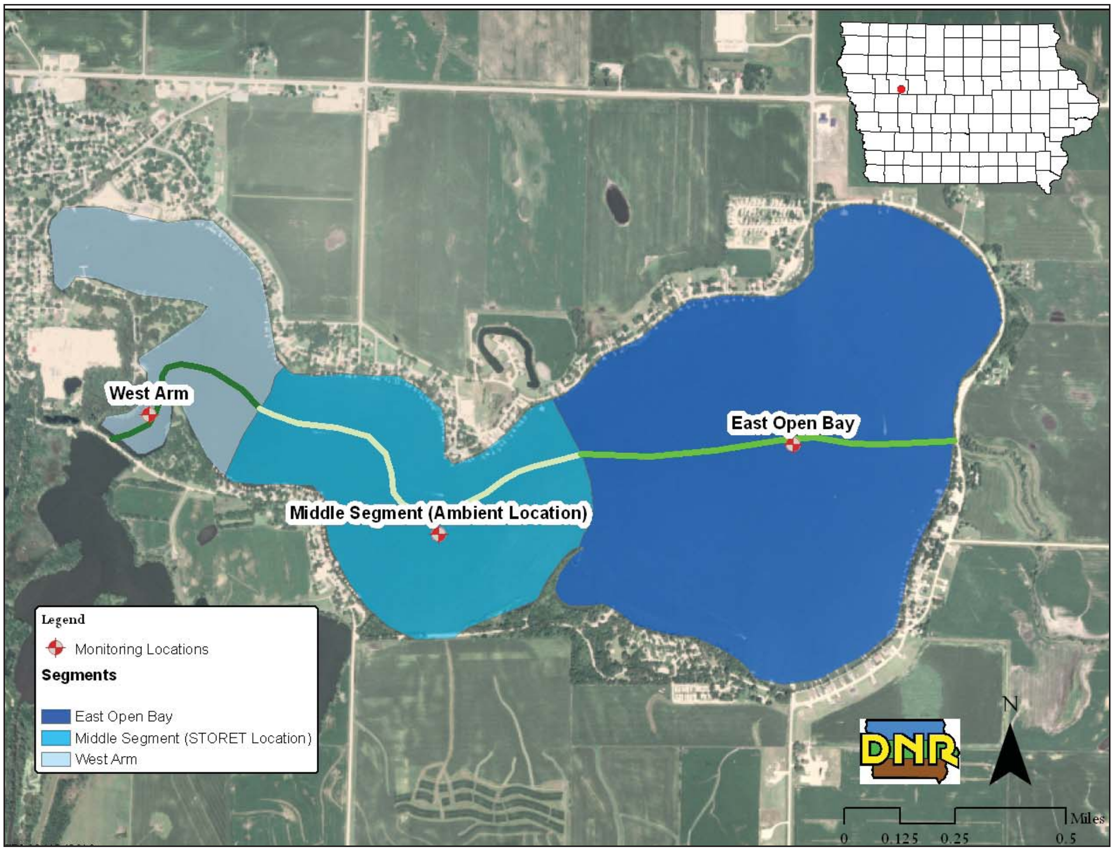

Figure F-2. Segmented configuration of Black Hawk Lake BATHTUB Model.

Table F-4. Segment morphometry for the segmented configuration.

Parameter	Measured or Monitored Data	BATHTUB Input
West Arm		
Lake Surface Area	102.0 acres	0.41 km^2
Mean Depth	6.0 feet	1.84 m
[1]Reservoir Length	761 meters	0.76 km
Mixed Layer Depth	6.0 feet	1.84 m
Hypolimnetic Depth	6.0 feet	1.84 m
Middle Segment (Ambient)		
Lake Surface Area	201.0 acres	0.81 km^2
Mean Depth	5.9 feet	1.79 m
[1]Reservoir Length	1,406 meters	1.41 km
Mixed Layer Depth	5.9 feet	1.79 m
Hypolimnetic Depth	5.9 feet	1.79 m
East Open Bay		
Lake Surface Area	457.7 acres	1.85 km^2
Mean Depth	5.2 feet	1.59 m
[1]Reservoir Length	1,366 meters	1.37 km
Mixed Layer Depth	5.2 feet	1.59 m
Hypolimnetic Depth	5.2 feet	1.59 m

[1] Estimated using GIS

Multiple scenarios were simulated using BATHTUB, with each scenario representing a distinct growing season or average conditions over several growing seasons between 2001 and 2008. Observed water quality data for each growing season is included in Appendix C – Water Quality Data. Mean water quality parameters observed for the 2005-2008 growing seasons are reported in Table F-5.

