Water Quality Improvement Plan
for

Union Grove Lake

Tama County, Iowa

Total Maximum Daily Load
For Algae, pH, and Turbidity

Total Maximum Daily Load
For Pathogen Indicators

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Watershed Improvement Section
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Report Summary

What is the purpose of this report?

This Water Quality Improvement Plan has two purposes. First, it is a resource to be used by watershed planners, water quality action groups, individual citizens, and local and state government staff. It serves as a guide to help these groups understand and identify the cause of Union Grove Lake water quality problems and to guide locally driven water quality improvements in the lake. These problems include excess algae, a lack of water clarity, high pH, and high concentrations of bacteria. Second, this report satisfies the Federal Clean Water Act obligation to establish a Total Maximum Daily Load (TMDL) for waterbodies on the 303(d) impaired waters list.

What is wrong with Union Grove Lake?

Union Grove Lake is impaired by excessive growth of algae, the lack of water clarity caused by algal growth and non-algal turbidity; and high pH resulting from algal photosynthesis. Union Grove Lake is also impaired for pathogen indicator bacteria counts over the Water Quality Standards (WQS) limit. Additionally, nuisance and potentially noxious blooms of blue green algae aggravate water quality conditions. Combined, these problems reduce recreational use of the lake and adversely affect aquatic life.

What is causing the problem?

Excessive concentrations of phosphorus in Union Grove Lake are causing algal blooms that decrease water clarity and raise pH. Additionally, poor water clarity is aggravated by high concentrations of non-algal inorganic suspended solids (ISS). Phosphorus and ISS that create poor water transparency originate from erosion of the surrounding land, runoff, and the resuspension of sediment from the bottom of the lake. Since a lot of the phosphorus washing off the land is attached to sediment particles, reducing erosion will simultaneously decrease both the sediment and phosphorus delivered to the lake. Phosphorus sources are row-crop land use, livestock manure, septic tanks, geese, and internal recycling of sediment stirred up by rough fish, such as carp, and waves.

Union Grove Lake is also impaired for bacteria at the lake's swimming beach. The bacteria problem, measured by *E. coli* concentration, is caused by livestock manure, poorly functioning septic tank systems, and wildlife.

What can be done to improve Union Grove Lake?

To improve the water quality of Union Grove Lake, sediment, phosphorus, and bacteria loads delivered to the lake must be reduced. A combination of the following management practices can be implemented to achieve these reductions:

- increased use of conservation tillage,
- adoption of manure and fertilizer application strategies that reduce phosphorus loss,
- restricting cattle from streams,

- management of geese population and removal of feces from the beach and lawn areas adjacent to the lake,
- construction of new and maintenance of existing grassed waterways, buffer strips, and sediment detention basins,
- creation of wetlands that filter sediment and nutrients from runoff and from streambed and bank erosion, and
- inspection, repair, and maintenance of septic tank systems to comply with state design standards.

In addition to managing watershed sources, phosphorus and sediment resuspended from the bottom of the lake must be reduced. This internal source of recycled phosphorus is the largest direct contributor to the algal problems in Union Grove Lake and is mostly caused by bottom feeding common carp. Wind-driven waves and currents that disturb sediments in shallow areas and can cause shoreline erosion are, to a lesser extent, contributing to the problem. Internal loads can be decreased by:

- Significantly reducing the numbers of bottom feeding common carp.
- Minimizing the factors that contribute to turbulence and resuspension of sediment in shallow areas.
- Encouraging the growth of rooted aquatic plants to stabilize bottom sediments thereby reducing resuspension. Aquatic vegetation also uses nutrients such as phosphorus making them unavailable for algae.
- Dredging to a mean depth of ten feet to establish a phosphorus sink with a thermal barrier that prevents phosphorus from rising to the surface layer where there is sufficient light for rapid algal growth.

The bacteria impairment can be remediated by managing many of the phosphorus sources already discussed, limiting where and when manure is applied, restricting grazing cattle from streams, removing goose droppings from beaches, and inspecting and repairing failing septic tank systems.

Who is responsible for a cleaner Union Grove Lake?

Everyone who lives, works, or plays in the Union Grove Lake 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 changes in tillage practices and manure management. Financial assistance may also be available for the creation of wetlands that filter sediment and nutrients from water before it reaches the lake. Funding opportunities also exist for in-lake improvement strategies to reduce internal recycling of sediment and phosphorus. Improving water quality in Union Grove Lake will require the collaboration of citizens and agencies with an interest in protecting the lake now and in the future.

Technical Elements of the TMDL

This Water Quality Improvement Plan has been prepared in compliance with the current regulations for TMDL development that were promulgated in 1992 as 40 CFR Part 130.7 in compliance with the Clean Water Act. These regulations and consequent TMDL development are summarized below:

Table 1 TMDL Elements

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Union Grove Lake, located in northwest Tama County, 4 miles south of Gladbrook, S33, T85N, R16W. Iowa ID 02-IOW-02195-L
Use designation classes:	Class A1 Primary Contact Recreation Class B (LW) Aquatic Life Class HH (Human Health)
Impaired beneficial uses:	Class A1 Primary Contact Recreation Class B (LW) Aquatic Life
Identification of the pollutants and applicable water quality standards:	Algae, pH, and Turbidity. Primary contact recreational use (Class A1) is not supported due to aesthetically objectionable conditions caused by algae and turbidity. The target of this TMDL is a Carlson's Trophic State Index (TSI) of less than 65 for chlorophyll a and less than 61 for Secchi depth. These values are equivalent to total phosphorus and chlorophyll concentrations of less than 56 and 33 ug/l, respectively, and a Secchi depth of greater than 0.8 meters. The assessment also names these pollutants as the cause of Class B(LW) aquatic life use non support for algae related pH problems. Pathogen Indicator, *E. coli*. Primary contact recreational use (Class A1) is not supported due to violation of the *E. coli* Water Quality Standard criteria of 126 organisms/100 ml for the geometric mean and 235 organisms/100 ml for the single sample maximum.
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	Algae, pH, and Turbidity. The cause of the nuisance algal blooms and high pH is excessive total phosphorus. The annual mass of phosphorus that can be delivered to the lake from the watershed is 3,006 lbs/year and the maximum daily load is 768 lbs/day. Pathogen Indicator, *E. coli*. The *E. coli* load capacity has been calculated for four flow recurrence intervals. Table 13 on page 41 lists these capacities.

Quantification of the amount or degree by which the current pollutant loads in the water body, including the pollutants from upstream sources that are being accounted for as background loading, deviate from the pollutant loads needed to attain and maintain water quality standards:	Algae, pH, and Turbidity. Based on 2006 to 2008 sampling data, the existing mean values for Secchi depth, chlorophyll a and total phosphorus are 0.7 meters, 70 ug/L and 139 ug/L, respectively. A minimum in-lake increase in Secchi transparency of 13 percent and minimum in-lake concentration reductions of 53 percent for chlorophyll a and 60 percent for total phosphorus are required to achieve and maintain lake water quality goals and protect beneficial uses. The estimated existing annual total phosphorus load to Union Grove Lake is 10,170 pounds per year. Based on BATHTUB lake modeling, the lake loading capacity is 3,006 pounds per year. The required load reduction is 70 percent for the pollutant sources. Pathogen Indicator, *E. coli*. The *E. coli* load departure from capacity has been calculated for four flow recurrence intervals. Table 15 on page 43 lists these departures from capacity.
Identification of pollution source categories:	Algae, pH, and Turbidity Nonpoint source phosphorus is identified as the cause of the Union Grove Lake impairments. Pathogen Indicator, *E. coli*. Nonpoint watershed *E. coli* sources are identified as the cause of the Union Grove Lake pathogen indicator impairment.
Wasteload allocations for pollutants from point sources:	There are not any permitted point sources in the watershed and the WLA is zero.
Load allocations for pollutants from nonpoint sources:	Algae, pH, and Turbidity. The total phosphorus annual load allocation is 2,706 pounds per year. The TP maximum daily load allocation is 691 pounds/day. Pathogen Indicator, *E. coli*. The *E. coli* load allocations have been calculated for four design flow recurrence intervals. Table 18 on page 50 lists the load allocations.
Margin of safety:	The margin of safety for all TMDLs in this report is an explicit 10 percent of the modeled load capacity.
Consideration of seasonal variation:	Algae, pH, and Turbidity. This TMDL was developed based on the annual phosphorus loading that will result in attainment of TSI targets for the growing season (May through September).

	Pathogen Indicator, *E. coli*. The recreation season as defined in the Iowa Water Quality Standards runs from March 15 through November 15. This is the season used in the development of the pathogen indicator TMDL for this document.
Allowance for reasonably foreseeable increases in pollutant loads:	Algae, pH, and Turbidity. An allowance for increased phosphorus loading was not included in this TMDL. Significant changes in the Union Grove Lake watershed land uses are unlikely. The Iowa Department of Natural Resources (IDNR) maintains most of the shoreline around the lake. Most of the watershed land use is in agricultural production with row crops predominating. These conditions are not expected to change. Pathogen Indicator, *E. coli*. An allowance for increased pathogen indicator loading was not included in this TMDL. The Iowa Department of Natural Resources owns and maintains most of the shoreline around Union Grove Lake. Some of the nearby watershed is in state owned forest, grass, and wetlands. Most of the rest is in agricultural production with row-crop predominating. A significant change in watershed land use is unlikely.
Implementation plan:	A general implementation plan is provided in Section 5 of this document to guide local citizens, government, and water quality groups.

1. Introduction

The Federal Clean Water Act requires states to assess their waterbodies every even numbered year and incorporate these assessments into the 305(b) Water Quality Assessment Report. Assessed lakes and streams that do not meet the Iowa Water Quality Standards criteria are placed on the 303(d) Impaired Waters List. Subsequently, a Total Maximum Daily Load (TMDL) for each pollutant must be calculated and a Water Quality Improvement Plan written for each impaired waterbody.

A TMDL is a calculation of the daily maximum amount of a pollutant a waterbody can receive without exceeding the water quality standards. The total maximum daily load is allocated to permitted point sources (wasteload allocations), nonpoint sources (load allocations), and to a margin of safety that accounts for uncertainty in the calculations.

This TMDL report is for Union Grove Lake in Tama County, Iowa. Union Grove Lake is on the 2006 impaired waters list for algae, turbidity, and pH that are the consequence of nuisance algal blooms. Phosphorus is the nutrient that limits excess algal growth. Union Grove Lake is also on the 2006 impaired waters list for *E. coli*, a pathogen indicator.

There are two primary purposes of this report: 1) Satisfy federal Total Maximum Daily Load requirements for impaired waters, and 2) Serve as a resource for guiding water quality improvement projects in the Union Grove Lake watershed that address algal blooms, high pH, turbidity, and bacteria problems. Local citizens, water quality groups, and government agencies will find it a useful description of the causes and solutions to Union Grove Lake water quality concerns.

A TMDL report has some limitations:

- The 305(b) water quality assessment is made with available data that may not sufficiently describe lake water quality. Additional targeted monitoring is often expensive and requires time. Assumptions and simplifications on the nature, extent, and causes of impairment can cause uncertainty in calculated values.
- A TMDL may not deal easily with unregulated nonpoint sources of pollutants. It can be challenging to reduce pollutant loads if nonpoint sources are significant contributors.

This document can guide local water quality improvement projects that are coordinated and targeted to address pollutant sources within the entire watershed. The lake water quality mirrors the land that drains to it and reflects how well that land is managed. Local landowners, tenants, and other stakeholders often have the greatest influence in determining water quality.

2. Description and History of Union Grove Lake

Union Grove Lake is located in northwest Tama County four miles south of Gladbrook, Iowa and is classified as a significant publically owned lake. It is the central feature of Union Grove State Park, a popular outdoor recreation area. The lake was constructed in 1938 and the park was established in 1940.

Today the lake and the parklands provide a pleasing contrast to the nearby residential and agricultural areas. Lake activities include boating, fishing, and swimming. Park facilities include a campground, boat ramps and a swimming beach. Lake information is shown in Table 2. Figure 1 is a map showing the lake and its watershed.

Table 2 Union Grove Lake

Waterbody Name	Union Grove Lake
12 Digit Hydrologic Unit Code (HUC):	070802080401 (Upper Deer Creek)
IDNR Waterbody ID	02-IOW-02195-L
Location	Tama County, S33, T85N, R16W
Latitude	42.12814
Longitude	-92.72223
Water Quality Standard Designated Uses	Class A1 Recreational Class B (WW-L) Aquatic Life HH (Human Health)
Tributaries	Deer Creek
Receiving Waterbody	Deer Creek
Lake Surface Area (excluding lake area behind the sediment dike)	96 acres
Maximum Depth	13.1 feet
Mean Depth	7.48 feet
Volume	744 acre-feet
Length of Shoreline	5.7 miles
Watershed Area (with lake)	6,949 acres
Watershed/Lake Area Ratio	59:1
Lake Detention Time (outlet)	0.12 year (44 days)

2.1. Union Grove Lake

Union Grove Lake was created by constructing a dam in Deer Creek. The original dam crest elevation was 937.6 feet. Over time the lake began to silt in. In 14 years, the surface area decreased from 118 acres to 105 acres and 168-acre-feet of volume was lost. In 1954, the dam crest was raised two feet to an elevation of 939.6 feet. It is estimated that raising the dam crest increased the lake volume by 231 acre-feet and increased the surface area by 23 acres.

Changes continued to be made to Deer Creek, minor lake tributaries, and the control structures in the 1960's and 70's. These consisted of sediment control basins and rock rubble dams that were mostly silted in by 1980.

Union Grove Lake was studied in the early 1980s by Iowa State University for the Iowa Conservation Commission and a Diagnostic/Feasibility Study was written in January 1983. The study recommended:

- Erosion control using terraces, no-till farming, contour farming, grassed waterways, and changes in crop rotation.
- Construction of sediment detention basins.
- Lake dredging to deepen the lake and restore it to its original volume.
- Lake aeration to provide dissolved oxygen in the winter to prevent winter fish kills.
- Aquatic plant control using grass carp.

Lake restoration activities were implemented from 1984 to 1992. These activities included:

- A dredging project that removed 275,000 cubic yards of sediment.
- A 550 foot long sediment retention berm transecting the lake just downstream from the Deer Creek inlet.
- Shoreline stabilization with rock riprap.
- Installation of a lake aeration system.
- Construction of terraces, grassed waterways, and sediment detention basins in the watershed.

The final report on the Union Grove Lake Restoration Project was released in April 1994. The document concluded that the project was successful in improving the lake's recreational usefulness.

Hydrology.
Union Grove Lake has one major surface tributary. Deer Creek enters the northwest end of Union Grove Lake and discharges over a 70-foot wide weir at the far southeast corner of the lake. Union Grove Lake is in the headwaters of Deer Creek, which then flows to the Iowa River in the City of Tama. There is a secondary tributary draining a large sediment detention basin that discharges to the southwest side of the lake.

The Deer Creek watershed consists of two HUC 12 sub watersheds, Upper Deer Creek (25,079 acres) and Lower Deer Creek (29,815 acres). The average annual precipitation is 34.0 inches/year and the average lake retention time is 44 days based on estimated outflow.

Morphometry.
New bathymetry of Union Grove Lake was done in 2006 by IDNR and the resulting lake map, Figure F3, can be found in Appendix F. It excludes the lake area upstream of the sediment detention dike. Based on this map, Union Grove Lake has a mean depth of 7.48 feet and a maximum depth of 13.1 feet. The lake surface area is 96 acres and the storage volume is 744 acre-feet. Temperature and dissolved oxygen sampling indicate that Union Grove Lake rarely stratifies and is most often mixed.

2.2. The Union Grove Lake Watershed

The Union Grove Lake watershed consists of 6,949 acres (including the lake) in the uppermost reaches of the Deer Creek basin. Without the lake, the watershed has a drainage area of 6,834 acres and a watershed to lake ratio of 59:1. This watershed to lake area ratio is high. IDNR Fisheries and lake restoration staff consider the ideal maximum ratio for a high quality lake to be less than or equal to 20:1. Figure 1 shows the lake and its watershed.

There are no cities or NPDES permitted point sources in the watershed, but there are 69 occupied residences adjacent to the lake. Some of these are part-time residences. All of the residences use onsite septic tank systems for wastewater treatment. Many of these are not functioning properly and some appear to be discharging directly to surface drainage. Union Grove State Park has "unimproved" sanitary facilities and 25 campsites.

Land Use.

Land uses and associated areas for the watershed are listed in Table 3. Figure F4 in Appendix F shows the 2004 land use map. Row crop agriculture is the predominant land use in the watershed (77 percent). There are two animal feeding operations in the watershed. The Iowa Department of Natural Resources (IDNR) owns or maintains the shoreline around the lake.

Table 3 Land use in the Union Grove Lake Watershed

Land Uses from Assessment	Area, acres	Percent of total
CRP/Grassland	146	2%
Farmstead	120	2%
Forest (Ungrazed)	217	3%
Hayland	154	2%
Parkland/Wildlife Area	284	4%
Pasture	413	5%
Residential	54	1%
Road	75	1%
Rowcrop	5,321	77%
Water	128	2%
Wetland	37	1%
Total	**6,949**	**100%**

Soils, climate and topography.

There are three general soil types in the Union Grove Lake watershed. The soil types in the headwaters of the watershed are the Tama Association and the Muscatine-Tama-Garwin Association. Closer to Union Grove Lake the soil type is Fayette-Downs Association. The descriptions of these soils are:

- Tama Association: Gently sloping to moderately steep, on uplands.
- Muscatine-Tama-Garwin Association: Nearly level to sloping, well drained, somewhat poorly to poorly drained silty soils formed in loess, on uplands.
- Fayette-Downs Association: Gently sloping to very steep, well drained silty soils formed in loess, on uplands.

