Water Quality Improvement Plan for

Lake Geode

Henry County, Iowa

Total Maximum Daily Load
for pH and Indicator Bacteria (*E. coli*)

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Watershed Improvement Section
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General Report Summary

What is the purpose of this report?

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

What's wrong with Lake Geode?

Lake Geode is not supporting two of the intended uses of the lake: primary contact recreation, Class A1; and aquatic life for lakes and wetlands, or Class B(LW). Primary contact recreation includes activities that involve full body contact with the water such as swimming, wading, and water skiing. This use is not supported due to high levels of potentially harmful bacteria and viruses (also called pathogens), and due to high pH levels. High pH in lakes and streams is usually associated with excess nutrients such as nitrogen and phosphorus in the water column. Aquatic life support is the ability of a waterbody to support and sustain a healthy population of aquatic organisms, and is also impaired by high pH in Lake Geode.

What is causing the problem?

Pollutants that affect water quality, such as bacteria, sediment, and nutrients, can originate from point or nonpoint sources, or a combination of both. Point sources of pollution are easily identified sources that enter a stream or lake at a distinct location, such as a wastewater treatment outfall. Nonpoint sources of pollution are discharged in a more indirect and diffuse manner, and are often more difficult to locate and quantify. Nonpoint source pollution is usually carried with rainfall or snowmelt over the land surface and into a nearby lake or stream. The area of land that drains to a lake or stream is called a watershed. Watershed runoff often carries pollutants with it that can degrade water quality. There are no permitted point sources of pollution in the Lake Geode watershed. Therefore, bacteria and nutrients are generated by nonpoint sources including wildlife, livestock, pets, and humans that live, work, and play in and around the lake.

What can be done to improve Lake Geode?

To improve the water quality and overall health of Lake Geode, the amount of bacteria, sediment, and phosphorus entering the lake must be reduced. A combination of land and animal management practices must be implemented on public and private lands in the watershed to obtain required reductions. Eliminating livestock access to streams will significantly reduce bacteria loading to the lake. Preventing geese from residing at the beach will help reduce high levels of bacteria in the swimming area. Careful management and application of livestock manure is an important part of reducing the bacteria concentrations in Lake Geode. Ensuring septic systems throughout the watershed are functioning properly can also reduce bacteria inputs.

The measures described above for reducing bacteria transport to the lake will help reduce phosphorus loading as well. High phosphorus loading contributes to excess aquatic plant growth, which can elevate the pH of the lake. Improvement of agricultural tillage practices, construction of sediment basins, and addressing gully erosion in the wooded areas of Geode State Park will also help reduce sediment and phosphorus loading to the lake, thereby reducing pH levels.

Who is responsible for a cleaner Lake Geode?

Everyone who lives, works, or plays in the Lake Geode watershed has a role in water quality improvement. Because there are no regulated point sources in the watershed, voluntary management of land and animals will be required to see positive results. Much of the land draining to the lake is in agricultural production, and financial assistance is often available from government agencies to individual landowners willing to adopt best management practices (BMPs). Interested homeowners can have their septic systems inspected to ensure they function properly. The Iowa Department of Natural Resources (IDNR) has assessed the gullies in Geode State Park and will be implementing BMPs to reduce sediment and nutrient loading from this source of erosion. Improving water quality in Lake Geode will require a collaborative effort of citizens and agencies with a genuine interest in protecting the lake now and into the future.

Technical Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Lake Geode, Waterbody ID IA 03-SKU-00650-L_0, located in Section 36, T70N, R5W, 4 miles southwest of Danville in Henry County, with a small area in Des Moines County. *(NOTE: Lake Geode has historically been called “Geode Lake.” For the purpose of this TMDL, the more commonly used name, Lake Geode, is used throughout)*
Surface water classification and designated uses:	A1 – Primary contact recreation B(LW) – Aquatic life (lakes/wetlands) C – Drinking water supply HH – Human health (fish consumption)
Impaired beneficial uses:	A1 – Primary contact recreation B(LW) – Aquatic life (lakes/wetlands)
TMDL priority level:	High
Identification of the pollutants and applicable water quality standards (WQS):	**pH** – Exceeds the Class A1 and Class B(LW) maximum criterion of 9.0 Indicator bacteria (***E. coli***) – *E. coli* concentrations exceed the Class A1 criteria of single-sample maximum = 235 colony forming units per 100 milliliters (cfu/100 mL) and geometric mean (5 samples in 30 days) = 126 cfu/100 mL. These standards apply only during the recreation season (March 15 to November 15).
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of WQS:	The **pH** impairment is attributed to total phosphorus (TP) load. The allowable average annual TP load = 8,576 lbs/year; the maximum daily TP load = 111 lbs/day

Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of WQS (continued):	***E. coli*** are expressed as a concentration of bacterial colonies. This concentration, rather than the mass load, is most relevant to human health. Therefore the TMDL loads are based on the WQS listed above. The allowable daily median load is 1.68E+11 cfu/day, which accounts for dry to normal conditions. The maximum daily load is 2.95E+11 cfu/day and is based on the 95th percentile load to reflect wet to high-flow conditions.
Quantification of the amount or degree by which the current pollutant loads in the waterbody, including the pollutants from upstream sources that are being accounted for as background loading, deviate from the pollutant loads needed to attain and maintain WQS:	To meet the **pH** criterion, the TP load must be reduced by 39.8 percent. To meet the ***E. coli*** WQS, the median daily *E. coli* load must be reduced by 93.8 percent, and the maximum daily load must be reduced by 93.5 percent.
Identification of pollution source categories:	There are no permitted point sources of phosphorus in the watershed. Nonpoint sources of phosphorus, which are contributing to high **pH** levels, include livestock manure application, cattle in streams, livestock grazing, geese, other wildlife, septic systems, phosphorus fertilizer, sheet and rill erosion, and gully erosion. Livestock manure application, cattle in streams, livestock grazing, geese, other wildlife, and septic systems also contribute ***E. coli*** pollution to Lake Geode.
Wasteload allocations (WLAs) for pollutants from point sources:	Because there are no permitted point sources, the sum of WLAs for both the pH and *E. coli* TMDLs is zero.
Load allocations (LAs) for pollutants from nonpoint sources:	The **pH** TMDL includes a total LA for TP. The allowable average annual TP LA is 7,718 lbs/year, and the allowable maximum daily LA is 100 lbs/day.

Load allocations (LAs) for pollutants from nonpoint sources (continued):	The LA for the ***E. coli*** TMDL is based on the applicable WQS for the lake's designated uses. The median daily LA is 1.51E+11 cfu/day, and the maximum daily LA is 2.66E+11 cfu/day.
A margin of safety (MOS):	An explicit MOS of 10 percent is used for both the pH and *E. coli* TMDL calculations.
Consideration of seasonal variation:	The **pH** TMDL is based on annual TP loading. Although critical TP loads and pH increases both generally occur during the growing season, long-term annual TP loads must be controlled.
Consideration of seasonal variation (continued):	The ***E. coli*** TMDL is based on the primary contact recreation season, which runs from March 15 to November 15. Both dry to normal and wet to high-flow conditions are considered.
Allowance for reasonably foreseeable increases in pollutant loads:	Because there are no urban areas in the watershed, no permitted point source dischargers, and significant land use change is unlikely, there is no allowance for reasonably foreseeable increases in pollutant loads.
Implementation plan:	An implementation plan is outlined in Section 5 of this Water Quality Improvement Plan. Phosphorus loading and the **pH** impairment will be addressed through a variety of voluntary land use, livestock, manure application, and wildlife management strategies. The reduction of ***E. coli*** concentrations will be accomplished using similar management practices, which are also discussed in Section 5.

1. Introduction

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

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

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

One purpose of this Water Quality Improvement Plan for Lake Geode, located in Henry and Des Moines Counties in southeast Iowa, is to serve as the TMDL for two impairments of the lake. The second purpose of the plan is to provide local stakeholders and watershed managers with a tool to promote awareness of water quality issues, assist the development of funding applications and a comprehensive watershed management plan, and guide water quality improvement projects. The first parameter addressed is pH, which is impairing primary contact recreation and aquatic life support in Lake Geode. The second pollutant addressed is indicator bacteria, specifically *Escherichia coli (E. coli)*, which is also preventing Lake Geode from meeting its primary contact recreation designated use. This plan outlines a phased approach to TMDL development and implementation. A phased approach is helpful when the origin, interaction, and quantification of pollutants contributing to water quality problems are complex and difficult to fully understand and predict.

Each TMDL includes an assessment of the existing pollutant loads to the lake and a determination of how much of a specific pollutant the lake can tolerate and still provide for its designated uses. The allowable amount of pollutant that the lake can receive is the loading capacity, also called the TMDL target load. The plan also includes a description of potential solutions to the water quality problems. This group of solutions is more precisely defined as a system of best management practices (BMPs) that will improve water quality in Lake Geode, with the ultimate goal of meeting water quality standards and supporting designated uses. These BMPs are outlined in the implementation plan in Section 5. A water quality monitoring plan designed to help assess water quality improvement and BMP effectiveness is provided in Section 6.

This Water Quality Improvement Plan will be of little value to real water quality improvement unless watershed improvement activities and BMPs are implemented. This will require the active engagement of local stakeholders and the collaboration of several state and local agencies. In addition to implementation of BMPs, completion of the TMDL must be followed by several other actions, including collection of water quality data as part of the ongoing monitoring plan, evaluation of collected data, and modification of the TMDL targets and/or implementation plan (if necessary). Monitoring is a crucial element to assess the attainment of water quality standards and designated uses, to determine if water quality is improving, degrading, or remaining unchanged, and to assess the effectiveness of implementation activities and the possible need for additional BMPs.

2. Description and History of Lake Geode

Lake Geode is a 174-acre lake located in Henry and Des Moines Counties in southeast Iowa. The lake is nestled within scenic Geode State Park, and is the 1,640-acre park's prime attraction. Lake Geode is a man-made reservoir constructed in the 1950s, is well-known for excellent fishing opportunities, and offers significant economic value to the region. The Iowa Department of Natural Resources (IDNR) identified Lake Geode as a major recreational area based on factors such as visitation rates, campground use, and population within a 50-mile radius of the lake. The Center for Agricultural and Rural Development (CARD) at Iowa State University estimates that between 2002 and 2005, Lake Geode averaged over 99,700 annual visitors. Those visitors spent an average of $7.35 million per year, which supported 146 jobs and $1.97 million of labor income in the region (CARD, 2008). Table 1 lists some of the general characteristics of Lake Geode and its watershed.

Table 1. Lake Geode watershed and lake characteristics.

IDNR Waterbody ID	IA 03-SKU-00650-L_0
12 Digit Hydrologic Unit Code (HUC)	070801071004
12 Digit HUC Name	Cedar Creek – Skunk River
Location	Henry/Des Moines Counties, S36, T70N, R5W
Latitude	40.8
Longitude	-91.4
Designated Uses	A1 – Primary contact recreation B(LW) – Aquatic life (lakes and wetlands) C – Drinking water supply HH – Human health (fish consumption)
Tributaries	Cedar Creek, multiple unnamed tributaries
Receiving Waterbody	Cedar Creek
Lake Surface Area	174 acres
Maximum Depth	44 feet
Mean Depth	21.9 feet
Lake Volume	3,756.9 acre-feet
Length of Shoreline	5.97 miles (31,528 feet)
Watershed Area (includes lake)	10,328 acres
Watershed:Lake Ratio	59:1
Lake Residence Time	98 days (estimated)

2.1. Lake Geode

Hydrology. Lake Geode is a man-made reservoir created by an earthen embankment that impounds its primary tributary, Cedar Creek. The lake's hydrology is driven primarily by surface water inflows from Cedar Creek and several smaller tributaries that either drain to Cedar Creek or directly to the lake. The Mt. Pleasant weather station is approximately 12 miles from Lake Geode, and reports an average annual precipitation of 33.7 inches per year between 1996 and 2007 (IEM, 2008). Precipitation events and the subsequent runoff and interflow to streams have the most influence on water quality and water level fluctuations in Lake Geode. However, the deep reservoir does have a groundwater connection, which can influence both water quality and reservoir hydrology under certain conditions. Based on precipitation inputs and hydrologic simulations, the average residence time in Lake Geode is 98 days.

Morphometry & Substrate. The surface area of Lake Geode is 174 acres, according to the bathymetry map prepared by IDNR in 2006. This differs from the 189-acre surface area reported in the 305(b) Water Quality Assessment Database, which was developed using an older bathymetry study. The lake is a reservoir impoundment with an elongated shape, as shown in Figure 1. The length of water that can be acted upon by wind in a lake is called the fetch. The relatively large fetch and north-south orientation of Lake Geode indicates the lake is highly impacted by wind. This can cause periods of high wave height and the possibility of water column mixing, even during periods of stratification. The shoreline development index of the lake is calculated to be 3.10 (Bachman et al., 1993). Values greater than 1.0 suggest the shoreline is highly dissected and indicative of a high degree of watershed influence (Dodds, 2000).

As indicated by its name, Geode State Park and Lake Geode have a unique geologic feature: the presence of rare rock formations called geodes. Geodes can be described as rocks with internal holes or cavities filled with crystal formations. Geodes are formed when dissolved silica carried by groundwater through cavities in sedimentary rock precipitates or crystallizes. The presence of geodes in the area indicates that limestone or related sedimentary rocks are prevalent. Limestone is not unique to Lake Geode, but the presence of geodes is relatively rare. There is no clear indication that the presence of geodes has a significant impact on water quality in Lake Geode.

The primary substrate at the bottom of Lake Geode is sand, silt, and clay deposited over a period of years. When floodwater enters the lake, the velocity of the water decreases as the water spreads out and is no longer able to carry sand and silt. This has created large deposits of sand and silt at the north end of the lake. Clay also drops from the water column to the lake bottom after a longer settling time. The deposition of these materials has resulted in Lake Geode losing surface area in areas where tributaries enter the lake, and losing depth. In 1980, the maximum depth was reported as 52.0 feet, with a mean depth of 24.0 feet (Bachmann, et al., 1980). By 2006, the maximum depth had decreased to 44.0 feet, and the mean depth to 21.9 feet. Surface area of the lake had decreased from 189 to 174 acres (IDNR, 2006). Although some of the discrepancy in surface area may be due in part to new data collection methods and Geographical Information Systems (GIS) technology, it is well-documented that the lake has lost depth and that large sediment deposits are present at the north end of the reservoir.

2.2. The Lake Geode Watershed

The drainage area to Lake Geode is a 10,328-acre watershed, including the surface area of the lake. The large lake to watershed ratio of nearly 60 to 1 indicates that rainfall runoff has a large potential impact on water quality.

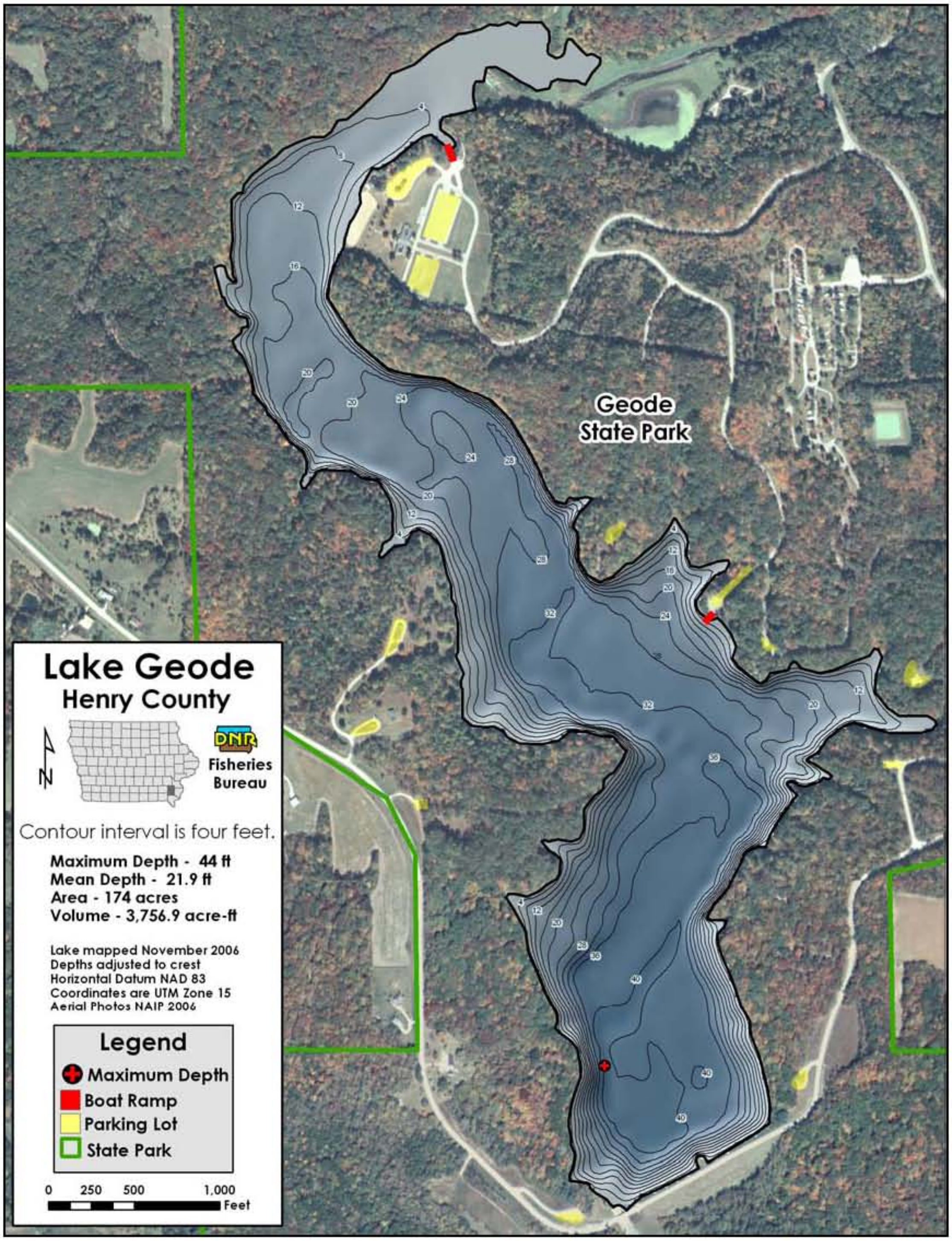


Figure 1. Aerial photo and bathymetry of Lake Geode.

The watershed is relatively long and narrow, which causes runoff events to have a larger time of concentration. Therefore, discharges from storm events tend to have longer duration and lower peak discharge than more rounded watersheds of a similar size. A dam was built on Cedar Creek, the main stream in the watershed, in the 1950s. This dam created the impoundment that is now Lake Geode. Several smaller tributaries streams also drain to the lake, either directly or via Cedar Creek.

Land Use. The predominant land use is row crop agriculture, most of which is in a corn-soybean rotation. Upwards of 75 percent of the watershed appears to be tile drained, based on the location of tile outlets. Conservation Reserve Program (CRP) ground accounts for less than four percent of the area typically in crop production. Other land uses include grazed pastures, farmsteads, timber, grasslands, and wildlife area. Wildlife area was treated as a mix of grass and timber. Forest, or timber, is concentrated along streams and in the 1,640-acre Geode State Park, which encompasses the lake. Table 2 reports the generalized land uses by acre and by percentage of watershed. Figure 2 shows a more detailed classification of land uses distributed throughout the watershed.

Table 2. Lake Geode watershed generalized land use areas.

General Land Use	Description	Area (Acres)	% of Watershed
Row Crops	corn, beans, oats, alfalfa, CRP	6,527	63.2
Grazed Lands	pasture, grazed timber	201	1.9
Farmsteads/Roads	homes, yards, roads, highways	865	8.4
Conservation Areas	forest, grassland, wildlife areas	2,557	24.8
Water	Lake Geode, wetlands, ponds	178	1.7
Total		**10,328**	**100**

Soils, climate, and topography. The largest soil association in the watershed is the Weller-Pershing-Grundy association, which includes a majority of the drainage area in Des Moines County. The Weller-Lindley-Keswick is the primary soil association in the Henry County portion of the watershed. It should be noted that soil surveys for Henry and Des Moines Counties were completed separately. The two soil associations mentioned above are adjacent to each other, and although they have different names, the soil properties are similar. Soils in these associations, other predominant soils in the watershed, and a brief summary of their properties are reported in Table 3.

Table 3. Predominant soils in the Lake Geode watershed.

Soil Name	Description	Typical Slopes (%)	Soil pH
Weller	silt loam, moderately eroded, moderately well drained	2-9	4.5-7.3
Pershing	silt loam, moderately eroded, somewhat poorly drained	2-9	4.5-7.3
Grundy	silty clay loam, somewhat poorly drained	1-4	5.1-7.3
Lindley	loam, moderately eroded, well drained	9-18	4.5-7.3
Keswick	loam, moderately eroded, well drained	9-14	4.5-7.3
Otley	silty clay loam, moderately well drained	2-5	5.1-7.3
Nira	silty clay loam, moderately eroded, moderately well drained	2-9	5.6-7.3

Source: NRCS, 2008

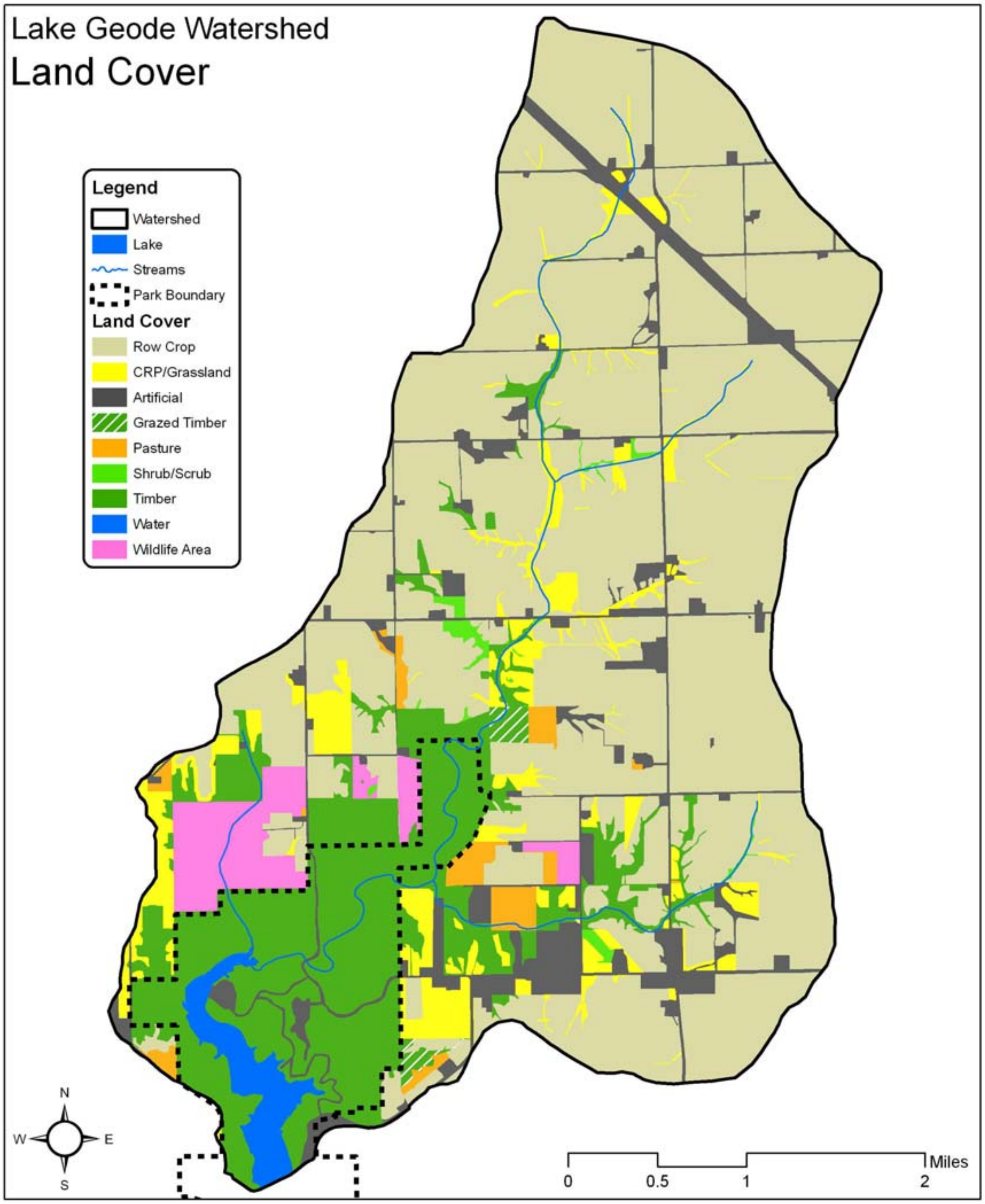


Figure 2. Detailed land cover distribution map for Lake Geode watershed.