Table F-5. Observed water quality (2005-2008 growing season means).

Parameter	Measured or Monitored Data	[1]BATHTUB Input
Total Phosphorus	163.2 ug/L	163.2 ppb
Total Nitrogen	3.205 mg/L	3,205 ppb
Chlorophyll-a	68.5 ug/L	68.5ppb
Secchi Depth	0.38 m	0.38 m
Ammonia	242.8 ug/L	[2]N/A
Nitrate/Nitrite	1.12 mg/L	[2]N/A
Organic Nitrogen	1.84 mg/L	1,842 ppb
Ortho P	25.0 ug/L	[2]N/A
TP – Ortho P	138.2 ug/L	138 ppb

[1] Measured or monitored data converted to units required by BATHTUB
ppb = parts per billion = micrograms per liter (ug/L)
[2] Used to calculate organic form of nutrient, not an input parameter

Inclusion of observed water quality data in the BATHTUB model allows built in assessment of model performance and convenient calibration. However, calibration factors in the Black Hawk Lake models were not adjusted because BATHTUB provided reasonable agreement with observed water quality for each scenario without calibration.

Because the 2nd order decay TP model was empirically calibrated during development of BATHTUB, effects of internal loading (phosphorus recycling from bottom sediments) are generally reflected in the model without manually inputting an internal load (Walker, 1999). However, there is potential for higher internal phosphorus recycling in lakes with low summer overflow rates (Walker, 1999). The growing season flows to Black Hawk Lake were extremely low in several years. Extreme low-flow designations were made for years in which BATHTUB overflow rates were less than 5 m/yr. Using that definition, low-flow years included 2001, 2002, 2006, and 2009. The BATHTUB model under-predicted nutrient concentrations and chlorophyll-a levels and over-predicted transparency in those years. Therefore, internal TP loads were added to the segment data until predicted concentrations were reasonably similar to observed data in low-flow years. No measured data regarding internal loads are available for Black Hawk Lake. Internal loads are discussed in more detail in Appendix F.3 – BATHTUB Model Performance.

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. The FLUX component of BATHTUB allows the user to estimate flow and nutrient loads based on a tributary monitoring network. This technique is similar to the methodology Iowa State University (ISU) utilized in the Diagnostic Feasibility Study. However, tributary data was available for less than one calendar year, which limits reliability and increases the uncertainty associated with water quality predictions.

Flow and nutrient loads used in the development of the Black Hawk Lake BATHTUB models utilize watershed hydrology and nutrient loads predicted using the SWAT model described in Appendix D. Output from SWAT is available for calendar years 1997-2009; however, in-lake water quality data necessary to assess model performance is only available from 2001-2009. SWAT flow and nutrient load output requires conversion into forms compatible with BATHTUB. This includes units conversion and converting nutrient loads into mean concentrations. Tributary input varies for each scenario (simulation period). Model runs for individual growing seasons and averages over several growing seasons were evaluated. Table F-6 shows tributary inputs averaged over the 2005-2008 growing seasons.

Table F-6. Tributary data (2005-2008 growing season means).

Parameter	Measured or Simulated Data	[1]BATHTUB Input
Flow Rate	23.5E+06 m^3/yr	[2]23.5 hm^3/yr
Total P	22,985 kg	980 ppb
Ortho P	4,988 kg	213 ppb
Total N	160,950 kg	6,862 ppb
Inorganic N	65,116 kg	2,776 ppb

[1] Measured data or SWAT output converted to units required by BATHTUB
[2] hm^3/yr = cubic hectometers per year

F.3. BATHTUB Model Performance

Performance of the BATHTUB model was assessed by comparing predicted water quality with observed data for several scenarios. Scenarios included averaging periods for each year between 2001 and 2008, averaging periods for growing seasons between 2001 and 2008, and averages over several growing seasons. The best agreement between observed and simulated TP occurred when growing season data (April-September) was considered, rather than annual loadings. There are two likely explanations for this. First, all in-lake data was collected during the growing season, therefore eutrophication-related parameters reflect growing season conditions, not annual averages. Second, the relatively low nutrient residence times (calculated within BATHTUB) in Black Hawk Lake suggest that seasonal averaging periods are most appropriate.