Tama County gets 34 inches of rain per year and snowfall is 31 inches. The average number of days with measurable precipitation is 95 per year and on average there are 191 sunny days per year. The average July high is 85 degrees Fahrenheit and the average January low is 9 degrees Fahrenheit.

This geomorphic region is characterized by stepped erosion surfaces with both glacial till and loess occupying the uplands and alluvium fills the larger valleys. Seventy five percent of the watershed is loess. Glacial till underlies eight percent of the drainage basin. The till and loess in the immediate vicinity of the lake is thin and there are many small outcrops of limestone.

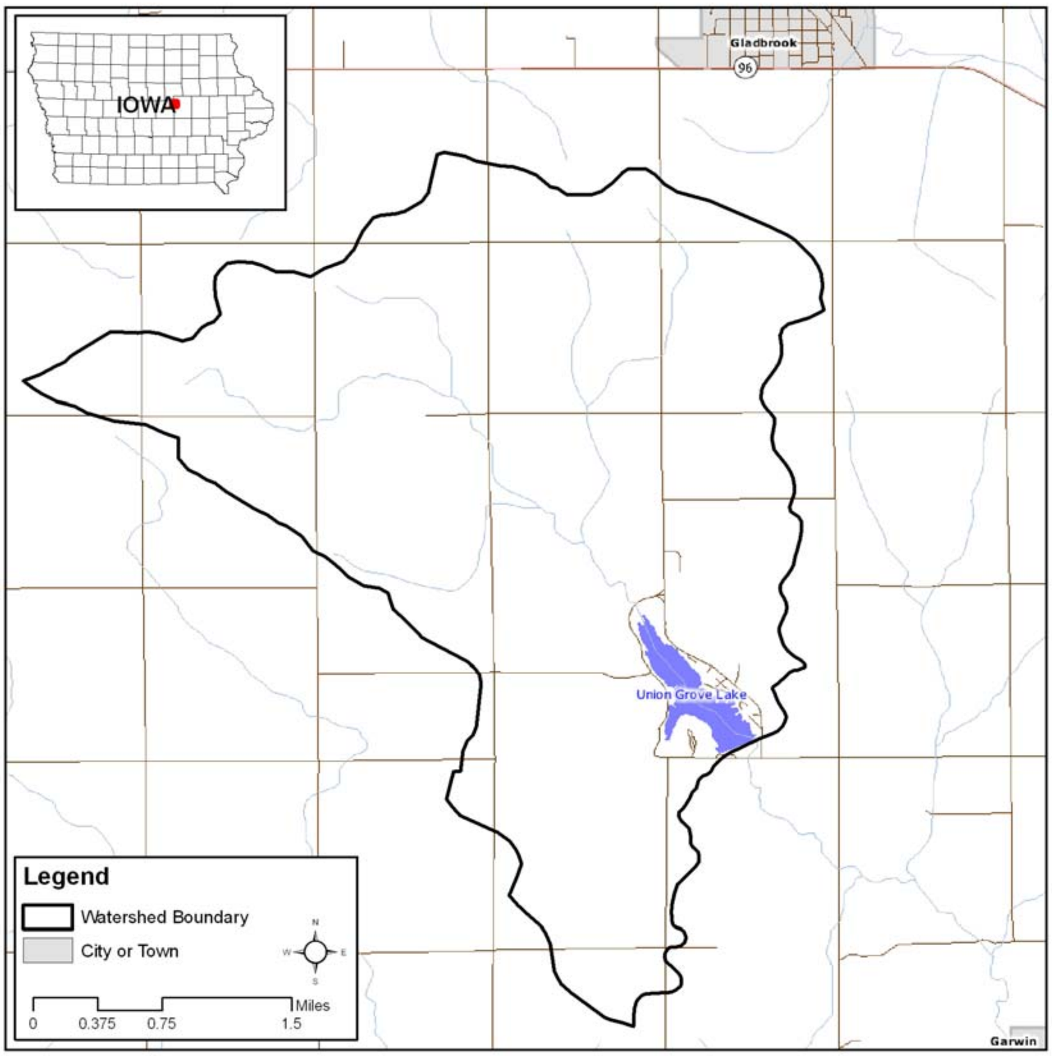


Figure 1 Union Grove Lake and its watershed

3. Total Maximum Daily Load for Algae, Turbidity, and pH

A Total Maximum Daily Load (TMDL) is required for Union Grove Lake by the Federal Clean Water Act because it is on the State of Iowa Impaired Waters List (303(d) list) as impaired for primary contact recreation and aquatic life uses. The impairment is for excess algae, algal and non-algal turbidity, and pH. All the impairments are closely related to rapid algal growth. Excess algae increases turbidity and algal photosynthesis increases lake pH by removing carbon dioxide and shifting the carbonate system equilibrium.

Evaluation of the Union Grove Lake monitoring data indicates that the limiting nutrient for algae growth in this lake is phosphorus. The following sections will estimate the existing total phosphorus (TP) load to the lake, the maximum allowable load to the lake while meeting water quality standards and necessary reductions.

There is a second primary contact recreation impairment. The Class A1 uses have been assessed (monitored) as “not supporting” due to high levels of *E. coli* indicator bacteria at the lake’s swimming beach. This was a new impairment for this lake in the 2006 impaired waters list. The TMDL for this pollutant and a description of the impairment are in Section 4.

3.1. Problem Identification

Applicable water quality standards.
The Iowa Water Quality Standards (IAC 567-61) list the designated uses for Union Grove Lake as Primary Contact Recreational Use (Class A1), Aquatic Life (Class B(LW)), and Human Health (HH - fish consumption). Recreational uses can be impaired by violations of narrative criteria for aesthetically objectionable conditions and by exceeding the numeric criteria for *E. coli* pathogen indicator. The Union Grove Lake primary contact recreational use assessment is “not supporting” due to:

- Aesthetically objectionable conditions caused by algae and turbidity, narrative criteria. (The TMDL for this impairment is covered here in Section 3).
- The relatively frequent violations of the Iowa criterion for pH.
- Exceptionally high levels of indicator bacteria during the 2004 through 2006 recreation seasons. (The TMDL for this impairment is covered in Section 4.)

Aquatic life uses are not supported because monitoring indicates pH often exceeds water quality standard criteria.

Problem statement.
Results of the ISU lakes survey suggest "partial support" of Class A uses due to aesthetically objectionable conditions (poor water transparency) related primarily to high levels of inorganic turbidity and secondarily to blooms of algae. Additional impairments to the Class A uses are due to:

(1) The high populations of nuisance aquatic life (blue green algae).
(2) The relatively frequent violations of the Iowa criterion for pH.

The 2008 305(b) water quality assessment for Union Grove Lake is included in Appendix G. It describes the rationale behind the finding that the primary contact recreation and aquatic life uses are not fully supported.

Data sources.
Sources of data for the 2008 assessment include (1) results of the statewide survey of Iowa lakes conducted from 2002 through 2006 by Iowa State University (ISU), (2) results of the statewide ambient lake monitoring program conducted from 2005 through 2006 by University Hygienic Laboratory (UHL), (3) information from the IDNR Fisheries Bureau, and (4) results from the IDNR-UHL beach monitoring program in 2004, 2005, and 2006.

The primary data used for the IDNR 305(b) Union Grove Lake water quality assessment are from the Iowa State University Lake Study begun in 2000. The study collected data from 2000 to 2007 that is summarized in Appendix C. This data was collected during seven summer growing season sampling visits. The samples were analyzed for variables including total and volatile suspended solids, Secchi depth, chlorophyll, total phosphorus, orthophosphate, total nitrogen, ammonia, and nitrate. Samples were also examined for phytoplankton and zooplankton composition.

In addition to the ISU Lake Study data, several other sources and types of data were used to develop this report:

- UHL data that was collected for IDNR. This data was collected and analyzed using similar procedures for the same water quality variables as the ISU Lake Study. It was collected from 2005 to 2008 and is expected to continue into the future. This is the data set used as input to the BATHTUB and WASP water quality models.

- Water column profile data was collected for both the ISU and UHL monitoring efforts. The profile consists of measurements for DO, pH, temperature, turbidity, and conductivity taken by data sensors as they are lowered down through the water column. Among other things, this data helps establish the lack of thermal stratification in the lake and support other model assumptions.

- A temporary USGS gage was installed at the discharge weir near the dam to provide continuous stage information and this information was used to develop a rating curve. Flow measurements were collected from September 17, 2007 to November 7, 2007 and from May 28, 2008 to October 2, 2008. This information was used to calibrate the BasinSims/GWLF watershed model. The flows from the calibrated watershed model were used in the BATHTUB and WASP lake models as well as to construct the flow and load duration curves used to develop the *E. coli* TMDL that follows in the next section.

- Continuous monitoring of the lake was performed by the USGS at the deep location where the ISU and UHL grab samples were collected. The sampling equipment collected data every 20 minutes for DO, pH, conductivity, and temperature from sensors suspended on a chain at depths of two feet and eleven feet. The time frame for this effort was the same as for the gage discharge measurement. Due to equipment problems, continuous data was not always collected. Data from the upper sensors was collected from October 3, 2007 to November 7, 2007 and from July 21, 2008 to October 2, 2008. Data from the lower sensors was collected from October 3, 2007 to November 7, 2007 and from August 23, 2008 to October 2, 2008. Charts of this data are shown in Figures 5, D18, and D19.

- In spring 2008, another data collection effort was started in support of an ongoing 319 nonpoint source watershed improvement project. Samples are collected at two Deer Creek sites and three sites in the lake. These sites are shown in Figures 9 and 16. This sampling was done biweekly from June 2 to October 20, 2008. The grab samples were analyzed for the nitrogen, phosphorus, and suspended solids series as well as *E. coli* and Secchi depth. Both the tributary and in-lake data were used to parameterize the WASP model.

Interpreting Union Grove Lake data.
Based on values from ISU sampling during 2000 to 2007, the mean ratio of total nitrogen to total phosphorus is 67:1 and the median ratio is 29:1. This ratio shows that nitrogen is not the limiting nutrient in Union Grove Lake.

Review of inorganic suspended solids (ISS) data from the ISU sampling shows that this lake is subject to episodes of high non-algal (inorganic) turbidity. The 2008 305(b) water quality assessment ranked Union Grove Lake 24th highest of 132 Iowa lakes for median inorganic suspended solids The median inorganic suspended solids concentration at Union Grove Lake was 9.4 mg/l.

Carlson's trophic state index (TSI) has been used to relate algae, as measured by chlorophyll; transparency, as measured by Secchi depth; and total phosphorus to one another and to set water quality improvement targets. TSI values for monitoring data are shown in Figure 2 and the seasonal average is shown in Figure 3.

If the TSI values for the three variables are the same, this shows that the relationships between total phosphorus (TP), algae, and transparency are strong. If the TP TSI values are higher than the chlorophyll values this means that there are limitations to algae growth besides phosphorus. Comparisons of the TSI values in Figure 2 for chlorophyll, Secchi depth and total phosphorus for the 2000 to 2002 in-lake sampling indicate some limitation of algal growth attributable to light attenuation by elevated suspended solids. The year 2003 shows the best water quality and relatively little variation through the summer.

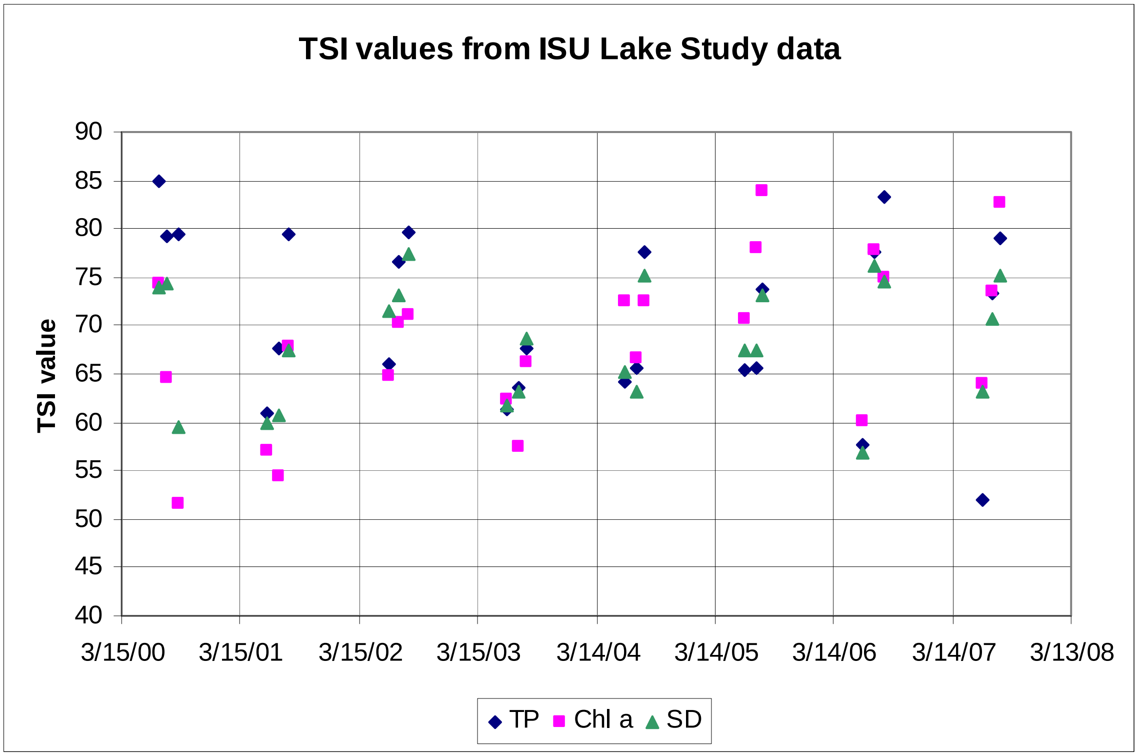


Figure 2 Union Grove Lake TSI values for ISU Study data, 2000 to 2007

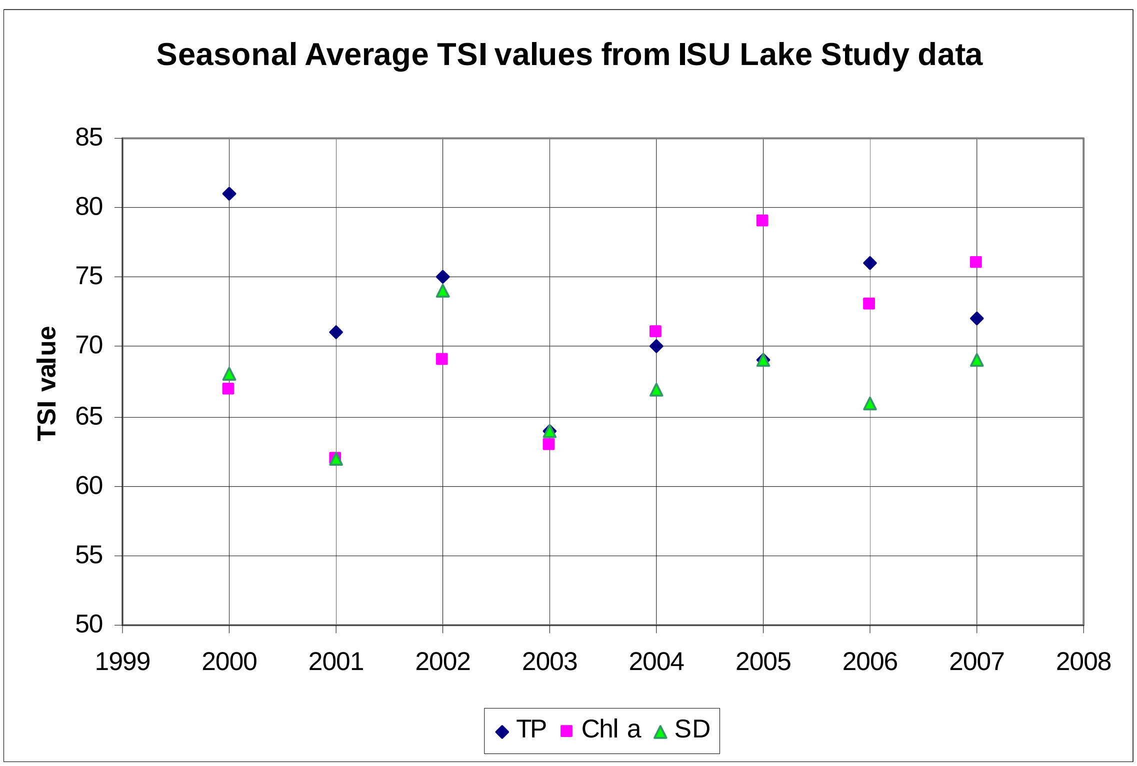


Figure 3 Seasonal Average TSI values from ISU Lake Study data

A plot that compares the three TSI variables and interprets the differences in the TSI variables is shown in Figure 4. This comparison shows that the Union Grove Lake system plots in the lower right hand quadrant. The interpretive plot on the right side of the figure shows that a point in this location indicates that there is a slight surplus of phosphorus, meaning not all available TP is expressed as algae. Other information that this plot provides is that the system is below the line where suspended solids create light limitation, meaning non-algal turbidity is a factor. It also suggests that zooplankton is grazing on the algae. A detailed explanation of the TSI can be found in Appendix E.