3. Total Maximum Daily Load (TMDL) for pH

A Total Maximum Daily Load (TMDL) is required for Lake Geode by the Federal Clean Water Act. High levels of pH in Lake Geode periodically exceed water quality standards (WQS) and impair two of the lake's designated uses. High pH in the lake is associated with photosynthesis by algae, for which total phosphorus (TP) is the limiting nutrient. This section of the document will quantify the maximum amount of TP the lake can assimilate without violating the state's WQS for pH.

3.1. Problem Identification

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

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

The 2006 Section 305(b) Water Quality Assessment Report states that primary contact recreation in Lake Geode is "not supported" due to high levels of indicator bacteria, specifically *Escherichia coli (E. coli)*, that violate the state WQS. Primary contact recreation is also impaired due to violations of the WQS by high pH levels. In addition, high pH has resulted in the warmwater aquatic life designated use to be assessed as impaired ("partially supporting"). This section details the development of the TMDL for pH, and the *E. coli* violations of the WQS are addressed in the TMDL for Indicator Bacteria in Section 4. The 2006 305(b) report can be accessed at http://wqm.igsb.uiowa.edu/wqa/305b.html.

Applicable water quality standards. The State of Iowa Water Quality Standards are published in the Iowa Administrative Code (IAC), Environmental Protection Rule 567, Chapter 61. According to the IAC, the WQS for pH in Class A waters is as follows: "The pH shall not be less than 6.5 nor greater than 9.0…" The IAC specifies the same pH criteria for Class B waters. Therefore, to meet WQS and protect the primary contact recreation and aquatic life uses, the pH in Lake Geode must remain between 6.5 and 9.0. The WQS can be accessed on the web at http://www.iowadnr.com/water/standards/files/chapter61.pdf.

Problem statement. The 2006 305(b) report assesses water quality in Lake Geode as follows:

> *"…SUMMARY: The Class A (primary contact recreation uses) are assessed (monitored) as "not supported" due to (1) levels of indicator bacteria that exceed state criteria and (2) to high levels of pH. The Class B(LW) aquatic life uses are assessed (monitored) as "partially supported" also due to high levels of pH. The Class C (drinking water) uses remain "not assessed" due to a lack of monitoring*

> *information. Fish consumption uses are assessed (evaluated) as "fully supported" based on results of U.S. [Environmental Protection Agency] EPA/IDNR fish contaminant (RAFT) monitoring in 1996. The sources of data for this assessment include (1) results of the statewide survey of Iowa lakes sponsored by IDNR and conducted by Iowa State University (ISU) from 2000 through 2004, (2) IDNR/[University of Iowa Hygienic Laboratory] UHL beach monitoring from 2002 through 2004, (3) surveys by IDNR Fisheries Bureau, (4) information on plankton communities collected at Iowa lakes from 2000 through 2005 as part of the ISU lake survey, and (5) results of U.S. EPA / IDNR fish tissue monitoring in 1996…"*

The 305(b) assessment continues with the following explanation of the pH problem:

> *"…The Class B(LW) aquatic life uses are assessed as "fully supported" based on information from the DNR Fisheries Bureau. Results of chemical water quality monitoring conducted as part of the ISU lake survey, however, suggest an impairment of the Class B(LW) uses. The ISU lake survey data show no violations of the Class B(LW) criteria for dissolved oxygen in the 14 samples collected during summers of 2000 through 2004. Four of 15 samples, however, exceeded the Class B(LW) criterion for pH ([sample] maximum = 9.5; [sample] minimum = 7.9 pH units). Based on IDNR's assessment methodology, these results suggest that significantly more than 10 percent of the samples exceed Iowa's pH criteria. Thus, these results suggest an impairment (partial support/monitored) of the Class A and Class B(LW) uses of this lake…"*

Data sources. The primary sources of data for the problem identification in this TMDL are the 2006 305(b) report, and water quality data collected by IDNR, ISU, and UHL. The 305(b) report cites the following data sources for the water quality assessment:

- Water quality data collected by UHL from 2005-2007 as part of the Ambient Lake Monitoring Program
- Results of statewide survey of Iowa lakes sponsored by IDNR and conducted by ISU from 2000 to 2007
- IDNR and UHL beach monitoring from 2002 through 2004
- Surveys by the IDNR Fisheries Bureau
- Information on plankton communities collected at Iowa lakes from 2000 through 2005 as part of the ISU lake survey, and
- Results of the U.S. Environmental Protection Agency (EPA) and IDNR fish tissue monitoring in 1996.

The sources outlined above, in addition to precipitation data from the Iowa Environmental Mesonet (IEM), were used to develop this TMDL. Tables that report the water quality data from these sources are provided in Appendix C.

Interpreting Lake Geode data. Primary contact recreation and aquatic life are impaired due to high pH levels. Data collected by ISU as part of the statewide survey of Iowa lakes reveal more than 10 percent of water samples/measurements exceeded the applicable WQS criterion of pH not greater than 9.0. Data from UHL also report violations of WQS. Therefore Lake Geode was assessed as not fully supporting its designated uses, listed as impaired on the 303(d) list, and required a TMDL to address the water quality problems. Figure 3 illustrates both ISU and UHL pH measurements and the applicable water quality criteria. Data points that lie above the maximum criterion of 9.0, as indicated by the solid line, represent violations of the WQS.

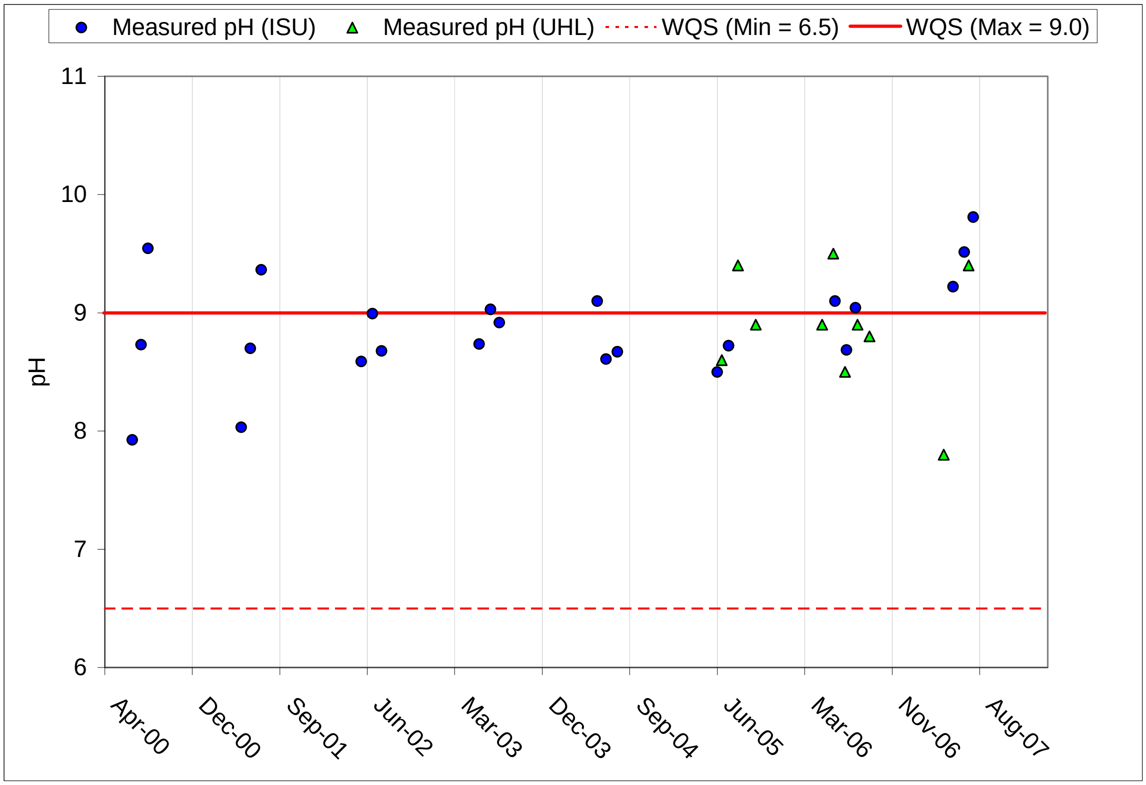


Figure 3. ISU and UHL pH data compared with applicable water quality criteria.

Carlson's trophic state index (TSI) was used to evaluate the relationships between TP, algae (chlorophyll-a), and transparency (Secchi depth) in Lake Geode. If the TSI values for the three parameters are the same, the relationships between the three are strong. If the TP TSI values are higher than chlorophyll TSI, it suggests there are limitations to algal growth besides phosphorus. Figure 4 illustrates each of the individual TSI values throughout the sampling period. The general trend is that TP and chlorophyll-a TSI values are higher than for Secchi depth. There are several dates for which the chlorophyll-a TSI value is significantly higher than for TP and Secchi depth, which suggests that even though overall water clarity is relatively good, periodic algal blooms do occur.

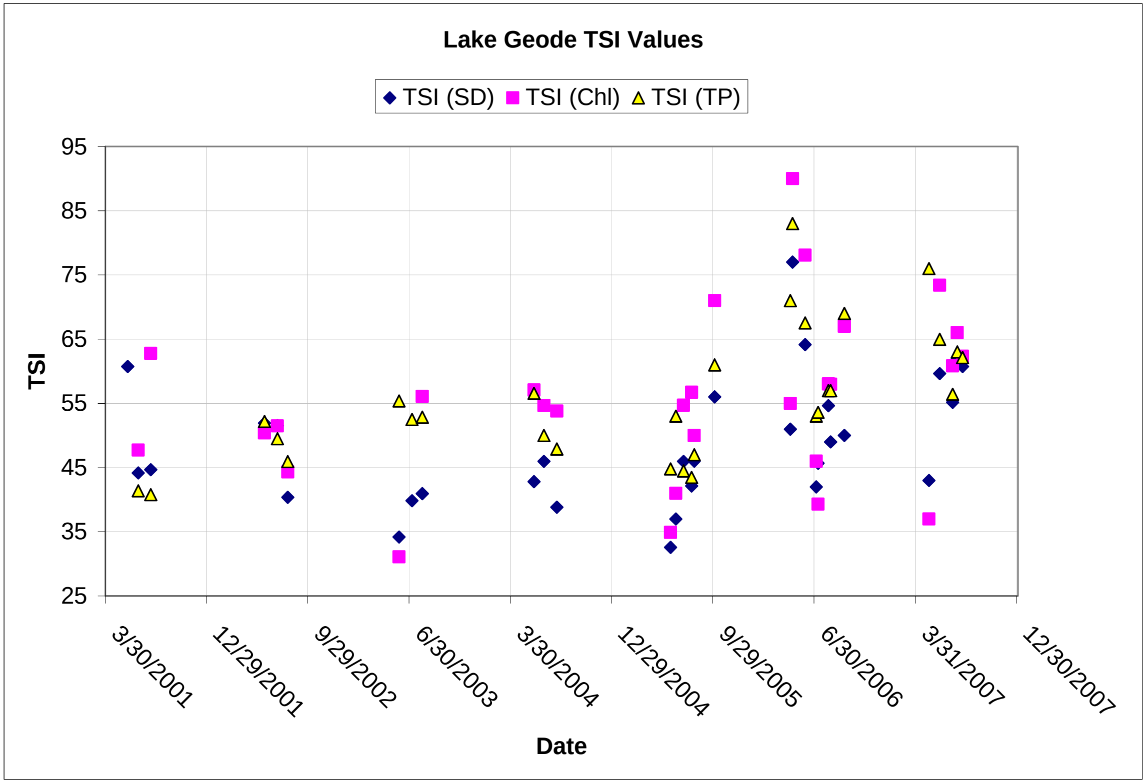


Figure 4. Lake Geode TSI values (2001-07 ISU and 2005-2007 UHL data sets).

Figures 5 and 6 illustrate a method for interpreting the meaning of the deviations between TSI values. The quadrant on the right side of the figure indicates the potential factors that may limit algal growth in a lake. A detailed description of this approach is available in *A Coordinator's Guide to Volunteer Lake Monitoring Methods* (Carlson and Simpson, 1996). If the deviation between the chlorophyll-a TSI and TP TSI (Chl TSI minus TP TSI) is less than zero, the data point will fall below the X-axis, which suggests that phosphorus may not be limiting algal growth. Points above the X-axis would indicate that phosphorus is the limiting factor. Points to the left of the Y-axis (Chl TSI < SD TSI) represent conditions in which transparency is reduced by non-algal turbidity, whereas points to the right reflect situations in which transparency is greater than chlorophyll-a levels would suggest, meaning that large particles may predominate.

The quadrant on the left of Figure 5 plots the deviations of TSI values computed using median concentration and Secchi depth data for Lake Geode from the combined ISU and UHL data. Figure 6 illustrates the deviations using mean data values. From the TSI data, it appears TP is the limiting nutrient, but larger algal particles may also play a role in light limitation (i.e., reduced transparency). TSI values for Lake Geode are reported in Table 4. The fact that the TSI for mean chlorophyll-a concentrations is much higher than for median concentrations suggests algal blooms may be a problem, even though chlorophyll-a levels are normally relatively low. Because the water quality model used for this TMDL simulates average concentrations, mean concentration data was emphasized in the analysis.

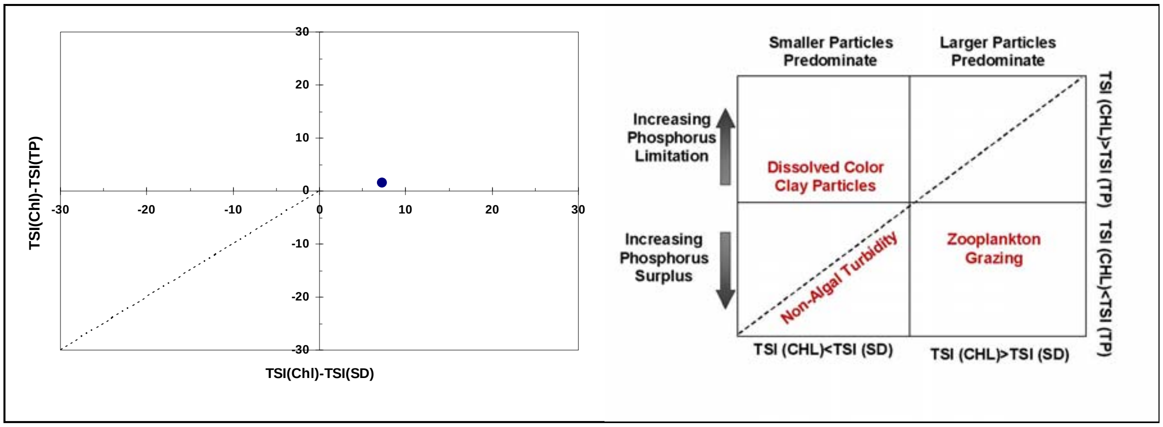


Figure 5. TSI deviations based on median concentrations and Secchi depth.

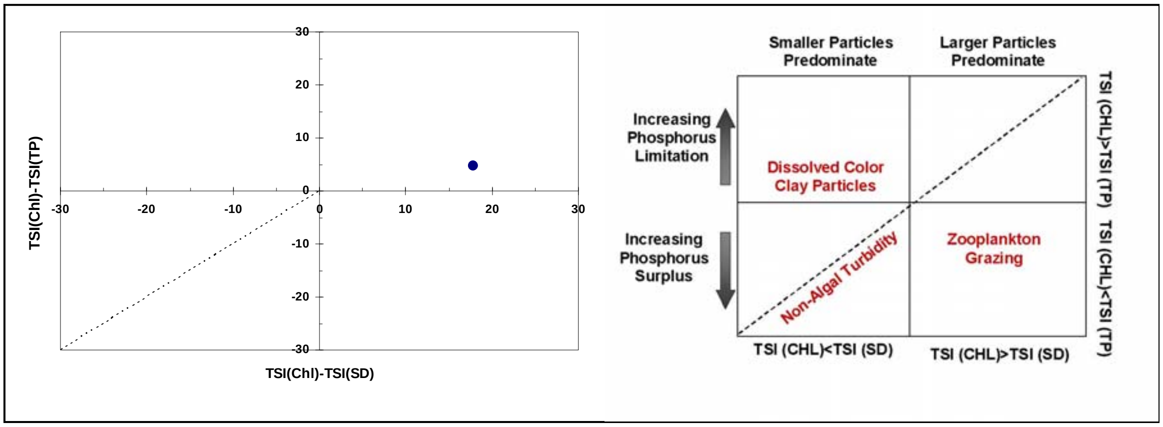


Figure 6. TSI deviations based on mean concentrations and Secchi depth.

Table 4. TSI values using mean and median concentrations.

	TSI (SD)	TSI (Chl)	TSI (TP)
Median Values	47	55	53
Mean Values	47	65	60

Table 5 describes likely attributes related to primary contact recreation and aquatic life for lakes that fall into one of several ranges in TSI values. Although Lake Geode has relatively good water clarity compared to other Iowa lakes, occasionally high levels of algae and phosphorus pose potential limitations to primary contact recreation and aquatic life support based on TSI values for mean chlorophyll-a and mean total phosphorus. This is consistent with the 305(b) assessment, which determined that these uses are not fully supported in Lake Geode.

Table 5. Implications of TSI values on lake attributes.

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

Note: Modified from Carlson and Simpson (1996).

3.2. TMDL Target

General description of the pollutant. The water quality parameter causing the impairment is pH, which is not a pollutant. Rather, pH is an expression of the concentration of hydrogen ions present. More simply stated, the pH of a waterbody is a measure of its acidity or alkalinity. The value of pH is reported on a logarithmic scale and ranges between 1 and 14. Each change of one pH unit represents a 10-fold change in hydrogen ion activity. Low values of pH are associated with acidic solutions. Conversely, high pH is representative of basic, or alkaline, solutions. Neutral solutions, those that are neither acidic nor alkaline, will have a pH near 7.

The pH of a waterbody is one of the primary indicators used to evaluate its overall water quality and potential for various designated uses. In their text book entitled Water Quality – The Prevention, Identification, and Management of Diffuse Pollution, Novotny and Olem (1994) offer several reasons why pH is so important in assessing surface water quality, including:

- dramatic pH fluctuation or extreme values can cause fish kills;
- many of the chemical/physical/biological reactions that affect fate and transport of pollutants in surface water are driven by and/or are sensitive to pH;
- almost all aquatic life is able to tolerate only a limited range of pH conditions, and most prefer near-neutral conditions; and
- the toxicity of certain metals and other compounds found in surface water is affected by pH.

Notice that several of the above examples relate directly to the aquatic life designated use.

There are a number processes occurring in Lake Geode that will have an impact on, and be affected by, pH. It is not possible to simply reduce the amount of pH that enters the lake to lower pH levels and meet water quality standards. The pH in Lake Geode is dynamic, and depends on other physical, chemical, and biological properties of the water column, surrounding soils, lake-bottom sediments, and the atmosphere and climate. When measured continuously, pH values of a lake often vary from one hour to the next and in some cases change even more quickly. To address the pH problem in Lake Geode, the lake must be understood as a complex system, and those factors most likely causing elevated pH values must be evaluated.

Of the many processes in a lake that affect pH, there are at least two phenomena that should be investigated in order to better understand pH dynamics. The first is the carbonate system, which is sometimes called bicarbonate equilibrium. The second is photosynthesis, also referred to as primary production or the production/respiration cycle (Dodds, 2000). A discussion of the carbonate system, photosynthesis, and data analysis and modeling methodology utilized in the development of the pH TMDL is provided in Appendix D. The analysis revealed that photosynthesis appears to have the largest impact on pH levels in Lake Geode.

Selection of environmental conditions. Aquatic plants, like other plants, have the ability to use solar energy and an inorganic (i.e., nonliving) food source to grow. This process is called production, or more specifically, photosynthesis. During photosynthesis, plants take up food (carbon dioxide, nutrients, and trace elements), build organic matter and store up energy, and release oxygen to the water column. The consumption of carbon dioxide results in an increase in the pH of the surrounding water, and the release of oxygen often causes the water to become saturated with dissolved oxygen.

Water quality data show that pH in Lake Geode is positively correlated to the amount of algae, as represented by a green pigment present in algal cells called chlorophyll-a. This relationship is based on both ISU and UHL monitoring data from 2000 through 2007 and is illustrated in Figure 7. Because phosphorus is the limiting nutrient for algal growth in Lake Geode, the TMDL target is based on the amount of phosphorus the lake can assimilate without causing algal blooms and subsequent pH violations of the WQS. The critical condition for the occurrence of algal blooms and pH violations is the growing season (April through September). However, phosphorus accumulates in reservoirs over time, so annual average TP loading must be controlled and is most relevant to long-term water quality improvement. A detailed explanation of the data, underlying assumptions, and modeling used to develop the TMDL phosphorus target is provided in Appendix D.

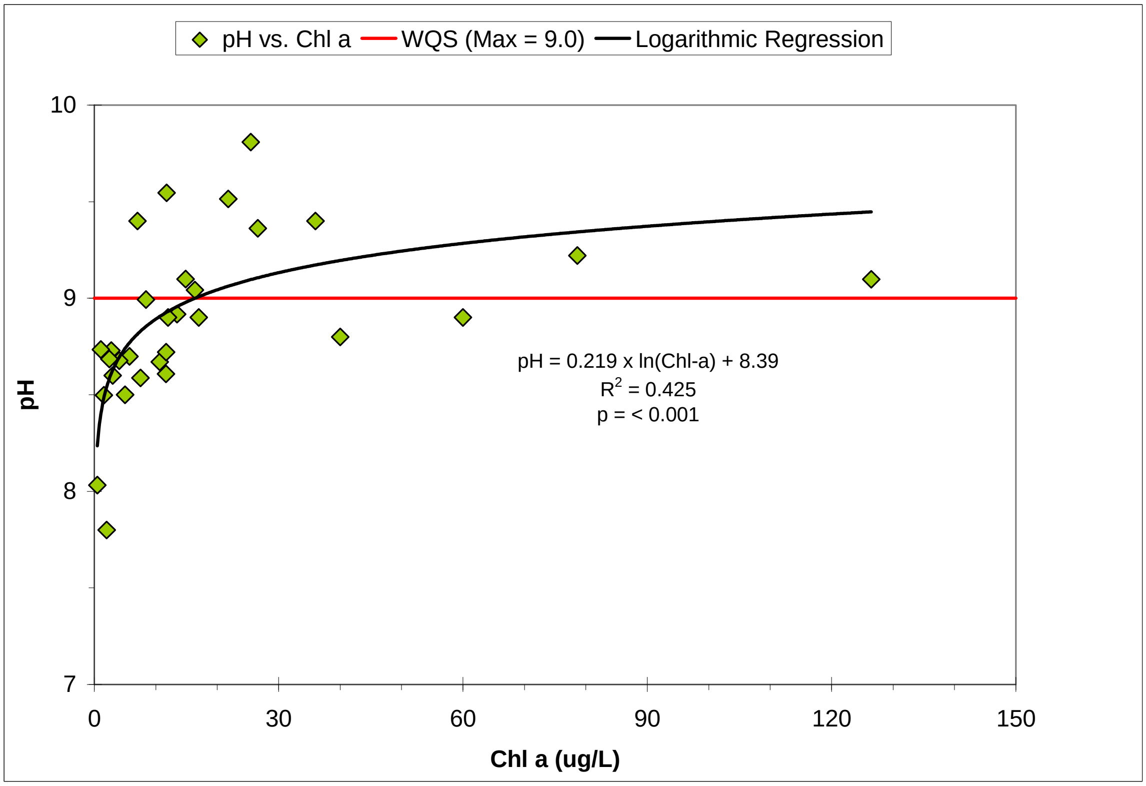


Figure 7. Regression of measured pH (ISU and UHL) versus chlorophyll-a.

Waterbody pollutant loading capacity (TMDL). The maximum allowable chlorophyll-a concentration in Lake Geode was developed using the statistical regression described above. The target in-lake chlorophyll-a concentration is established as a mean of 16.5 micrograms per liter (ug/L). Maintaining in-lake concentrations at or below this level should limit algae blooms that cause pH violations of the WQS. This threshold was based on the previously described relationship between pH and chlorophyll-a, and also the historical water quality data set, which includes a wide range of water conditions that affect the variability of observed pH. The allowable in-lake chlorophyll-a concentration was translated to the TP loading capacity by simulating in-lake water quality using the BATHTUB model. BATHTUB is a steady-state water quality model that performs empirical eutrophication simulations in lakes and reservoirs (Walker, 1999).

The annual TP loading rate is a key input for the BATHTUB model, and is calculated internally from annual flow and average concentration input parameters. The annual TP load was adjusted iteratively by changing the average TP concentration input until BATHTUB simulations produced the allowable in-lake chlorophyll-a target concentration of 16.5 ug/L. The maximum TP load at which the target concentration is obtained is the loading capacity. The methodology used to calculate the loading capacity is described in more detail in Appendix D.