Simulation of TP concentration was given highest priority, followed by chlorophyll-a and transparency. Nitrogen constituents are less important because Black Hawk Lake is not nitrogen limited, except in a few rare occurrences. In-lake TP data collected and analyzed by the Limnology Laboratory at ISU was utilized for years 2001-2004. Data from the University of Iowa Hygienic Laboratory (UHL) was used for years 2005-2008. TP data collected by ISU in 2000 was disregarded due to known problems with the data. TP data collected by ISU in 2009 was also excluded from the analysis due to inconsistencies in the data for Black Hawk Lake. All chlorophyll-a data collected by ISU was excluded from evaluation of model performance due to similar problems with data quality. These issues have been documented by Watershed Improvement Section and Watershed Monitoring and Assessment Section staff at IDNR, and were discussed in more detail in Section 3.1.

Calibration/Validation

Table F-7 reports observed and simulated TP and chlorophyll-a for the calibration period (2005 growing season) and the validation period (2007 and 2008 growing seasons). The predicted TP matched observed TP in the calibration growing season (2005) with no adjustment of the calibration coefficient in the BATHTUB model. Simulated chlorophyll-a concentration was 14 percent lower than observed chlorophyll-a in the calibration period. The average simulated TP concentration for the 2007-2008 growing seasons was 218 ug/L, 11.9 percent higher than the simulated TP of 196 ug/L over both growing seasons. Simulated average chlorophyll-a concentration (71 ug/L) was 21 percent lower than observed chlorophyll-a (90 ug/L) in the validation period.

Table F-7. BATHTUB model calibration and validation results.

Growing Season	TP (ug/L)		Chl-a (ug/L)	
	Observed	Simulated	Observed	Simulated
2005 (calibration)	143	143	43	37
2007 (validation)	184	232	108	77
2008 (validation)	208	203	72	64
2007-08 average	196	218	90	71

2001-2008 Total Phosphorus Simulation

Observed and simulated TP concentrations (growing season means) for 2001-2008 are reported in Table F-8. The third column, “No internal loads added,” reflects simulated concentrations for each growing season using the global variables, model selections, segment data, and tributary data described in Section F.2. Tributary data was obtained from the monthly output files of the Black Hawk Lake SWAT model for each growing season.

Extreme low flow in years 2001, 2002, and 2006 resulted in a poor correlation between observed and simulated TP levels, with a linear regression slope of 0.86 but an extremely week R^2 value of -0.003. Overflow rates calculated in BATHTUB using SWAT hydrology reveal that flow is significantly lower in those years than in other years in the evaluation period. In most cases, the effects of internal loads are inherently reflected in the empirical relationships utilized by the BATHTUB model. However, low overflow rates reduce the dilution of internal loads and enhance the effects of internal recycling on in-lake water quality.

For this reason, model performance was evaluated with the low-flow years excluded from the analysis (see fourth column of Table F-8). Linear regression of the data excluding low-flow years indicates excellent correlation between observed and simulated TP, with a regression slope of 1.11 and R^2 of 0.68.

To address potential internal loads in the quantification of existing loads and TMDL targets, internal TP loads were added in the segment data of the 2001, 2002, and 2006 BATHTUB models. Internal loads were adjusted so that reasonable agreement between simulated and observed in-lake concentrations was obtained. Internal load amounts were 24,997 lbs (10.1 mg/m^2/day) in 2001, 20,542 pounds (8.3 mg/m^2/day) in 2002, and 4,752 pounds (1.9 mg/m^2/day) in 2006. Resulting BATHTUB output is reported in the fifth column of Table F-8. Linear regression reveals very good agreement with observed data, indicated by a regression slope of 1.06 and R^2 of 0.71. The linear regression with the inclusion of internal loads in low flow years is illustrated in Figure F-3.

Table F-8. Observed and simulated TP (growing season means).

