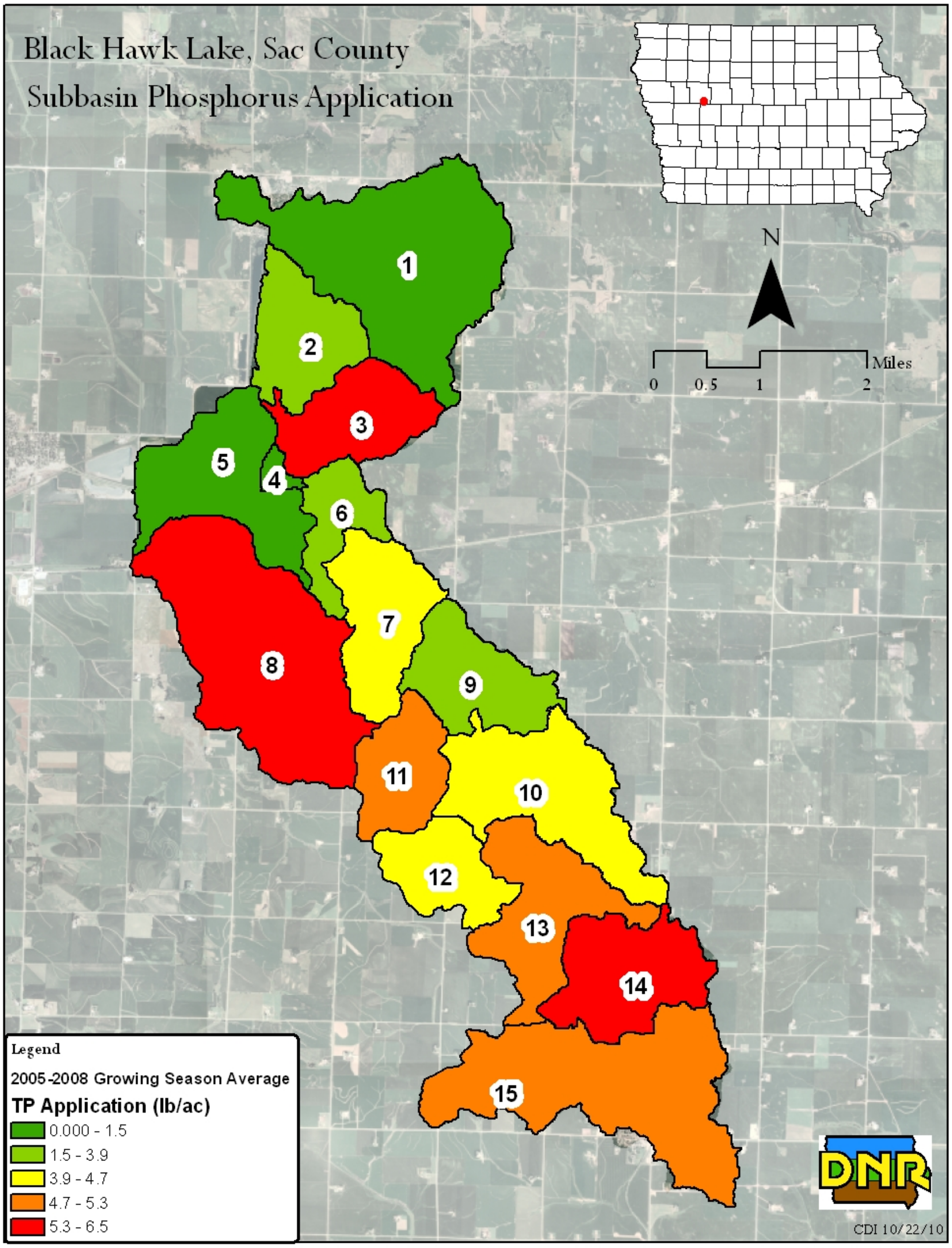

Figure 4-3. Subbasin average phosphorus application rates.