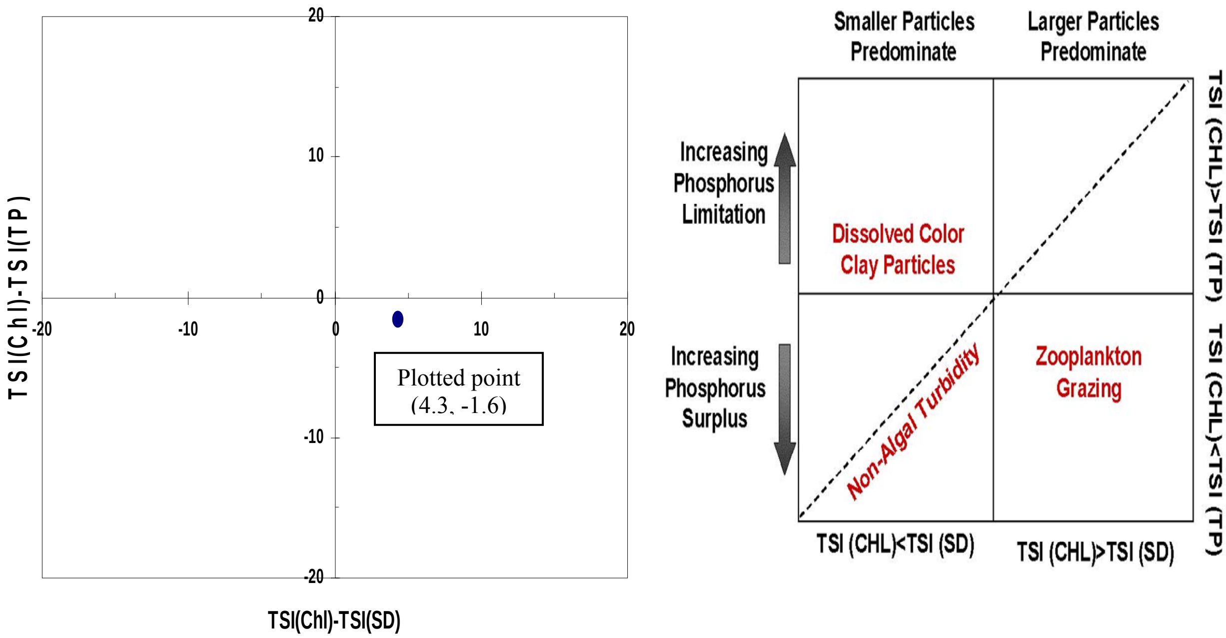


Figure 4 Union Grove Lake Mean TSI Multivariate Comparison Plot

Phytoplankton (algae) composition is an indicator of the extent of the algae problem. Blue green algae cause taste and odor problems, form dense mats on the water surface, and can produce toxins such as microcystin. Data from the 2002 to 2006 ISU and UHL surveys suggest a moderately large population of blue green algae at Union Grove Lake that contributes to the impairment. Blue green algae comprised 79 percent of the phytoplankton wet mass at this lake. The median blue green algae wet mass, 32.9 mg/l, was the 35th highest of the 132 lakes sampled.

Interpreting High pH.
High pH, defined as over the WQS criterion of 9.0, has been measured in 23 percent of samples between 2002 and 2006 in Union Grove Lake. Continuous dissolved oxygen, temperature, and pH data collected from July 21, 2008 to October 2, 2008 clearly show a response to algal productivity and respiration. Algal photosynthesis and metabolism cause inverse diurnal variations in dissolved oxygen and carbon dioxide concentrations. As the sun comes up, photosynthesizing algae remove dissolved carbon dioxide from, and add dissolved oxygen to, the upper level of the water column. At night, the opposite

occurs during algal respiration as dissolved oxygen is taken up and dissolved carbon dioxide (CO_2) is released.

The major influence on the pH of natural waters is the carbonate system. In this system, shifts in equilibrium between carbon dioxide (aqueous and atmospheric), bicarbonate, and carbonate shift the pH as the relative concentration of the three carbonate species changes. As CO_2 is removed from the system during the day, the hydrogen ion concentration decreases and the pH increases. At night when CO_2 is produced by algal respiration, the hydrogen ion concentration increases causing the pH to decrease. As can be seen from the following chemical equations, six molecules of carbon dioxide react to make six oxygen molecules for photosynthesis and vice versa for respiration.

- Photosynthesis equation
  $6CO_2 + 6H_2O + \text{Energy} \rightarrow C_6H_{12}O_6 + 6O_2$
  (carbon dioxide + water + sunlight = algae growth + dissolved oxygen)
- Cellular respiration equation
  $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$
  (algae + dissolved oxygen = carbon dioxide + water + metabolism)

This balance means that the dissolved oxygen concentration is inversely proportional to the CO_2 concentration. The pH rises and falls as the DO concentration rises and falls. This is shown in Figure 5 where the hourly DO and pH are plotted together using the continuous in-lake data collected by the USGS.

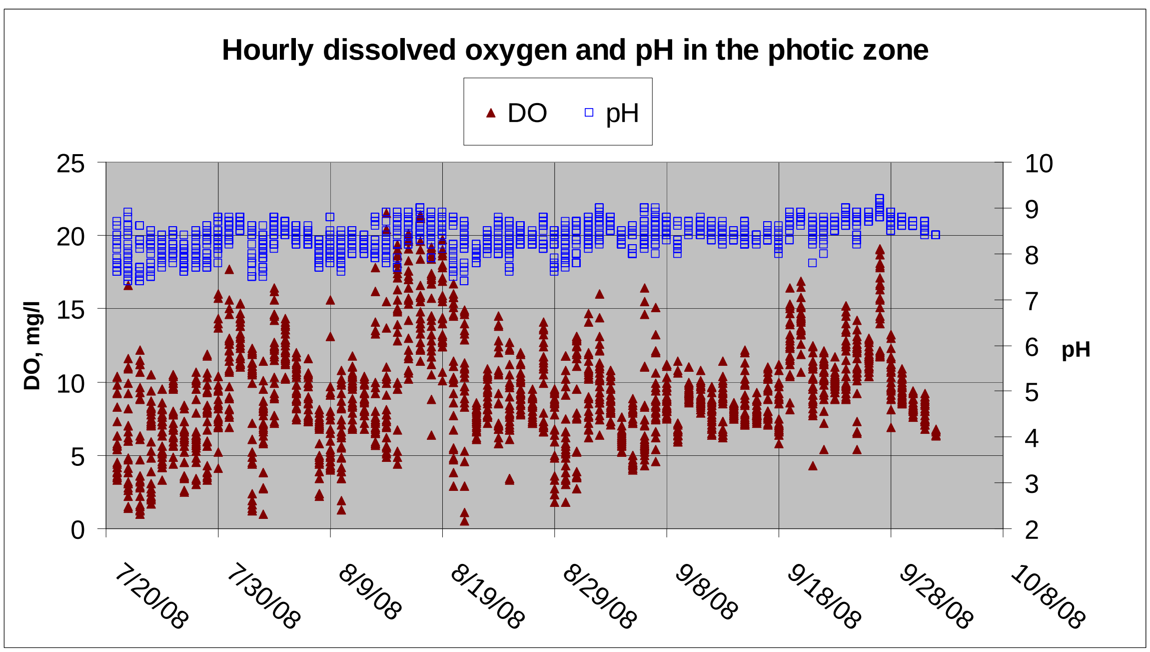
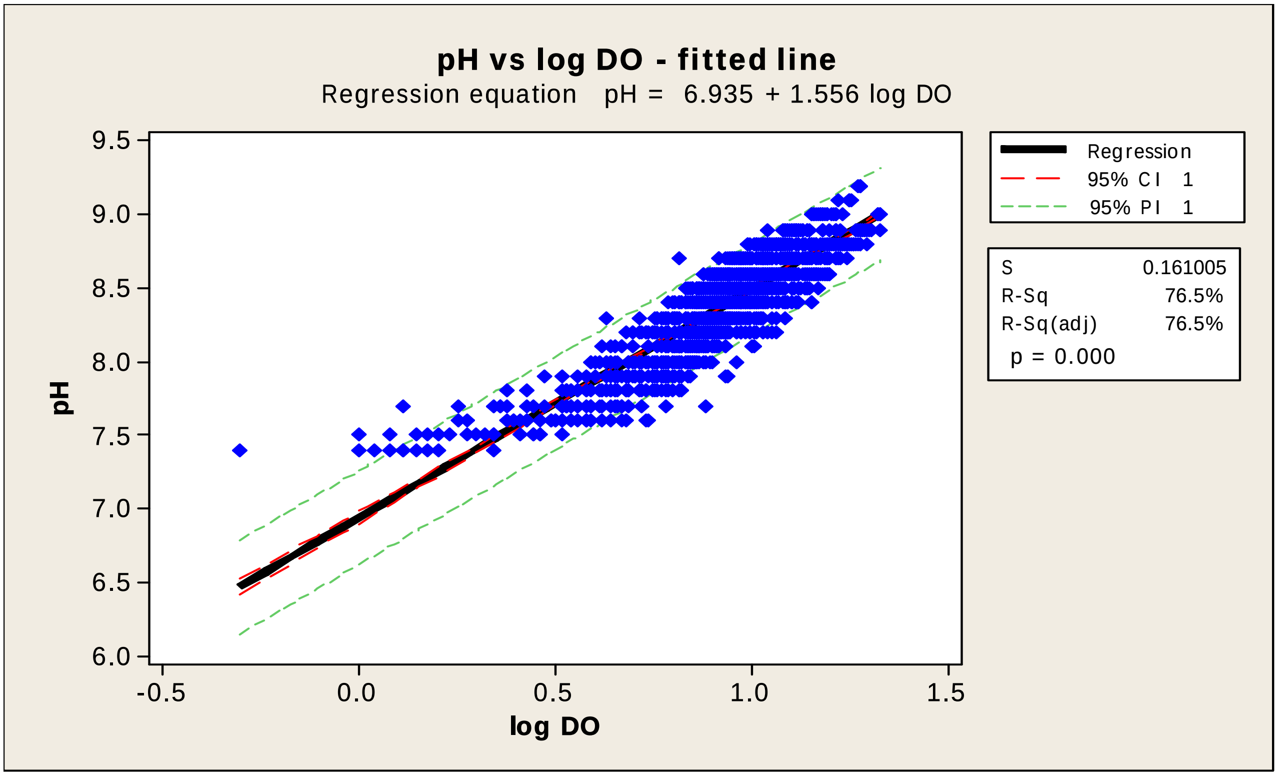


Figure 5 Monitored hourly dissolved oxygen and pH

Figure 5 shows the relationship between the DO concentration and pH and the algal metabolic link between them. Each day's data are displayed as a column for both. The spread between the highest and the lowest DO and pH measurements represents the shift in the light available for photosynthesis. As shown, the pH increases when the DO increases from the removal of dissolved carbon dioxide. Figure 6 shows a statistical regression of the relationship between the log DO and pH. The relationship is significant. The correlation coefficient, R^2, indicates that 76.5 percent of the rise in pH is explained by the dissolved oxygen concentration.



1. CI is confidence interval and PI is prediction interval.

Figure 6 Data from the continuous USGS monitoring showing pH as a linear function of log DO

The continuous data set from summer 2008 collected by USGS does not include measurements of CO_2, but the data collected for the ISU lake study does. This data was collected from 2000 to 2007. The regression shown in Figure 7 shows a strong inverse correlation between pH and carbon dioxide. This is predicted in a natural water system where pH is driven by carbonate equilibrium. Together with the Figure 6 regression, this establishes the connection between pH, carbon dioxide, and dissolved oxygen. As shown in the WASP modeling section of Appendix D, the dissolved oxygen - dissolved carbon dioxide dynamics are the consequence of algal photosynthesis and respiration. Therefore, decreasing the mass and duration of algal blooms in Union Grove Lake will control the diurnal rises in pH that exceed the water quality standard criteria.

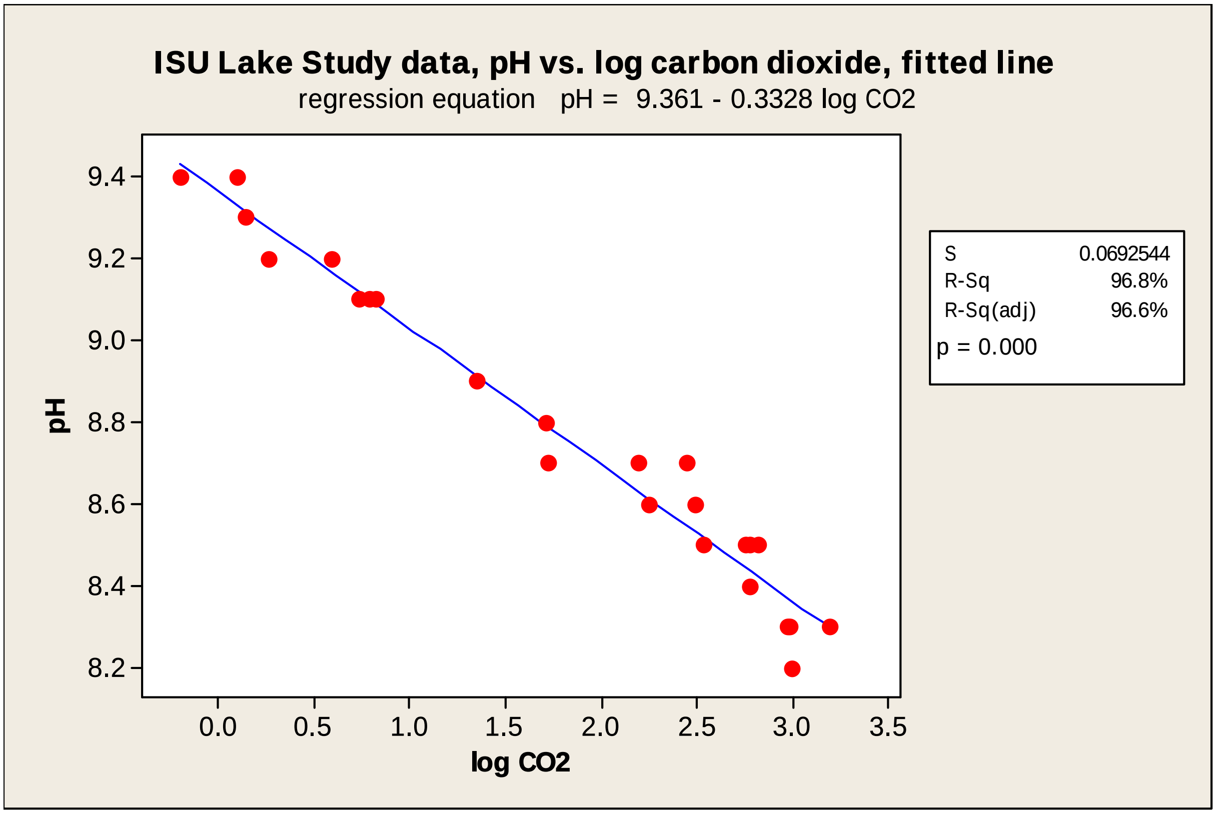


Figure 7 pH versus log carbon dioxide - ISU Lake Study data, 2000 to 2007

3.2. TMDL Target

When water quality assessments are determined for lakes, the assessment listing methodology used is the trophic state index. For this reason, the basis for algae related targets for this TMDL incorporate a TSI approach.

Based on the Iowa 305(b) assessment methodology a lake is impaired by algae and turbidity when the mean TSI value is greater than 65 for both chlorophyll and Secchi depth. These values are equivalent to a chlorophyll concentration of less than 33 ug/l and a Secchi depth greater than of 0.7 meters. The targets for this TMDL are mean TSI values of less than 65 for chlorophyll and less than 61 for Secchi depth. The Secchi depth selected for the target is greater than 0.8 meters because a mean value of 0.7 meters does not provide adequate protection from episodes of very low transparency. A Secchi depth of greater than 0.8 meters has a TSI value of less than 61.

The annual phosphorus target was developed using a BATHTUB eutrophication model set to the observed data means for chlorophyll and Secchi depth targets. The model was run and calibrated to existing conditions for annual mean observed TP, chlorophyll, and Secchi depth as shown in Table 4. The modeled phosphorus load was then reduced until the chlorophyll and Secchi depth targets were achieved. The TP target concentration is less than 56 ug/l. The existing and target values for concentration and TSI are shown in Table 4.

Table 4 Union Grove Lake Existing vs. Target TSI Values

Parameter	2006-2008 Mean TSI	2006-2008 Mean Value	Target TSI	Target Value	Water quality improvement needed
Chlorophyll a	72	70 ug/l	<65	<33 ug/l	Decrease 53%
Secchi Depth	65	0.7 meters	<61	>0.8 meters	Increase 13 %
Total Phosphorus	75	139/ug/l	NA	<56 ug/l	Decrease 60%

General description of the pollutant.
Summer algal blooms directly relate to the TP load. Although it is not the only factor in algal productivity (light attenuation from non-algal turbidity and clouds also affect algal growth), excess TP is the primary reason for blooms of algae and the resulting turbidity.

Inorganic suspended solids (i.e. non-algal turbidity) also contribute to lake turbidity. Most TP is attached to soil particles. Therefore, to reduce the amount of phosphorous entering the waterbody, there must be a reduction of sediment inputs, which also reduces the turbidity caused by inorganic suspended solids. This will result in a reduction of both algal and non-algal turbidity. Future monitoring will determine if the targeted phosphorus reductions and corresponding reduction in suspended solids loading result in achievement of the TSI targets for chlorophyll and Secchi depth.