Growing Season	[1]Observed TP concentration (ug/L)	Simulated TP concentration (ug/L)		
		[2]No internal loads added	[3]Low-flow years excluded	[4]Internal loads added in low-flow years
2001	202	84	low flow year	202
2002	193	131	low flow year	193
2003	113	141	141	141
2004	117	144	144	144
2005	143	143	143	143
2006	128	61	low flow year	129
2007	184	232	232	232
2008	208	203	203	203
Mean	161	142	173	173
Linear Regression	Slope R^2	0.86 -0.003	1.11 0.68	1.06 0.71

[1] Collected/analyzed by ISU (2001-2004) and UHL (2005-2008)
[2] BATHTUB output without addition of internal TP loads
[3] BATHTUB output excluding low flow years of 2001, 2002, and 2006
[4] BATHTUB output after addition of internal TP loads in low flow years

2005-2008 Chlorophyll-a Simulation

BATHTUB performs reasonably well in the simulation of chlorophyll-a levels in Black Hawk Lake. Model performance is illustrated in Figure F-4, which plots simulated versus observed chl-a concentrations (growing season means) for 2005-2008. Observed data in this analysis is limited to UHL data due to the documented problems with ISU data previously discussed. Simulated concentrations were obtained from model runs that incorporate the internal TP added for 2006. The regression reveals good agreement between simulated and observed chl-a levels, indicated by a regression slope of 0.77 and R^2 of 0.86. Agreement is especially good considering the increased complexity and variability inherent with eutrophication response parameters such as chlorophyll-a.

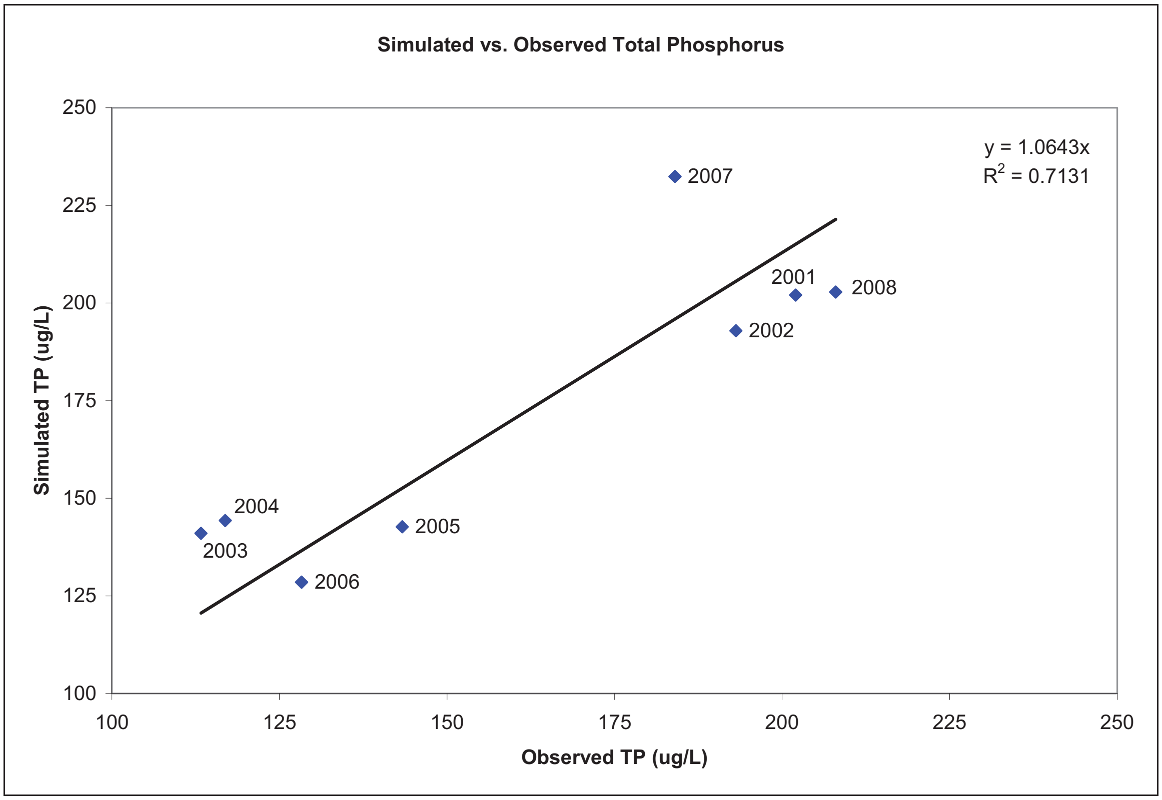

Figure F-3. Simulated vs. observed TP concentration in Black Hawk Lake.