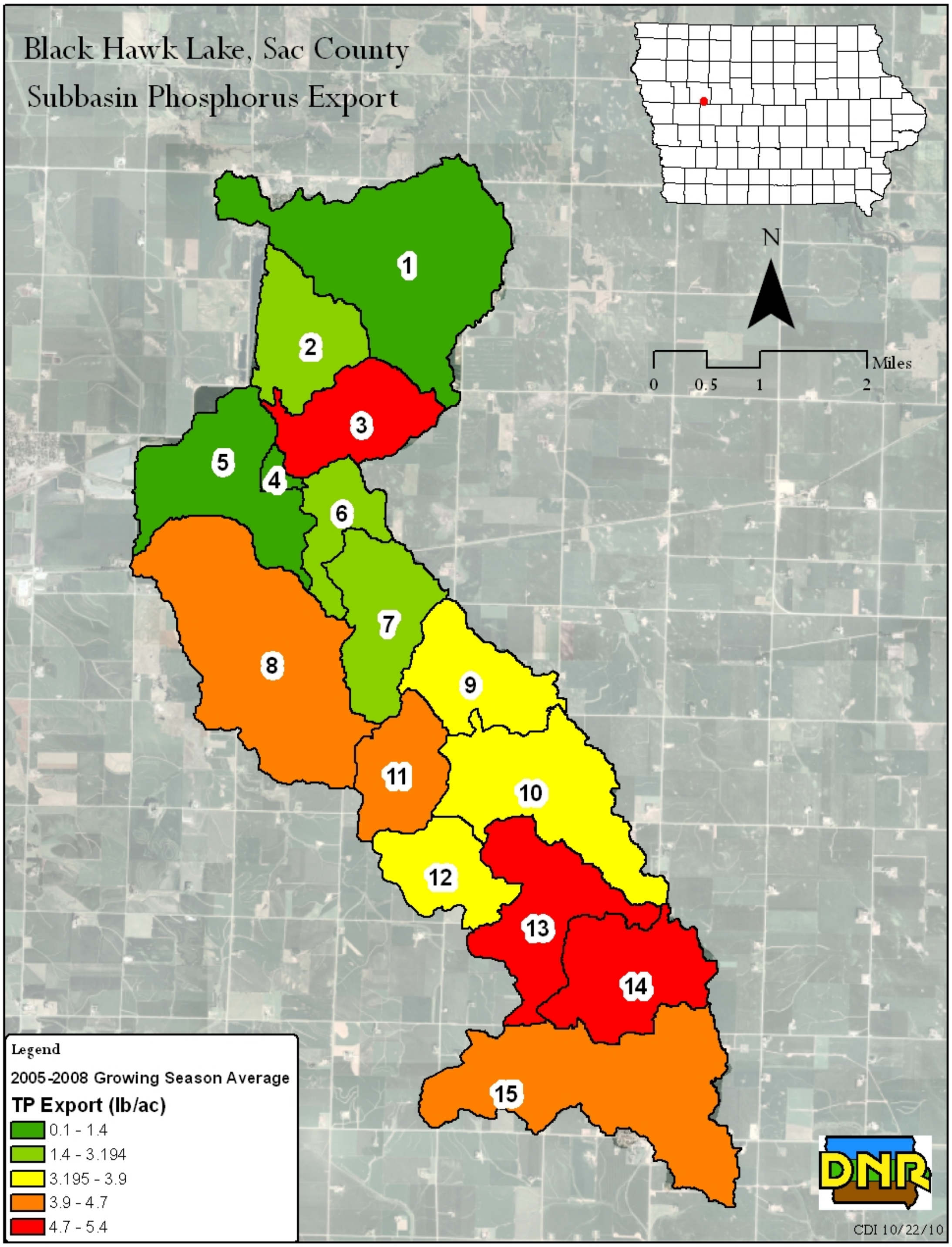

Figure 4-4. Phosphorus export rates (2005-2008 growing season averages).

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.