Selection of environmental conditions.
The critical condition for which the TMDL TSI targets apply is the growing season of May through September. It is during this period that nuisance algal blooms are prevalent. The existing and target TP concentrations and load estimates for the lake are expressed as annual averages.

Potential Pollution Sources.
There are no permitted point sources in the watershed. Watershed nonpoint sources and internal recycling of pollutants from bottom sediments adversely affect water quality in Union Grove Lake. The potential nonpoint sources are agricultural activities, inadequate on-site septic tank treatment systems, wildlife, runoff from the lakeshore residential area, atmospheric deposition, groundwater, and internal recycling loads.

Natural Background Conditions.
The natural background condition is atmospheric direct deposition to the lake surface. The phosphorus load attributed to direct deposition is included separately in the BATHTUB and WASP lake models. Based on a review of available literature (Anderson and Downing, 2006), estimated direct deposition is an annual average areal load of 30 $mg/m^2/yr$, yielding a load of 31 lbs/year. Groundwater contribution is not considered a natural background in this report since it originates as precipitation infiltration and land use has a strong influence on the pollutant load it carries. It is accounted for as a source in the streamflow load and is included in the GWLF/BasinSims watershed model.

Water body pollutant loading capacity (TMDL).
The annual average chlorophyll and Secchi depth targets are related through the BATHTUB lake nutrient model to total phosphorus. The load capacity is the annual average TP load Union Grove Lake can receive while meeting the chlorophyll and Secchi depth targets. Based on meeting the annual average TP concentration of 56 ug/l estimated using the BATHTUB model, the annual average loading capacity is 3,006 lbs/year of TP.

Criteria for water quality standards attainment.
Iowa does not have numeric water quality criteria for algae or turbidity. The cause of the Union Grove Lake algae and turbidity impairments are algal blooms resulting from excessive phosphorus input and inorganic suspended solids in watershed runoff and from resuspension of lake sediment and the recycling of phosphorus.

The criteria for assessing lake algae and turbidity impairments are based on TSI scores for chlorophyll and Secchi depth. The 305(b) assessment thresholds for nuisance conditions are TSI values of 65 for both chlorophyll and Secchi depth. These TSI values translate to a chlorophyll concentration of 33 ug/l and a Secchi depth of 0.7 meters. As noted earlier, the Secchi depth selected for the target is greater than 0.8 meter because the observed mean value is already 0.7 meters and improvement is still necessary to attain the chlorophyll target. A Secchi depth of 0.8 meters has a TSI value of 61. The average annual TP concentration goal for these targets has been estimated using the BATHTUB model and is less than 56 ug/l. Appendix E – Carlson's Trophic State Index further explains the TSI and its use in lake water quality assessments.

Inorganic suspended solids (non-algal turbidity) also contribute to lake turbidity. Since load reductions from phosphorus sources will require reductions in sediment and suspended solids loads, the targeted pollutant is phosphorus. Monitoring will determine if the targeted phosphorus reductions and corresponding reduction in suspended solids results in achievement of the chlorophyll and Secchi depth targets.

3.3. Pollution Source Assessment

The TMDL approach is to separate pollutant sources into those that are regulated by discharge permits (point sources) from those that are not (nonpoint sources). There are no point sources in the Union Grove Lake watershed.

There are four quantified phosphorus sources for Union Grove Lake in this TMDL.

- The first of these sources is the phosphorus from the watershed land use areas draining into the lake. Watershed phosphorus loads are calculated in the GWLF/BasinSims model. These include loads from the residential septic tanks adjacent to the lake and geese feces. Figure 8 shows the relative annual contributions of phosphorus from the various watershed land uses, septic tanks and geese.
- The second is the groundwater seeping into the lake from fractured rock. This is included in the BATHTUB and WASP water quality models as a constant inflow.

This inflow is assumed to have the same TP concentration as the groundwater in the watershed modeling. It is referred to as seepage in the models.

- The third is the phosphorus recycled from lake sediments. An estimate of the internal recycled phosphorus load is calculated in both the BATHTUB and WASP models. In the BATHTUB model this is estimated to be 10 mg/m^2/day (3,739 lbs/year).
- The fourth is natural background atmospheric direct deposition. The direct deposition load of 30 mg/m^2/year (31 lbs/year) is included in both the BATHTUB and WASP models.

All of the watershed sources shown in Figure 8 are included in the BasinSims/GWLF watershed modeling. The other two sources, lake bottom resuspension and atmospheric deposition are included in the BATHTUB and WASP lake water quality models.

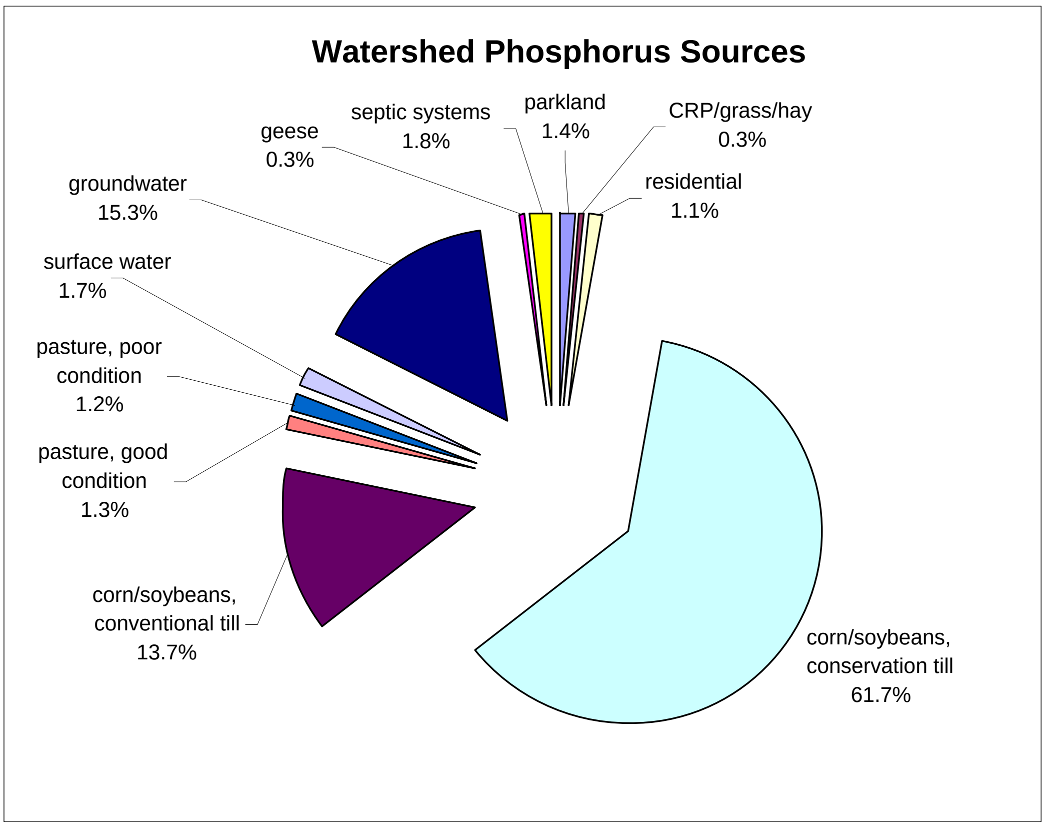


Figure 8 Watershed nonpoint sources of phosphorus

The Union Grove Lake watershed modeling was divided into three subbasins that input three separate flows and loads into the BATHTUB and WASP water quality models. The flows and loads from these subbasins are modeled separately in the BasinSims/GWLF model because subbasin characteristics such as ecoregion sediment delivery ratios, pollutant sources, and sediment control structures are dissimilar. Table 5 shows how the loads haves been distributed to these subbasins. Figure 9 displays a map of the three subbasins and their relationship to watershed drainage and the lake.

Table 5 Water quality modeling subbasins

Subbasin	Description	Load sources
One	Upland headwaters of Deer Creek lying in the Iowan Surface ecoregion - NRCS SDR is 14 percent. This subbasin is drained entirely by Deer Creek.	Row crop land use, field applied manure, livestock pastured and in the stream, stream bed and bank erosion.
Two	Subbasin surrounds the lake and includes the residential area with septic tanks, in the Southern Iowa Drift Plain ecoregion – NRCS SDR is 20 percent because it lies in an area of ecoregion transition. This subbasin is partly drained by Deer Creek, partly by other small tributaries and partly by overland flow directly into the lake.	Row crop land use, field applied manure, livestock pastured and in the stream, stream bed and bank erosion. Includes septic tank system loads and geese that are both directly adjacent to the lake.
Three	Subbasin drains the area southwest of the lake through an independent tributary. There is a large sediment detention basin on this tributary upstream from the lake. It is estimated that the trap efficiency of the basin is 90 percent.	Row crop land use, field applied manure, livestock pastured and in the stream, stream bed and bank erosion.

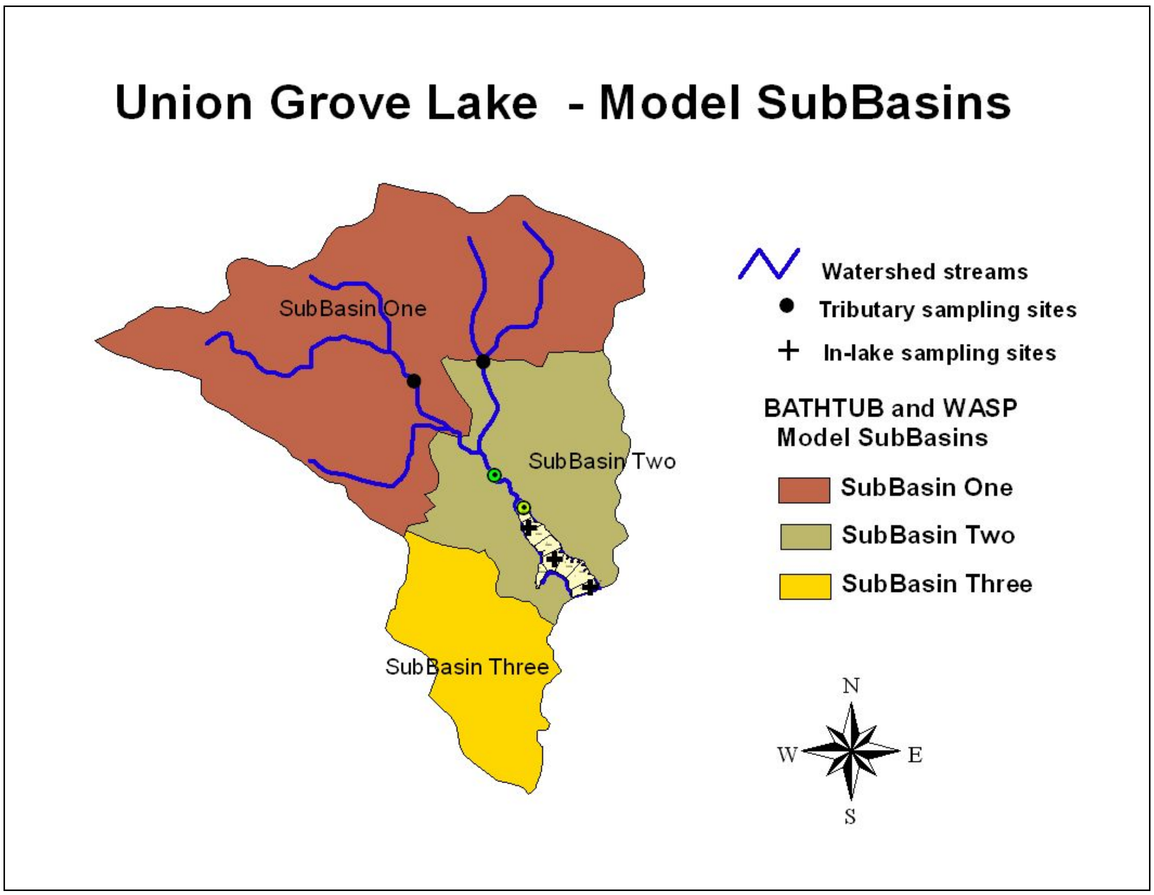


Figure 9 Watershed Subbasins configured for BATHTUB and WASP models

Existing load.
The existing total annual average load based on the BATHTUB eutrophication model is 10,170 lbs/year. The largest part of the average annual Union Grove Lake TP load consists of watershed loads. This estimate uses an annual averaging empirical model as described in Appendix D. This empirical regression/mass balance model does not show system response to the seasonal changes and episodic conditions that cause water quality impairments. This is addressed using the mechanistic WASP model also described in Appendix D.

The internal recycling load is also a large fraction of the phosphorus problem in Union Grove Lake as shown in Figure 10. This load, along with atmospheric deposition, is assumed to be constant over the growing season. Table 6 shows all existing loads.

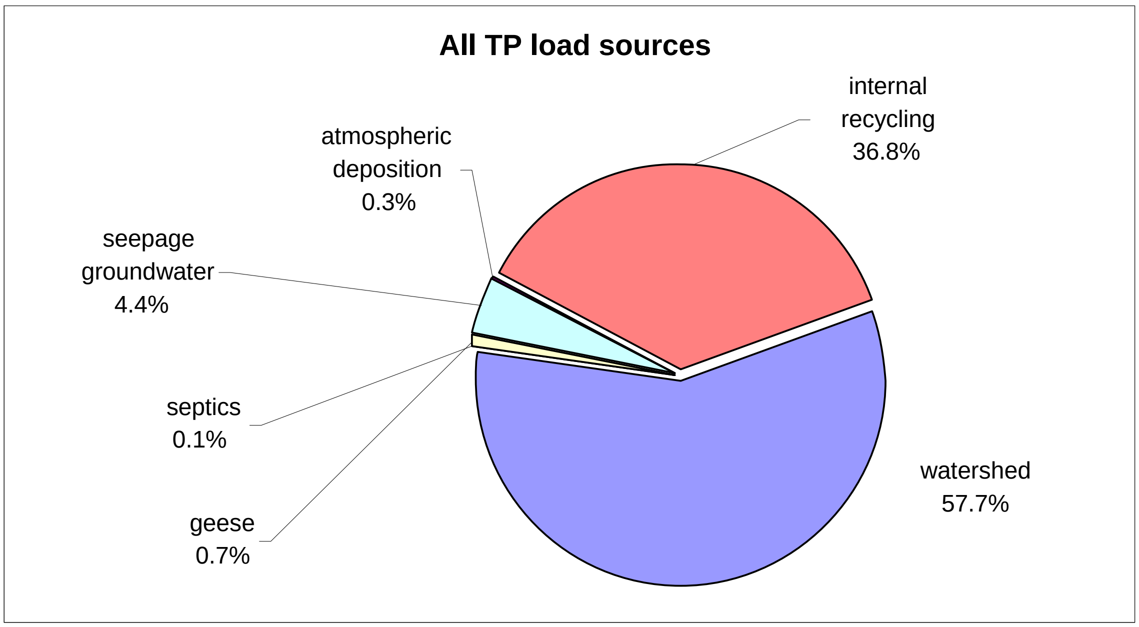


Figure 10 All loads to Union Grove Lake

Table 6 Existing TP loads to Union Grove Lake

Load source	TP Load, lb/yr	Percent of total
watershed	5,870	57.7
septic tank systems	13	0.1
geese	68	0.7
groundwater seepage	449	4.4
atmospheric deposition	31	0.3
internal recycling	3,739	36.8
total	**10,170**	**100.0**

Departure from load capacity.
Using the annual averaging empirical BATHTUB model, the targeted total phosphorus load capacity for Union Grove is 3,006 lbs/year. The existing estimated load is 10,170 lbs/year, which is a departure of 7,164 lbs/year from load capacity.

Identification of pollutant sources.
Point Sources: There are no permitted point sources in the Union Grove Lake watershed.

Nonpoint Sources: As noted in the previous section, all phosphorus is delivered to the lake from either watershed nonpoint sources or internally recycled loads. Figures 8 and 10 show the total phosphorus loads for the watershed sources and for all sources, respectively.

Linkage of Sources to Target.
The phosphorus load to Union Grove Lake originates from the sources listed in Table 6, and has been linked to the water quality impairment through the evaluation of existing data and modeling. The watershed sources have been estimated using the GWLF/BasinSims model to determine monthly and annual phosphorus delivery. All sources listed in Table 6 have been linked to the nuisance algae condition using the BATHTUB and WASP lake models.

Allowance for increases in pollutant loads.
An allowance for increased phosphorus loading was not included in this TMDL. Significant changes in the Union Grove Lake watershed land uses are unlikely. The Iowa Department of Natural Resources (IDNR) maintains the shoreline around the lake. Much of the watershed land use is in agricultural production with row crops predominating. These conditions are not expected to change.

3.4. Pollutant Allocations

Wasteload allocation.
There are not any permitted point sources in the Union Grove Lake watershed. Therefore, the sum of the wasteload allocations is zero.

Load allocation.
As noted, the existing average annual TP load to Union Grove Lake is 10,170 lbs/year from all sources. As modeled in BATHTUB, the average annual allowable load is 3,006 lbs/year to achieve the target TP concentration of less than 56 ug/l. BATHTUB was run repeatedly with incremental TP load reductions until the chlorophyll and Secchi depth targets were attained. Watershed loads were estimated using the GWLF/BasinSims model as described in Appendix D and in the TMDL Support Documentation, a folder that contains the data, spreadsheets, and modeling. (File descriptions for this folder are in Appendix D and it is available from IDNR.) The watershed load allocation was developed using averaged output for three years (2006 to 2008) from GWLF/BasinSims.