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

05-5015, (April 25, 2006) and Implications for NPDES Permits. In the context of the memorandum, EPA

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

Per the EPA recommendations, the loading capacity of Lake Geode for TP is expressed as both a maximum annual average and a daily maximum load. The annual average load is more applicable to the assessment of in-lake water quality and water quality improvement actions, while the daily maximum load expression satisfies the legal uncertainty addressed in the EPA memorandum. The average annual loading capacity is 8,576 pounds per year (lbs/yr).

The maximum daily load was estimated from the annual average load using a statistical approach outlined in more detail in Appendix D. This approach uses a lognormal distribution to calculate the daily maximum from the long-term (e.g., annual) average load. The methodology for this approach is taken directly from a follow-up guidance document entitled *Options for Expressing Daily Loads in TMDLs* (EPA, 2007), which was issued shortly after the November 2006 memorandum cited previously. This methodology can also be found in EPA's 1991 *Technical Support Document for Water Quality Based Toxics Control*. Using the approach, the allowable maximum daily load (loading capacity) is calculated to be 111 lbs/day.

Decision criteria for water quality standards attainment. The criteria for attainment of the pH standard are clearly defined in the WQS. Ultimately, monitoring pH levels in Lake Geode, especially at small time intervals during the growing season, will identify whether or not the WQS is attained and the designated uses are supported. However, this TMDL attributes the cause of the pH violations to algal blooms, which are limited by phosphorus concentrations in the lake. Because there is some uncertainty regarding the relationships between pH, chlorophyll-a, and TP, all three parameters should be assessed to evaluate water quality trends and relationships. The State of Iowa does not currently have numeric water quality criteria for algae or phosphorus, but water quality analysis and modeling in this TMDL determined that maintaining a maximum annual average chlorophyll-a concentration of 16.5 ug/L should result in attainment of the WQS for pH.

3.3. Pollution Source Assessment

Existing load. Existing TP load to Lake Geode has not been monitored, therefore long-term simulations of loading were developed using the Generalized Watershed Loading Function (GWLF) model, within the BasinSim windows-based interface. GWLF has been used nationally for research and TMDL development, and is particularly useful for simulating sediment, nitrogen, and phosphorus loading from a mixed-use watershed. Key model inputs include parameters that are based on soil information, land use, and land practice management (Haith et al., 1996). GWLF includes the ability to simulate point sources, septic tanks, and manure applied to croplands, which are often important considerations in TMDL development.

Using GWLF, the existing annual average TP load to Lake Geode from April 2005 through March 2008 was estimated to be 14,235 lbs/yr, or 39 lbs/day. This period was selected for two primary reasons: annual GWLF simulations must begin on April 1 and end on March 31, and water quality monitoring data from UHL during the 2005-07 growing seasons were utilized in the calibration of the BATHTUB lake water quality model. The existing daily maximum load is 184 lbs/day. For consistency, the existing maximum daily load was estimated from the annual average load (GWLF output) using the same statistical approach described for the loading capacity in Section 3.2.

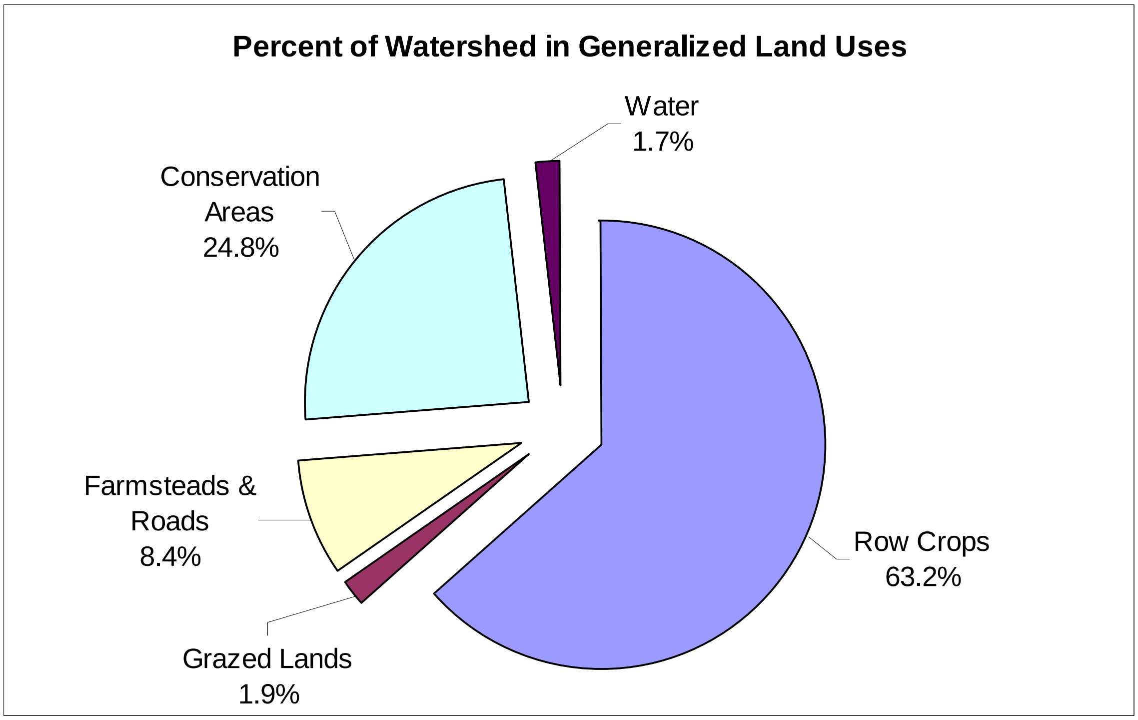
Departure from load capacity. The target TP load, also referred to as the load capacity, for Lake Geode is 8,576 lbs/yr (average annual) and 111 lbs/day (maximum daily). To meet the target loads, a reduction of 39.8 percent of the TP load is required. This is an aggressive goal, and will require that a comprehensive package of BMPs and other water quality improvement activities be implemented in the watershed. The implementation plan included in Section 5 describes recommended BMPs and outlines a preliminary implementation schedule.

Identification of pollutant sources. The existing TP load to Lake Geode stems from nonpoint sources of pollution. Table 6 reports existing TP loads from each source, as simulated using GWLF and 2005-07 climate data input. Figure 8 illustrates the percent of generalized land uses that make up the watershed, as well as the relative TP contributions from various sources. The largest source of TP is runoff from row crop agriculture, which contains phosphorus bound to sediment, and phosphorus in manure or synthetic fertilizer applied to cropland. Other nonpoint sources include runoff that contains manure from pasture or grazed timber, discharge from failing or inadequate septic systems, and livestock with access to the streams that flow into Lake Geode.

Table 6. Existing TP source loads simulated using GWLF.

TP Source (land uses and other inputs)	Descriptions and Assumptions	Existing Load (lb/yr)	% of TP Load
Row Crops	corn, beans, oats, alfalfa, CRP	10,316	72.5
Grazed Lands	pasture, grazed timber	301	2.1
Farmsteads/Roads	homes, yards, roads, highways	641	4.5
Conservation Areas	forest, grassland, wildlife areas	1,067	7.5
Septic Systems	119 septic systems, 30% contributing to lake	171	1.2
Geese	150 geese (Oct-Apr); 70 geese (May-Sep)	44	0.3
Groundwater	TP inputs based on land use	1,695	11.9
Total		**14,235**	**100.0**

Groundwater sources of TP are dissolved phosphorus (DP), and can result from synthetic fertilizer and transformations that occur in the soil as part of the phosphorus cycle. The GWLF model associates groundwater DP concentrations with land uses in the watershed. These input groundwater concentrations are available in the GWLF user manual, and parameterization is discussed in detail in Appendix D. The largest source of groundwater DP is from row crop land use.



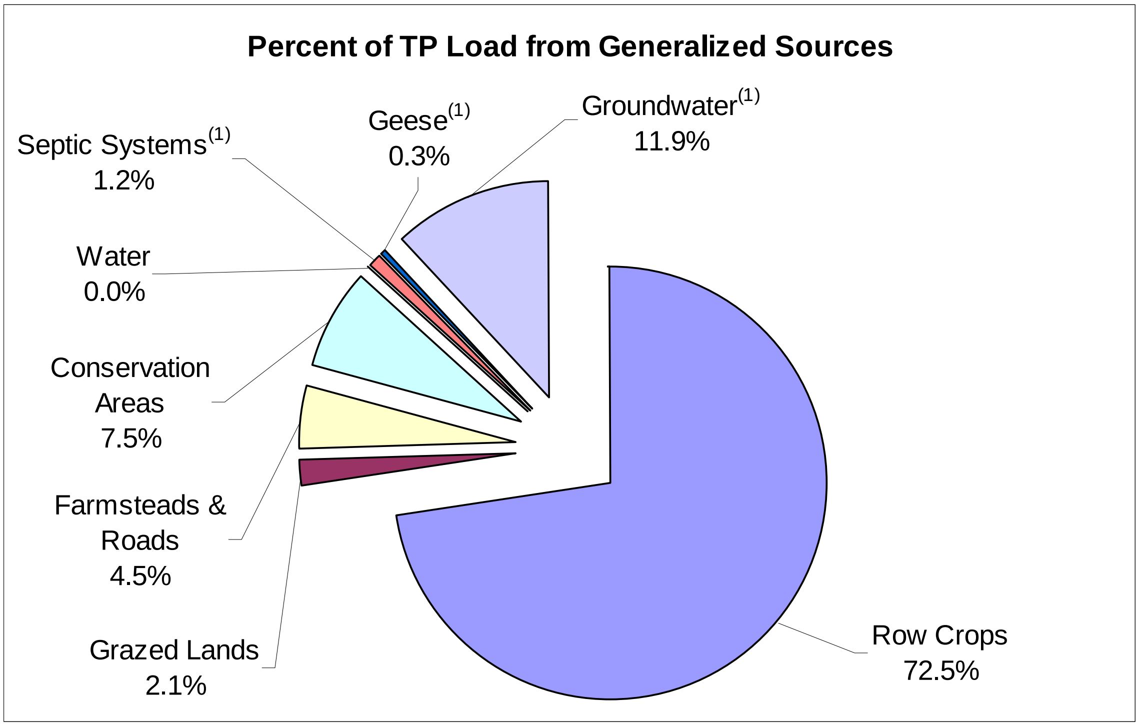


Figure 8. Percent of watershed in generalized land uses compared with relative TP load contributions. Note: (1) Indicates that TP source does not have an area associated with it.

There are 119 septic systems in the watershed, but only 45 of these systems are within a quarter mile of the nearest tributary stream or tile drain intake. Assuming that approximately 80 percent of septic systems are improperly designed or failing in some way results in 30 percent of all systems (36 of 119) contributing TP to the lake.

Erosion and sediment from gully erosion also contributes to the TP load, and is classified as a nonpoint source. Although the TP load from gully erosion was not explicitly quantified as part of this TMDL, it may comprise a large portion of the existing load. To account for gully erosion, conservative assumptions were made regarding sheet and rill erosion, especially from areas with row crop and forest land cover. BMPs to address gully erosion and resulting phosphorus loads are included in the implementation plan. A stream assessment has not been completed for Cedar Creek or other tributaries in the watershed.

Many Iowa lakes have an internal, or in-lake, source of phosphorus in addition to external sources from the watershed. In shallow lakes that have accumulated large amounts of sediment at the lake bottom over time, phosphorus mixes back into the water column from the sediment. The presence of bottom-feeding fish, such as carp and bullhead, long periods of high winds, and heavy boating activity can exacerbate this problem in shallow lakes. Water quality modeling indicated internal phosphorus loading is not a significant source of the TP load to the lake. Lake Geode is a deep reservoir with relatively good water clarity, and a no-wake boating restriction is enforced for the entire lake. These facts support the assumption that internal TP loading is negligible.

Natural or background sources of phosphorus contribute to TP load, and include wildlife in the watershed, geese that reside at the lake, and atmospheric deposition. There are no regulated point sources of phosphorus in the watershed. However, geese residing at the beach were considered point sources for modeling purposes.

Allowance for increases in pollutant loads. There is no allowance for increased TP loading included as part of this TMDL. A majority of the watershed is in agricultural row crop production, and is likely to remain in cropland in the future. Geode State Park, which surrounds the lake, is unlikely to undergo significant land use changes. There are no incorporated unsewered communities in the watershed; therefore, it is unlikely that a future WLA would be needed for a permitted point source discharge. There may be an increase in residential construction in the watershed in the future. However, any transition from agriculture to residential land use would change the nature and the source of loading, but not the total LA as set forth in the TMDL.

3.4. Pollutant Allocation

Wasteload allocation. There are no permitted point source dischargers in the Lake Geode watershed, therefore, the TMDL wasteload allocation is set to zero. It should be noted that Geode State Park has historically used a lagoon for wastewater treatment within the park. This lagoon was not permitted, and wastewater was pumped from the lagoon and hauled from the watershed since 2003. The lagoon was replaced with separate on-site zero-discharge treatment systems in the summer of 2008. Therefore, TP loads from on-site wastewater systems in the park were not incorporated into the TMDL.

Load allocation. The entire TP load to Lake Geode is attributed to nonpoint sources, including natural/background loading, and is included in the TMDL total load allocation of 7,718 lbs/yr when expressed as an annual average, and 100 lbs/day when expressed as a maximum daily load. Table 7 shows a potential load allocation scheme for the Lake Geode watershed that would meet the overall target TP load. Individual reductions shown in Table 7 are not required, but rather, provide an example of how the overall required reduction may be accomplished.

Margin of safety. To account for uncertainties in data and modeling, a margin of safety (MOS) is a required component of all TMDLs. An explicit MOS of 10 percent was utilized in the development of this TMDL. This equates to 858 lbs/yr in the annual average expression, and 11 lbs/day in the daily maximum expression.

Table 7. Potential load allocation scheme to meet target TP load.

	Existing Load (lb/yr)	**LA (lb/yr)**	**Load Reduction (%)**
Row Crops	10,316	4,333	58
Grazed Lands	301	178	41
Farmsteads/Roads	641	609	5
Conservation Areas	1,067	854	20
Septic Systems	171	5	97
Geese	44	44	0
Groundwater	1,695	1,695	0
Total	**14,235**	**7,718**	**45.8**

3.5. TMDL Summary

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

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

Where:
TMDL = total maximum daily load
LC = loading capacity
Σ WLA = sum of wasteload allocations (point sources)
Σ LA = sum of load allocations (nonpoint sources)

MOS = margin of safety (to account for uncertainty)

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

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

TMDL = LC = Σ WLA (0 lbs-TP/year) + Σ LA (7,718 lbs-TP/year)
+ MOS (858 lbs-TP/year) = **8,576 lbs-TP/year**

Expressed as the maximum daily load:

TMDL = LC = Σ WLA (0 lbs-TP/day) + Σ LA (100 lbs-TP/day)
+ MOS (11 lbs-TP/day) = **111 lbs-TP/day**

4. Total Maximum Daily Load (TMDL) for Indicator Bacteria

A Total Maximum Daily Load (TMDL) is required for Lake Geode by the Federal Clean Water Act. This section will quantify the maximum amount of indicator bacteria, specifically, *Escherichia coli (E. coli)*, that Lake Geode can tolerate without violating the state's water quality standards (WQS).

4.1. Problem Identification

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

- Primary contact recreation – Class A1
- Aquatic life – Class B(LW)
- Drinking water – Class C
- Fish consumption – Class HH

The 2006 Section 305(b) Water Quality Assessment Report states that primary contact recreation in Lake Geode is "not supported" due high levels of *E. coli* that violate the state WQS, and also due to high levels of pH. This section addresses the impairment caused by *E. coli* and discusses the subsequent TMDL. The impairments caused by high pH are addressed in the TMDL for pH in Section 3. The 2006 305(b) report can be accessed at http://wqm.igsb.uiowa.edu/wqa/305b.html.

Applicable water quality standards. The State of Iowa Water Quality Standards are published in the Iowa Administrative Code (IAC), Environmental Protection Rule 567, Chapter 61. Table 8 reports the bacteria criteria for Class A1 waters, which are taken directly from the WQS. The WQS can be accessed on the web at http://www.iowadnr.com/water/standards/files/chapter61.pdf.

Table 8. Class A1 bacteria criteria table reproduced from IAC Chapter 61.

Designated Use	Geometric Mean	Sample Maximum
Class A1		
March 15 to Nov 15	126 cfu/100 mL	235 cfu/100 mL
Nov 15 to March 14	Does not apply	Does not apply

Problem statement. The 2006 305(b) report assesses water quality in Lake Geode as follows:

> *"…SUMMARY: The Class A (primary contact recreation uses) are assessed (monitored) as "not supported" due to (1) levels of indicator bacteria that exceed state criteria and (2) to high levels of pH. The Class B(LW) aquatic life uses are assessed (monitored) as "partially supported" also due to high levels of pH. The Class C (drinking water) uses remain "not assessed" due to a lack of monitoring information. Fish consumption uses are assessed (evaluated) as "fully supported" based on results of U.S. [Environmental Protection Agency]*

> *EPA/IDNR fish contaminant (RAFT) monitoring in 1996. The sources of data for this assessment include (1) results of the statewide survey of Iowa lakes sponsored by IDNR and conducted by Iowa State University (ISU) from 2000 through 2004, (2) IDNR/[University of Iowa Hygienic Laboratory] UHL beach monitoring from 2002 through 2004, (3) surveys by IDNR Fisheries Bureau, (4) information on plankton communities collected at Iowa lakes from 2000 through 2005 as part of the ISU lake survey, and (5) results of U.S. EPA / IDNR fish tissue monitoring in 1996…"*

The 305(b) assessment continues with the following explanation of the *E. coli* problem:

> *"…Results of IDNR beach monitoring at Lake Geode from 2002 through 2004 suggest that the Class A uses are "not supported." Levels of indicator bacteria were monitored once per week during the primary contact recreation seasons ([samples collected in] May through September) of 2002 (31 samples), 2003 (29 samples), and 2004 (22 samples) as part of the IDNR beach monitoring program. According to IDNR's assessment methodology, two conditions need to be met for results of beach monitoring to indicate "full support" of the Class A (primary contact recreation) uses: (1) all five-sample, thirty-day geometric means for the three-year assessment period are less than the state's geometric mean criterion of 126 E. coli orgs/100 ml [cfu/100 mL] and (2) not more than 10 % of the samples during any one recreation season exceeds the state's single-sample maximum value of 235 E. coli orgs/100 ml [cfu/100 mL]. If a 5-sample, 30-day geometric mean exceeds the state criterion of 126 orgs/100 ml [cfu/100 mL] during the three-year assessment period, the Class A uses should be assessed as "not supported". Also, if more than 10% of the samples in any one of the three recreation seasons exceed Iowa's single-sample maximum value of 235 E. coli orgs/100 ml [cfu/100 mL], the Class A uses should be assessed as "partially supported". This assessment approach is based on U.S. EPA guidelines (see pgs 3-33 to 3-35of U.S. EPA 1997b).*
>
> *At Lake Geode beach, the geometric means of 5 of the 25 thirty-day periods during the summer recreation season of 2003 exceeded the Iowa water quality standard of 126 E. coli orgs/100 ml [cfu/100 mL]. None of the geometric means exceeded this standard during the recreational seasons of 2002 or 2004. Also, the percentage of samples exceeding Iowa's single-sample maximum criterion (235 E. coli orgs/100 ml [cfu/100 mL]) was greater than 10% in the 2003 recreation season (31%). No more than 10% of the samples exceeded this standard during the recreational seasons of 2002 (10%) and 2004 (5%). According to IDNR's assessment methodology and U.S. EPA guidelines, these results suggest impairment (nonsupport) of the Class A (primary contact recreation) uses…"*

In summary, the primary contact recreation designated use in Lake Geode is considered impaired. The Federal Clean Water Act requires a TMDL be developed for *E. coli*, the pollutant causing the impairment.

Data sources. The primary sources of data for the problem identification in this TMDL are the 2006 305(b) report, and water quality data collected by IDNR, ISU, and UHL. The 305(b) report cites the following data sources for the water quality assessment:

- Results of statewide survey of Iowa lakes sponsored by IDNR and conducted by ISU from 2000 to 2004
- IDNR and Iowa Geological Survey (IGS) beach monitoring from 2002 through 2004
- Surveys by the IDNR Fisheries Bureau
- Information on plankton communities collected at Iowa lakes from 2000 through 2005 as part of the ISU lake survey, and
- Results of the U.S. Environmental Protection Agency (EPA) and IDNR fish tissue monitoring in 1996.

The sources outlined above, in addition to precipitation data from the Iowa Environmental Mesonet (IEM), were used to develop this TMDL. Actual data from these sources is provided in Appendix C of this report.

Interpreting Lake Geode data. Figure 9 shows both the water quality criteria and IDNR/IGS sample data collected from 2000-07.

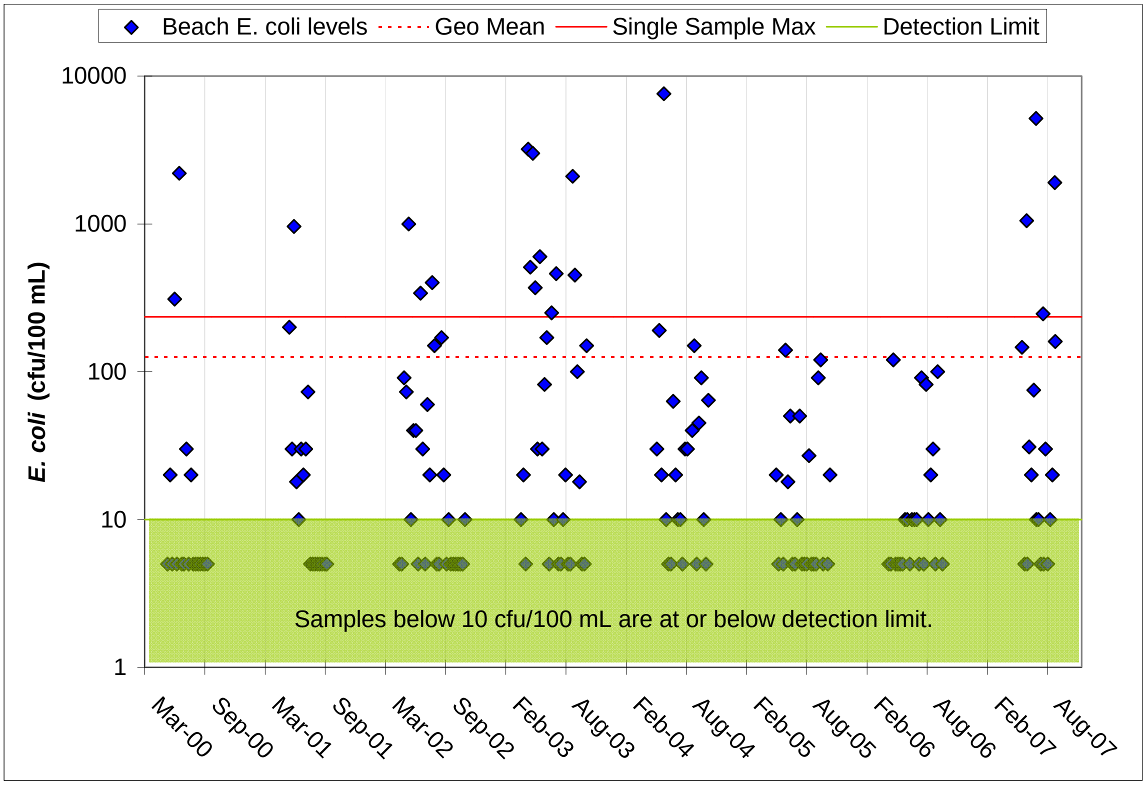


Figure 9. IDNR/IGS Beach Monitoring Program *E. coli* data (Iowa STORET)

Primary contact recreation, the Class A1 designated use, is considered to be impaired due to high levels of *E. coli* bacteria that exceeded both the geometric mean and single-sample maximum criteria within the assessment period. Only data collected from 2002 through 2004 was used in the development of the 2006 305(b) report. Notice that no composite samples collected from 2004-06 exceeded the single-sample maximum criteria of 235 cfu/100 mL; however, several samples collected in the 2007 primary recreation season did exceed the single-sample maximum criterion.

4.2. TMDL Target

General description of the pollutant. Digestive waste, sometimes called fecal material, from warm-blooded animals contains many microorganisms. Some of these microorganisms can cause illness or disease if ingested by humans. The term pathogen refers to a disease-causing microorganism, and can include bacteria, viruses, and other microscopic organisms. Humans can become ill if they come into contact with and/or ingest water that contains pathogens.