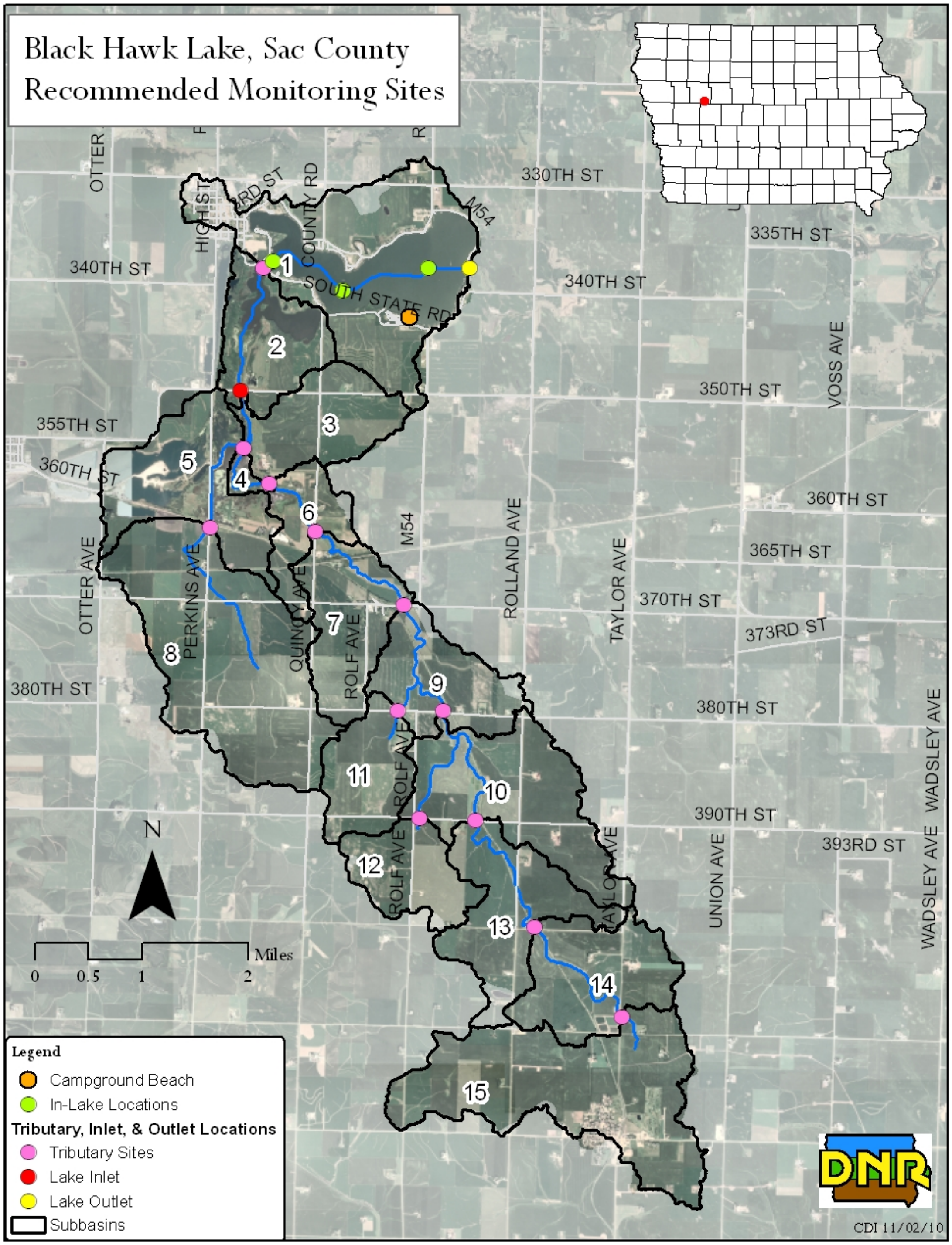

Figure 5-1. Recommended monitoring locations.

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.