The existing loads in Table 6 consist of those where reductions are possible and those where reductions are impractical. Those that cannot be reduced are the atmospheric deposition and groundwater seepage loads. The geese are considered a natural background load as long as they are not over-wintering at the lake. In the past, aerators have been put in the lake to provide a dissolved oxygen supply for aquatic life in the wintertime. If aerators are being used and the resulting open water attracts large numbers of over-wintering geese, the condition would not be considered natural background. The current information from the IDNR Wildlife Bureau on Union Grove Lake geese populations indicates that aerators are not being used at this time.

This means that reductions must come from watershed sources, mostly row crop agriculture, and internal lake phosphorus recycling. Together these make up 94.5 percent of the lake phosphorus load and each must be substantially reduced.

Row crop land comprises 75 percent of the estimated watershed TP load (see Figure 8). This load can be decreased by implementing best management practices as described in the Section 5, Implementation Plan. Therefore the watershed load reduction is 64 percent.

However, internal loading caused by the resuspension of lake bottom sediment by carp and wind can be reduced through the removal of carp and the establishment of aquatic plants in shallow areas susceptible to waves. Reducing the internal load is primarily accomplished by removing all of the carp from the lake. Therefore, the target internal load reduction is assumed to be 90 percent.

The reductions in septic tank loads while small, is important because of their proximity to the lake and because they are discharging soluble phosphorus even in dry periods. It is during these dry periods that available phosphorus can have an impact out of proportion to its mass. This is also true of loads from geese. Table 7 shows the reductions that are needed for the major source categories. While the distribution of these source reductions could be changed, the reduction in all phosphorus currently delivered to the lake must be at least 70 percent to meet load targets.

Table 7 Target TP loads for Union Grove Lake

Load source	Existing TP Load, lb/yr	TP Load Reduction, lb/yr	Percent Reduction	Target Load, lbs/yr
watershed	5,870	3,755	64%	2,115
septic tank systems	13	10	77%	3
geese	68	34[1]	50%	34
groundwater seepage	449	0	0%	449
atmospheric deposition	31	0	0%	31
internal recycling	3,739	3,365	90%	374
Total	**10,170**	**7,164**	**70%**	**3,006**

1. IDNR Parks has begun removing goose feces from the beach and adjacent park areas to reduce geeese loads that are currently categorized as natural background.

The total load allocation (LA) for Union Grove Lake is the sum of all nonpoint source load allocations. The load allocations are the modeled allowable load less the explicit ten percent margin of safety (MOS). The LA for this TMDL is 2,706 lbs of TP per year. These are shown in Table 8.

Table 8 Maximum Annual Average TP Load Allocations

Source	Annual average allowable TP load, lbs/year	Annual Average TP load allocation (10% MOS applied), lbs/year
watershed	2,115	1,904
septic tank systems	3	2
geese	34	31
groundwater seepage	449	404
atmospheric deposition	31	28
internal recycling	374	337
Total LA	**3,006**	**2,706**

Margin of safety.
The explicit numeric margin of safety for this TMDL is a 10 percent reduction of the allowable load of 3,006 lbs/year or 300 lbs/year. This leaves a load allocation of 2,706 lbs/year.

3.5. TMDL Summary

Lakes with levels of nutrients that cause algae and turbidity impairments, such as Union Grove Lake, do not function hydrologically, ecologically or chemically in daily time steps. Average annual targets as previously described are more appropriate for analysis and modeling purposes. In addition, natural systems undergo extreme daily fluctuations and assessments using annual averages are better suited for bringing the system into compliance with water quality standards. Therefore, the TMDL is calculated based on average annual maximum load as well as maximum daily load. The daily load is included to meet regulatory requirements.

Average Annual Maximum Load.
The TMDL based on a maximum average annual TP load is:

TMDL = WLA (zero lbs/year) + LA (2,706 lbs/year) + MOS (300 lbs/year) = 3,006 lbs/year

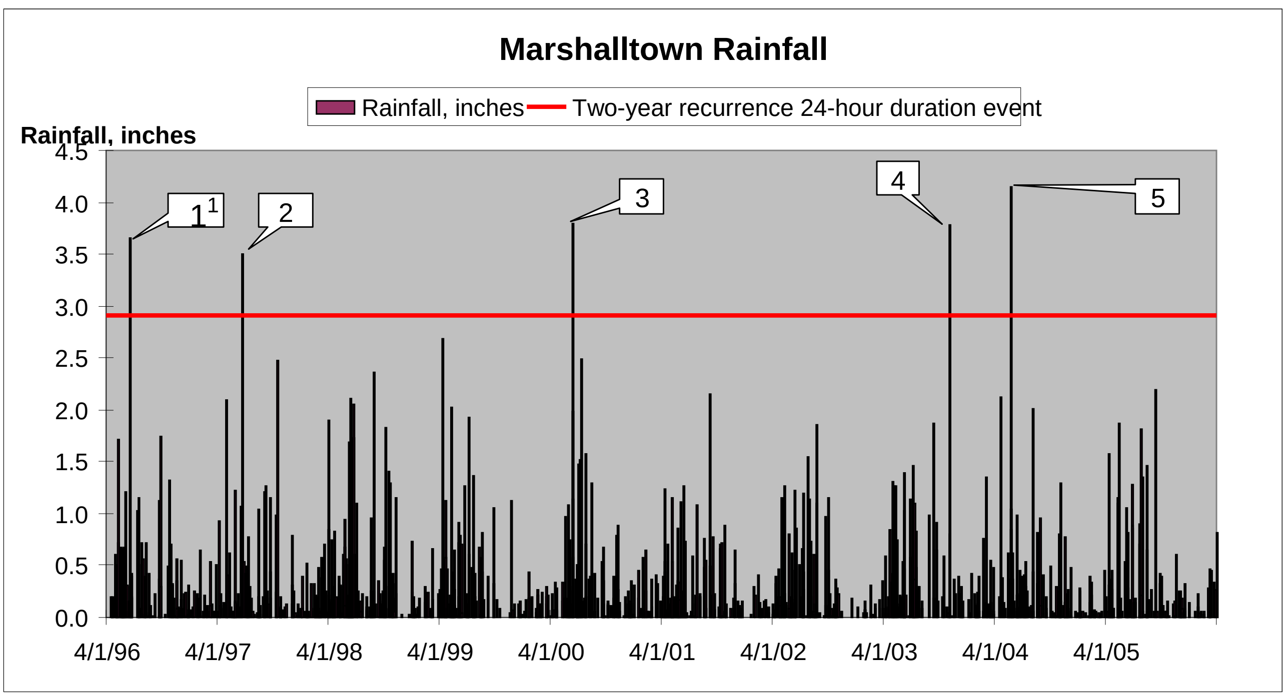
The procedures and information used to calculate these loads were described previously.

Total Maximum Daily Load.
Federal regulations require that a maximum daily load be calculated for this report.
As represented here, the total phosphorus load for Union Grove Lake has two major components:

- The watershed load that consists of TP from precipitation driven erosion, geese feces, and septic tanks estimated using the BasinSims/GWLF watershed model.
- The loads that are included in the BATHTUB lake water quality model. These are atmospheric deposition, groundwater seepage, and internal recycling.

Internal recycling, atmospheric deposition, and groundwater seepage loads are more consistent over time. Therefore, the allowable maximum daily loads for atmospheric deposition, groundwater seepage, and internal recycle loads are the average annual load divided by 365 days. This component of the daily load, two pounds per day, is small in comparison to that carried to the lake by storm event runoff. Transported by rainfall, the runoff load varies considerably through the year. The runoff, septic tank and geese feces maximum daily loads are estimated from the BasinSims/GWLF daily flow and load output for storm events that represent the maximum daily load.

The two-year return 24-hour duration storm is the runoff condition that is used to define the maximum daily erosion load for TMDL purposes. During precipitation events, most of the delivered TP is attached to sediment. The two-year return 24-hour duration event in the Union Grove Lake region is 2.91 inches. The nearest weather station to Union Grove Lake is in Marshalltown. Figure 11 shows the Marshalltown precipitation from 1996 to 2006. During this ten-year period, there were five days when precipitation events exceeded 2.91 inches.



1. The numeric labels identify the five rainfall events and are shown in Table 9.

Figure 11 Marshalltown rainfall showing five storms exceeding the two-year return 24-hour duration event of 2.91 inches.

The daily watershed TP load for each of these five events was generated using BasinSims/GWLF. The average for the five events was reduced by the same fraction, 64 percent, as the sum of the existing annual loads for watershed land uses, septic tanks, geese feces, and internal recycling was reduced to achieve target annual loads. The annual existing and target loads are shown in Table 7. Table 9 shows the precipitation, existing daily TP load and the reduced maximum daily target load.

Table 9 Existing and target daily loads for five rain events

ID	Date	Precip., in	Daily TP load, lb	TP Load reduced 64%
1	6/17/1996	3.65	1,938	698
2	6/21/1997	3.50	1,398	503
3	6/12/2000	3.80	780	281
4	11/4/2003	3.78	4,069	1,465
5	5/23/2004	4.15	2,440	878
	Average of 5 events		**2,125**	**765**

The septic tank, geese feces, and internal recycling loads are assumed to be continuous and the average annual maximum loads are divided by 365 days to obtain the target daily load. These and the target daily watershed load are shown in Table 10. The load allocations with the MOS applied to the targets are also shown in Table 10. The MOS is an explicit ten percent and is 77 pounds per day.

Table 10 Maximum Daily Load Allocations

Source	**Daily target TP load, lbs/day**	**Daily TP load allocation, lbs/day (MOS applied)**
Watershed LA[1]	765.0	689.0
Atmospheric deposition	0.1	0.1
Groundwater seepage	1.2	1.1
Internal recycling	1.0	0.9
Total	**768**	**691**

1. The watershed load allocation includes septic tank and geese feces loads.

The equation for the total maximum daily load is the lake total phosphorus load capacity.

TMDL = Load Capacity (768 lbs/day) = WLA (0 lbs/day) + LA (691 lbs/year) + MOS (77 lbs/year)

4. Total Maximum Daily Load for Pathogen Indicators (*E. coli*)

A Total Maximum Daily Load (TMDL) for the pathogen indicator *E. coli* is required for Union Grove Lake by the Federal Clean Water Act. This section quantifies the maximum daily *E. coli* load that can be in Union Grove Lake and not exceed the state's water quality standards.

4.1. Problem Identification

Applicable water quality standards.
The applicable designated uses and water quality standards for pathogen indicators are found in *Iowa Administrative Code 567, Chapter 61, Water Quality Standards.* Table 11 summarizes the water quality standards for pathogen indicators for the Class A1 use.

Table 11 *E. coli* bacteria criteria (organisms/100 ml of water) for Class A1 Uses

Use *Class A1 - Primary Contact Recreational Use.*	***Geometric Mean Concentration***	***Sample Maximum Concentration***
Class A1		
3/15 – 11/15	*126*	*235*
11/16 – 3/14	*Does not apply*	*Does not apply*

Problem statement.
The 2008 305(b) water quality assessment for Union Grove Lake is included in Appendix G. It describes the rationale behind the finding that the primary contact recreation use is not fully supported.

Data sources.
The assessments of the pathogen indicator impacts on the Class A1 use is based on the results of the IDNR-UHL summer beach-monitoring program that has collected samples from Union Grove Lake from 2000 through 2008. The bacteria samples were collected at the lake's beach once a week, usually from mid-April to mid-October. In October 2002, bacteria samples were collected once at six watershed tributary sites and five in-lake sites.

Flow data was obtained from a temporary USGS gage installed at the lake's discharge weir from September 2007 to October 2008. This data was used to calibrate a BasinSims/GWLF watershed model. Watershed model output was then used to generate simulated flows into the lake for other periods.

Interpreting Union Grove Lake E. coli data.
Flow and load duration curves and statistical analysis have been used to establish the flow conditions where water quality standards violations occur. Load duration curves are derived from flow plotted as a percentage of their recurrence and pollutant loads

calculated from pollutant concentrations and flow volume. Load duration methods have also been applied to the Union Grove Lake data to establish the load reductions needed at four flow conditions. Figure 12 is an example of a load duration curve.

Flow duration curves were developed for the modeled flow during the recreation season for 2004 through 2008 to describe the hydrologic conditions that exist when the bacteria impairment occurs. To do this, the lake bacteria monitoring data and the Water Quality Standard (WQS) sample max (235 *E. coli* organisms/100 ml) were plotted on the same chart as the flow duration percentile. The chart shows the flow conditions when the criteria are exceeded. High flow violations indicate that the problem occurs during run-off conditions when bacteria washing off from nonpoint sources predominate. Criteria exceeded during low or base flow, when runoff is generally not occurring, indicate that continuous sources such as septic tanks and geese are the problem. Figure 15 on page 47 is an example of a flow duration curve.

In addition to the flow duration curve described above, a runoff flow duration curve was developed to establish the flow conditions in which nonpoint sources transported during precipitation events could be more clearly defined. The runoff duration curve shows the flow conditions during which runoff occurs.

4.2. TMDL Target

The target for this TMDL is the water quality standard for Class A1, Primary Contact Recreational Use. The standard is a geometric mean of 126 *E. coli* organisms/100ml and a single sample maximum of 235 *E. coli* organisms/100ml. The load associated with this concentration is based on the lake volume and the assumption that the lake is completely mixed. The criteria used to determine attainment of the water quality standards is explained in the 305(b) report assessment protocol described in Appendix G.

In 2004, the Iowa Department of Natural Resources converted from fecal coliform to *E. coli* bacteria as the indicator for primary contact recreation assessment. Although *E. coli* may be a better indicator of human health issues for primary contact recreation assessment, it was not always used in the development of this report because much of the pollutant source reference material, particularly for the Bacteria Indicator Tool (BIT) spreadsheet calculations, used fecal coliform as the pathogen indicator.

EPA's Bacteria Indicator Tool (USEPA, 2001) estimates watershed bacteria accumulation available for washoff when it rains. It is a spreadsheet model that estimates the bacteria contribution from multiple sources based on land use, livestock and wildlife populations, septic tanks, and built up area contributions. The BIT spreadsheet is currently only configured for and enabled for fecal coliform.

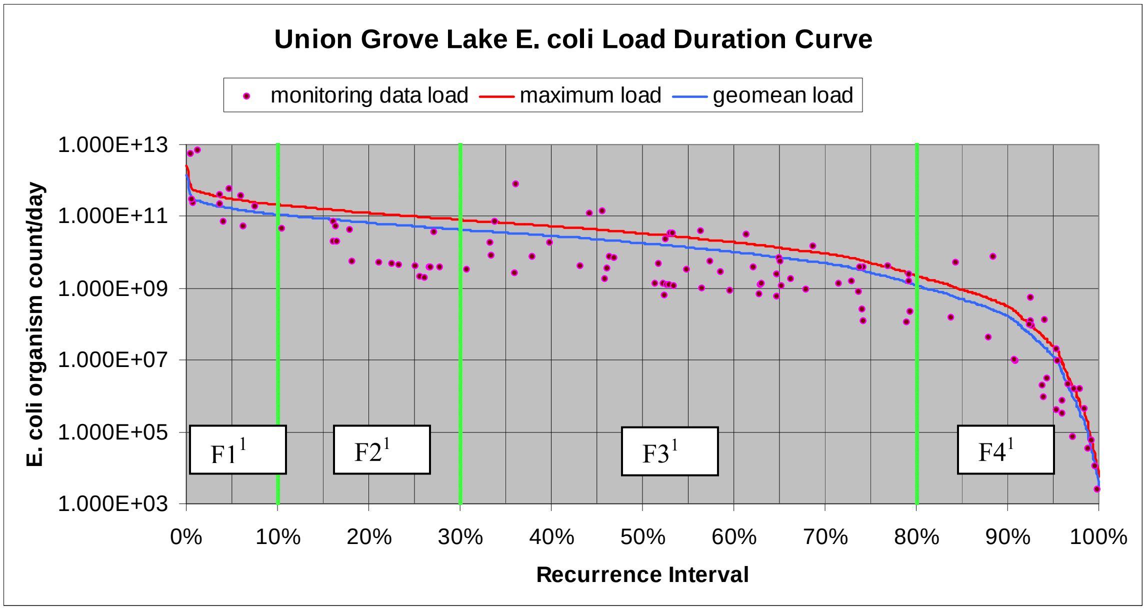
The fecal coliform/*E. coli* relationship used in this TMDL is based on the WQS geometric mean for fecal coliform that was used before the *E. coli* standard was adopted. The values, respectively, for these geometric means are 200 fecal coliform organisms/100 ml and 126 *E. coli* organisms/100 ml and the ratio is 1.59 - rounded to 1.6 for this document. Until November 2006, this was the ratio used by the IDNR wastewater discharge-permitting program for fecal coliform limits in NPDES permits.

TMDL targets for *E. coli* based on the BIT modeling fecal coliform output were converted using this ratio. Note that by definition *E. coli* is always a subset of fecal coliform.

General description of the pollutant.
The nonpoint pathogen indicator sources for the Union Grove Lake watershed are livestock, manure applied to fields, wildlife, and failed onsite septic tank systems. The nonpoint source (NPS) pollutant source has two components. One is episodic and comprised of livestock and wildlife fecal material that is transported periodically during precipitation events. The other is continuous such as discharges from leaking septic tank treatment systems and manure from cattle in and near streams.

Selection of environmental conditions.
The recreation season as defined in the Iowa Water Quality Standards runs from March 15 through November 15. This is the season used in the development of the pathogen indicator TMDL for this document.