It is not practical to test water for every possible pathogen that may be present – there are simply too many different kinds of pathogens. Instead, water quality assessments typically test for an organism such as total coliform, fecal coliform, or *E. coli* to indicate the presence of pathogens from fecal material. *E. coli* is a type of fecal coliform, and its presence correlates well with illnesses that result from human exposure to water that is contaminated with fecal material (Mishra et al, 2008). It should be noted that not all types of *E. coli* cause human illness; however, the presence of *E. coli* indicates the likelihood that pathogens are present. For the purposes of this TMDL, *E. coli* is used as the indicator bacteria. The two primary reasons for using *E. coli* are: (1) the EPA currently considers *E. coli* to be the preferred bacterial indicator, and (2) Iowa's WQS are written for *E. coli*.

Selection of environmental conditions. The critical period in which the impairment occurs is the primary contact recreation season, which runs from March 15 to November 15 each year. The volume of water near the beach, referred to as the near-shore beach volume (NSBV), is critical for WQS attainment for the following reasons:

- This relatively small volume is most susceptible to loads from geese at the beach and is also susceptible to watershed loads.
- It is the area of the lake in which humans, especially small children, most frequently come into contact with the water
- The shallow, gradual sloping and sandy lake bottom at the beach may contribute to lower bacteria die-off rates than in other areas of the lake.

The beach is located at the northeast corner of the lake, as illustrated in Figure 1. The highest *E. coli* concentrations at the Lake Geode swimming beach generally occur during or shortly after precipitation, and a majority of the single-sample violations occur within 48-hours of precipitation. However, violations of the water quality criteria have been detected during both wet and dry conditions, which have different pollutant loading processes. To account for both wet and dry conditions, and to allow for natural variability in *E. coli* levels, both dry to normal conditions and wet to high-flow conditions during the primary contact recreation season are considered in the development of the *E. coli* TMDL. Figure 10 shows the measured *E. coli* concentrations at the Lake Geode beach plotted against flow exceedance, as simulated by the GWLF model. A flow exceedance value of 10 percent implies that 10 percent of all simulated discharge values equal or exceed the corresponding flow. Similarly, an exceedance of 50 percent implies that half of all flows equal or exceed the flow that corresponds to the 50 percent exceedance.

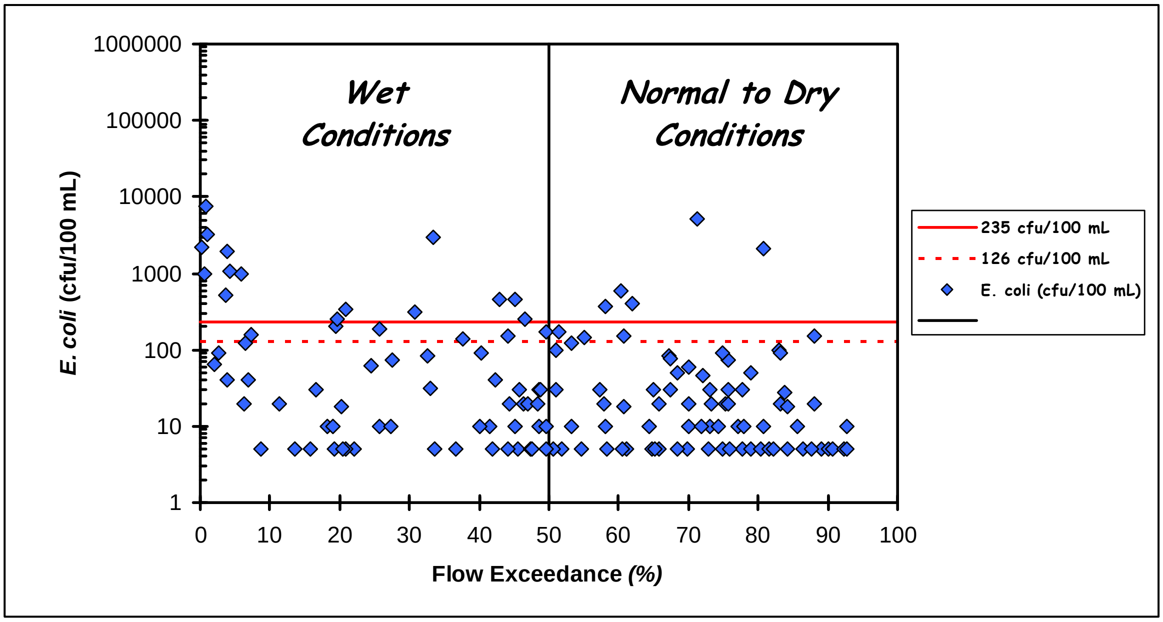


Figure 10. Observed *E. coli* concentrations versus simulated flow exceedance.

Waterbody pollutant loading capacity (TMDL). E. coli are expressed as a concentration of bacterial colonies. This concentration, rather than the mass load, is most relevant to human health. Attainment of the WQS requires that the geometric mean be no greater than 126 cfu/100 mL and that the single-sample maximum be no greater than 235 cfu/100 mL. In November of 2006, The U.S. Environmental Protection Agency (EPA) issued a memorandum entitled *Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. circuit in Friends of the Earth, Inc. v. EPA, et al., No. 05-5015, (April 25, 2006) and Implications for NPDES Permits.* In the context of the memorandum, EPA

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

To account for natural variability, to meet water quality criteria, and to satisfy the recommendations put forth in the November 2006 EPA memorandum, two target loads were set for this TMDL: a median daily *E. coli* load of 1.68E+11 cfu/day to represent dry to normal conditions, and a maximum daily load of 2.95E+11 cfu/day, which is the 95th percentile load and represents wet to high-flow conditions.

Both target and existing *E. coli* loads were modeled using a combination of several modeling tools. These modeling tools include the EPA Bacterial Indicator Tool (BIT), the Generalized Watershed Loading Function (GWLF) model, and a lake bacteria spreadsheet (LBS) developed specifically for the Lake Geode TMDL. A detailed summary of the modeling approach is provided in Appendix E.

BIT is a spreadsheet model that estimates bacteria contributions from multiple sources in a watershed (EPA, 2000). BIT was utilized to develop bacteria buildup and washoff coefficients based on land use, animals in the watershed, manure application and grazing practices, and wildlife populations. Buildup/washoff methodology was taken from Butcher (2003). The BIT tool also accounts for in-stream bacteria loading due to direct deposition by cattle and discharge from septic systems. The BIT model for the Lake Geode TMDL was modified slightly to incorporate in-stream loading by wildlife.

The GWLF model used for the *E. coli* TMDL is the same model used for the pH TMDL described in Section 3 and Appendix D of this report. However, only hydrologic simulation output from GWLF was utilized in the development of this *E. coli* TMDL. GWLF was utilized to develop a daily flow set, which is required to estimate bacteria loading using the buildup/washoff coefficients generated using BIT.

The LBS was developed internally by IDNR staff and utilizes the buildup/washoff parameters developed in the BIT model and the daily flows simulated using GWLF to calculate daily bacteria loads to the lake. The LBS also incorporates first-order decay kinetics, as documented in *Rates, Constants, and Kinetic Formulations in Surface Water Quality Modeling* (EPA, 1985), to model in-lake bacteria concentrations on a daily time step.

Decision criteria for water quality standards attainment. The criteria for attainment of the *E. coli* standard are clearly defined in the state WQS. Ultimately, monitoring *E. coli* levels at the Lake Geode swimming beach during the recreation season will identify whether or not the WQS is attained and primary contact recreation is supported. The IDNR/IGS Beach Monitoring Program utilizes a sampling technique that focuses on this near-shore beach volume. Monitoring *E. coli* concentrations and stream flow in Cedar Creek and other tributaries to Lake Geode would be helpful in more accurately determining the source of *E. coli* pollution and whether or not the loading capacity is exceeded.

4.3. Pollution Source Assessment

Existing load. During periods of wet weather, excess rainfall runs off the land surface into ditches, lakes, and streams. This runoff has high potential for carrying fecal material that has built up on the land surface over time. Most of the WQS violations in Lake Geode occur during these runoff events, and are primarily due to runoff from manure application areas, pastures, feedlots, and areas containing wildlife. However, violations occur during dry periods (dry to normal conditions) as well. Violations under dry conditions are primarily due to *E. coli* sources that are independent of flow, such as direct deposition of fecal material into the lake or streams by livestock, wildlife, and septic systems. Water quality can be impaired by much smaller *E. coli* loads during dry periods, because there is less dilution of pollutants. Watershed and water quality modeling simulations estimated the existing median *E. coli* load to Lake Geode to be 2.72E+12 cfu/day, and the existing maximum (95th percentile) load is 4.54+E12.

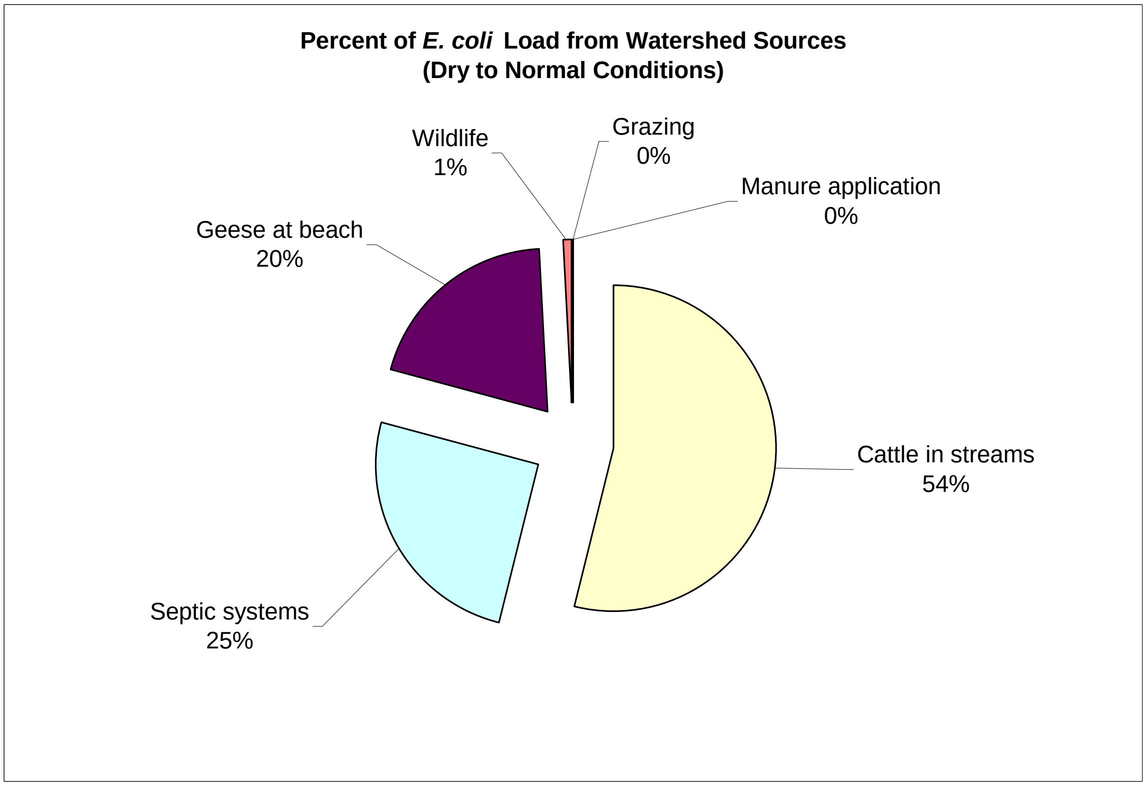
Departure from load capacity. Based on the existing loads and the loading capacity, the median daily *E. coli* load must be reduced by 93.8 percent, and the daily maximum load must be reduced by 93.5 percent. Table 9 reports the existing and target loads and the required reductions.

Table 9. Existing *E. coli* loads, loading capacity, and required reductions.

Condition	Existing Load (cfu/day)	Loading Capacity (cfu/day)	Required Reduction (%)
Dry to Normal (Median Load)	2.72E+12	1.68E+11	93.8
Wet to High-Flow (95th Percentile)	4.54E+12	2.95E+11	93.5

Identification of pollutant sources. A buildup/washoff approach with the BIT model was used to develop *E. coli* loads generated in the Lake Geode watershed. A first-order kinetic spreadsheet model is used to simulate decay and die-off in the lake. *E. coli* modeling details are discussed more thoroughly in Appendix E. Contributing sources include manure application to row crops, manure runoff from grazed lands, cattle in streams, septic systems, geese at the Lake Geode swimming beach, and other wildlife in the watershed. Relative contributions of each source will vary seasonally and with flow. Sources deposited directly to the lake or stream, such as illegal septic drains, geese, and cattle in the stream, will have larger contributions during dry to normal conditions because there is no dilution from rainfall runoff. Conversely, sources such as runoff from pastures and manure application areas will be much larger during periods of runoff. The upper pie chart in Figure 11 summarizes the relative contributions of *E. coli* from various sources during normal to dry conditions, whereas the lower pie chart illustrates the source loading during wet conditions.

Allowance for increases in pollutant loads. There is no allowance for increased *E. coli* loading included as part of this TMDL. A majority of the watershed is in agricultural row crop production, and is likely to remain as cropland in the future. There are no incorporated unsewered communities in the watershed; therefore, it is unlikely that a future WLA would be needed for a permitted point source discharge. There may be an increase in residential construction in the watershed in the future. However, any transition from agriculture to residential land use would change the nature and the source of loading, but not the total load allocation (LA) set forth in the TMDL.



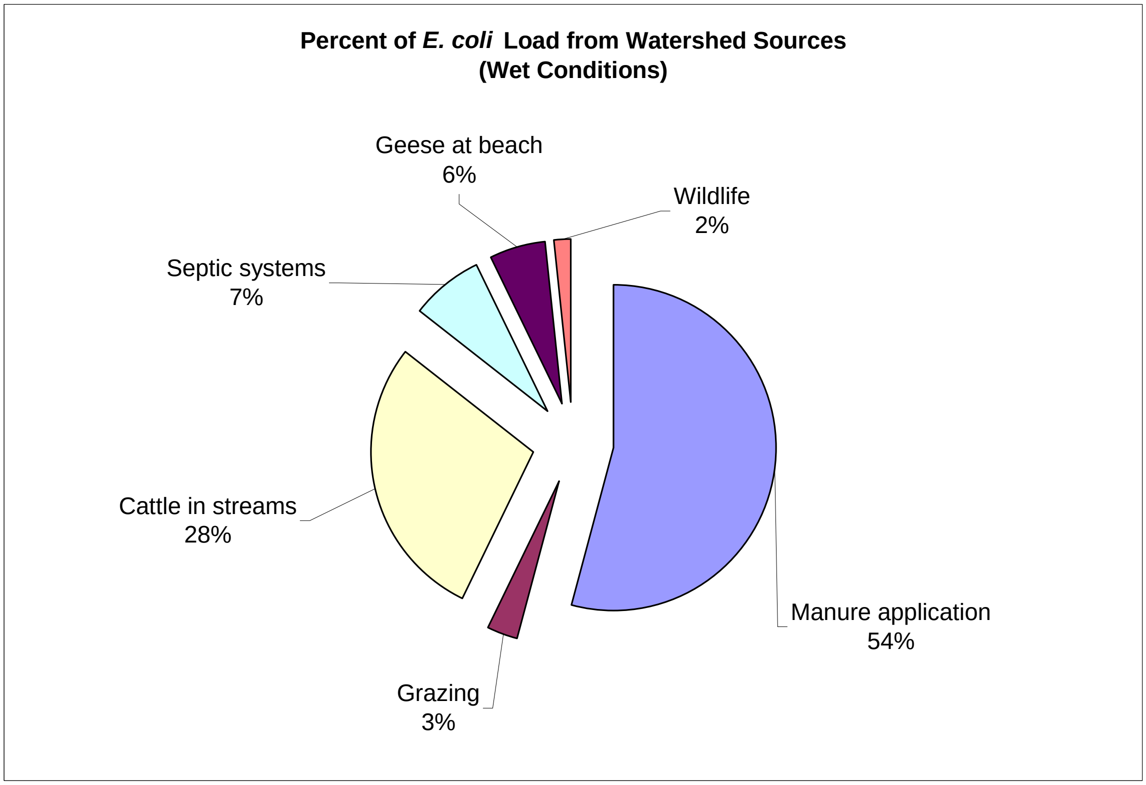


Figure 11. Percent of *E. coli* loads from watershed sources simulated for dry to normal conditions (median load) and wet conditions (95th percentile load).

4.4. Pollutant Allocation

Wasteload allocation. There are no regulated point source dischargers in the Lake Geode watershed, therefore, the TMDL wasteload allocation is zero. It should be noted that Geode State Park historically used a lagoon for wastewater treatment within the park. This lagoon was not allowed to discharge, and hence, not permitted by NPDES. Wastewater was pumped from the lagoon and hauled from the watershed since 2003. The lagoon was replaced with separate zero-discharge on-site treatment systems in the summer of 2008. Therefore, *E. coli* loads from this lagoon were not incorporated into the TMDL.

Load allocation. The entire *E. coli* load to Lake Geode is attributed to nonpoint sources of pollution, including natural/background loading. Allocations are based on compliance with the single-sample maximum criterion of 235 cfu/100 mL. A potential load allocation scheme showing reductions required to meet the loading capacity during wet conditions is reported in Table 10. The individual reductions shown in Table 10 are not required, but provide an example of how the overall required reduction and total LA might be achieved. The same percent reductions shown for the wet weather allocation in Table 10 for cattle in streams, septic systems, and geese at the beach, result in an acceptable dry weather load allocation scenario.

Table 10. Potential load allocation scheme to meet target *E. coli* load.

	(1)Existing Load (cfu/day)	**LA (cfu/day)**	**Load Reduction (%)**
Manure Application	2.46E+12	1.23E+11	95
Grazing	1.31E+11	2.63E+10	80
Cattle in Streams	1.29E+12	1.29E+10	(3)99
Septic Systems	3.28E+11	3.28E+09	(3)99
Geese at Beach	2.57E+11	2.63E+10	(3)90
Wildlife	7.39E+10	7.39E+10	0
Total	**4.54E+12**	**(2)2.66E+11**	**94.2**

(1) 95th percentile loads, which represent wet conditions.
(2) The example LA is equal to the loading capacity of 2.95E+11 minus a 10% MOS
(3) These percent reductions result in an acceptable dry weather load allocation.

Margin of safety. To account for uncertainties in data and modeling, a margin of safety (MOS) is a required component of all TMDLs. An explicit MOS of 10 percent was utilized in the development of this TMDL. This equates to 1.68E+10 cfu/day for dry to normal conditions, and 2.95E+10 cfu/day for wet conditions.

4.5. TMDL Summary

This TMDL is based on meeting the water quality criteria for primary contact recreation at the Lake Geode swimming beach. Though the WQS is based on *E. coli* concentration, the TMDL is also expressed as a load, in light of the November 2006 EPA memorandum.

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

TMDL = LC = Σ WLA + Σ LA + MOS

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

Once the loading capacity, waste load allocations, load allocations, and margin of safety are determined for the Lake Geode watershed, the general equation above can be expressed for the Lake Geode *E. coli* TMDL.

Expressed as a median daily load to reflect dry to normal conditions, which is helpful for water quality assessment and watershed management:

TMDL = LC = Σ WLA (0 cfu/day) + Σ LA (1.51E+11 cfu/day)
+ MOS (1.68E+10 cfu/day) = **1.68E+11 cfu/day**

Expressed as a maximum daily load to account for high-flow conditions:

TMDL = LC = Σ WLA (0 cfu/day) + Σ LA (2.66E+11 cfu/day)
+ MOS (2.95E+10 cfu/day) = **2.95E+11 cfu/day**

5. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources (IDNR) recognizes that technical guidance and support are critical to achieving the goals outlined in this Water Quality Improvement Plan. Therefore, this plan is included to be used by local agencies, watershed managers, and citizens for decision-making support and planning purposes. The best management practices (BMPs) listed below represent a package of tools that will help achieve water quality goals if appropriately utilized. It is up to land managers, citizens, and local conservation professionals to determine exactly how best to implement them.

5.1. General Approach & Timeline

Collaboration and action by residents, landowners, lake patrons, and local agencies will be required in order to improve water quality in Lake Geode to support all of its designated uses. Locally-driven efforts have proven to be the most successful in obtaining real and significant water quality improvements. Improved water quality in Lake Geode would have economic and recreational benefits for people that live, work, and play in the watershed. Therefore, each group has a stake in promoting awareness and educating others about Lake Geode, working together to adopt a comprehensive watershed improvement plan, and applying BMPs and land practice changes in the watershed. Because Lake Geode lies within Geode State Park, IDNR has a heightened interest and responsibility in implementing BMPs within the park boundaries. This large and diverse group of stakeholders provides the opportunity for an effective network of partnerships to be built.

General approach. Both the pH and *E. coli* TMDLs utilize a phased approach to improving water quality. The existing loads, loading targets, a general listing of BMPs needed to improve water quality, and a monitoring plan to assess progress are established in this TMDL. Ideally, the TMDL would be followed by the development of a watershed management plan. The watershed plan should include more comprehensive and detailed actions to better guide the implementation of specific BMPs. Other ongoing tasks required to obtain real and significant water quality improvements include continued monitoring, assessment of water quality trends, assessment of WQS attainment, and adjustment of proposed BMP types, location, and implementation schedule.

Timeline. Development of a comprehensive watershed management plan may take one to three years. Implementation of watershed BMPs could take upwards of five to ten years, depending on funding, willingness of landowner participation, and time needed for design and construction of any structural BMPs. Realization and documentation of water quality benefits may take 10 years or longer, depending on weather patterns, amount of water quality data collected, and the successful location, design, construction, and maintenance of BMPs. Utilization of the monitoring plan as outlined in Section 6 should begin immediately to establish a baseline, and should continue throughout implementation of BMPs and beyond.

5.2. Best Management Practices

No single BMP will be able to sufficiently reduce pollutant loads to Lake Geode. Rather, a comprehensive package of BMPs will be required to address both the pH and *E. coli* violations and allow the lake to fully support its designated uses. Many of the same BMPs will benefit both the pH and *E. coli* issues; however, some BMPs are specific to each pollutant. Table 11 provides a list of potential BMPs for improving water quality, indicates which parameter (pH or *E. coli*) the BMP is most beneficial to, and the relative efficiency of each BMP. A brief discussion of potential BMPs follows Table 11. This list is not all-inclusive, and further investigation may suggest that some alternatives should be implemented in favor of others. A more detailed watershed management plan would be helpful in selecting, locating, and implementing the most effective and comprehensive package of BMPs possible.

Table 11. Potential BMPs for water quality improvement in Lake Geode.

BMP or Activity	Target[1]	Relative[1] Efficiency
Sediment control basins	pH/*E. coli*	High/Med
Terraces and grass waterways	pH/*E. coli*	Med/Low
Constructed wetlands	pH	Med
Conservation tillage (no-till, strip-till, etc.)	pH	High
Increased crop rotation including oats and meadow	pH	Med
Winter cover crop	pH	Med
Manure application methods (incorporation)	pH/*E. coli*	High/High
Manure application rates (nutrient management plan)	pH/*E. coli*	High/High
Manure application timing (avoid frozen/wet periods)	pH/*E. coli*	High/High
Manure export (haul outside of watershed)	pH/*E. coli*	High/High
Livestock fencing (eliminate stream access)	pH/*E. coli*	High/High
Riparian buffer strips	pH/*E. coli*	Med/Med
Gully erosion control (grade-control/sediment basins)	pH/*E. coli*	High/Low
Manage goose population at beach	pH/*E. coli*	Low/High
Remove goose manure from beach (beach groomer)	pH/*E. coli*	Low/High

(1) If the Target is listed as pH/*E. coli*, and the Relative Efficiency is Med/High, the BMP is expected to have medium benefits to pH, and high reduction of *E. coli*. Relative efficiencies are based on modeling results and/or removal efficiencies found in literature.

BMPs for reducing pH in Lake Geode. As reported in Figure 8 and Table 6, the primary source of existing total phosphorus (TP) loads to Lake Geode is row crop agriculture. Many agricultural BMPs are designed to reduce erosion and/or capture sediment before it reaches a stream or lake. Because a large portion of TP is adsorbed to sediment, BMPs that reduce erosion and sediment transport will also reduce TP loads. Structural BMPs such as sediment control basins, wetlands, grass waterways, and terraces should be implemented in row crop areas. Additionally, nonstructural conservation practices such as contour farming, no-till and strip-till farming, diversified crop rotation methods, and use of a winter cover crop are recommended. To obtain the reductions in TP load required to meet the water quality criteria for pH, these practices should be implemented to the maximum extent practicable.