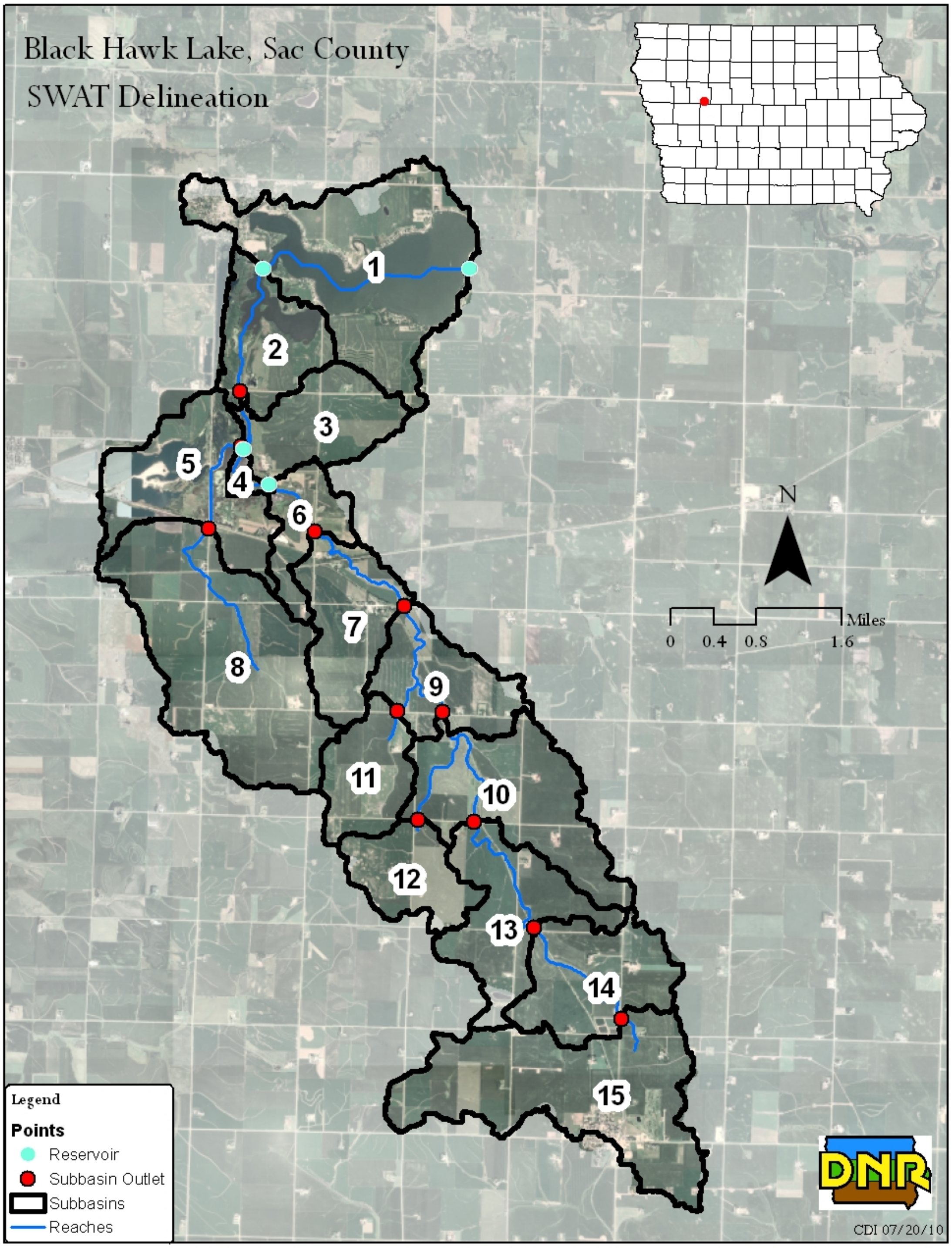

Figure D-1. SWAT delineation.

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.