Waterbody pollutant loading capacity (TMDL).
The *E. coli* load capacity for Union Grove Lake is the number of organisms that can be in the lake and still meet the water quality criteria. A load duration curve based on the calibrated flows from the BasinSims/GWLF model has been used to establish the target loads for Union Grove Lake. Evaluation of the flow duration curve and the runoff duration curve resulted in four different flow conditions. The load duration curve is shown in Figure 12. The upper curve shows the maximum *E. coli* count for the geometric mean criteria and the lower curve shows the maximum *E. coli* count for a single sample. The points on the chart represent observed (monitored) *E. coli* concentrations converted to loads using simulated flow. Points above the load duration curves are violations of the WQS criteria.



1. Flow condition identification matches that in Tables 12 and 13.

Figure 12 Union Grove Lake Load Duration Curve

Table 12 shows the maximum, minimum, and mid-range flows. The loading capacity for each of the four flow conditions is calculated by multiplying the mid-range flow of the interval and the *E. coli* criteria concentrations. Table 13 shows the loads resulting from this calculation.

Table 12 Maximum, minimum and mid-range flows for flow intervals

Flow condition	Flow range (mid %)	Middle of flow range, m^3/day	Maximum of flow range, m^3/day	Minimum of flow range, m^3/day
F1	0 to 10 (5%)	133,046	1,128,836	90,361
F2	10 to 30 (20%)	53,386	90,361	34,306
F3	30 to 80 (55%)	10,974	34,306	940
F4	80 to 100 (90%)	135	940	0.002

Table 13 Load capacities for design flow conditions

Flow condition	Load range (mid %)	Geometric mean allowable *E. coli* load, organism count/day	Sample maximum allowable *E. coli* load, organism count/day
F1	0 to 10 percent (5%)	1.68E+11	3.13E+11
F2	10 to 30 percent (20%)	6.75E+10	1.26E+11
F3	30 to 80 percent (55%)	1.38E+10	2.53E+10
F4	80 to 100 percent (90%)	1.70E+08	3.17E+08

Decision criteria for water quality standards attainment.

Water Quality Standards will be attained in Union Grove Lake when the monitored *E. coli* concentrations meet the criteria of a geometric mean of 126 org/100 ml and a single sample maximum concentration of 235 org/100 ml.

4.3. Pollution Source Assessment

There are two mechanisms of *E. coli* transport from the Union Grove Lake sources. The first is the wash-off load from the bacteria accumulation on watershed land surfaces when it rains. The other is from livestock that are in the tributary streams and septic tanks in the residences adjacent to the lakeshore and in 13 farmsteads scattered through the watershed. These sources of *E. coli* are assumed to be continuously delivered to the lake.

Existing load.
The maximum existing load to the lake occurs during precipitation events when maximum runoff and runoff flow bacteria concentrations are highest. These high loads and flows cause the lake bacteria concentration to exceed the criteria. The other condition leading to criteria violations occurs when there is a long hydraulic residence time in the lake, i.e., flows are minimal, and the continuous loads from livestock in the stream, local wildlife, and lakeshore septic tanks accumulate and cause a problem.

The existing loads to the lake are estimated using a load duration curve methodology. This consists of evaluating where in the flow duration curve violations of the *E. coli* criteria occur. Figure 12 in the previous section shows the *E. coli* criteria limit load curves plotted with the bacteria monitoring data converted to loads for Union Grove Lake. The assessment methodology used to evaluate pathogen indicator criteria assume that if 10 percent or more of samples exceed the *E. coli* criteria then the waterbody is not supporting recreational use. Therefore, the 90th percentile of the monitoring data at the mid-range point for each flow condition in the load duration curve is the existing load. Table 14 shows the existing loads for each flow condition.

Table 14 Existing loads at the four recurrence intervals

Flow condition	Flow condition, percent recurrence	Associated midrange flow, m^3/day	Existing 90th percentile *E. coli* conc., org/100ml	Estimated flow interval existing *E. coli* org count/day
F1	**Runoff dominated, 0 to 10%**	133,046	1,700	2.26E+12
F2	**Mixed, 10% to 30%**	53,386	85	4.55E+10
F3	**Mixed, 30% to 80%**	10,974	313	3.43E+10
F4	**Base flow, 80% to 100%**	135	920	1.24E+09

Departure from load capacity.
The departure from load capacity is the difference between the existing load and the load capacity. This varies for each of the four flow conditions. Table 15 shows this difference. At high flow runoff conditions loads are elevated, since this is when watershed bacteria are washed off by storm events. In high flow runoff conditions, the

concentration is usually higher than when runoff is not occurring. This high runoff bacteria concentration combined with high flow results in very high bacteria counts.

Table 15 Departure from load capacity

Design flow condition, percent recurrence	Existing *E. coli* org count/day	Load capacity[1], org counts/day	Departure from capacity, org counts/day
Runoff dominated, 0 to 10%	2.26E+12	3.13E+11	1.95E+12
Mixed, 10% to 30%	4.55E+10	1.26E+11	Meets criteria
Mixed, 30% to 80%	3.43E+10	2.53E+10	9.00E+09
Base flow, 80% to 100%	1.24E+09	3.17E+08	9.23E+08

1. This is calculated using the single sample maximum of 235 organisms/100 ml.

Identification of pollutant sources.

There are two categories of pollutant sources evaluated for TMDL development. One of these categories is permitted point sources and includes municipal and industrial wastewater treatment facilities and stormwater NPDES permits. The second category is nonpoint sources that include all discharges that do not require a permit. Nonpoint sources are often of a diffuse nature such as runoff from agricultural areas.

Point Sources: There are no permitted point sources in the Union Grove Lake watershed.

Nonpoint Sources: The nonpoint sources of pathogen indicators include contributors that do not have localized points of release into a stream. In the Union Grove Lake watershed these sources are:

- Land application of manure
- Grazing animals
- Wildlife – especially geese
- Cattle contributions directly deposited in a stream
- Failing septic tank systems
- Built-up residential area runoff

The contributions from each of these sources have been estimated using information from:

- IDNR and Iowa State University (ISU) wildlife biologists who provided data on watershed wildlife populations. (Guy Zenner, IDNR Wildlife Waterfowl Biologist, December 2008. Personal communication.)
- Lake Association members and property owners familiar with the septic tank situation in the residential area adjacent to Union Grove Lake.
- Natural Resources Conservation Service (NRCS) and ISU researchers who provided information on manure application practices and loading rates for hog farms and cattle operations in the watershed.

Livestock in the watershed.
Livestock sources in the watershed were estimated using assessments made by IDNR staff. The livestock estimates used in the Bacteria Indicator Tool model are shown in Table 16:

Table 16 Estimated Union Grove Lake watershed livestock numbers

Livestock type	Number of animals
Beef Cattle	399
Swine (hogs)	1,440
Sheep	36

Nonpoint source analysis for the watershed.
Figures 13 and 14 show total recreation season *E. coli* percentages for nonpoint sources. The first chart, Figure 13, shows *E. coli* load distribution as a percentage by land use for the Union Grove Lake watershed. These sources require a precipitation event for *E. coli* transport to the lake and only a fraction of the load available for wash off is delivered to the lake. The accumulated loads available for wash off are relatively constant through the recreation season until October and November when it is assumed most manure is applied. During periods of manure application bacteria loads increase.

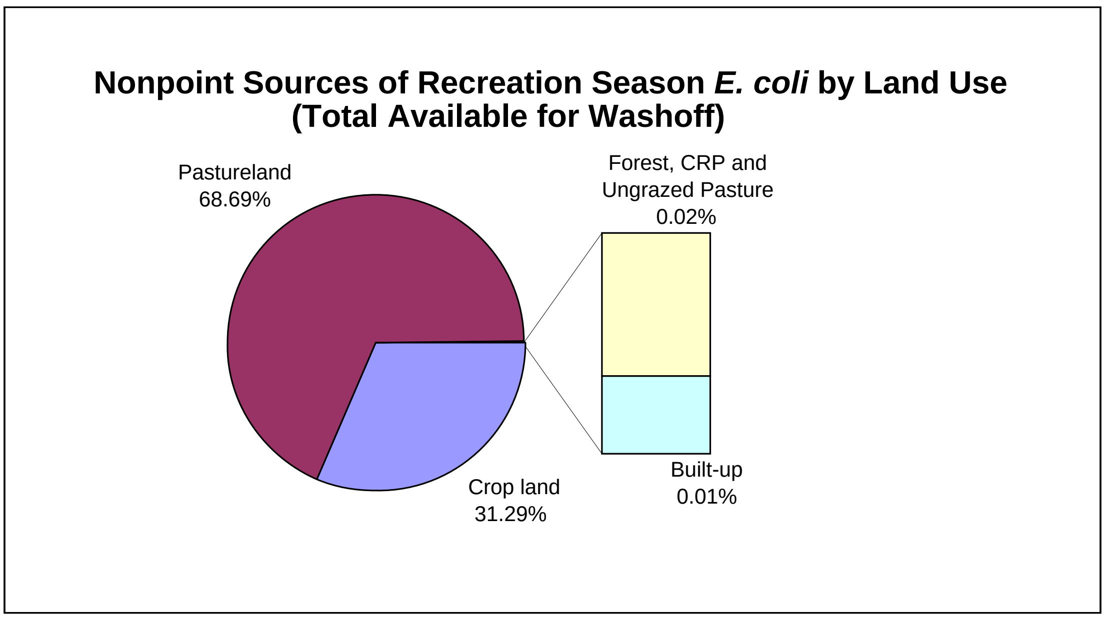


Figure 13 Nonpoint sources of *E. coli* by land use available for wash off by precipitation events

The second chart, Figure 14, shows the nonpoint source loads as a percentage of the total that are assumed to discharge continuously to the lake with or without precipitation occurring. These are the loads from failing septic tank systems and cattle in streams. It is assumed that all of the load from the lakeshore septic tanks is discharged to the lake since their location is adjacent to the beach where the *E. coli* samples are taken. Only a fraction of the cattle in stream load is delivered to the beach zone where the samples are collected. (Figure F3 in Appendix F is an aerial photo map of the lake. The beach is the sand colored area just west of the east parking lot.) This is because bacteria die-off during transport from the riparian grazing areas and due to the predation that occurs in the lake where velocities are especially slow in dry periods. The impact of loads from cattle in the stream, relative to the septic tanks adjacent to the beach, will not be as large as suggested in Figure 14.

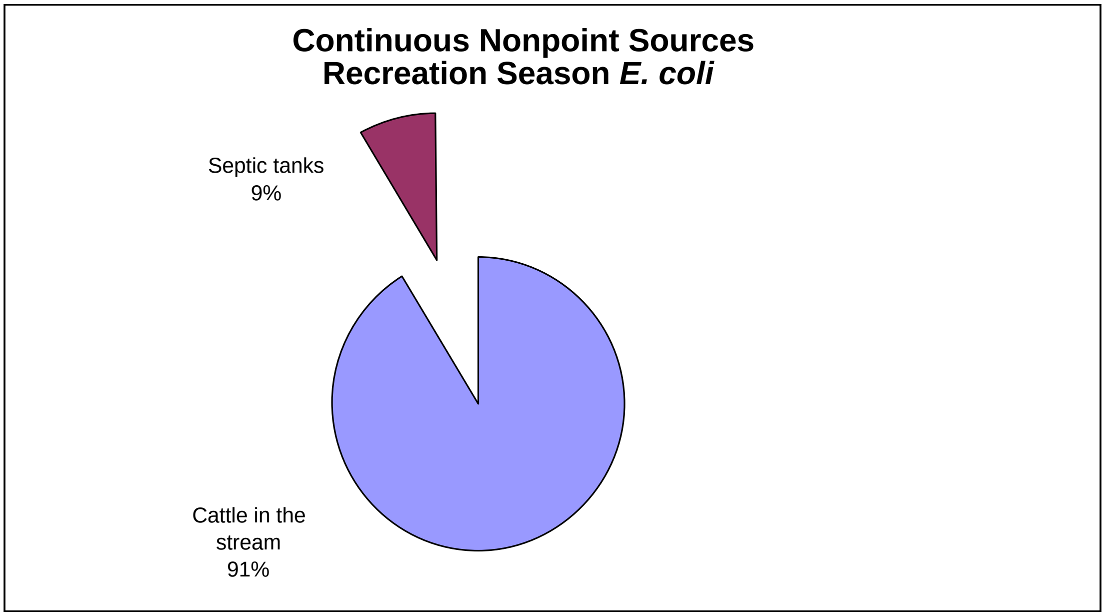
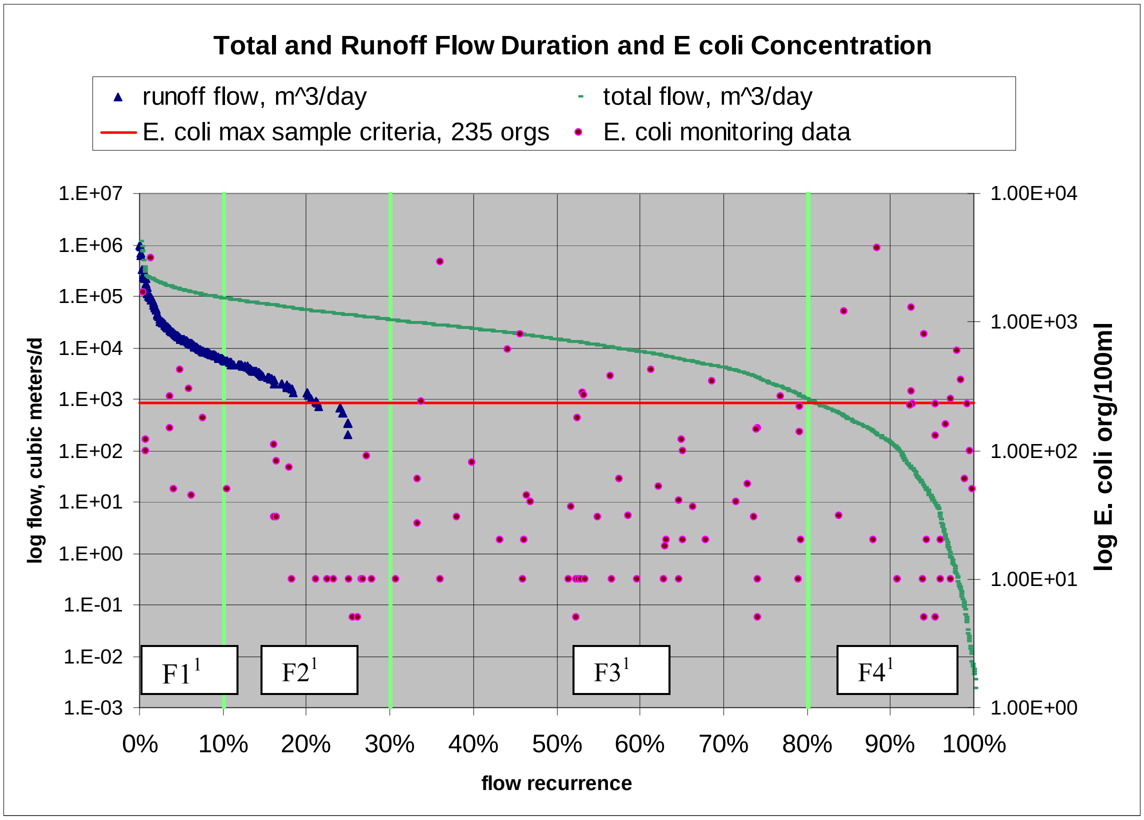


Figure 14 Continuous nonpoint sources of E. coli by land use

Linkage of E. coli sources to the lake, flow and load analysis.
The loads delivered to the lake vary with runoff conditions in the watershed. During peak runoff conditions the loads are dominated by washed off bacteria. The maximum bacteria available for wash off for each land use are estimated by the BIT model. Only a fraction of the bacteria available for wash off is actually delivered to the lake. The flow and load duration curves estimate existing loads at each of the four flow conditions. The fraction delivered by precipitation is the existing observed load during runoff conditions divided by the maximum load available for washoff. Figure 15 shows the flow and runoff duration curves plotted together with the monitoring data.



1. The identification labels are the four flow conditions also listed in Table 17.

Figure 15 Union Grove Lake total flow and runoff duration curves

This figure illustrates:

- The runoff flow as a fraction of total flow. Runoff quickly decreases as a part of total flow. Runoff approaches zero at the 25 percent recurrence level.
- Non-runoff flow (interflow and baseflow) increases as a fraction of total flow until it completely dominates at the 25 percent recurrence level and higher.
- The maximum sample criteria concentration of 235 *E. coli* organisms/100 ml as a red horizontal line.
- The monitored *E. coli* data plotted at its associated flow rate. Values over the WQS criteria are above the criteria concentration line.

The flow conditions used for TMDL targets are based on an evaluation of Figure 15. The four derived flow conditions are shown in Table 17. There is a more extensive analysis and evaluation of the four flow conditions, how they were derived, and bacteria die-off calculations in Appendix D.