Figure 12 illustrates areas in the watershed most prone to high erosion rates. Figure 13 shows the relative sediment deliver ratio (SDR) in smaller drainage basins, called catchments. Figure 13 also indicates which catchments already have a sediment control structure or grass waterway in place. Catchments with existing sediment basins are outlined in pink, and catchments with grass waterways are outlines in green. Prioritization and location of sediment and erosion control practices should be guided by these figures, because they show the areas in which BMPs will provide the largest potential TP reductions. Highest priority should be given to areas that exhibit high erosion rates, high SDR, and do not currently have a sediment reduction BMP in place. Additionally, widespread adoption of BMPs, and techniques that implement multiple BMPs in series (treatment-train approach) will enhance reductions in TP loading to the lake.

Management of livestock manure is another agricultural BMP that would significantly reduce TP loads to Lake Geode. It is estimated that nearly 85 percent of hog manure currently applied to cropland is incorporated into the soil during manure application (McLaughlin and Mallam, 2008). This is a large percentage and suggests that producers in the watershed are aware of the benefits of proper manure management. Achieving 100-percent incorporation throughout the watershed would reduce potential TP losses to the lake even further. Proper timing of manure application and avoiding over-application may have even greater benefits to water quality than incorporation. Application on frozen ground should be avoided, as should application prior to likely periods of heavy rainfall. The Henry and Des Moines County Soil and Water Conservation Districts (SWCDs) and the Iowa State University (ISU) Extension can help local producers determine how and when to best apply manure. Another potential manure management practice may be to export manure produced in the watershed out of the drainage area for land application. The feasibility of this practice will depend on the availability of nearby cropland that does not drain to the lake. Care should be taken to ensure that other water resources are not compromised for the sake of improving Lake Geode.

Direct deposition of cattle manure occurs when cattle have full access to streams in unfenced pastures or livestock crossing areas. This direct deposition is a large source of phosphorus, bacteria, and other pollutants to Lake Geode. Construction of fences, riparian buffers, and/or livestock crossings that prevent access to the stream will reduce TP loads to the lake and help improve overall water quality.

Row crops located on moderately steep hill slopes and the steeply sloping forested lands in Geode State Park are known to have gully erosion issues. Sediment transport to the lake from eroded gullies is likely a significant source of TP load to the lake. Gully erosion can be reduced by constructing grade control structures and/or sediment control basins in problem areas. Gully restoration areas are illustrated in Figure 14, with high priority areas shown in red.

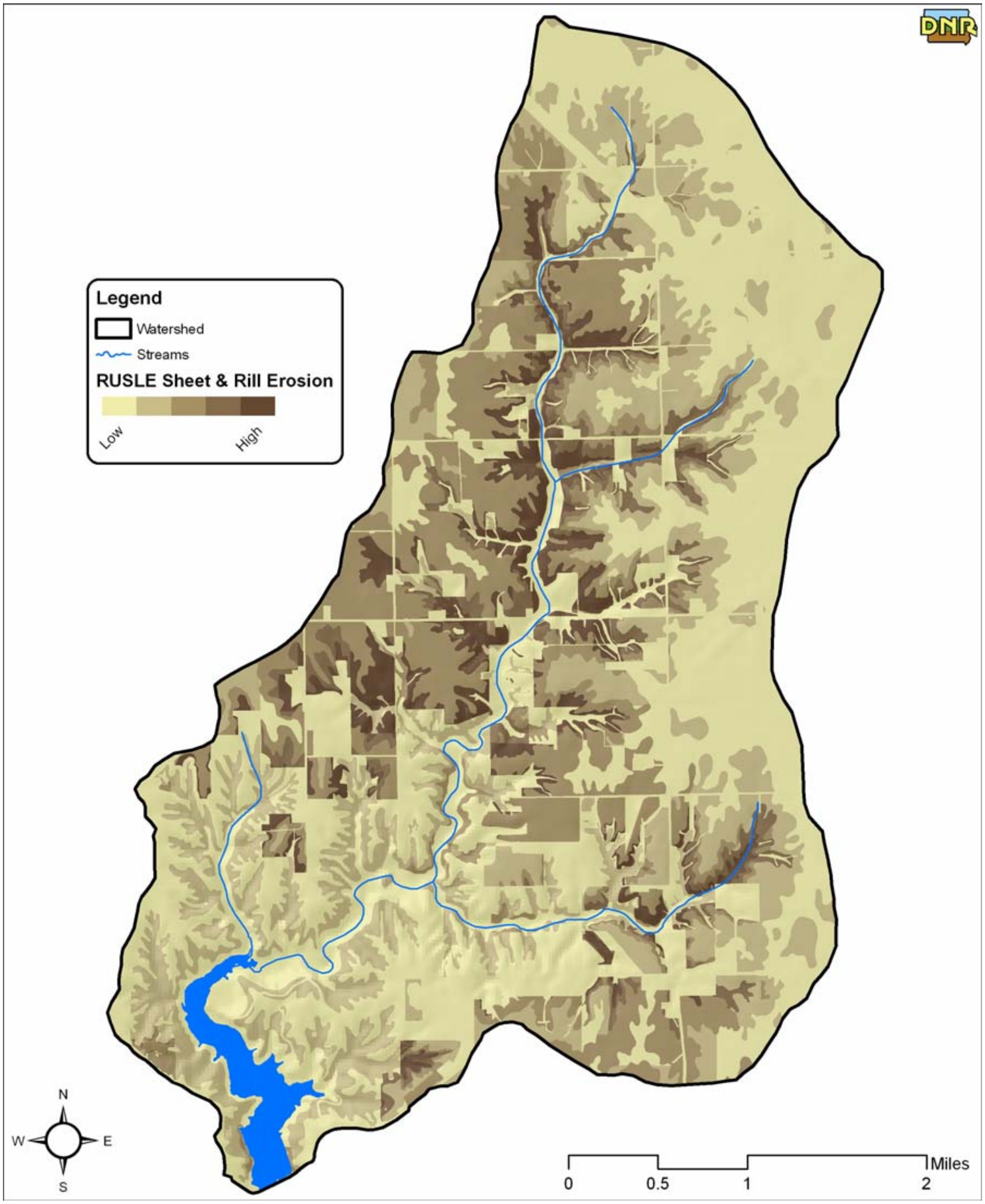


Figure 12. Sheet and rill erosion rates throughout the Lake Geode watershed.

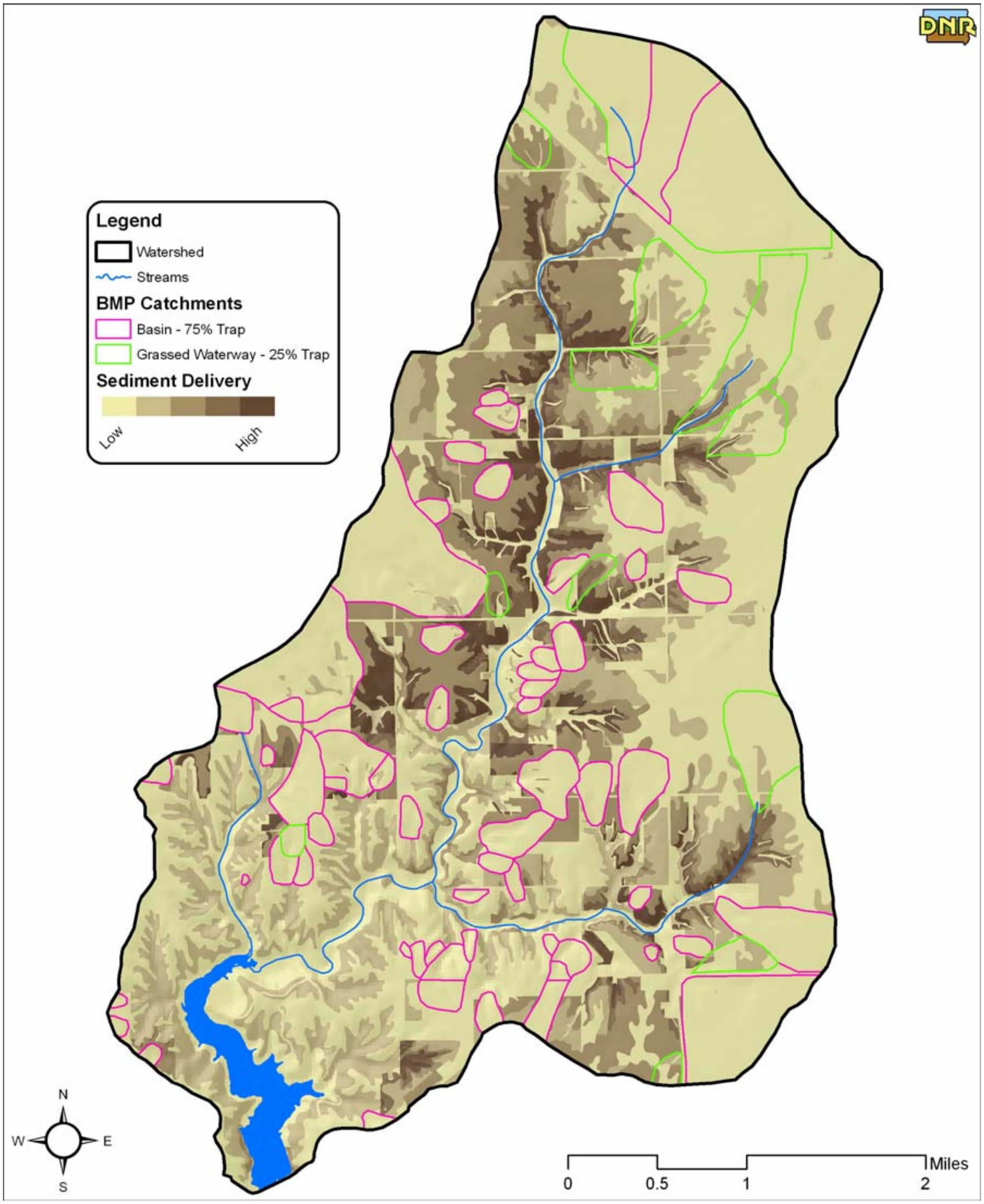


Figure 13. Relative sediment delivery ratio (SDR) and existing BMPs.

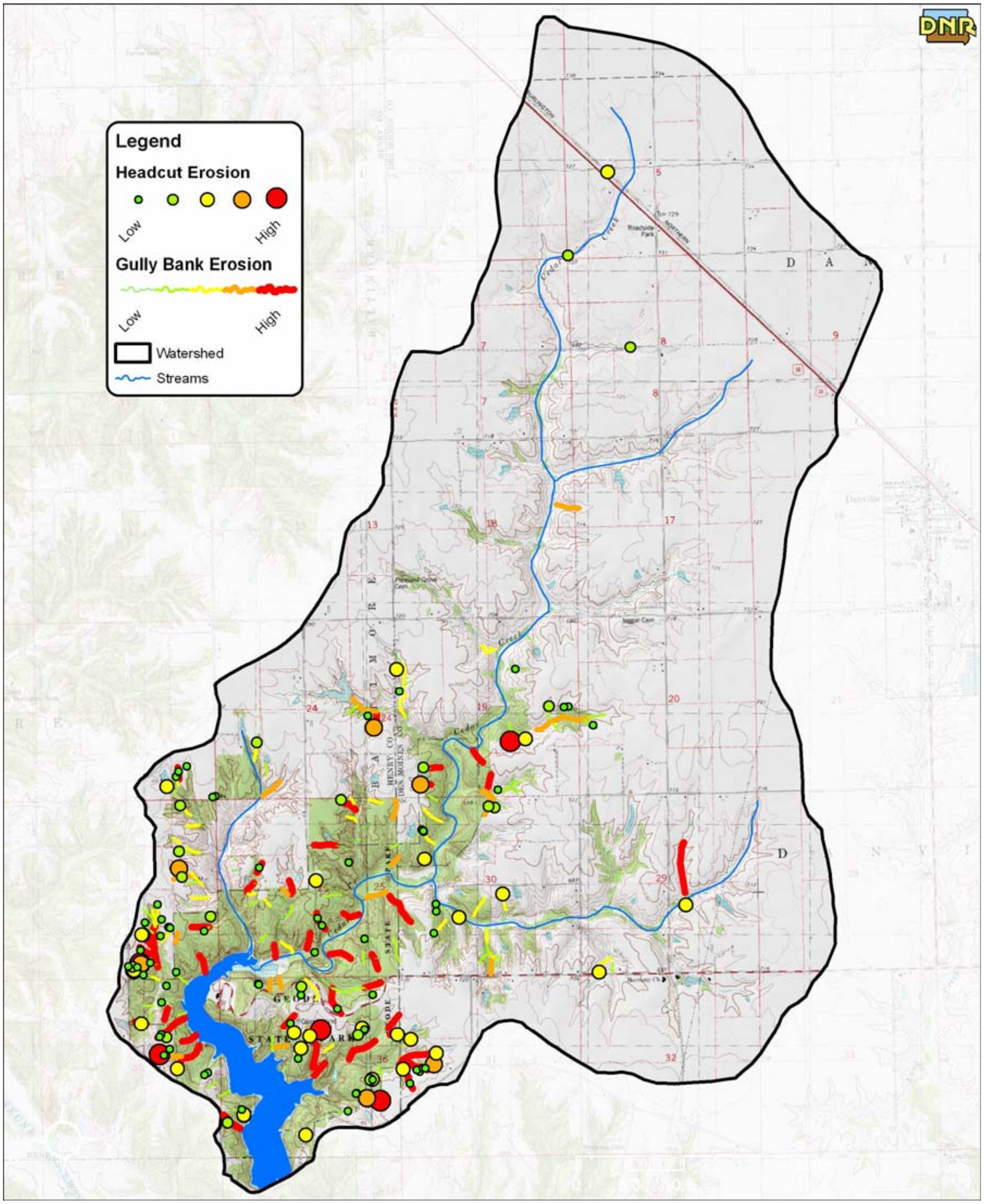


Figure 14. Observed gully erosion in the Lake Geode watershed.

There are an estimated 119 septic systems in the Lake Geode watershed. Many of these systems were constructed prior to 1969 and are not permitted. Unpermitted systems are more likely to have improper designs and malfunction than newer, permitted systems. Improperly designed and failing septic systems can have significant negative impacts on the water quality of nearby lakes and streams. Iowa Senate File (SF) 261 was passed in the 2008 legislative session, and becomes effective July 1, 2009. SF 261 requires existing septic systems be inspected before transfer of property from one owner to the next. However, this legislation does not address failing septic systems on properties that do not change hands. A thorough septic system inspection program would detect systems that need repair or replacement. The inspection program would be voluntary, and the willingness of private property owners could be enhanced through locally-led outreach efforts. IDNR offers financial assistance to private septic system owners for system replacement through the Onsite Wastewater Systems Assistance Program (OSWAP). Although TP loads from septic systems do not comprise a large portion of the overall TP load, achieving optimum water quality will require that every potential TP source be reduced as much as possible.

BMPs for reducing E. coli in Lake Geode. Many of the BMPs described above to reduce TP loading and reduce pH levels in Lake Geode will also help reduce potentially harmful *E. coli* levels in the lake. This includes BMPs that reduce sediment delivery to the lake, since many pathogens attach to sediment particles. However, bacteria reductions from sediment control BMPs are relatively low. To maximize bacteria reductions, BMPs should be located in areas of known bacteria sources, including manure application areas, feedlots, and grazed land. One additional practice vital to *E. coli* reduction will be management of the goose population at the swimming beach. Although loads from direct deposition by cattle in streams and from manure application to row crops are estimated to be the largest overall sources of *E. coli* to the lake, loads from geese at the beach are also critical. Loads from the beach are concentrated in the small volume of water humans frequently contact. A variety of techniques can be utilized to remove geese from the beach, including construction of barriers, translocation of geese, and removal of food sources. Selection of the most efficient means of population reduction is site-specific, and should be based on the knowledge of Geode State park officials and IDNR waterfowl biologists. In addition to reducing the goose population, goose manure deposited on the beach should be removed with grooming equipment. Beach grooming equipment comes in two distinct forms: groomers that physically pick up and remove manure droppings, and disks that incorporate droppings into the sand. Groomers that remove manure from the sand are the preferred means of reducing manure transport from the beach.

BMPs that reduce *E. coli* are listed below, from highest to lowest priority, to guide implementation location and scheduling. However, because large reductions are needed to attain WQS, all recommended BMPs should be implemented to the maximum extent practicable:

- Management of geese at beach (population reduction and/or manure removal)
- Elimination of livestock access to streams
- Manure management (incorporation, timing, proper application rates)
- Septic system inspection and repair or replacement
- Crop rotation schemes (to help minimize manure fertilizer requirements)
- Sediment control BMPs (reduces transport of attached pathogens)

6. Future Monitoring

Water quality monitoring is critical for assessing the status of water resources and historical 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 Lake Geode 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 that provides training to interested volunteers. This program is called IOWATER, and 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.

6.1. Monitoring Plan to Track TMDL Effectiveness

Future water quality data collection in Lake Geode 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., north, middle, south) 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 Lake Geode. 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 12. At least three sampling events are scheduled every summer, typically between Memorial Day and Labor Day.

Table 12. 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)

6.2. Idealized Plan for Future Watershed Projects

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 will be required to reduce the level of uncertainty associated with water quality trend analysis, to gain a better understanding of the impacts of implemented watershed projects, and to 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 13 outlines the idealized monitoring plan by listing the components in order, starting with the highest priority. Proposed monitoring locations are illustrated in Figure 15.

Table 13. Idealized monitoring plan.

Parameter(s)	Intervals	Duration	Location(s)
Continuous flow, pH, DO, and temperature	15-60 minute	May through September	B1, L1, L2, L3
E. coli, TP, SRP, TSS, and flow	Daily	10-day periods (multiple wet and dry periods)	B1, L1, L2, L3, CC1, CC2, CC3, NT1, ET1, WT1
E. coli, TP, SRP, TSS, and flow	Hourly	24 to 48 hour periods (during runoff events)	B1, L1, L2, L3, CC1, CC2, CC3, NT1, ET1, WT1
E. coli – Source Tracking	One-time	DNA source tracking to	B1 (beach)

Continuous pH, DO, and temperature data at one or more locations in the lake would address the following questions:

- Are pH violations occurring throughout the lake, or are they localized?
- Can we confirm photosynthesis as the primary driver for pH by correlating pH and DO, and by observing diurnal effects (changes throughout the day)?
- Can a predictive model be developed to simulate and analyze spatial and temporal trends?

Daily monitoring for *E. coli*, TP, SRP, TSS, and flow (at tributary sites) for 10-day periods during wet and dry conditions would help confirm and/or reveal information helpful in locating and scheduling BMP construction. Potentially helpful information from this monitoring includes:

- Observed relationships between bacteria and nutrient levels and flow: are levels high during times of low flow, high flow, or both?
- Locations of the highest phosphorus and bacteria levels in the watershed to confirm priority sources.
- More extensive flow and concentration data to allow calculation of observed pollutant loads under wet and dry conditions.
- Confirmation of water quality improvement, or lack of improvement, resulting from implementation of BMPs throughout the watershed.

In addition to daily data, several occasions of hourly data would provide a more complete picture of water quality. Hourly data during runoff events would reveal how pollutant levels change throughout the storm event. If hourly monitoring shows that concentrations spike quickly towards the beginning of a storm, then BMP implementation should focus on capturing the first flush of runoff. Hourly data would also allow calculation of the total pollutant load for several storm events, which could guide BMP selection and design.

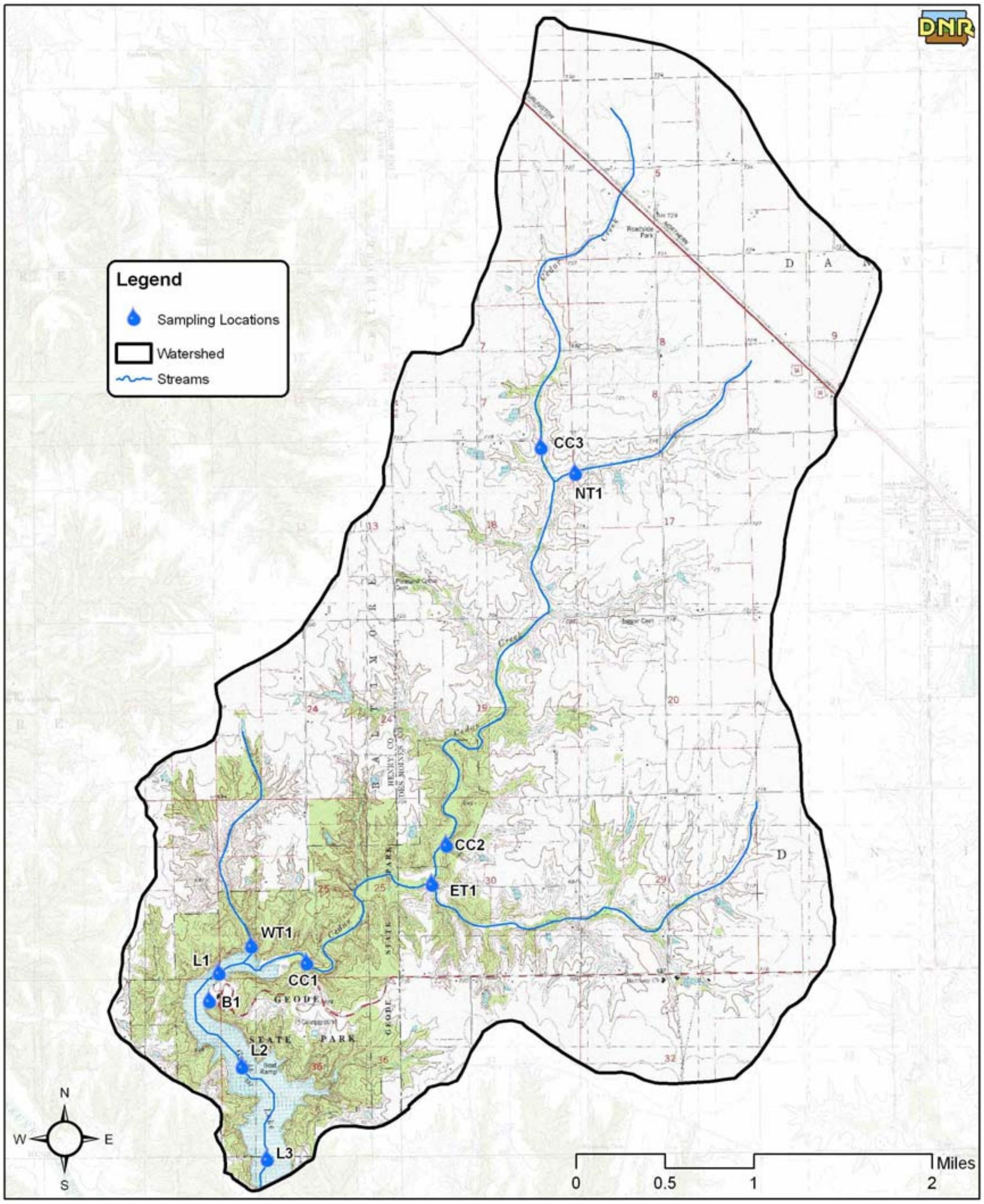


Figure 15. Idealized monitoring plan sample locations.

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. 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 suggest that septics are a significant source of *E. coli*.

All of the proposed monitoring information would assist in the development and calibration of more complex watershed and water quality models to guide future efforts to simulate various scenarios and watershed response to BMP implementation. Monitoring parameters and locations should be continually evaluated. Adjustment of parameters and/or stations 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 Lake Geode watershed.

7. 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 Lake Geode. During the development of this TMDL, efforts were made to ensure that local stakeholders were involved in the decision-making process to agree on feasible and achievable goals for the water quality in Lake Geode.

7.1. Agency Stakeholder Meeting

In the early stages of TMDL development, an agency stakeholder meeting was conducted at Geode State Park office on January 24, 2008. The meeting was facilitated by the Iowa Department of Natural Resources (IDNR) in cooperation with the Iowa Department of Agriculture and Land Stewardship (IDALS). Stakeholder groups represented at the meeting included the Henry and Des Moines County Soil and Water Conservation Districts (SWCDs), and other agency personnel that would lead local watershed planning and public involvement efforts.

Key agency attendees included:

- IDNR – Geode State Park Manager
- IDNR – Section 319 Program
- IDNR – Watershed Improvement Section (TMDL)
- IDNR – Watershed Monitoring and Assessment (Section 305(b) Report)
- IDNR – Beach Monitoring Program (*E. coli* monitoring)
- IDALS – Division of Soil Conservation (Regional Coordinator)
- Henry County Soil and Water Conservation District
- Des Moines County Soil and Water Conservation District
- USDA-NRCS - Geode Resource Conservation & Development

IDNR staff provided information regarding past monitoring activities and results, including the IDNR Beach Monitoring Program. An informal presentation regarding general background information related to TMDLs was provided, and the planned schedule for the Lake Geode TMDL was discussed. One key outcome of the meeting was increased coordination between various agency led planning efforts.