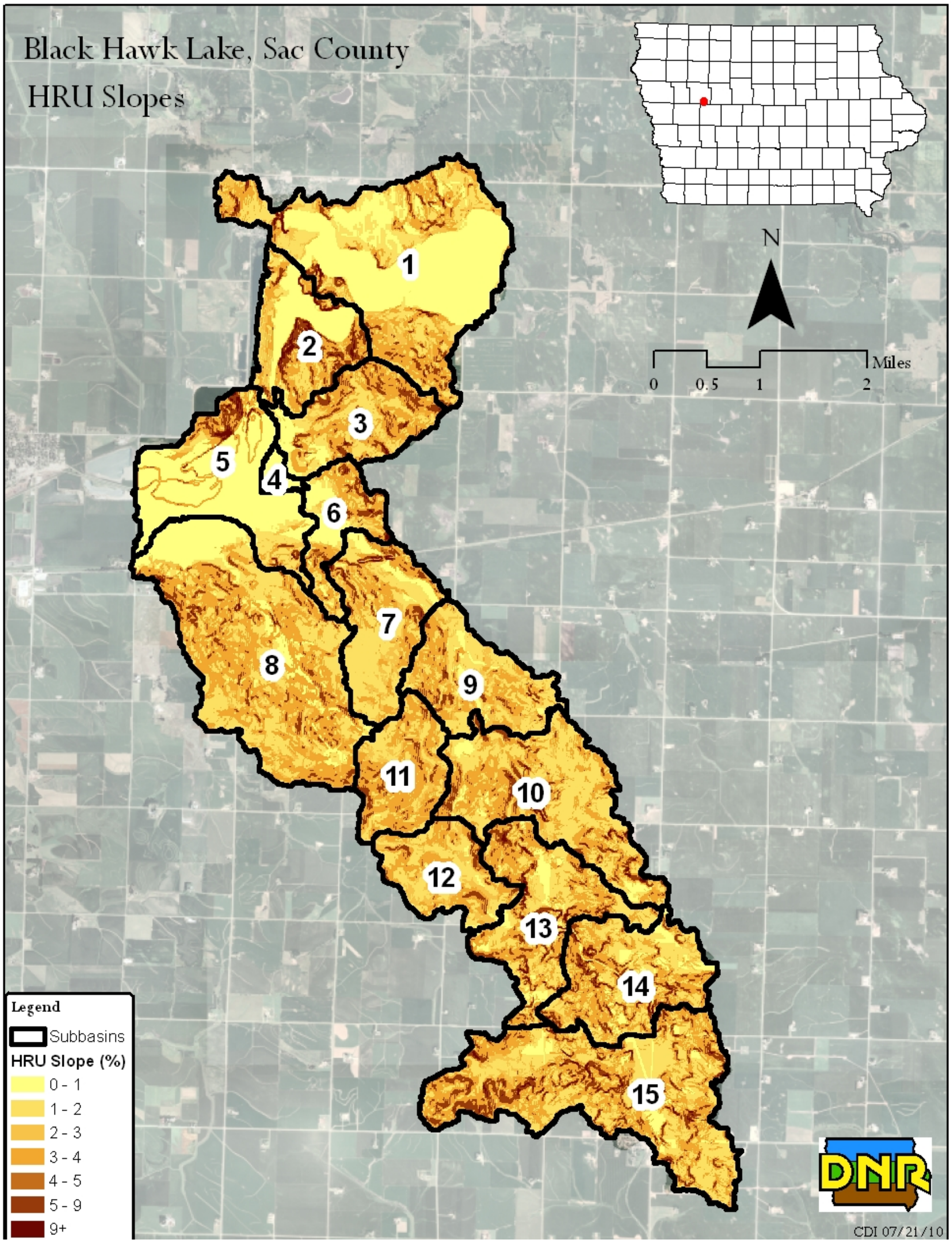

Figure D-2. Average HRU slope in the Black Hawk Lake SWAT model.