Table 17 Four flow conditions used to establish existing loads

Flow ID	Flow condition	Description
F1	Zero to ten percent recurrence interval	Runoff conditions predominate here and the flows and loads are the greatest. There are five samples that exceed the *E. coli* maximum sample criteria in this flow condition.
F2	Ten to thirty percent recurrence interval	Runoff conditions are decreasing in volume and bacteria load and their influence is diminishing. Interflow and groundwater are relatively greater and dilution from these cleaner flows reduces the *E. coli* concentration from the continuous septic tanks, cattle in the stream, and goose loads. There are not any monitored violations of the *E. coli* criteria in this recurrence interval.
F3	Thirty to eighty percent recurrence interval.	There are minimal impacts from runoff in this flow recurrence interval. Flow consists of groundwater and interflow. There are ten samples that exceeded the *E. coli* criteria for this recurrence interval. Loads originate from minor occurrences of local runoff and mostly from the continuous septic tank, cattle in stream, and goose sources.
F4	Eighty to one hundred percent recurrence interval.	This is the low flow to no flow condition. Loads in this flow condition are nearly all from local continuous sources although the delivery of these continuous loads can be greatly reduced in the driest conditions. There are eight exceedances of the *E. coli* criteria in this recurrence interval.

Allowance for increases in pollutant loads.
An allowance for increased pathogen indicator loading was not included in this TMDL. The Iowa Department of Natural Resources owns and maintains most of the shoreline around Union Grove Lake. Some of the nearby watershed is in state owned forest, grass, and wetlands and most of the rest is in agricultural production with row-crop predominating. A significant change in watershed land use is unlikely.

4.4. Pollutant Allocation

Wasteload allocation.
There are no permitted point sources in the Union Grove Lake watershed and, therefore, there are no *E. coli* wasteload allocations and the sum of the wasteload allocations is zero.

Load allocation.
The load allocations for this *E. coli* TMDL are the load capacity less an explicit 10 percent margin of safety (MOS). There is a separate load allocation set for each of the target recurrence intervals. The load allocations are shown in Table 18.

Table 18 Union Grove Lake *E. coli* load allocations

Design flow condition, percent recurrence	Load capacity, org counts/day[1]	MOS, explicit 10%, org counts/day	Load Allocation, org counts/day
Runoff dominated, 0 to 10%	3.13E+11	3.13E+10	2.82E+11
Mixed, 10% to 30%	1.26E+11	NA	1.26E+11
Mixed, 30% to 80%	2.53E+10	2.53E+09	2.28E+10
Base flow, 80% to 100%	3.17E+08	3.17E+07	2.85E+08

1. Based on single sample maximum, 235 *E. coli* organisms/100 ml

Margin of safety.
The margin of safety for *E. coli* is an explicit 10 percent of the load capacity at each of the design recurrence intervals as shown in Table 18.

4.5. TMDL Summary

The following equation represents the total maximum daily load (TMDL) and its components for Union Grove Lake.

Total Maximum Daily Load = Σ Load Allocations + Σ Wasteload Allocations +MOS

A Total Maximum Daily Load calculation has been made for each of the design flow conditions and these are shown in Table 19.

Table 19 TMDL calculations for the four design flow conditions

Design flow condition, percent recurrence	Σ Load Allocations, org counts/day	Σ Wasteload Allocations, org counts/day	MOS, explicit 10%, org counts/day	Total Maximum Daily Load, org counts/day
Runoff dominated, 0 to 10%	2.82 E+11	zero	3.13 E+10	3.13 E+11
Mixed, 10% to 30%	1.26E+11	zero	NA	1.26E+11
Mixed, 30% to 80%	2.28 E+10	zero	2.53 E+09	2.53 E+10
Base flow, 80% to 100%	2.85 E+08	zero	3.17 E+07	3.17 E+08

5. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources recognizes that implementation guidance is important for the attainment of TMDL goals. Local watershed managers and citizens can use this report as a general guide for decision making and planning. The management practices discussed below are tools that may direct watershed activities towards achievement of water quality goals. Ultimately, it is up to land managers, citizens, and local conservation professionals to determine which management practices to use and how best to apply them.

A nonpoint source watershed improvement project was begun in the Union Grove Lake watershed on April 1, 2008. In conjunction with IDNR, the Tama County Soil and Water Conservation District (SWCD), the Natural Resources Conservation Service (NRCS), the Iowa Department of Agriculture and Land Stewardship (IDALS) – Division of Soil Conservation (DSC), and the Iowa Valley Resource Conservation and Development (RC&D), fund this watershed project. The DNR and DSC manage the project. The project contract runs through June 30, 2011.

The project focus is the algae and turbidity problem resulting from excess phosphorus and inorganic turbidity and with a goal to reduce sediment and phosphorus delivery from the watershed to the lake by 57 percent. Proposed best management practices include grade stabilization structures, sediment control basins, terraces, grassed waterways, wetlands, nutrient management, no-till farming, buffer strips, stream corridor fencing/protection, and stream bank restoration. An education program is targeted at landowners and an assessment of the stream corridor has been completed to identify and target areas of bed and bank erosion.

The problem of *E. coli* pathogen indicators will benefit from many of the project activities since there are similar sources and delivery mechanisms for phosphorus and bacteria. The following suggestions for implementation actions and timelines incorporate and add to the watershed improvement work already under way. The implementation discussion to address the algae and turbidity problem in this section is handled separately from the discussion for the bacteria impairment.

5.1. Implementation Approach – Algae and Turbidity Reduction

The best way to reduce Union Grove Lake algae blooms is to reduce the lake phosphorus concentration by systematically reducing the significant phosphorus sources. For Union Grove Lake these sources are erosion from row crop land use and the internal resuspension and recycling of silt and phosphorus in the lake itself. Evaluating relative contributions from different sources provides possibilities for decreasing loads where success is most likely.

The existing watershed and internal loads are shown in Figure 10. The watershed contributes 58 percent and internal recycle 37 percent of the estimated annual TP load.

Figure 8 shows that the largest percentage of the watershed load comes from row crop agriculture followed by groundwater, pasture, and septic tanks. Based on this analysis, the greatest reductions will come from decreases in watershed sediment delivery and in minimizing resuspension of silt and phosphorus from the lake bottom. Eliminating septic tank loads and minimizing geese feces will also reduce phosphorus in the lake during the critical late summer period.

Loads from all sources are shown in Table 20. Two of these loads, atmospheric deposition and groundwater seepage, cannot be practically reduced. The allocation of watershed loads was previously discussed in Section 3.3 and is shown in Figure 8. Table 20 lists a suggested distribution for reducing existing loads by source.

Table 20 Existing TP loads, load reductions, and target loads for Union Grove Lake

Load source	Existing load, lb/yr	Load reduction, lb/yr	Target load, lb/yr	Suggested reduction, percent
Watershed	5,870	3,755	2,115	64%
Septic tank systems	13	10	3	77%
Geese[1]	68	34	34	50%
Groundwater seepage	449	0	449	0%
Atmospheric deposition	31	0	31	0%
Internal recycling	3,739	3,365	374	90%
Total	**10,170**	**7,164**	**3,006**	**70%**

1. The reduction in geese loading is the result of an ongoing program to pick up feces from the beach and adjacent park areas by IDNR Parks.

Agricultural BMPs.
Agricultural source controls should include the implementation of best management practices (BMP) that are both practical and effective. For example, attainable unit reductions (lbs/acre) for ungrazed grassland will not be as great as those that can be achieved for row-crop land where effective management of erosion and fertilizer application can have a significant impact on pollutant loading. Many agricultural BMPs are designed to reduce erosion and/or capture sediment before it reaches a stream or lake. A large portion of TP is adsorbed to sediment so reducing erosion and sediment delivery also reduces TP loads. Practices should be focused in areas with the highest potential to contribute sediment and phosphorus to the lake. Agricultural BMPs may include the following:

1. Nutrients applied to production agricultural ground should be managed to achieve the optimum soil test category. Over the long term, maintaining this soil test category is the most profitable for producers.

2. Manure and commercial fertilizer should be incorporated while controlling soil erosion. Incorporation physically separates phosphorus from surface runoff.
3. Adoption of no till and strip tillage reduced tillage systems should be encouraged.
4. A fall-seeded cover crop incentive program should be initiated that targets low residue producing crops (e.g. soybeans) or low residue crops after harvest (e.g. corn silage fields). This practice increases residue cover on the soil surface and improves water infiltration.
5. Landscape diversity should be encouraged to reduce runoff volume and velocity by strategically locating filter strips and grass waterways.
6. Terraces, ponds, and other erosion and water control structures should be appropriately located in the watershed and maintained to control erosion and reduce delivery of sediment and phosphorus to the lake.
7. The number of open vertical intakes connected to tile lines in crop land and road ditches should be reduced or converted to filtered systems. Vertical intakes provide a short fast trip to the lake for soil particles and attached phosphorus.

Figure F2 in Appendix F shows areas in the watershed most prone to high erosion rates. Prioritization and location of sediment and erosion control practices should be in locations where BMPs will provide the largest phosphorus reductions. Many of these locations were identified in the 1980's project work and were implemented then. However, in the 25 or 30 years since they were constructed some effectiveness has likely been lost.

More effective management of livestock manure and fertilizer can also reduce phosphorus loads to the lake. Incorporation of applied manure and fertilizer into the soil reduces phosphorus, nitrogen and bacteria in runoff from application sites. The timing of manure and fertilizer application and avoiding over-application will also benefit water quality. Application of manure on frozen ground should be avoided, as should application prior to snowmelt or heavy rainfall.

Table 21 lists many of the BMPs that will reduce sediment and phosphorus delivery. Several of these will also inhibit the release of bacteria to the lake from grazing livestock and manure application.

Table 21 Potential agricultural BMPs and their potential benefit for water quality improvement.

BMP or Activity	[1] Potential TP Reduction
Conservation Tillage:	
Moderate vs. Intensive Tillage	50%
No-Till vs. Intensive Tillage	70%
No-Till vs. Moderate Tillage	45%
Cover Crops	50%
Diversified Cropping Systems	50%
In-Field Vegetative Buffers	50%
Terraces	50%
Pasture/Grassland Management:	
Livestock Exclusion from Streams	75%
Rotational Grazing vs. Constant Intensive Grazing	25%
Seasonal Grazing vs. Constant Intensive Grazing	50%
Phosphorus Nutrient Application Techniques	
[2]Deep Tillage Incorporation vs. Surface Broadcast	-15%
[2]Shallow Tillage Incorporation vs. Surface Broadcast	-10%
Knife/Injection Incorporation vs. Surface Broadcast	35%
Phosphorus Nutrient Application Timing and Rates:	
Spring vs. Fall Application	30%
Soil-Test P Rate vs. Over-Application Rates	40%
Application: 1-month prior to runoff event vs. 1-day	30%
Riparian Buffers	45%
[3]Wetlands	20%

(1) Source: IDNR and USDA-ARS (2004). Actual reduction percentages may vary widely across sites and runoff events.
(2) Note: Tillage incorporation can increase TP in runoff.
(3) Note: TP reductions in wetlands vary greatly depending on site-specific conditions. Increasing surface area, implementing multiple wetlands in series, and managing vegetation can result in significantly higher TP reductions.

In-lake and non-agricultural BMPs.

In the short term, restoration of Union Grove Lake requires extensive in-lake renovation in addition to work that reduces watershed phosphorus loads. The recycling of phosphorus in Union Grove Lake is the most direct and important factor driving the summer and fall algae blooms. If this problem is not fixed then other watershed improvement activities are not likely to succeed at reducing phosphorus and chlorophyll concentrations. Once the recycling starts in midsummer after the heavy May and June precipitation and lake flushing, there is a steady increase in phosphorus and chlorophyll concentrations, and a loss of transparency.

In-lake efforts to restore Union Grove Lake would have a direct and noticeable affect on water quality. Efforts to achieve the internal phosphorus load reduction goal of 90 percent need to be focused and determined. These efforts must include the following:

- The numbers of bottom feeding fish must be reduced significantly and measures need to be taken to prevent their reintroduction after removal.
- Minimize the factors that contribute to turbulence in shallow areas. These are carp, wind and waves.
- Encouraging the growth of rooted aquatic plants in shallow areas to stabilize bottom sediments.
- Remove silt that has settled behind the sediment dike at the lake inlet.

There are three other phosphorus sources that should be controlled. These are septic tank systems, residential runoff from the lakefront community, and geese. While these are less significant phosphorus sources, they can have an impact in the critical late summer and fall period when smaller loads in the immediate proximity of the lake are more important. They are also important sources of *E. coli* as noted in the next section. Management of these phosphorus sources should include the following steps:

- Identify, repair, or replace improperly connected and malfunctioning septic tank systems with on-site systems that meet state design standards. Alternatively, construct a community wastewater treatment facility that discharges downstream from the lake.
- Remove pet feces from the ground in residential areas, especially adjacent to the lake.
- Use lawn fertilizers that are phosphorus free.
- Implement aerator operation procedures that do not encourage the overwintering of geese by creating year round open water.
- Remove geese feces from lawns and beaches next to the lake. (This is an ongoing activity that should be continued.)

Dredging is another restoration approach previously used at Union Grove Lake that could have a significant impact on lake water quality. In deeper lakes with strong thermal stratification, phosphorus and silt are usually confined to the hypolimnion once they have settled. This greatly reduces the availability of recycled phosphorus. IDNR Fisheries has a target mean depth of ten feet that they believe allows a lake to stratify strongly enough to positively impact water quality.

According to the 2006 lake bathymetry data that excludes the lake area behind the sediment dike, Union Grove Lake has an existing mean depth of 7.48 feet and a surface area of 96 acres. Dredging the lake to a mean depth of 10 feet would require the removal of a volume of 240 acre-feet or 387,000 cubic yards of sediment. In the 1984 to 1992 restoration efforts, dredging removed a volume of 275,000 cubic yards. Therefore, dredging to establish a hypolimnion may be a possibility, especially since there is some capacity remaining in the original spoils basin. This option should be evaluated.

Table 22 lists recommended in-lake practices that can have a large impact on reducing the internal recycling of phosphorus.

Table 22 In-lake practices for water quality improvement.

In-lake practice	Comments	Relative TP Reduction [1]
Carp removal and fisheries management	Significant internal TP load reductions will occur when the carp population is eradicated. This probably requires draw down of the lake as well as other procedures to remove undesirable fish. As water quality improves and desirable fish populations increase, strong efforts to exclude carp from the lake should be made, including a barrier at the discharge weir to Deer Creek.	High
Aquatic vegetation establishment	Rooted vegetation competes with algae for available phosphorus and nutrients; overall impact of large wetland/marsh areas on water quality can be significant; vegetation may require annual harvesting to remove accumulated nutrients; reduces a portion of open water areas of the lake, requires water level manipulation.	Medium
Shoreline and riparian maintenance and stabilization	The establishment and maintenance of vegetation along the lakeshore reduces sediment and pollutant runoff from the zone immediately adjacent to the water. It also helps to reduce shoreline erosion from waves. Maintenance should also include removal of goose feces.	Medium to low
Dredging to a mean depth of ten feet	If used as a water quality improvement technique, dredging should be focused on creating deep water areas that will maintain good thermal stratification through the summer and early fall. Dredging should also include areas of recent siltation such as behind the silt retention dike.	High

(1) Reductions are relative to each other and based on past IDNR experience and projects.

5.2. Implementation Timeline– Algae and Turbidity Reduction

The establishment of an implementation timeline for management practices to improve Union Grove Lake water quality can be a guide for the initiation of these improvements. Most watershed improvement practices require planning, design, and construction phases before implementation. In-lake activities that need to be coordinated such as lake draw downs, dredging and carp removal require detailed preparation and a time table.

While some natural variability and data gaps are inevitable, the procedures used in this report provide a reasonable explanation of the pollutant sources and water quality condition. However, since there is some uncertainty in the quantitative conclusions of this report, watershed and in-lake water quality improvement projects should proceed methodically and with an eye towards evaluating their effectiveness.

Applying adaptive management strategies is a sensible and efficient way to ensure that phosphorus reduction actions are having the desired impact. Adaptive management is a procedure through which BMPs and in-lake restoration efforts are introduced into the watershed incrementally.

Most potential watershed load reduction strategies require adjustments to existing agricultural practices as described in the previous section. Implementation of watershed BMPs and the maintenance of those already in place cannot be done all at once. Changes like these require time to implement. The existing watershed improvement project is currently contracted to run from April 1, 2008 to June 30, 2011. Table 23 outlines a preliminary suggestion for a watershed and in-lake water quality improvement timetable.

Table 23 Preliminary implementation timeline

Water Quality Improvement Activity	start	midpoint	complete
Erosion control BMPs- 319 project			
• Inventory and evaluate existing structures.	May 2009	Aug 2009	May 2010
• Carry out maintenance on existing structures.	May 2010	May 2011	Aug 2012
• Identify and design sites for new BMPs	Sept 2009	Aug 2009	May 2010
• Construct new BMPs	May 2010	May 2011	Aug 2012
Livestock controls			
• Provide for livestock watering	Aug 2009	Aug 2010	Aug 2011
• Fence out livestock from streams	Aug 2009	Aug 2010	Aug 2011
In-lake phosphorus recycling control			
• Design procedure for carp removal	June 2009	Sept 2009	Nov 2009
• Identify locations of carp upstream and outside of the lake and eliminate them	June 2009	May 2010	Sept 2010
• Construct barrier to prevent carp from entering the lake from downstream	May 2010	-	Sept 2010
• Remove carp	July 2011	-	Sept 2011
• Introduce aquatic plants to shallow areas during drawdown.	Aug 2011	-	Sept 2011
Septic tanks			
• Inspect and evaluate all residential septic tank systems	June 2009	-	Sept 2009
• Assess the best wastewater treatment approach, septics vs. community treatment discharging downstream from the lake	Sept 2009	Dec 2009	May 2010
• Repair and maintain existing septic systems or begin design and construction of community treatment system.	May 2010	May 2011	May 2012
Dredging			
• Evaluate existing spoils basin for storage capacity	May 2011	-	Sept 2011
• Design dredging plan to attain ten foot mean depth by removing 387,000 cubic yards.	Sept 2011	Jan 2012	June 2012
• Dredge to ten foot mean depth.	May 2013	May 2014	May 2015

5.3. Implementation Approach and Timeline – *E. coli* Pathogen Indicators

This water quality improvement plan sets specific targets for *E. coli* concentrations in Union Grove Lake and allocates allowable loads to bacteria sources. To be effective, watershed stakeholders will need to participate in the implementation of bacteria controls and continuing water quality evaluations. The first steps towards improving Union Grove Lake water quality have already been taken. Work is ongoing to develop best management practices in the watershed through a project funded by the IDNR Nonpoint Source water quality improvement program. There is also a local stakeholders group in the form of the lake association, Lake and Park Holding Corporation.