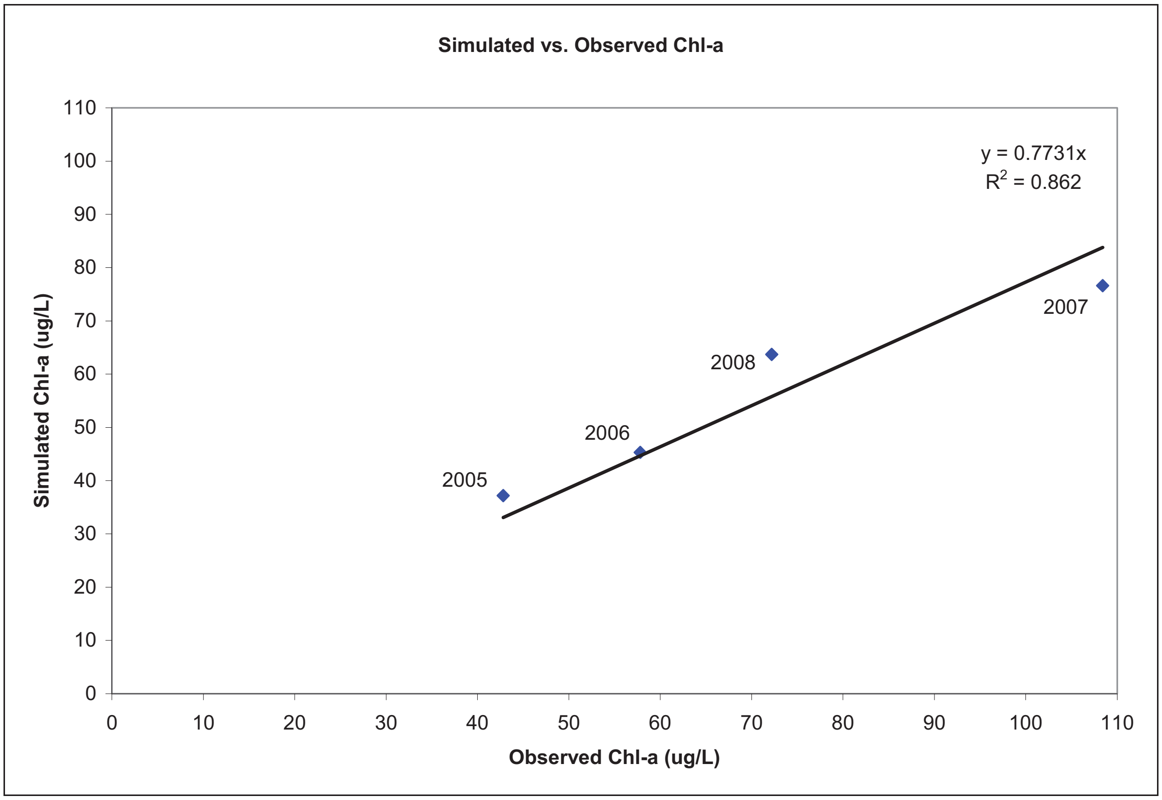

Figure F-4. Simulated vs. observed chlorophyll-a in Black Hawk Lake.

No calibration parameters were adjusted for any parameter in BATHTUB to obtain the level of agreement described above. This further suggests that BATHTUB, and the flow and nutrient loads from SWAT that drive the empirical relationships within BATHTUB, provide a reasonable representation of eutrophication in Black Hawk Lake. Therefore, IDNR determined model performance to be acceptable for the estimation of existing nutrient loads and development of TMDL targets. Estimation of existing loads and TMDL targets (discussed in Section 3) are based on average conditions simulated during the 2001-2008 growing seasons.

F.4. References

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

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

Appendix G --- Expressing Average Loads as Daily Maximums

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

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

Per the EPA recommendations, the loading capacity of Black Hawk Lake for TP is expressed as both a maximum growing season (April-September) average and a daily maximum load. The growing season 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 growing season average was derived using the BATHTUB model described in this Appendix F, and is 9,366 lbs/season.

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

The *Options for Expressing Daily Loads in TMDLs* document presents a similar case study in which a statistical approach is considered the best option for identifying a maximum daily load (MDL) that corresponds to the allowable average load. The method calculates the daily maximum based on a long-term average and considers variation. This method is represented by the equation:

$$MDL = LTA \times e^{[z\sigma - .05\sigma^2]}$$

Where: MDL = maximum daily limit
LTA = long term average
z = z statistic of the probability of occurrence
$\sigma^2 = \ln(CV^2 + 1)$
CV = coefficient of variation

The allowable growing season average of 9,366 lbs/season is equivalent to a long-term average (LTA) daily of 51.5 lbs/day. The LTA is the allowable growing season load divided by the 182-day averaging period (i.e., the length of the growing season). The average growing season allowable load must be converted to a MDL. The 182-day averaging period equates to a recurrence interval of 99.4 percent and corresponding z statistic of 2.541, as reported in Table G-1. The coefficient of variation (CV) is the ratio of the standard deviation to the mean of the simulated SWAT TP loads for the 2001-2008 period, and is 0.73. The resulting σ^2 value is 0.43. This yields a TMDL of 219 lbs/day. The TMDL calculation is summarized in Table G-2.