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

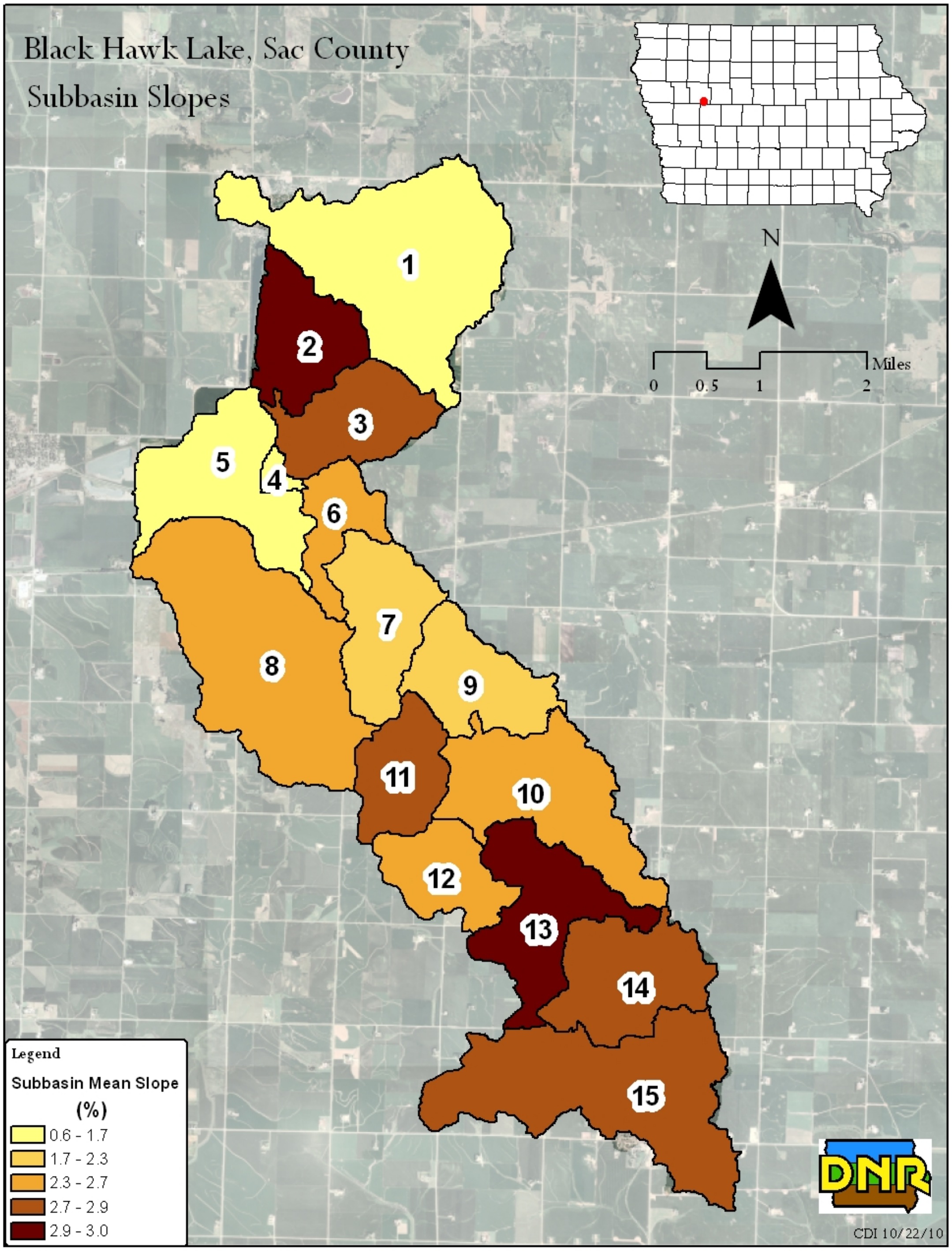

Figure D-3. Average subbasin slope in the Black Hawk Lake SWAT model.

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).