7.2. Public Meeting

A formal public meeting was held at the Geode State Park office on near Danville, Iowa, from 6:00 to 8:00 pm on January 15, 2009. Over 30 citizens attended this meeting, not including state agency personnel. The primary purposes of the meeting were to present the draft of the Lake Geode TMDL for pH and *E. coli* to the public, and to provide stakeholders with an opportunity to ask questions and offer input. Additionally, IDNR personnel explained the next steps required to improve water quality in Lake Geode, and stakeholders were informed of technical assistance and possible funding opportunities available through IDNR. A community-based planning process for watershed improvement and lake restoration was also discussed.

Key agency attendees included:

- IDNR – Geode State Park Manager
- IDNR – Section 319 Program
- IDNR – Watershed Improvement Section (TMDL)
- IDNR – Lakes Restoration Program
- IDNR – Southeast Iowa District Fisheries Biologist
- IDALS – Division of Soil Conservation (Regional Coordinator)
- Henry County Soil and Water Conservation District
- Des Moines County Soil and Water Conservation District
- USDA-NRCS

Key stakeholder groups represented included:

- Watershed residents, land owners, and agricultural producers
- Citizens from nearby towns, including New London, Danville, Burlington, Mt. Pleasant, Sperry, Mt. Union, Oakville, Keokuk, West Burlington, and Lowell
- Lake Geode patrons
- City of Burlington – Parks and Recreation
- City of Burlington – City Council
- City of New London
- New London Chamber of Commerce
- Mt. Pleasant Area Chamber Alliance

Additionally, at least two media outlets attended and reported on the public meeting, including The Burlington Hawk Eye, and The New London Journal.

7.3. Written Comments

IDNR received one electronic comment on the draft of the Lake Geode TMDL. The comment and IDNR response letter are included in Appendix F of this document.

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9. Appendices

Appendix A --- Glossary of Terms 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 just 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.
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.
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 facility 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.
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.
Cyanobacteria (blue-green algae):	Members of the phytoplankton community that are not true algae but can photosynthesize. Some species can be toxic to humans and pets.
Designated use(s):	Refer to the type of economic, social, or ecologic 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:	A system used to classify geographic areas based on similar physical characteristics such as soils and geologic material, terrain, and drainage features.
EPA (or USEPA):	United States Environmental Protection Agency.
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.
GIS:	Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.

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.
Integrated report:	Refers to a comprehensive document which 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 waste load and load allocations.)
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.
MOS:	Margin of Safety. A required component of the TMDL that accounts for the uncertainty in the response of the waterbody to loading reductions.
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 which 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).
Phytoplankton:	Collective term for all self-feeding (photosynthetic) organisms suspended in the water quality which provide the basis for the aquatic food chain. 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 an NPDES permit.
PPB:	Parts per Billion. A measure of concentration which is the same as micrograms per liter (µg/l).
PPM:	Parts per Million. A measure of concentration which is the same as milligrams per liter (mg/l).

Riparian:	Refers to site conditions that occur near water, including specific physical, chemical, and biological characteristics that differ from upland (dry) sites.
RUSLE:	Revised Universal Soil Loss Equation. An empirical model for estimating long term, average annual soil losses due to sheet and rill erosion.
Secchi disk:	A device used to measure transparency in waterbodies. The greater the Secchi depth (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 which actually reaches a waterbody of concern.
Seston:	All particulate matter (organic and inorganic) in the water column.
Sheet & rill erosion	Soil loss which occurs diffusely over large, generally flat areas of land.
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 fraction of discharge (flow) in a river which arrived as surface runoff directly caused by a precipitation event. *Stormwater* generally refers to runoff which is routed through some artificial channel or structure, often in urban areas.
STP:	Sewage Treatment Plant. General term for a facility that processes municipal sewage into effluent released to public waters according to the conditions of an NPDES permit.
SWCD:	Soil and Water Conservation District. Agency which provides local assistance for soil conservation and water quality project implementation, with support from the Iowa Department of Agriculture and Land Stewardship.
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.

TSI (or Carlson's TSI):	Trophic State Index. A standardized scoring system (scale of 0-100) used to characterize the amount of algal biomass in a lake or wetland.
TSS:	Total Suspended Solids. The quantitative measure of seston, all materials, organic and inorganic, which are held in the water column.
Turbidity:	The degree of cloudiness or murkiness of water 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 and impaired water assessments.
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 (measured in units of surface area) which drains water to a particular body of water 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). Alternatively, the allowable pollutant load that an NPDES permitted facility may discharge without exceeding water quality standards.
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.
WWTP:	Wastewater Treatment Plant. General term for a facility which processes municipal, industrial, or agricultural waste into effluent released to public waters or land applied according to the conditions of the facility's NPDES permit.

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.

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 which does not maintain perennial (year-round) flow of water or pools of water in most years (i.e. ephemeral or intermittent waterways). In other words, stream channels or basins which consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use 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 which maintain flow throughout the year, or at least hold pools of water which are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are a total of thirteen different designated use classes (Table B-1) which may apply, and a 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, the Iowa Department of Natural Resources and University Hygienic Laboratory (IDNR/UHL) Ambient Lake Monitoring Program, and the IDNR and Iowa Geologic Survey (IGS) Beach Monitoring Program.

Table C-1. ISU physical/chemical sampling data (2000-07).

Date	Secchi (m)	Water Temp (Celsius)	DO (mg/L)	Field pH	Chl-a (ug/L)	TP (ug/L)	TN (mg/L)	Alkalinity as CaCO3 (mg/l)
6/28/00	0.9	21.9	9.0	7.9	--	--	2.87	276
7/25/00	1.5	23.9	6.1	8.7	2.8	--	1.50	108
8/15/00	1.6	26.6	10.4	9.5	11.8	--	1.21	98
5/30/01	0.9	16.7	7.2	8.0	< 1	182	4.89	90
6/27/01	3.0	25.2	12.9	8.7	5.7	13	5.70	108
7/31/01	2.9	28.9	14.5	9.4	26.6	13	2.65	87
6/4/02	1.8	25.6	--	8.6	7.5	28	4.93	116
7/9/02	1.8	32.4	10.9	9.0	8.4	23	4.20	102
8/6/02	3.9	28.5	8.6	8.7	4.1	18	3.08	109
6/3/03	6.0	19.5	9.3	8.7	1.1	35	3.00	94
7/8/03	4.1	29.1	11.3	9.0	--	29	1.86	92
8/5/03	3.8	27.1	14.3	8.9	13.5	29	1.14	81
6/2/04	3.3	22.7	10.5	9.1	14.9	38	2.63	128
6/29/04	2.7	23.8	10.9	8.6	11.7	24	2.74	124
8/3/04	4.3	26.2	11.6	8.7	10.6	21	1.65	119
6/7/05	6.7	23.8	8.8	8.5	1.6	17	4.02	156
7/12/05	2.7	27.8	12.0	8.7	11.7	16	3.23	134
8/3/05	3.5	--	--	--	14.3	15	2.13	119
6/6/06	0.8	20.1	10.4	9.1	126.5	81	3.36	93
7/11/06	2.7	24.5	9.8	8.7	2.4	31	2.31	114
8/8/06	1.5	26.8	9.7	9.0	16.4	39	1.23	101
7/10/07	1.4	28.6	12.8	9.5	21.8	37	2.7	88.6
6/5/07	1.0	23.3	14.0	9.2	78.6	68	3.8	96.0
8/6/07	0.9	26.6	8.8	9.8	25.5	56	< 1.38	81.0

Note: Dashes (--) indicate that no data was reported.

Table C-2. ISU biological sampling data (2000-07).

Date	Cyanobacteria Wet Mass (mg/L)	Phytoplankton Wet Mass (mg/L)	Zooplankton Mass (mg/L)
6/28/00	1.35	3.74	--
7/25/00	26.45	26.50	82.89
8/15/00	261.90	263.12	1.19
5/30/01	0.08	0.80	212.98
6/27/01	4.73	6.29	376.16
7/31/01	0.27	1.88	18.79
6/4/02	75.13	77.70	245.76
7/9/02	43.85	43.97	32.74
8/6/02	18.64	19.72	99.71
6/3/03	14.17	14.25	196.38
7/8/03	90.78	91.67	152.19
8/5/03	49.06	49.21	127.53
6/2/04	4.23	6.13	371.87
6/29/04	10.04	13.54	295.56
8/3/04	10.09	10.81	118.68
6/7/05	1.12	2.91	26.65
7/12/05	4.58	8.34	14.63
8/3/05	1.47	8.43	6.72
6/6/06	29.27	29.36	58.45
7/11/06	101.82	110.15	46.64
8/8/06	53.27	53.94	14.08
7/10/07	683.7	685.2	42.8
6/5/07	25.7	25.8	222.1
8/6/07	98.9	100.5	11.9

Note: Dashes (--) indicate that no value was reported.

Table C-3. UHL physical/chemical sampling data (2005-07).

Date	Water Temp (Celsius)	DO (mg/L)	Secchi (m)	Chl-a (ug/L)	TP (mg/L)	TKN (mg/L)	pH	Alkalinity as CaCO3 (mg/l)
6/21/05	26.3	8.4	4.8	3	0.03	0.89	8.6	140
8/10/05	28.3	7.3	2.6	7	0.02	0.7	9.4	100
10/4/05	21.4	8.8	1.3	60	0.05	0.8	8.9	110
4/27/06	16.2	10.6	1.9	12	0.1	1	8.9	130
5/31/06	25.8	9.2	0.3	430	0.23	3.8	9.5	82
7/6/06	26.5	7.5	3.6	5	0.03	1	8.5	99
8/14/06	26.5	9.4	2.1	17	0.04	0.8	8.9	99
9/20/06	19.5	8.2	2	40	0.09	0.8	8.8	110
5/7/07	17.7	8.9	3.3	2	0.15	1	7.8	120
7/23/07	25.9	10.8	0.9	36	0.06	0.8	9.4	80

Table C-4. IDNR/IGS beach sampling data (2002-04).

Date	Enterococci (cfu/100 mL)	*E. coli* (cfu/100 mL)	Fecal coliform (cfu/100 mL)
4/15/02	< 10	< 10	< 10
4/22/02	10	< 10	< 10
4/29/02	440	91	140
5/6/02	60	73	73
5/13/02	5,200	1,000	1,200
5/20/02	20	10	10
5/27/02	130	40	40
6/3/02	45	40	40
6/10/02	20	< 10	< 10
6/17/02	20	340	350
6/24/02	10	30	30
7/1/02	10	< 10	< 10
7/8/02	< 10	60	60
7/15/02	< 10	20	20
7/22/02	90	400	410
7/29/02	290	150	270
8/5/02	10	< 10	< 10
8/12/02	< 10	< 10	< 10
8/19/02	220	170	170
8/26/02	10	20	10
9/3/02	10	< 10	< 10
9/9/02	< 10	10	10
9/16/02	< 10	< 10	10
9/23/02	10	< 10	< 10
9/30/02	30	< 10	< 10
10/7/02	< 10	< 10	< 10
10/14/02	< 10	< 10	< 10
10/21/02	< 10	< 10	< 10
10/28/02	< 10	10	10
4/13/03	20	10	10
4/21/03	140	20	20
4/28/03	50	< 10	< 10
5/5/03	1,400	3,200	3,200
5/12/03	590	510	510
5/19/03	70	3,000	3,300
5/26/03	82	370	410
6/2/03	60	60	30
6/9/03	1,500	600	660
6/16/03	< 10	30	30
6/23/03	< 10	82	82
6/30/03	550	170	210
7/7/03	< 10	< 10	< 10
7/14/03	< 10	250	250
7/21/03	20	10	10
7/28/03	750	460	530

Table C-4 (continued)

Date	Enterococci (cfu/100 mL)	*E. coli* (cfu/100 mL)	Fecal coliform (cfu/100 mL)
8/4/03	< 10	< 10	< 10
8/11/03	10	< 10	< 10
8/18/03	< 10	10	20
8/25/03	150	20	20
9/1/03	20	< 10	< 10
9/8/03	560	< 10	< 10
9/15/03	1,400	2,100	2,200
9/22/03	80	450	450
9/29/03	10	100	120
10/6/03	< 10	18	18
10/13/03	< 10	< 10	< 10
10/20/03	< 10	< 10	< 10
10/27/03	27	150	160
5/24/04	10	30	--
5/31/04	180	190	--
6/7/04	40	20	--
6/14/04	1,400	7,600	--
6/21/04	< 10	10	--
6/28/04	20	< 10	--
7/5/04	< 10	< 10	--
7/12/04	90	63	--
7/19/04	60	20	--
7/26/04	< 10	10	--
8/2/04	< 10	10	--
8/9/04	30	< 10	--
8/16/04	< 10	30	--
8/23/04	20	30	--
9/7/04	< 10	40	--
9/13/04	27	150	--
9/20/04	10	< 10	--
9/27/04	< 10	45	--
10/4/04	64	91	--
10/11/04	< 10	10	--
10/18/04	10	< 10	--
10/25/04	590	64	--

Note: Fecal coliform sampling was discontinued in 2004.

Appendix D --- pH Data Analysis and Modeling Methodology

D.1. Background Discussion

There are a number of processes occurring in Lake Geode that will have an impact on, and be affected by, pH. It is not possible to simply reduce the amount of pH that enters the lake to lower pH levels and meet water quality standards. The pH in Lake Geode is dynamic, and depends on other physical, chemical, and biological properties of the water column, surrounding soils, lake-bottom sediments, and the atmosphere and climate. When measured continuously, pH values of a lake often vary from one hour to the next, and in some cases change even more quickly. To address the pH problem in Lake Geode, the lake must be understood as a complex system, and those factors most likely causing elevated pH values must be evaluated. Of the many processes in a lake that affect pH, at least two phenomena should be considered to better understand pH dynamics. The first is the carbonate system, sometimes called bicarbonate equilibrium. The second is net photosynthesis, also referred to as primary production or the production/respiration cycle (Dodds, 2000). A discussion of the carbonate system and photosynthesis, and data analysis and modeling methodology utilized in the development of the pH TMDL for Lake Geode is provided in this appendix.

Carbonate system. The amount of dissolved carbonate and bicarbonate in a lake determines its alkalinity, or ability to neutralize acids. This neutralizing effect is often referred to as a lakes buffering capacity. Lakes with high alkalinity are typically resistant to drops in pH, and tend to have relatively high pH values (8.0 or greater). The more bicarbonate minerals present in an aquatic system, the higher its alkalinity. Highly alkaline lakes occur when limestone, sandstone, and other rocks containing carbonate minerals degrade and are transported to the lake by surface water or groundwater flow. Conversely, in the absence of sources of carbonate, lakes tend to be less alkaline and more susceptible to drops in pH (acidity).

As illustrated in Figure D-1, the median pH in Lake Geode, based on the compilation of data from the University of Iowa Hygienic Lab (UHL) and Iowa State University (ISU), is 8.9. This ranks just above the 3rd quartile (75th percentile) of all Iowa impoundments. Conversely, alkalinity in Lake Geode ranks just above the first quartile (25th percentile) compared with other Iowa impoundments. In other words, over 75 percent of Iowa impoundments have a lower pH than Lake Geode, while only about 25 percent of Iowa impoundments have a lower alkalinity. Detailed information required to thoroughly analyze the carbonate/bicarbonate system of Lake Geode is not available. Although the carbonate/bicarbonate system does influence pH dynamics in Lake Geode, elevated levels are almost certainly driven by photosynthesis. For this reason, the TMDL for pH focused on photosynthesis of algae as the primary cause of elevated pH levels in Lake Geode.

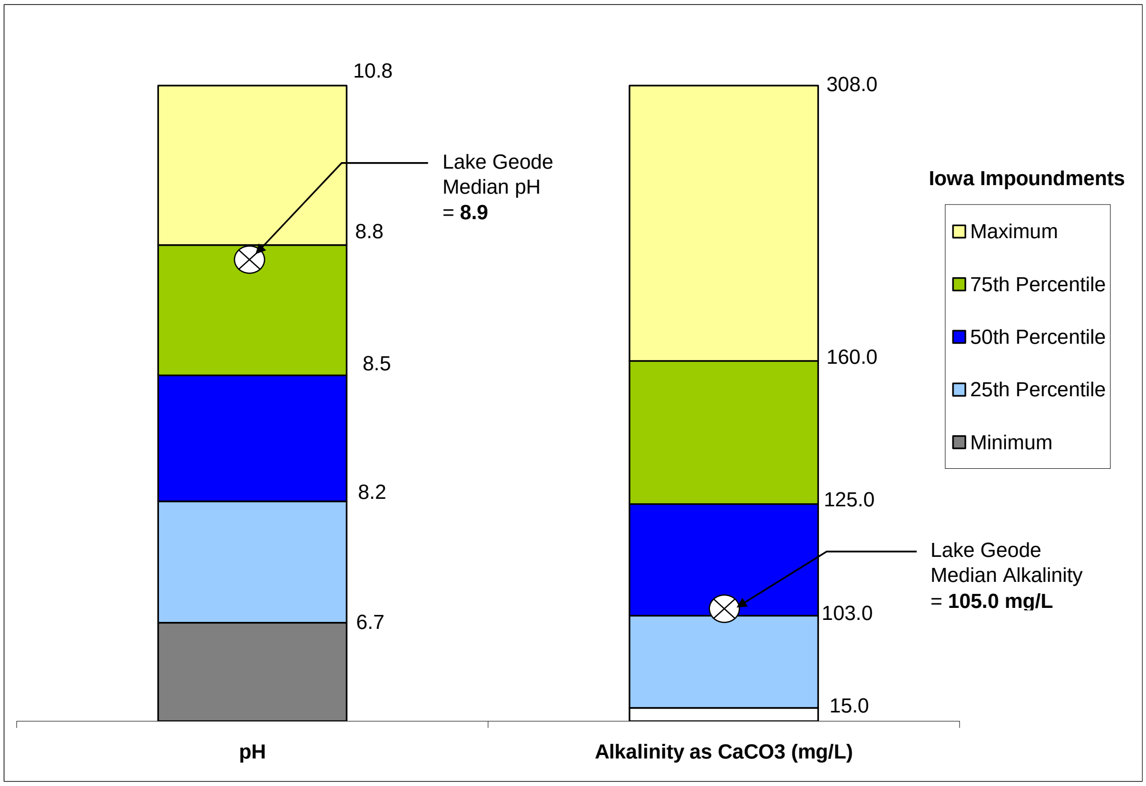


Figure D-1. Median pH and alkalinity in Lake Geode compared with Iowa impoundments.

Photosynthesis. Aquatic plants have the ability to use solar energy and an inorganic (i.e., nonliving) food source to grow. This process is called production, or more specifically, photosynthesis. During photosynthesis, aquatic plants take up food (carbon dioxide, nutrients, and trace elements), build organic matter and store energy, and release oxygen to the water column. The consumption of carbon dioxide results in an increase in the pH of the surrounding water, and the release of oxygen often causes the water to become saturated with dissolved oxygen (DO).

After a period of photosynthesis, the plants must use stored energy to perform required metabolic functions. This process is called respiration, and occurs when conditions no longer support photosynthesis. Respiration by plants is similar to humans using food as energy for walking up stairs, growing new cells, and performing other vital bodily functions. When aquatic plants respire, they consume oxygen and release carbon dioxide back to the water column. This has the opposite effect of photosynthesis and decreases the pH and DO concentration. Decomposition of dead plant cells has the same effect on the water column as respiration.

D.2. Linking pH and Chlorophyll-a

Statistical correlation of a number of monitored water quality parameters was performed on the Lake Geode data set using Microsoft® Office Excel and MINITAB™ Statistical Software. The objective was to determine if Lake Geode is correlated to one or more factors, including other water quality constituents, climate-related data, and/or physical characteristics of the lake itself.

A best subsets regression was performed using pH as the response variable, and a number of independent variables as potential predictors. Predictors included parameters such as precipitation, solar radiation, thermocline depth, water temperature, and other variables generally accepted as being independent of pH. Subset regression results that had promising R-squared values and other descriptive statistics were then used for multi-parameter regression analysis in an effort to develop a regression model that could be used for pH TMDL. The specific goal of the desired regression model was to determine which pollutants and other parameters are affecting pH, and to develop a relationship that could be used to develop a water quality target. Unfortunately, none of the multiple regression models developed between pH and the independent variables described above yielded satisfactory results.

Observed pH was also correlated to a number of dependant parameters to investigate the potential for using another water quality constituent as a surrogate for pH. Potential surrogates evaluated include DO, mass of cyanobacteria (blue-green algae), alkalinity, turbidity, and chlorophyll-a. A positive correlation (R-squared = 0.425, $p < 0.001$) of measured pH values with coincident chlorophyll-a concentrations was observed. A plot and the regression equation are shown in Figure D-2. Chlorophyll-a and pH measurements used in the regression analysis include both ISU and UHL monitoring data from 2000 through 2007.

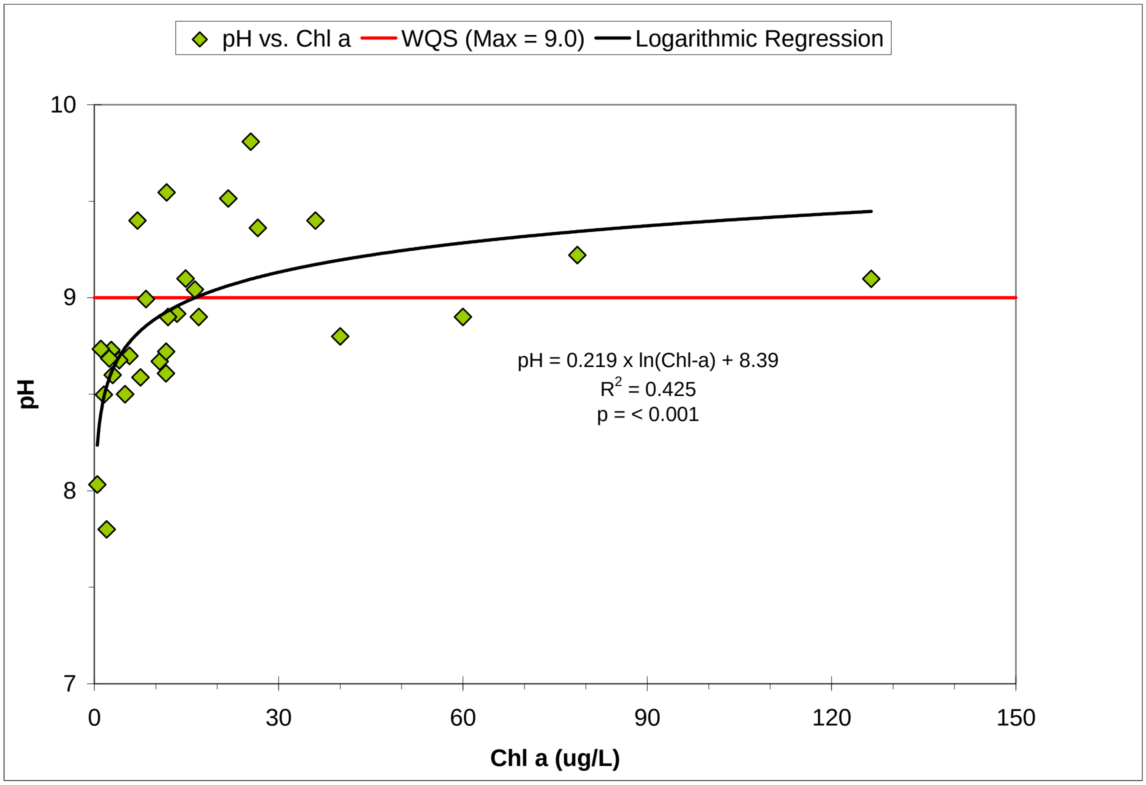


Figure D-2. Regression of measured pH (ISU and UHL) versus chlorophyll-a.

The results of the pH and chlorophyll-a regression reveal that chlorophyll-a may account for only 43 percent of the variability in observed pH. However, this relationship was the strongest among all single and multiple regressions using the dependant variables cited above (DO, cyanobacteria, alkalinity, turbidity, and chlorophyll-a). Uncertainty resulting from this regression equation was factored into the TMDL by the adoption of conservative assumptions regarding TP loading and the 10 percent explicit MOS. Moreover, the target chlorophyll-a concentration was set at a threshold that would result in zero pH violations in the historical data set, which includes a wide range of conditions regarding other dependant water quality variables.

Table D-1 reports the measured and modeled pH statistics for the purposes of comparing measured data to regression model output. The model performs reasonably well, and results in close approximations of the mean and median values. Approximations of the maximum are better than for minimum values.