Because the WLA is for a controlled discharge lagoon, the allowable maximum daily load from the lagoon is calculated by multiplying the maximum allowable discharge, as specified in the current NPDES permit, by the allowable effluent TP concentration of 3.6 mg/L. This results in a daily maximum WLA of 37 lbs/day. The daily MOS is an explicit 10 percent of the TMDL, 22 lbs/day. The LA is the TMDL minus the WLA minus the MOS, or 160 lbs/day. The resulting TMDL, expressed as a daily maximum, is:

TMDL = LC = Σ WLA (37 lbs-TP/day) + Σ LA (160 lbs-TP/day)
+ MOS (22 lbs-TP/day) = **219 lbs-TP/day**

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

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

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

Parameter	Value	Description
LTA	51.5 lbs/day	Growing season MOS (9,366 lbs/ 182 days)
Z Statistic	2.541	Based on 180-day averaging period
CV	0.73	Used CV from annual GWLF TP loads
σ^2	0.43	ln $(CV^2 + 1)$
MDL	**219 lbs/day**	**TMDL expressed as daily load**

Appendix H --- 2008 305(b) Water Quality Assessment

Black Hawk Lake
2008 Water Quality Assessment: Assessment results from 2004 through 2006
Release Status: Final

Segment Summary
Waterbody ID Code: IA 04-RAC-00475-L_0
Location: Sac County, S35,T87N,R36W, at Lake View.
Waterbody Type: Lake
Segment Size: 925 Acres
This is a Significant Publically Owned Lake
Segment Classes: Class A1Class B(LW)Class HH

Assessment Comments
Assessment is based on: (1) results of the IDNR-UHL beach monitoring program in the summers of 2004, 2005, and 2006 (2) results of the statewide survey of Iowa lakes conducted from 2002 through 2006 by Iowa State University (ISU), (3) results of the statewide ambient lake monitoring program conducted from 2005 through 2006 by University Hygienic Laboratory (UHL), (4) information from the IDNR Fisheries Bureau, and (5) results of EPA/DNR fish contaminant (RAFT) monitoring in 2003.

Assessment Summary and Beneficial Use Support
Overall Use Support - Not supporting
Aquatic Life Support - Fully
Fish Consumption - Fully
Primary Contact Recreation - Not supporting
Assessment Type: Monitored
Integrated Report Category: 5a – Water is impaired or a declining water quality trend is evident, and a TMDL is needed.
Trend: Stable
Trophic Level: Hypereutrophic

Basis for Assessment and Comments
SUMMARY: The Class A1 (primary contact recreation) uses are assessed (monitored) as “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 Class B(LW) (aquatic life) uses are assessed (monitored) as “fully supported.” Fish consumption uses are assessed (monitored) as “fully supported.” Sources of data for this assessment include (1) results of the IDNR-UHL beach monitoring program in the summers of 2004, 2005, and 2006 (2) results of the statewide survey of Iowa lakes conducted from 2002 through 2006 by Iowa State University (ISU), (3) results of the statewide ambient lake monitoring program conducted from 2005 through 2006 by University Hygienic Laboratory (UHL), (4) information from the IDNR Fisheries Bureau, and (5) results of EPA/DNR fish contaminant (RAFT) monitoring in 2003.