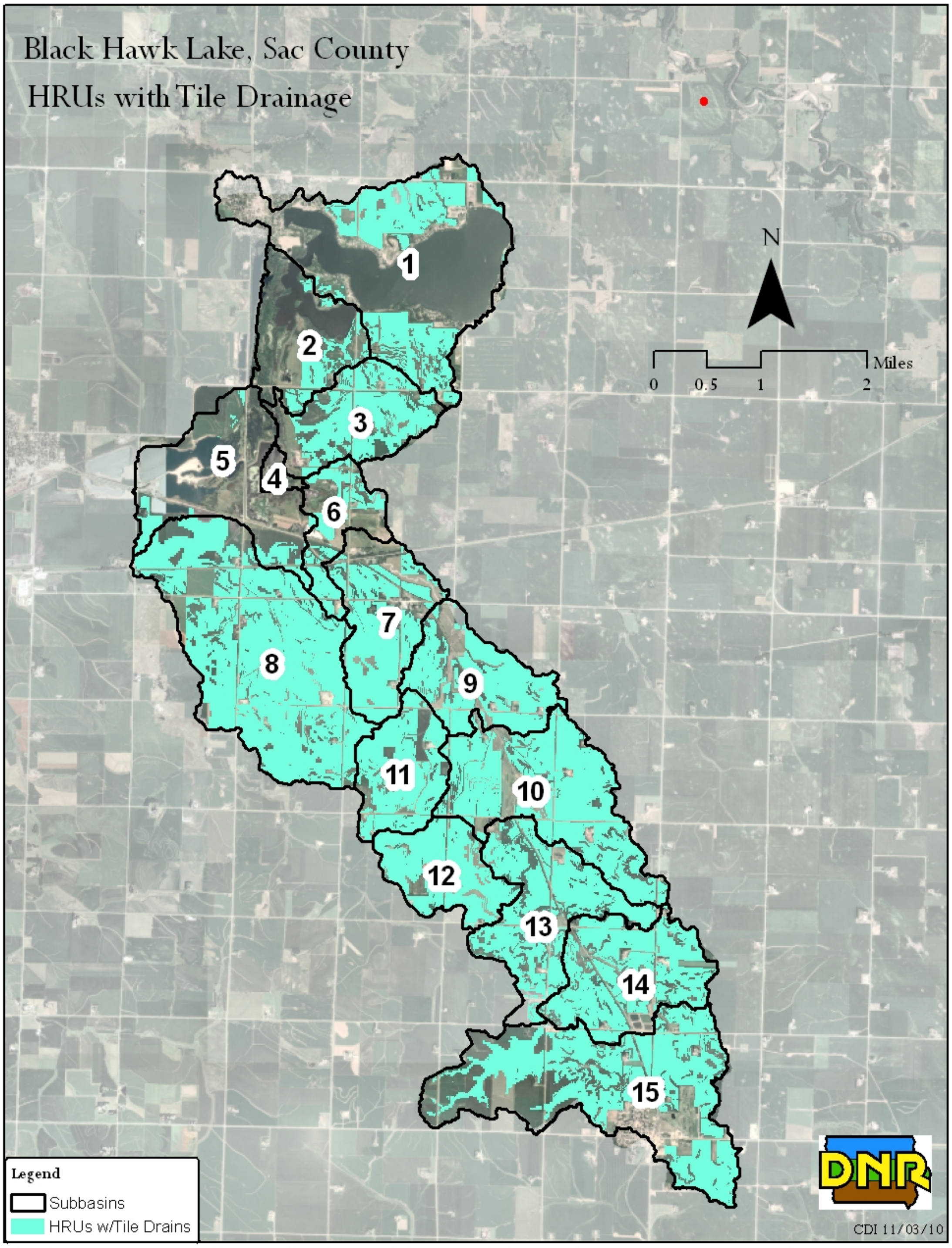

Figure D-4. HRUs with tile drainage in the Black Hawk Lake SWAT model.

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