Table D-1. Comparison of measured and modeled pH values.

pH	Monitored	Modeled
Mean	8.9	8.9
Median	8.9	8.9
Minimum	7.8	8.4
Maximum	9.8	9.5

Using the relationship established between chlorophyll-a and pH, an in-lake target of 16.5 ug/L was developed. This in-lake target was related to total phosphorus (TP) loading using BATHTUB simulations, discussed at the end of Section D.3 of this appendix.

D.3. GWLF and BATHTUB Models and Methodology

A combination of spreadsheet tools and modeling software packages were used to develop the pH TMDL. Watershed hydrology and pollutant loading was simulated using the Generalized Watershed Loading Function (GWLF) model, within the BasinSim 2.0 windows-based interface. In-lake water quality simulations were performed using BATHTUB 6.1.

GWLF has been used nationally for research and TMDL development, and is particularly useful for simulating sediment, nitrogen, and phosphorus loading from a mixed-use watershed. Key model inputs include parameters based on soil information, land use, and land practice management (Haith et al., 1996). GWLF also includes the ability to simulate point sources, septic tanks, and manure applied to croplands, which are often important considerations in TMDL development. BATHTUB is a steady-state water quality model developed by the U.S. Army Corps of Engineers that performs empirical eutrophication simulations in lakes and reservoirs (Walker, 1999).

GWLF parameterization. The GWLF model consists of three main input files, called the weather, transport, and nutrient files. The weather file was populated with National Weather Service (NWS) Cooperative Observer Program (COOP) data obtained through the Iowa Environmental Mesonet (IEM). Daily temperature and precipitation for the Mount Pleasant weather station (Station IA5796) was downloaded and formatted to meet GWLF requirements. The IEM can be accessed at the following web site: *http://mesonet.agron.iastate.edu/COOP/*

The transport file includes inputs that describe the watershed's soil, land use, erosion, and sediment delivery characteristics. Key inputs are reported in Table D-2 and include Revised Universal Soil Loss Equation (RUSLE) parameters and hydrologic curve numbers (CN) to describe each land cover area. Site-specific RUSLE parameters were obtained from the Henry and Des Moines County Soil and Water Conservation Districts (SWCDs). The RUSLE parameters are based on local land cover, soil type, slope, and other characteristics, and were calculated using methodology included in the Agriculture Handbook 703. The RUSLE parameters are also discussed in the GWLF/BasinSim user's guide (Dai et al., 2000), and the RUSLE equation is defined below:

$$A = R * K * LS * C * P$$

Where: A = Average annual soil loss in tons per acre per year
R = Rainfall/runoff erosivity
K = Soil erodibility
LS = Hillslope length and steepness
C = Cover management
P = Support practice

Other transport parameters include monthly evapotranspiration (ET) coefficients based on land cover and growing season, typical daylight hours in each month, and the overall watershed sediment delivery ratio (SDR). The ET coefficients and daylight hours were estimated using the GWLF/BasinSim user's guide (Dai et al., 2000). The SDR for Lake Geode was calculated to be 19.5 percent, using the "Erosion and Sediment Delivery" method developed by the state geologist for Iowa NRCS (Natural Resources Conservation Service Field Office Technical Guide, Section 1, Erosion Prediction: IA-198 "Erosion and Sediment Delivery", Schneider, March 27, 1998). This method uses SDR curves, which have been derived from numerous sediment surveys and vary based on the landform regions and drainage areas of the watersheds in Iowa.

The nutrient file is populated with inputs to calculate the nutrient loads generated by watershed sources. Parameters include sediment nutrient concentrations, information regarding runoff concentrations of row crops with and without manure applications, groundwater nutrient concentrations, number of people served by various types of septic systems, and point source inputs. Key nutrient inputs are reported in Table D-3, and were derived using the GWLF/BasinSim user's guide (Dai et al., 2000).

Table D-2. Key GWLF transport file parameters used for existing condition simulation.

Land Use / Land Cover	Hectares	(1)K	(1)LS	(1)C	(1)P	(2)K(LS)CP	(3)HSG	(4)CN
CAFO	6.2	0.282	1.683	0.900	1.000	0.4271	C	87
CB, Mulch Till, Average, Contour	10.6	0.281	0.544	0.140	0.700	0.0150	C	80
CB, Mulch Till, Average, Straight	1,805.1	0.252	0.550	0.175	1.000	0.0243	B	80
CB, Mulch Till, Average, Terraces, Straight	545.4	0.296	1.120	0.140	0.530	0.0246	D	85
CB, Mulch Till, Average, Terraces, Contour, Buffers	15.8	0.264	0.468	0.140	1.000	0.0173	C	82
CB, Mulch Till, Average, Terraces, Contour	30.1	0.302	0.638	0.140	0.330	0.0089	C	75
CB, Mulch Till, Poor, Straight	62.6	0.285	0.831	0.140	0.370	0.0123	C	77
CB, No Till, Average, Straight	7.3	0.300	0.524	0.050	1.000	0.0079	D	85
CB, N/A, Average, Straight	1.4	0.261	2.897	0.235	1.000	0.1777	D	88
CBOMMM, Mulch Till, Average, Straight	43.5	0.298	0.805	0.056	1.000	0.0134	D	82
CBOMMM, Mulch Till, Good, Straight	12.1	0.294	0.900	0.048	1.000	0.0127	C	76
CRP	101.3	0.286	1.073	0.001	1.000	0.0003	C	71
Farmstead/Cemetery/Garden	94.8	0.266	0.991	0.003	0.997	0.0008	C	82
Grassland	169.6	0.277	1.211	0.001	0.998	0.0003	C	71
Grazed Timber	18.8	0.273	1.939	0.060	1.000	0.0318	C	77
Pasture	62.5	0.281	1.823	0.030	1.000	0.0154	D	84
Shrub/Scrub	21.0	0.265	2.355	0.078	1.000	0.0487	C	70
Timber	713.6	0.273	1.997	0.011	1.000	0.0060	C	73
Water	72.1	0.005	0.002	0.000	0.000	0.0000	D	100
Wildlife Area	130.5	0.278	1.843	0.011	1.000	0.0056	C	72
Residential/Roads	255.1	0.265	0.793	0.005	1.000	0.0011	C	90
Total Area	**4,179.4**							

(1) Individual RUSLE parameters from Agriculture Handbook 703 and GIS calculations
(2) Product of individual RUSLE parameters (GWLF input)
(3) HSG = hydrologic soil group
(4) Curve number based on land use and HSG (GWLF input)

Table D-3. Key GWLF nutrient file parameters used for existing condition simulation.

Land Use / Land Cover	Hectares	(1)Runoff N (mg/L)	(2)Runoff P (mg/L)	(3)Manured N (mg/L)	(3)Manured P (mg/L)
CAFO	6.2	29.3	0.4	12.2	1.9
CB, Mulch Till, Average, Contour	10.6	2.9	0.4	12.2	1.9
CB, Mulch Till, Average, Straight	1,805.1	2.9	0.4	12.2	1.9
CB, Mulch Till, Average, Terraces, Straight	545.4	2.9	0.4		
CB, Mulch Till, Average, Terraces, Contour, Buffers	15.8	2.9	0.4		
CB, Mulch Till, Average, Terraces, Contour	30.1	2.9	0.4		
CB, Mulch Till, Poor, Straight	62.6	2.9	0.4		
CB, No Till, Average, Straight	7.3	2.9	0.4		
CB, N/A, Average, Straight	1.4	2.9	0.4		
CBOMMM, Mulch Till, Average, Straight	43.5	2.7	0.3		
CBOMMM, Mulch Till, Good, Straight	12.1	2.7	0.3		
CRP	101.3	2.8	0.15		
Farmstead/Cemetery/Garden	94.8	1.9	0.28		
Grassland	169.6	2.8	0.15		
Grazed Timber	18.8	1.9	0.2		
Pasture	62.5	3.0	0.25		
Shrub/Scrub	21.0	0.8	0.06		
Timber	713.6	0.8	0.06		
Water	72.1	0	0		
Wildlife Area	130.5	1.8	0.11		
Residential/Roads	255.1	(4)0.101	(5)0.0112		
Total Area	**4,179.4**				

(1) Groundwater N = 0.65 mg/L
(2) Groundwater P = 0.055 mg/L
(3) Assumed manure application on three land uses
(4) Urban N buildup in kg/ha-day
(5) Urban P buildup in kg/ha-day

There are 119 septic systems in the watershed, but only 45 of these systems are within a quarter mile of the nearest tributary stream or tile drain intake. Assuming that approximately 80 percent of septic systems are improperly designed or failing in some way results in 30 percent of all systems (36 of 119) contributing TP to the lake.

The GWLF model simulates four types of septic systems: normally functioning systems, ponded systems, short-circuited systems, and direct discharge systems. The latter three types are considered improperly functioning or illegal systems. Table D-4 reports assumptions regarding septic systems. Note that the 36 contributing systems were spread evenly among the various failure types.

Table D-4. Septic system assumptions used in nutrient file development.

System Type	Number of Systems	Persons per House	Number of Persons Served
Normal	83	2.4	199
Pond	12	2.4	29
Short-circuited	12	2.4	29
Direct discharge	12	2.4	29
Totals	**119**		**286**

Geese have the potential to significantly contribute phosphorus to a lake if they congregate in large numbers. The GWLF model does not simulate nutrient inputs from geese directly. However, for the purpose of this TMDL, geese inputs were modeled as point sources that vary seasonally depending on population. Population estimates are based on visual counts by IDNR state park staff and IDNR wildlife biologists. Assumptions used in modeling nutrient loads from geese are reported in Table D-5.

Table D-5. Goose population estimates and monthly nutrient loads.

Time Period	Goose population	kg-TN/month	kg-TP/month
October – April	150	6.4	2.0
May – September	70	3.0	0.9

GWLF calibration. Because watershed loads were not monitored, it was not possible to calibrate the GWLF model to observed data. Nutrient inputs are based on literature values that designate runoff concentrations for each land use. These parameters are available in the GWLF model documentation (Haith et. al., 1996) and were previously discussed in this appendix.

Simulated unit loads of TP were compared to a range of literature values reported by Caraco and Brown (2001), provided in Table D-6 below. The comparison reveals simulated loads are near the upper end of the expected range. Simulated loads from conservation areas were likely higher than literature values due to the presence of gullies in the forested areas of the Lake Geode watershed. Additionally, forested areas have significantly steeper slopes than the upper portions of the watershed dominated by other land uses.

Table D-6. Comparison of GWLF simulated loads and literature values.

Geode Land Use	[1]Literature Land Use	Literature Range (lbs/ac)	GWLF Output (lbs/ac)
Row Crops	Ag	0.96-1.62	1.58
Grazed Lands	Ag	0.96-1.62	1.50
Farmsteads/Roads	Rural	0.12-0.75	0.74
Conservation Areas	Forest	0.10-0.20	0.42

(1) Literature values reported by Caraco and Brown in *Crafting an Accurate Phosphorus Budget for Your Lake*, Watershed Protection Techniques, Urban Lake Management, Vol. 3, No. 4.

Because the Lake Geode watershed has a significant amount of tile drainage, TP exports simulated using GWLF were compared with studies conducted in agriculturally dominated watersheds with similar tile drainage systems. A study of three watersheds in Illinois found that annual TP exports ranged from 0.1 to 2.1 kilograms per hectare (kg/ha), or 0.1 to 1.9 lbs/ac (Royer, et al., 2006). The Lake Geode watershed GWLF model resulted in a total TP export of 1.38 lbs/ac, slightly higher than the exports reported in the Illinois study. This seems reasonable based on the relatively steeper slopes in the Lake Geode watershed, and the fact that the Lake Geode watershed is nearly an order of magnitude smaller than the Illinois watersheds evaluated by Royer et al. A watershed’s sediment deliver ratio is inversely related to its drainage area. Hence, lower TP exports should be expected in large watersheds compared to small watersheds with similar slopes and land use activities.

In an assessment of the Iowa River’s South Fork watershed in central Iowa, researchers estimated average annual TP exports in the range of 0.4 to 0.6 lbs/ac (Tomer et al., 2008). However, this study area lies in the heart of the Des Moines Lobe ecoregion, which is much flatter than the landscape in the vicinity of Lake Geode. It is logical to expect higher TP exports in steep watersheds. Similar to the 2006 study by Royer et al., the South Fork watersheds evaluated were several times larger than the Lake Geode watershed. As noted previously, the sediment deliver ratio becomes lower for larger watersheds.

USGS published an investigation of nutrient and sediment exports from eastern Iowa river basins as part of the National Water Quality Assessment Program (USGS, 2001). Two streams in the USGS study were relatively close in proximity to the Lake Geode watershed. From 1996 to 1998, the annual TP export in the Skunk River at Augusta, Iowa averaged 2.5 lbs/ac. During the same period, TP export on the Iowa River at Wapello, Iowa averaged 0.88 lb/ac.

Based on the available literature for tile-drained watersheds and considering differences in slope and watershed size, it was determined that TP exports simulated by GWLF were adequate for calculation of the Lake Geode TMDL. A comparison of TP exports for tile-drained watersheds is provided in Table D-7.

Table D-7. Comparison of TP export to other tile-drained watersheds.

Watershed/Location	Source	TP Export (lb/ac)
East Central Illinois	Royer et al., 2006	0.1-1.9
South Fork Iowa River	Tomer et al., 2008	0.4-0.6
Skunk River at Augusta, IA	USGS, 2001	2.5
Iowa River at Wapello, IA	USGS, 2001	0.88
Lake Geode	**TMDL**	**1.38**

BATHTUB parameterization. The BATHTUB model includes several data input menus/modules to describe lake characteristics and to set up water quality simulations. Data menus utilized to develop the BATHTUB model for Lake Geode include: model selections, global variables, segment data, and tributary data. The model selections menu allows the user to specify which modeling equations are to be used in the simulation of in-lake nitrogen, phosphorus, chlorophyll-a, transparency, and other parameters. Global variables describe parameters consistent throughout the lake such as precipitation and evaporation. The segment data menu is used to describe existing lake morphometry, observed water quality, calibration factors, and internal loads. GWLF hydrology and nutrient loads were converted to the appropriate BATHTUB input units and entered in the tributary data menu.

BATHTUB input segment data for Lake Geode is reported in Table D-8, and tributary data inputs are summarized in Table D-9. The tributary data shown in Table D-9 is based on GWLF simulations from 2005-07. The BATHTUB model was calibrated to observed water quality as measured by UHL from 2005-07, reported in Table D-8.

Table D-8. Key segment data for the Lake Geode BATHTUB model.

Parameter	Measured or Monitored Data	(1)BATHTUB Input
Lake Surface Area	174 acres	0.70 km^2
Mean Depth	21.9 feet	6.68 m
Reservoir Length	1.67 miles	2.68 km
Mixed Layer Depth	11.8 feet	3.06 m
Hypolimnetic Depth	17.5 feet	5.33 m
Total Phosphorus	63 ug/L	63 ppb
Total Nitrogen	2.26 mg/L	2,264 ppb
Chlorophyll-a	20.2 ug/L	20.2 ppb
Secchi Depth	2.5 m	2.5 m
Ammonia	63 ug/L	(2)N/A
Nitrate/Nitrite	1.4 mg/L	(2)N/A
Organic Nitrogen	0.8 mg/L	802 ppb
Ortho P	27 ug/L	(2)N/A
TP – Ortho P	36 ug/L	36 ppb

(1) Measured or monitored data converted to units required by BATHTUB
(2) Not a BATHTUB input

Table D-9. Key tributary data for the Lake Geode BATHTUB model.

Parameter	[1]Measured or Simulated Data	[2]BATHTUB Input
Watershed Area	10,328 acres	41.8 km^2
Flow Rate	17.7E+06 m^3/yr	[3]17.7 hm^3/yr
TP Concentration	[4]6.5 mtons	364.3 ppb
Ortho P Concentration	[4]2.3 mtons	130.9 ppb
Total N Concentration	[4]39.9 mtons	2248.9 ppb
Inorganic N Concentration	[4]20.8 mtons	1175.4 ppb

(1) Watershed area measured from GIS delineation; Simulated data represents existing condition average annual GWLF output from 2005-07.
(2) Measured/simulated data converted to units required by BATHTUB
(3) hm3/yr = cubic hectometers per year
(4) mtons = metric tons

The BATHTUB model selections menu allows the user to specify one of several potential models for simulating a conservative substance, total phosphorus, total nitrogen, chlorophyll-a, and transparency in the lake/reservoir. Each of the models has advantages and disadvantages, with some models more applicable to certain site-specific conditions than others. For the Lake Geode TMDL, the conservative substance model was not used. Each of the available phosphorus, nitrogen, chlorophyll-a, and transparency models were ran to evaluate the best fit to observed data.

The Canfield and Bachman Reservoir Model (Option 4) was selected for phosphorus simulation. This model provided a reasonable calibration to observed data, and is based on TP rather than distinguishing between total and ortho-phosphorus (ortho-P) as the default model does. Because the water quality data set was missing several ortho-P data points, it was preferred to use a model based solely on TP. In addition, the Canfield and Bachman Reservoir Model was developed specifically for reservoirs, and Lake Geode is a reservoir rather than a natural lake. For nitrogen simulations, Model 7 provided the best fit to observed data. However, because Lake Geode is not nitrogen limited, the nitrogen model is not a critical element of the TMDL.

The default model (Option 2) was selected for chlorophyll-a simulations. This model considers TP, light, and non-algal turbidity in predicting chlorophyll-a levels, and provided the best fit to observed data. The default model (Option 1) was selected for transparency simulations, and is based on chlorophyll-a and non-algal turbidity.

BATHTUB calibration. The existing condition BATHTUB model was calibrated to 2005-2007 water quality data collected by UHL. The predicted and observed in-lake values, along with calibration coefficients, are reported in Table D-10. The Lake Geode model over-predicted TP by 10.3 percent, even after the calibration coefficient was adjusted to the maximum recommended value of 2.0. However, the model predictions for TN, chlorophyll-a, and Secchi depth were closely matched observed data. After the model was calibrated to UHL data from 2005-2007, it was tested against the individual years within that same time frame to examine the ability of the model to capture year to year variability. In 2007, the model under-predicted TP by 18.5 percent, but over-predicted chlorophyll-a by 16.3 percent. Similarly, the model under-predicted TP by 18.5 percent in 2006, but under-estimated chlorophyll-a by 9.7 percent. A formal validation study was not developed due to the low number of observed data points available.

Table D-10. Calibration data for Lake Geode BATHTUB model (2005-07).

Parameter	Observed Data	BATHTUB Output	% Error	Calibration Coefficient
TP	63.0 ug/L	69.5 ug/L	10.3	2.00
TN	2.26 mg/L	2.26 mg/L	< 0.1	0.98
Chl-a	20.2 ug/L	20.1 ug/L	0.5	0.64
Secchi	2.5 m	2.5 m	0.0	1.00

Use of BATHTUB to develop loading capacity. The in-lake chlorophyll-a target was established (in Section D.2 of this appendix) as maximum allowable concentration of 16.5 ug/L. This in-lake target was translated to a loading capacity using the calibrated BATHTUB model. The tributary input TP load, as represented in BATHTUB by average concentration and annual flow rate, was adjusted iteratively until simulations resulted in the desired target for chlorophyll-a. The maximum TP load that met this criterion was 3.89 metric tons (mtons), or 8,576 pounds per year (lbs/year). This load represents the allowable annual average TP load to Lake Geode, and is the basis for developing the daily loading capacity required in the TMDL.

D.4. Expressing the Maximum Daily Load

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

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

Per the EPA recommendations, the loading capacity of Lake Geode for TP is expressed as both a maximum annual average and a daily maximum load. The annual average load is more applicable to the assessment of in-lake water quality and water quality improvement actions, while the daily maximum load expression satisfies the legal uncertainty addressed in the EPA memorandum. The allowable annual average was derived using the BATHTUB as described in previously in this appendix, and is 8,576 pounds per year (lbs/yr).

The maximum daily load was estimated from the allowable annual average load using a statistical approach. The methodology for this approach is taken directly from the follow-up guidance document titled *Options for Expressing Daily Loads in TMDLs*

(EPA, 2007), which was issued shortly after the November 2006 memorandum cited previously. This methodology is also found in EPA’s 1991 *Technical Support Document for Water Quality Based Toxics Control*.

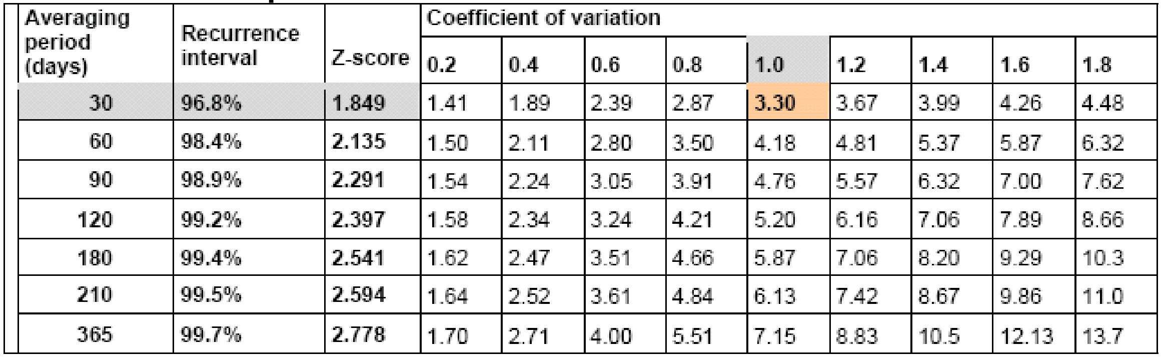
The *Options for Expressing Daily Loads in TMDLs* document presents a similar case study in which a statistical approach is considered to be the best option for identifying a maximum daily load that corresponds to the allowable average load. The method calculates the daily maximum based on a long-term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

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

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

The long-term average load (LTA) is 23.5 lbs/day, which is the allowable annual load derived using BATHTUB divided by the 365-day averaging period. The 365-day averaging period equates to a recurrence interval of 99.7 percent and corresponding z statistic of 2.778, as reported in Table D-11. The coefficient of variation (CV) is the ratio of the standard deviation to the mean of the simulated GWLF TP load data set for the 2005-07 period, and is 0.7. The resulting σ^2 value is 0.399. This yields a final LTA multiplier of 4.74 and results in a daily TMDL of 111 lbs/day. This calculation is summarized in Table D-12.

Table D-11. Multipliers used to convert a LTA to an MDL.



Averaging period (days)	Recurrence interval	Z-score	Coefficient of variation								
			0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
30	96.8%	1.849	1.41	1.89	2.39	2.87	3.30	3.67	3.99	4.26	4.48
60	98.4%	2.135	1.50	2.11	2.80	3.50	4.18	4.81	5.37	5.87	6.32
90	98.9%	2.291	1.54	2.24	3.05	3.91	4.76	5.57	6.32	7.00	7.62
120	99.2%	2.397	1.58	2.34	3.24	4.21	5.20	6.16	7.06	7.89	8.66
180	99.4%	2.541	1.62	2.47	3.51	4.66	5.87	7.06	8.20	9.29	10.3
210	99.5%	2.594	1.64	2.52	3.61	4.84	6.13	7.42	8.67	9.86	11.0
365	99.7%	2.778	1.70	2.71	4.00	5.51	7.15	8.83	10.5	12.13	13.7

Table D-12. Summary of LTA to MDL calculation for Lake Geode.

Parameter	Value	Description
LTA	23.5 lbs/day	Allowable annual load
Z Statistic	2.778	Based on 365-day averaging period
CV	0.7	Used CV from annual GWLF TP loads
σ^2	0.399	ln $(CV^2 + 1)$
MDL	**111 lbs/day**	**TMDL (expressed as daily load)**

D.5. References

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Appendix E --- *E. coli* Modeling and Methodology

E. coli loads were simulated using a combination of several modeling tools. These tools include the EPA Bacterial Indicator Tool (BIT), the Generalized Watershed Loading Function (GWLF) model, and a lake bacteria spreadsheet (LBS) developed specifically for the Lake Geode TMDL.

BIT is a spreadsheet model that estimates bacteria contributions from multiple sources in a watershed (EPA, 2000). BIT was utilized to develop bacteria buildup and washoff coefficients based on land use, animals in the watershed, manure application and grazing practices, and wildlife populations. The BIT tool also accounts for in-stream bacteria loading due to direct deposition by cattle and from septic systems.

The GWLF model used for the *E. coli* TMDL is the same model used for the pH TMDL as described in Section 3 and Appendix D of this report. However, only hydrologic output from GWLF simulations was utilized in the development of this *E. coli* TMDL. Specifically, GWLF was used to develop a daily flow set, which is required to estimate bacteria washoff and loading using the buildup coefficients generated using BIT.