EXPLANATION: Results of IDNR beach monitoring from 2004 through 2006 suggest that the Class A1 uses are "not supported." Levels of indicator bacteria at Blackhawk Lake beach were monitored once per week during the primary contact recreation seasons (May through September) of 2004 (16 samples), 2005 (23 samples), and 2006 (28 samples) as part of the IDNR beach monitoring program. According to IDNR's assessment methodology, two conditions need to be met for results of beach monitoring to indicate "full support" of the Class A1 (primary contact recreation) uses: (1) all thirty-day geometric means for the three-year assessment period are less than the state's geometric mean criterion of 126 E. coli orgs/100 ml and (2) not more than 10 % of the samples during any one recreation season exceeds the state's single-sample maximum value of 235 E. coli orgs/100 ml. If a 5-sample, 30-day geometric mean exceeds the state criterion of 126 orgs/100 ml during the three-year assessment period, the Class A1 uses should be assessed as "not supported." Also, if significantly more than 10% of the samples in any one of the three recreation seasons exceed Iowa's single-sample maximum value of 235 E. coli orgs/100 ml, the Class A1 uses should be assessed as "partially supported." This assessment approach is based on U.S. EPA guidelines (see pgs 3-33 to 3-35 of U.S. EPA 1997b).

At Blackhawk Lake beach, the geometric means of 2 thirty-day periods during the summer recreation season of 2005 exceeded the Iowa water quality standard of 126 E. coli orgs/100 ml. No geometric means violated this criterion in 2004 or 2006. The percentage of samples exceeding Iowa's single-sample maximum criterion (235 E. coli orgs/100 ml) was not significantly greater than 10% in any of the years (2004: 0%, 2005: 13%, 2006: 11%). According to IDNR's assessment methodology and U.S. EPA guidelines, these results suggest impairment (nonsupport) of the Class A1 (primary contact recreation) uses.

Blackhawk Lake was sampled as part of IDNR's Safe Lakes Program, which aims to identify sources of bacteria to selected beaches where bacteria levels have consistently violated the state water quality criteria. The Safe Lakes Program found human contamination in a tile about 200 meters east of the beach. This tile had very high concentrations of detergents present and blood worms where the tile was discharging. The tile line was reported to the IDNR Field Office who could not find it when they went to investigate in the summer of 2006. During follow-up sampling in 2007 the IDNR Safe Lakes Program also could not find the tile. This tile was gone, capped off, or underwater as the lake water level was higher in 2007. This tile was a likely source of contamination to Blackhawk Lake beach. Continued follow-up monitoring including investigation for this tile will occur in 2008.

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.

The median concentration of inorganic suspended solids is very high and contributes to the impairment at Blackhawk Lake. Results from the ISU and UHL lake surveys show that the median level of inorganic suspended solids in Blackhawk Lake from 2002-2006 was 18.0 mg/L, which was the 10th highest concentration of the 132 lakes monitored by these programs.

Data from the 2002-2006 ISU and UHL surveys suggest a moderate population of cyanobacteria exists at Blackhawk Lake, which does not contribute to impairment at this lake. These data show that cyanobacteria comprised only 48% of the phytoplankton wet mass at this lake. The median cyanobacteria wet mass (12.3 mg/L) was also the 44th lowest of the 132 lakes sampled.