The LBS was developed by IDNR staff and utilizes the buildup/washoff parameters developed in the BIT model and the daily flows simulated using GWLF to calculate daily bacteria loads to the lake. The LBS also incorporates first-order decay kinetics, as documented in *Rates, Constants, and Kinetic Formulations in Surface Water Quality Modeling* (EPA, 1985), to model in-lake bacteria concentrations on a daily basis. Most water quality models, including BIT, perform bacteria simulations using fecal coliform rather than *E. coli*. Conversion of fecal coliform to *E. coli* concentration for this TMDL is calculated in the LBS. The calculation is based on the ratio of the previous fecal coliform single-sample maximum standard of 400 colony forming units per 100 milliliters (cfu/100 mL) to the existing *E. coli* single-sample maximum standard of 235 cfu/100 mL. The resulting conversion factor is 0.59.

Development of the BIT model. The BIT model includes a number of data input worksheets required by the model to develop fecal coliform buildup coefficients and in-stream bacteria loads. Input worksheets include land use areas, number/density of animals, grazing practices, and septic system information. Land uses are generalized as reported in Table E-1, which also reports the area of each land use.

The animals input sheet includes livestock population and wildlife densities for each land use. Based on permitted animal feeding operation records, a field assessment, and anecdotal data from local agency staff, there are an estimated 150 cattle, 6,200 hogs, and 20 horses in the watershed. Ducks and geese are assumed to be limited to Geode State Park. It should be noted that in addition to the goose population indicated for the forest land use, additional geese inputs directly from the beach are accounted for separately in the LBS tool, discussed later in this appendix. All wildlife population estimates are for the recreation season only (March 15 through November 15), the period when the Class A1 water quality criteria apply. Deer populations are significantly larger during the winter months, and there can be as many as 700 deer in Geode State Park over the winter. According to an IDNR wildlife biologist, approximately 80 percent of the deer population disperses in March and does not return until late November (W. Suchy, personal communication).

Table E-1. Generalized land use areas for BIT input.

Land Use	Description	Area (acres)
Built-Up	Includes residential, roads, etc.	865
Cropland	Row crops, small grains, alfalfa, etc.	6,261
Pastureland	Includes pasture and grazed timber	216
Forest	Includes ungrazed (natural) grasslands, timber, etc.	2,807
	(1)Total Area =	**10,149**

(1) Areas with land use classified as water are not included in BIT calculations. Watershed area including Lake Geode and other small waterbodies is 10,328 acres.

Livestock manure application input includes the fraction of manure applied each month, as well as the percent of manure incorporated into the soil for each type of livestock in the watershed. The existing condition BIT model assumes 60 percent of hog and cattle manure is applied in March and April (30 percent in each month), and 40 percent is applied in October and November (20 percent each month). Based on communications with the Des Moines and Henry County soil conservationists, approximately 85 percent of hog manure is incorporated into the soil. It was assumed that only 10 percent of cattle manure is incorporated using some unspecified means of tillage during or shortly after application.

The existing condition BIT model input also specifies the amount of time that livestock is confined in feedlots versus grazing in pastures. The confinement time is assumed to be 100 percent during winter months and decreases from March through October when cattle are sent to pasture. It was assumed that spend 25 percent of the time grazing in March, 50 percent in April and October, and 90 percent from May through September.

The BIT model considers all bacteria inputs described above to develop buildup and washoff coefficients that vary monthly. The resulting monthly coefficients for each land use were area-weighted, and are reported in Table E-2. The ACCUM parameter represents the rate of buildup of fecal coliform in fecal coliforms per acre per day (FC/acre/day). The SQOLIM parameter represents the maximum buildup that can occur in FC/acre considering die-off on the land surface. The REMDSP is the removal rate of accumulated fecal coliform in units per time (1/day) due to die-off and other processes. REMDSP can be calculated by dividing the buildup rate by the maximum accumulation (ACCUM divided by SQOLIM) (Butcher, 2003). The coefficients generated using the BIT model were utilized to determine watershed loads to Lake Geode for existing conditions. In order to fully quantify washoff and subsequent fecal coliform loads, a daily flow set is needed.

Table E-2. Fecal coliform buildup coefficients for existing conditions.

Month	ACCUM (FC/acre/day)	SQOLIM (FC/acre)	REMDSP (1/day)
January	2.76E+08	4.96E+08	0.56
February	2.76E+08	4.96E+08	0.56
March	3.72E+08	6.69E+08	0.56
April	1.72E+10	2.59E+10	0.66
May	1.74E+10	2.62E+10	0.66
June	1.24E+09	1.95E+09	0.64
July	1.18E+09	1.85E+09	0.64
August	1.13E+09	1.78E+09	0.64
September	1.24E+09	1.95E+09	0.64
October	1.13E+10	2.03E+10	0.56
November	1.13E+10	2.04E+10	0.56
December	2.76E+08	4.96E+08	0.56

Grazing is further broken down based on the percent of cattle with access to streams while grazing, which affects the amount of direct deposition of bacteria to streams. Percent of stream access increases from 5 percent of grazing time in April to 28 percent in August, then gradually decreases as the average temperature drops in the fall.

The EPA BIT model was modified slightly to consider direct deposition of bacteria to streams by wildlife. This is a conservative assumption since the BIT model default normally considers all wildlife manure to be deposited on the ground surface and subject to the buildup/washoff equations.

It is estimated that there are currently 119 septic systems in the Lake Geode watershed. Based on the known age of existing systems and anecdotal data from local agency staff, it is assumed that 80 percent of those systems are failing, illegally hooked up, or not functioning properly. However, only 45 of septic systems are within a quarter mile of the lake, nearest tributary stream, or tile drain intake. Assuming that only failing systems within the quarter mile buffer distance actively contribute *E. coli* to the lake results in an effective contribution rate of 30 percent, or 36 of 119 systems.

Total direct deposition rates of fecal coliform vary monthly from 1.18E+09 FC/day from November through March, to as much as 1.65E+11 in August during peak grazing season. The in-stream load from septics is assumed constant year-round, and is estimated at 9.99E+11 FC/day.

GWLF hydrology. The same GWLF model utilized to simulate total phosphorus (TP) loads for the pH TMDL described in Section 3 and Appendix D of this report was used to obtain daily flows for the *E. coli* TMDL. GWLF is typically used to generate monthly or annual flow and pollutant loads. However, a modified executable file allows the user to obtain daily flow as tabulated output. The daily runoff obtained from GWLF simulations was input into the LBS along with the bacteria buildup coefficients obtained from BIT.

Because Lake Geode resides in a relatively small and ungauged watershed, there were no historical flow data available to calibrate GWLF hydrology. Instead, GWLF output was compared to peak flow estimates from regional regression equations for several storm events that occurred during the GWLF simulation period. The regression equations were developed by the US Geological Survey (USGS), and published in WRIR 00-4233 (USGS, 2000). Table E-3 reports the regression equation results, as well as average daily flow simulated for several events using GWLF. Historical storms in Table E-3 approximate the 2 and 5-year events. These were the largest events that occurred within the modeling period for which historical data was available. Events equal to and slightly less than this magnitude are likely responsible for the majority of sediment, and hence phosphorus loads, to the lake. Reasonable prediction of flows under these conditions would provide some confidence that GWLF-simulated TP loads are reasonable.

The storm event on May 14, 2001, resulted in a GWLF daily flow of 1,372 cubic feet per second (cfs). The precipitation on this date was approximately 2.5 percent lower than a 5-year storm, and the simulated daily flow was approximately 24 percent lower than the peak flow predicted by the regression equation. This seems like a reasonable difference considering the regression equation is for peak flow and the GWLF output is a daily average. The average precipitation for the remaining rainfall events in Table E-3 is 2.83 inches, which is approximately 90 percent of the two-year storm total. However, the simulated GWLF flow for these events is 317 cfs, or 50 percent higher than the 2-year peak flow predicted by the regression equations. Differences may be due to antecedent moisture conditions, localized rainfall patterns, or other hydrological parameters not considered in the regression equation, which has a potential error of nearly 45 percent. Note that flow for the approximate 2-year events varies widely, but good agreement between GWLF simulations and regression equation predictions is observed on June 24, 2000, September 19, 2001, and June 26, 2003. Despite the lack of available calibration data, it appears the GWLF hydrology simulations are reasonable for individual storm events.

Table E-3. Comparison of USGS regression equation and GWLF flows.

Regression Equation	**Storm Frequency**	**Precipitation (in)**	**Peak Flow (cfs)**
(1)$Q_2 = 182 \times DA^{0.054}$	2-year	3.14	211
(1)$Q_5 = 464 \times DA^{0.490}$	5-year	4.03	1,812
GWLF Simulation Date	**Approx. Frequency**	**Precipitation (in)**	**Daily Flow (cfs)**
9/28/1999	> 2-year	3.40	440
6/24/2000	< 2-year	2.40	152
5/14/2001	< 5-year	3.93	1,371
9/19/2001	< 2-year	2.70	174
8/23/2002	2-year	3.00	305
6/26/2003	< 2-year	2.60	150
10/23/2004	< 2-year	2.70	214
3/13/2006	2-year	3.00	781

(1) DA = drainage area = 16.1 square miles

Average annual flows simulated using the Lake Geode GWLF model were also compared to estimations of streamflow using multiple linear regression models developed specifically for Iowa watersheds (Schilling and Wolter, 2005). The regression models were developed for 33 test watersheds throughout Iowa and extended to watersheds ranging in size from 12-digit hydrologic unit codes (HUC-12) to 8-digit HUCs. The test watershed nearest Lake Geode was the Cedar Creek near Oakland Mills, Iowa. The authors estimated the average long-term stream flow for Cedar Creek to be 10.5 inches/yr. The estimated flow for the HUC-8 in which Lake Geode is located was between 11 and 13.5 inches/yr. The annual average flow (1997-2007) simulated using the GWLF model developed for the Lake Geode TMDL was 16.4 inches, which is approximately 21 percent greater than the flow predicted by the regression models. However, the test watershed for the regression equation was over 530 square miles, or 33 times larger than the Lake Geode watershed. Schilling and Wolter note that lack of stream gauges in smaller basins prevented calibration of the regression models across different watershed sizes. However, the regression equation results are informative and show how streamflow varies on a statewide basis.

Despite the absence of observed streamflow data required for thorough calibration, the Lake Geode GWLF model appears to provide reasonable estimates of flow. Comparison of GWLF-simulated flows with regression model flows developed specifically for Iowa watersheds (provided in Table E-3 and the text above) indicates that GWLF simulations may slightly over-estimate flows on an anuual and event basis. Over-estimation of flows would lead to conservative estimates of pollutant loads, thus providing an additional factor of safety in the development of TMDL calculations.

Development of the Lake Bacteria Spreadsheet (LBS). The pollutant buildup coefficients (reported in Table E-2) and in-stream bacteria loads developed using BIT were input to the LBS, along with daily flows simulated using GWLF. The LBS utilized the following pollutant buildup/washoff equations to model: (1) the stored fecal coliform load, (2) the washoff fraction of the stored load, and (3) the runoff load to Lake Geode from the watershed:

$$N_{(t)} = N_{(t-1)} \times e^{-REMDSP \times \Delta t} + SQOLIM \times \left(1 - e^{-REMDSP \times \Delta t}\right) - W_{kt}$$

Where: $N_{(t)}$ = stored fecal coliform load at time = t (FC/acre)
t = time step (days)
REMDSP = removal rate (1/day)
SQOLIM = maximum buildup (FC/acre)
W_{kt} = runoff load (FC/acre)

$$w_{kt} = 1 - e^{-(2.303/WSQOP) \times Q_{kt}}$$

Where: w_{kt} = fraction of fecal coliform washed off
WSQOP = runoff depth at which 90 percent of fecal coliform is assumed to washoff = 1.25 inches
Q_{kt} = runoff depth (inches)

$$W_{kt} = w_{kt} \times \left[N_{(t-1)} \times e^{-REMDSP \times \Delta t} + SQOLIM \times \left(1 - e^{-REMDSP \times \Delta t} \right) \right]$$

Where: W_{kt} = runoff load (FC/acre)
w_{kt} = fraction of fecal coliform washed off
$N_{(t-1)}$ = stored fecal coliform load at time = t-1 (FC/acre)
t = time step (days)
REMDSP = removal rate (1/day)
SQOLIM = maximum buildup (FC/acre)

The last equation multiplies the stored load (FC/acre) calculated using the first equation by the runoff fraction calculated using the second equation. The result is the runoff load in FC/acre, which is then multiplied by the drainage area to obtain the runoff load in FC/day. The total in-stream load (from direct deposition and septic systems) is added to this washoff load to obtain the total watershed load to Lake Geode in FC/day.

The LBS also estimates the contributions from deposition of goose manure at the swimming beach and adds this to the overall fecal coliform load. Using anecdotal evidence and best professional judgment, it is assumed 20 geese typically reside at the swimming beach and 80 percent of fecal coliform deposited by geese at the beach is transported to the near-shore beach volume (80 percent transport efficiency).

The first-order die-off rate constant for fecal coliform in Lake Geode is assumed to be 0.96 1/day. The LBS calculates daily concentrations based on the buildup/washoff loads, in-stream loads, and contributions from geese at the beach. Fecal coliform loads are converted to *E. coli* loads using the 0.59 ratio described previously.

LBS Simulation Results. The daily LBS simulations are compared to observed data received from the IDNR/IGS Beach Monitoring Program in Figure E-1. A statistical comparison of simulated output and observed data is reported in Table E-4. The comparison reveals the LBS model does a reasonable job of estimating the mean *E. coli* concentration, but does not capture extreme values as well. Because the model includes daily *E. coli* inputs from geese residing at the beach, regardless of rainfall, die-off never results in non-detectable concentrations occasionally observed in the monitoring data. This inflates the median concentration of the simulated data set. The LBS model accurately predicts the frequency of exceedance of the single-sample maximum criterion of 235 cfu/100 mL. The observed exceedance frequency is 9.88 percent, according to the IDNR/IGS Beach Monitoring Program data, whereas the simulated exceedance frequency is 9.96 percent. Considering the extreme variability frequently exhibited by measured *E. coli* levels in natural systems, and the excellent agreement in exceedance frequency, it is reasonable to use LBS model to determine the loading capacity. The loading capacity is obtained by finding the maximum allowable load that results in zero violations of the water quality standard (zero exceedance frequency).

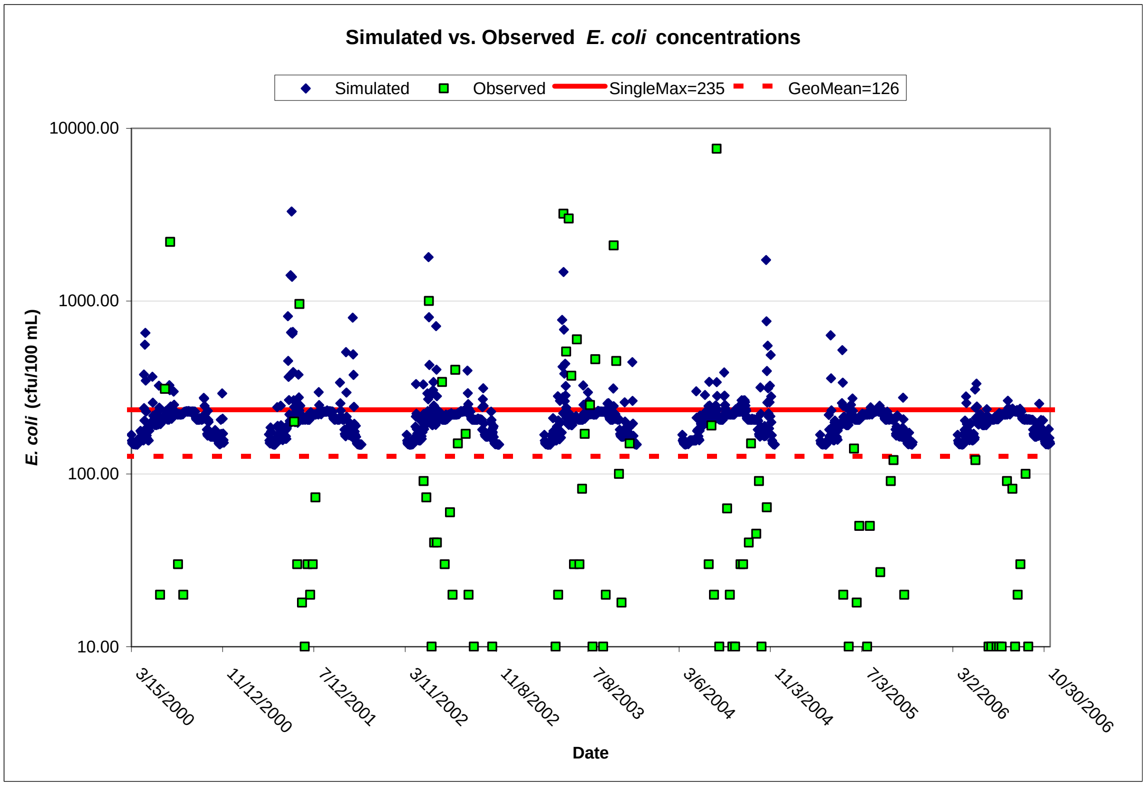

Figure E-1. Observed and simulated *E. coli* values. Note: Detection limit = 10 cfu/100 mL.

Watershed and water quality modeling simulations estimated the existing median *E. coli* load to Lake Geode to be 2.72E+12 cfu/day. The existing maximum (95th percentile) load is 4.54+E12

Table E-4. Comparison of LBS output to observed *E. coli* data.

Metric	(1)Observed	(1)Simulated	Difference
Mean (cfu/100 mL)	172	215	24.9 %
Median (cfu/100 mL)	10	206	1.31 log
Min (cfu/100 mL)	Non-detect	148	--
Max (cfu/100 mL)	7,600	3,298	- 56.6 %
(2)Exceedance (%)	9.88	9.96	- 0.08 %

(1) Simulated and observed concentrations are measured at the swimming beach.
(2) Exceedance = the % of samples/simulations that exceed 235 cfu/100 mL

E. coli loading capacity. To develop the loading capacity for the Lake Geode *E. coli* TMDL, the existing conditions LBS model was modified to reflect the impact of load reductions on water quality standards attainment. Loads were reduced until the LBS inputs (buildup/washoff, in-stream, and geese loads) resulted in simulation output that complies with the single-sample maximum water quality criterion of 235 cfu/100 mL at each daily time step throughout the 10-year simulation period. The resulting TMDL loads are 1.68E+11 cfu/day for dry to normal conditions, as represented by the median load, and 2.95E+11 cfu/day for wet conditions, represented by the 95th percentile load.

E.2. References

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Appendix F --- Public Comments

The Iowa Department of Natural Resources (IDNR) received one electronic comment on the draft of the Lake Geode TMDL. The comment and IDNR response letter are included in this appendix.

Berckes, Jeff [DNR]

From: HEATER, RICHARD S [AG/1630] [richard.s.heater@monsanto.com]
Sent: Tuesday, January 27, 2009 12:43 PM
To: Berckes, Jeff [DNR]
Subject: Geode watershed comments

Jeff;

Sorry about not being able to make it to the public meeting on the Lake Geode watershed issues. As you will remember the weather was extremely cold and taking care of livestock on those extremely cold days can be challenging and time consuming. I did take the time to read the DNR report on the Lake Geode watershed problems; I would like you to explain in more detail the projected sources of livestock manure from the model that you ran for determining the % of sources of E. coli. I agree that using bathtub type models can save lots of time, water sampling and work in projecting probable causes; the biggest concern that I have using these types of models is that the data generated is only as good as the information imputed into the model. I feel that the % of E. coli attributed to livestock manure as compared to the % generated by wildlife is off by quite a large ratio. By using the USDA report of beef cows for Des Moines and Henry counties as compared to the DNR projected report of deer populations in the same two counties; there seems to be some discrepancy in waste generated in this area. I will accept that it would take approximately 6 deer to equal 1 cow on body size and that same ratio would hold true to food consumed and waste generated. I hope you will accept that in this watershed area the ratio of deer to cows is probably 2 to 1. I think we both know that the deer population in this area is extremely high due to the park restrictions and the number of acres that are fenced; that prevent cattle from grazing in this watershed area. I would accept that with correct information entered into the model; that the amount of livestock waste generated by the cattle in the area could be 3 times higher than the waste generated by the deer in the area; but I have a hard time accepting the correct information was entered into the model when your report shows that 25 to 40 times more E. coli is attributed to the cattle grazing in the area of the watershed then the wildlife in the area. I would appreciate it if you would share the information that was entered into the model that was used to generate the probable causes. As you can tell I am very sensitive to livestock; especially cattle being blamed for environmental issues; especially when all the local papers are running articles that have headlines listing livestock as the major contributor to the watershed problems of Lake Geode. When I questioned the newspapers about the information they had reported; they both told me the information came from the IDNR. My discussion with your organization is what led me to the above mentioned DNR report for the Lake Geode watershed. I would like to discuss this issue future with you or any other member of your group if you feel it would be beneficial. Thanks for your time!!!!!!

Scott Heater
Heater Farms
Wapello, Iowa
319-523-3891

Iowa
Fields of Opportunities

STATE OF IOWA

CHESTER J. CULVER, GOVERNOR
PATTY JUDGE, LT. GOVERNOR

DEPARTMENT OF NATURAL RESOURCES
RICHARD A. LEOPOLD, DIRECTOR

January 30, 2009

Scott Heater
Heater Farms
Wapello, Iowa

Dear Mr. Heater:

I'm sorry you were unable to make the meeting as well, but it is certainly understandable given the bitter cold conditions that night. I appreciate your attention to the TMDL and am happy to clarify any questions you have. I have reviewed your comments with Charles Ikenberry, the Project Manager for the Lake Geode TMDL. I hope the following response addresses your questions.

The number of deer in the park was determined by personal communication with Willie Suchy, DNR wildlife biologist, who estimated 700 deer live in the park during the winter months. This number is approximately 70 times greater than the county-wide density, due in part to the physical features of the watershed you described. However, Mr. Suchy estimates that 80% of the deer disperse from the park in March and do not return until November. The TMDL reflects this behavior by conservatively estimating that 175 deer (25 percent of full winter population) remain in the watershed during the recreation season (March to November). For the purpose of the TMDL, the recreation season of March to November is the important time period.

The number of beef cattle in the watershed was derived by DNR visual reconnaissance efforts and Henry and Dickinson County SWCD staff estimates. The resulting beef cattle population used in the TMDL was 150 head. The ratio of deer to cattle in the watershed is 6 deer for every 5 beef cattle during the recreation period.

DNR is required to estimate contributions from each of the suspected E. coli sources in the TMDL report. In addition, the relative importance of various sources must be quantified in order to develop an effective plan for improving water quality. It is important to acknowledge that there is some uncertainty associated with estimated pollutant loads and percent contributed by each source. However, the assumptions and methods used to calculate these numbers are well-documented and based on the best available data.

The TMDL reports that grazing contributes zero *E. coli* during dry weather conditions (Figure 11). The same figure reports wildlife play a small role (1%) during dry conditions whereas geese contribute 20%, septic systems 25% and cattle in streams 54%. Cattle in streams are large contributors under this condition for two primary reasons. First, manure deposited directly to the stream delivers high numbers of bacteria with little *E. coli* die-off before reaching the lake.

Second, there are no contributions from sources that build up on the land surface during dry weather.

During wet conditions, runoff from grazed lands accounts for only about 3% of the bacteria, whereas wildlife contributes 2% and geese on the beach add an additional 6%. The contribution from cattle in the streams (28%) is less compared to dry conditions (54%) because other sources contribute more bacteria during periods of rainfall runoff from the land surface. Runoff from ground where manure is applied accounts for 54% during wet weather conditions, but most of this manure comes from the hogs rather than beef cattle.

Based on the information gathered, it was reasonably determined that livestock manure in its various forms (direct deposition, manure application, and to a lesser extent, grazing) contribute significantly more *E. coli* to Lake Geode than the deer population. Please note that several sources were determined to have a greater impact than livestock grazing including; manure application, direct deposition by cattle in streams, geese droppings at the beach, and failing or illegal septic systems.

After reviewing your comments and the TMDL report and documentation, cattle grazing in the watershed do not appear to be a large contributor to the overall *E. coli* impairment. However, it is evident that cattle with access to streams in the Lake Geode watershed, and subsequent direct deposition of manure, have a major impact to bacteria levels in the lake. This information provides land owners with an idea of how to reduce a significant portion of the loading with effective best management practices.

Thank you for taking the time to comment on the Lake Geode TMDL. Your comments and this response will be included with the finalized TMDL submitted to the EPA Region VII office in Kansas City for approval. The interest and knowledge of landowners like you will be critical in developing options that improve water quality in Lake Geode. If you have further questions or are interested in getting involved in the restoration efforts in the watershed, I can be reached at 515-281-4791.

Sincerely,

Jeff Berckes, TMDL Program Coordinator
Watershed Improvement Section