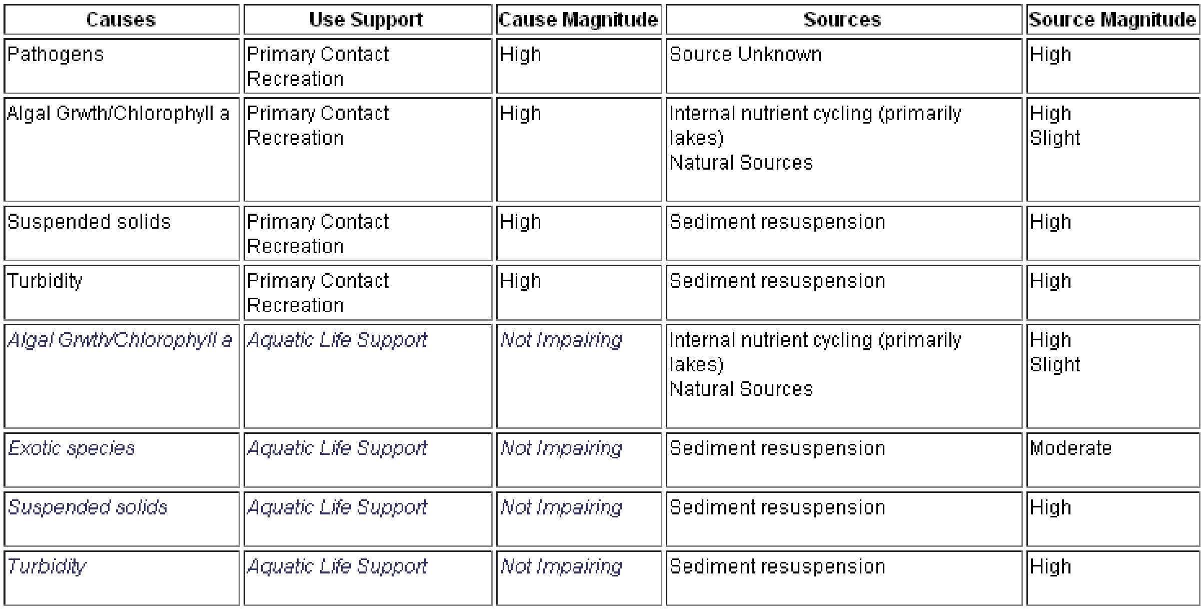
The Class B(LW) (aquatic life) uses are assessed as “fully supported” based on information from the IDNR Fisheries Bureau, results from the ISU and UHL lake surveys, and results of physical and chemical monitoring associated with IDNR’s beach monitoring program. The following factors, however, remain concerns at this lake: nuisance blooms of algae, re-suspension of sediment; the increasing population of common carp, and their tendency to increase levels of turbidity through re-suspension of sediment and algal nutrients. The ISU and UHL lake survey results show good chemical water quality at Blackhawk Lake. During 2002-2006 there were no violations of the Class B(LW) criterion for dissolved oxygen (27 samples) or pH (27 samples). There was one violation in 21 samples of the Class B(LW) criterion for ammonia. Based on IDNR’s assessment methodology, the one violation of the ammonia criterion does not constitute an impairment of water quality at Blackhawk Lake. The physical/chemical data associated with the beach monitoring data from 2004 through 2006 show 1 violation of the Class B(LW) criteria for dissolved oxygen in 64 samples (1%) and 1 violation of the Class B(LW) criterion for pH in 64 samples (1%). According to IDNR’s assessment methodology these results suggest full support of the Class B(LW) uses at Blackhawk Lake.

Fish consumption uses were assessed (monitored) as “fully supported” based on results of U.S. EPA/IDNR fish contaminant (RAFT) monitoring at Black Hawk Lake in 2003. The composite samples of fillets from common carp and black crappie had low levels of contaminants. Levels of primary contaminants in the composite sample of common carp fillets were as follows: mercury: <0.0181 ppm; total PCBs: 0.09 ppm; and technical chlordane: <0.03 ppm. Levels of primary contaminants in the composite sample of black crappie fillets were as follows: mercury: <0.0181 ppm; total PCBs: 0.09 ppm; and technical chlordane: <0.03 ppm. The existence of, or potential for, a fish consumption advisory is the basis for Section 305(b) assessments of the degree to which Iowa’s lakes and rivers support their fish consumption uses. The fish contaminant data generated from the 2003 RAFT sampling conducted at this lake show that the levels of contaminants do not exceed any of the advisory trigger levels, thus indicating no justification for issuance of a consumption advisory for this waterbody.

Monitoring and Methods
Assessment Key Dates
5/20/2002 Fixed Monitoring Start Date
9/11/2003 Fish Tissue Monitoring
10/3/2006 Fixed Monitoring End Date

Methods
Primary producer surveys (phytoplankton/periphyton/macrophyton)
Surveys of fish and game biologists/other professionals
Non-fixed-station monitoring (conventional during key seasons and flows)
Fish tissue analysis
Water column surveys (e.g. fecal coliform)

Causes and Sources of Impairment



Causes	Use Support	Cause Magnitude	Sources	Source Magnitude
Pathogens	Primary Contact Recreation	High	Source Unknown	High
Algal Grwth/Chlorophyll a	Primary Contact Recreation	High	Internal nutrient cycling (primarily lakes) Natural Sources	High Slight
Suspended solids	Primary Contact Recreation	High	Sediment resuspension	High
Turbidity	Primary Contact Recreation	High	Sediment resuspension	High
Algal Grwth/Chlorophyll a	*Aquatic Life Support*	*Not Impairing*	Internal nutrient cycling (primarily lakes) Natural Sources	High Slight
Exotic species	*Aquatic Life Support*	*Not Impairing*	Sediment resuspension	Moderate
Suspended solids	*Aquatic Life Support*	*Not Impairing*	Sediment resuspension	High
Turbidity	*Aquatic Life Support*	*Not Impairing*	Sediment resuspension	High

Appendix I --- Public Comments

The Iowa Department of Natural Resources (IDNR) received no public comments regarding the Black Hawk Lake TMDL.