It might be useful to create a local watershed advisory committee that could help identify high priority areas where resources can be concentrated for the greatest effect. In addition, priority best management practices based on effectiveness should be identified for implementation. Since the impairment problem occurs at many flow conditions, solutions will need to be implemented for nonpoint sources with event driven transport, and continuous sources such as cattle in streams and failed septic tank systems.

Existing pathogen loading to the lake originates from nonpoint sources in the watershed. These sources include septic systems, livestock grazing, manure applications, and wildlife. Reductions in these loads will require changes in the way manure and other waste is managed and will take time to implement.

Best management practices for reducing pathogen indicators are:

- Limiting livestock access to waterways in pastures and providing alternate watering sources.
- Control manure runoff. Manure application should utilize incorporation or subsurface application of manure while controlling soil erosion. Incorporation physically separates fecal material from surface runoff. Buffer strips should be installed and maintained along the lake tributaries to slow and divert runoff.
- Identify, repair, or replace improperly connected and malfunctioning septic tank systems with on-site systems that meet state design standards. Alternatively, construct a community wastewater treatment facility that discharges downstream from the lake.
- Remove pet feces from the ground in residential areas, especially adjacent to the lake.

Actions taken to reduce algae in the lake will also have the effect of reducing *E. coli*. *E. coli* declines with algae removal because:

- algae shades the water column from penetration by natural UV radiation that kills the bacteria,
- algae provides favorable *E. coli* attachment sites to avoid zooplankton predation, and

- at night algae hampers wind driven oxygen exchange at the lake surface needed to support predator zooplankton populations.

A schedule is a useful tool to structure the achievement of *E. coli* reduction targets. Below are objectives and a suggested schedule to improve Union Grove Lake bacteriological water quality.

- Identify, assess, and rank the potential sources within a quarter mile of the lakeshore. Select best management practices for each source. Complete by May 2011.
- Begin implementation of the best management practices by priority ranking for the sources identified in step 1. Reduce the identified source pathogen loading 25 percent by May 2012.
- Continue the process of identifying, assessing and ranking bacteria sources and selecting BMPs outward from the streams in quarter-mile increments every year.

6. Future Monitoring

6.1. Union Grove Lake Monitoring

Watershed and in-lake water quality monitoring are important elements in any plan to improve Union Grove Lake. They play key roles in the analysis and modeling of pollutant sources and water quality. Watershed stream monitoring provides information for several purposes related to Union Grove Lake water quality improvement. Table 24 outlines the purposes, time frames, and general procedures for engaging in this type of monitoring.

Table 24 Watershed stream monitoring

Type ID	Purpose	Time frame	General procedure
M1[1].	Measure continuous flow. Required for calculating loads, baseflow separation, flow and load duration curves, model calibration, etc.	Stage measured hourly, April to Oct.	Requires continuous stage monitoring, monthly or biweekly field measurement of flow, and the development of a hydrograph from these.
M2[1].	Event sampling for phosphorus, nitrogen, suspended solids, and *E. coli*. Provides information on loads during runoff conditions.	Once an hour for at least 24 hours.	Auto-sampler set to begin sampling as stage increases. Samples at preset interval to capture most of hydrograph rise and fall.. Operates in conjunction with flow measurement.
M3[1].	Base flow grab sampling for phosphorus, nitrogen, suspended solids, and *E. coli* Also field measurements of pH, DO and flow. Provides data for watershed and lake model parameterization.	Once or twice a month, April to Oct.	Grab samples, field pH, DO, flow. These need to be collected at a range of flow conditions to be most useful.
M4[1].	Long term sampling for phosphorus, nitrogen, suspended solids, and *E. coli* to evaluate long term trends and BMP effectiveness	Once or twice a month for 5 to 10 years, April to Oct.	Determine confidence required, usually 95%, and calculate number of samples needed to detect a long term trend. Design a statistical model that uses event and monthly sampling data to evaluate watershed loads and detect trends.

1. These are watershed monitoring type identifications used in Table 26.

In-lake monitoring is used to assess Union Grove Lake water quality and support lake eutrophication modeling. Table 25 outlines the purposes, time frames, and general procedures for in-lake monitoring.

Table 25 In-lake monitoring

Type ID	Purpose	Time frame	General procedure
L1[1].	Measure continuous discharge from the lake. Required for estimating total flow into the lake and doing a water balance, developing flow and load duration curves, and providing lake model input and calibration.	Stage measured hourly, ice out to ice in.	Requires continuous stage monitoring, at the discharge weir. The USGS has developed a rating curve for the weir so field measurements can be infrequent.
L2[1].	Daily precipitation near the lake. Needed for both watershed and lake models.	Long term and year round.	Well maintained automatic rain gage.
L3[1].	Continuous in-lake measurement of DO, temperature, pH, and conductivity. Provides a direct view of algae dynamics. If done at two depths provides data on photic zone productivity vs. respiration in deeper lightless zone. This data is central to calibrating mechanistic lake water quality models such as WASP.	Hourly measurement May to October	Requires the installation of an anchored buoy with sensors suspended at two depths. Data download and maintenance every two to four weeks. May require a boat with a davit to raise and lower the equipment. Accurate sensor timekeeping is needed to track diurnal DO and temperature effects.
L4[1].	Long term regularly scheduled samples from the deep part of the lake. This is the type of sampling that was done for the ISU Lake Study. It is now being done by UHL for IDNR. The long term variable averages from this data set are used in TSI evaluation as well as in empirical mass balance eutrophication models such as BATHTUB.	Sampling visits once or twice a month May through Oct. Ongoing for the life of the lake.	Grab samples analyzed back in the lab, field pH, DO, and temperature. These need to be collected for an extended period of time, decades if possible, to be most useful. Sampling for phosphorus, nitrogen, suspended solids, chlorophyll, transparency, and *E. coli*.
L5[1]	Water column profiles are done in the deepest part of the lake in conjunction with the long term grab sampling. They show DO, temperature and other variables continuously from the water surface to the bottom. Needed to determine if thermal stratification occurs, DO depth gradient, etc.	Sampling visits once or twice a month May through Oct. Ongoing for the life of the lake.	Requires that a sensor be lowered through the water column to the bottom. Done at the same time as the regularly scheduled grab samples.
L6[1].	Beach *E. coli* samples collected at the lake swimming beach to determine if water is safe for swimming. It is also needed for load duration curve evaluation.	Sampling done once a week May through Oct.	Consists of grab samples collected at the swimming beach and analyzed for *E. coli*.

1. These are lake monitoring type identifications used in Table 26.

6.2. Future Monitoring to Support Watershed Improvement Projects

Many lake water quality improvement activities require or can benefit from monitoring. Table 26 provides a framework for the monitoring that is necessary or is recommended for each of these.

Table 26 Monitoring for future watershed and water quality evaluation and improvement activities

Activity	Time frame and site locations	Necessary monitoring types	Recommended monitoring types
Erosion and sediment control - BMP effectiveness	Two years before and five years after BMP installation, at tributary sites	M1, M2, M4	M3
Watershed BasinSims/GWLF modeling	Ten years of precipitation data and two years of lake discharge.	L1, L2	M1, M2, M3
Carp removal effectiveness	Three years after removal at deep lake site.	L3, L4	L1, L5
Empirical/mass balance lake eutrophication BATHTUB modeling	Five years at deep lake site.	L4	M3, L1, L5
Mechanistic lake eutrophication WASP modeling	Two years at deep lake site.	M3, L1, L2, L3	L4, L5
Load duration curves for bacteria	Five years of precipitation and discharge data.	L1, L6	L2
Dredging for thermal stratification	Five years after project completion at deep lake site.	L3, L5	L4

6.3. Current Monitoring to Support Lake Water Quality and BMP Evaluation

It is expected that monitoring similar to that done for the ISU Lake Study and the 2005-08 UHL sampling will continue at Union Grove Lake for some time. This monitoring, consisting of three to six samples taken in the growing season and provides information used in the biannual 305b water quality assessment. Weekly beach monitoring for *E. coli* is also likely to continue. Currently these two efforts form the foundation of the Union Grove Lake monitoring activities. Over time, this data can detect impairments and statistical water quality trends in the lake.

In spring 2008, another data collection effort was started in support of an ongoing 319 nonpoint source watershed improvement project. Samples are collected at two Deer Creek sites and three sites in the lake. This sampling was done biweekly from June 2 to

October 20, 2008. The grab samples were analyzed for the nitrogen, phosphorus, and suspended solids series as well as *E. coli* and Secchi depth. Both the tributary and in-lake data were used to parameterize the WASP model. This monitoring will be done through the life of the project. Figure 16 shows the locations of these monitoring sites.

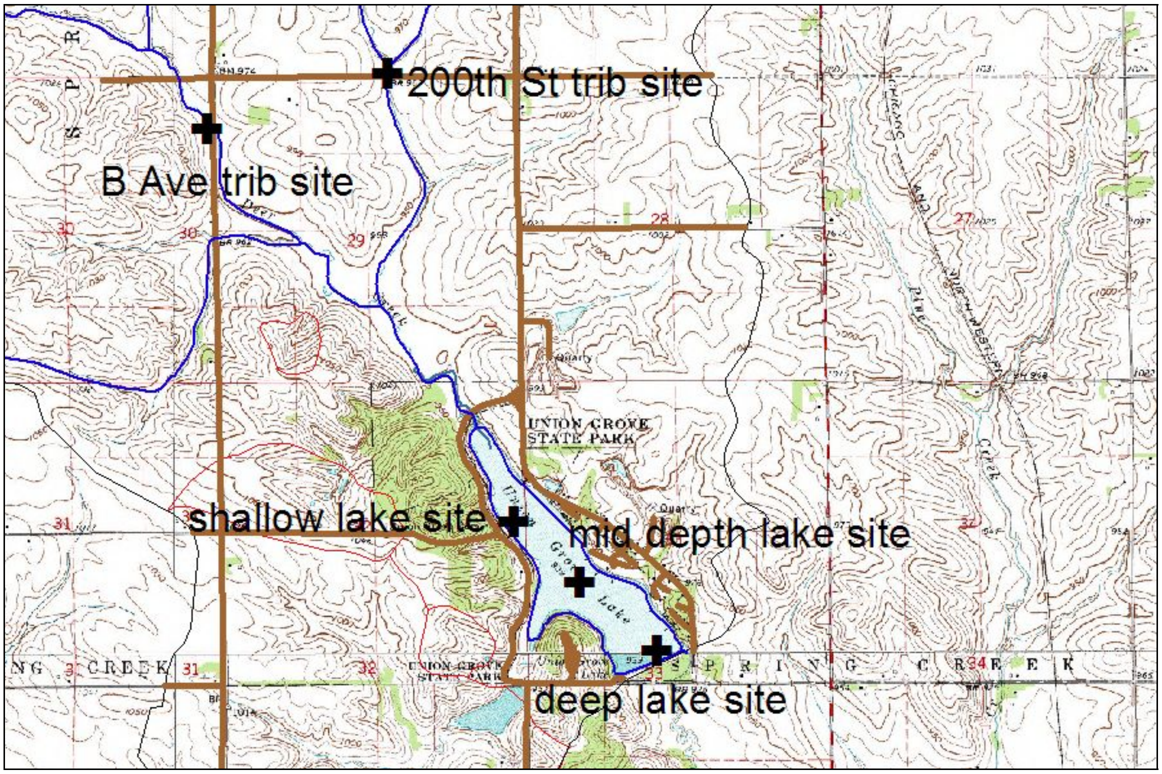


Figure 16 Nonpoint source project monitoring sites

7. Public Participation

Public involvement is important in the TMDL process since it is the land owners, tenants, and citizens who directly manage land and live in the watershed that will determine Union Grove Lake water quality. During the development of this TMDL, efforts were made to ensure local stakeholder involvement.

7.1. Public and Stakeholder Meetings

The first meeting to provide information on the water quality improvement plan was held on April 26, 2007 at the Youth Center in the residential area adjacent to the lake. Representatives of the Lake and Park Holding Corporation, an association of lakeshore property owners, the IDNR Lake Restoration Program and Fisheries Bureau, and the NRCS and SWCD attended the meeting. Lake water quality issues and pollutant sources were discussed. It was observed that there are large numbers of carp in the lake, sometimes geese over-winter due to the aeration used to reduce winter fish kills, and a large number of the septic tanks in the residential area were older and probably not functioning properly.

On May 28, 2008 there was an event held at the Youth Center to kick-off the 319 Nonpoint Source Watershed Improvement Project. The meeting was attended by local and state leaders and local landowners. It included presentations and demonstrations of water sampling and conservation practices.

7.2. Written Comments

One comment letter was received during the public comment period of May 28 – June 29, 2009. A copy of the comments and IDNR response is located in Appendix H.

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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 water bodies (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 water bodies ability to support their general and designated uses. Those found to be not 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. States receive EPA grants to provide technical & financial assistance, education, and monitoring for local nonpoint source water quality improvement projects.

AFO: Animal Feeding Operation. A livestock operation, either open or confined, where animals are kept in small areas (unlike pastures) allowing manure and feed become concentrated.

Base flow: The fraction of stream flow from ground water.

BMP: Best Management Practice. A general term for any structural or upland soil or water conservation practice. Examples are terraces, grass waterways, sediment retention ponds, and reduced tillage systems.

CAFO: Confinement Animal Feeding Operation. An animal feeding operation in which livestock are confined and totally covered by a roof.

Cyanobacteria (blue green algae): Phytoplankton that are not true algae but can photosynthesize. Some species produce toxins that can be harmful to humans and pets.

Designated use(s): Refer to the type of economic, social, or ecologic activities that a specific water body is intended to support. See Appendix B for a description of 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.

General use(s): Refer to narrative water quality criteria that all public water bodies must meet to satisfy public needs and expectations. See Appendix B for a description of 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 loss occurring in upland channels and ravines that are too wide and deep to fill with traditional tillage methods.

HEL: Highly Erodible Land. Land defined by NRCS as having the potential for long term annual soil losses that exceed the tolerance for an agricultural field eightfold.

LA: Load Allocation. The fraction of a waterbody pollutant load that comes from *nonpoint sources* in a watershed.

Load: The total amount (mass) of a particular pollutant in a waterbody.

MOS: Margin of Safety. In a total maximum daily load (TMDL) report, it is a set-aside amount of a pollutant load to allow for any uncertainties in the data or modeling.

Nonpoint source pollutants: Contaminants that originate from diffuse sources not covered by NPDES permits.

NPDES: National Pollution Discharge Elimination System. A federal system of regulatory discharge controls that sets pollutant limits in permits for point source discharges to waters of the United States.

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

Periphyton: Algae that are attached to stream substrates (rocks, sediment, wood, and other living organisms).

Phytoplankton: Collective term for all suspended photosynthetic organisms that are the base of the aquatic food chain. Includes algae and cyano-bacteria.

Point source pollution: Point sources are regulated by an NPDES permit. Point source discharges are usually from a location of flow concentration such as an outfall pipe.

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

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

Riparian: The area near water associated with streambanks and lakeshores and the physical, chemical, and biological characteristics that cause them to be different from dry upland 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 water bodies. The greater the secchi depth, the greater the water transparency.

Sediment delivery ratio: The fraction of total eroded soil that is actually delivered to the stream or lake.

Seston: All suspended particulate matter (organic and inorganic) in the water column.

Sheet & rill erosion Water eroded soil loss that occurs diffusely over large flatter landscapes before the runoff concentrates.

Storm flow (or stormwater): The fraction of stream flow that is direct surface runoff from precipitation.

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

TMDL: Total Maximum Daily Load. The maximum allowable amount of a pollutant that can be in a waterbody and still comply with the Iowa Water Quality Standards and support 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. Index values for TP, chlorophyll, and transparency are calculated for this purpose.

TSS: Total Suspended Solids. The quantitative measure of seston, all materials, organic and inorganic, which are held in the water column. It is defined by the lab filtration procedures used to measure it.

Turbidity: A measure of the scattering and absorption of light in water caused by suspended particles.

UHL: University Hygienic Laboratory (University of Iowa). Collects field samples and does lab analysis of water for assessment of water quality.

USGS: United States Geologic Survey. Federal agency responsible for flow gauging stations on Iowa streams.

Watershed: The land surface that drains to a particular body of water or outlet.

WLA: Waste Load Allocation. The allowable pollutant load that a point source NPDES permitted point source 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: Waste Water Treatment Plant. A facility that treats municipal and industrial wastewater so that the effluent discharged complies with NPDES permit limits.

Zooplankton: Collective term for small suspended animals that are secondary producers in the aquatic food chain and are a primary food source for larger aquatic organisms.

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

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

Here are some examples of scientific notation.

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

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

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

Introduction

Iowa's Water Quality Standards (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code) provide the narrative and numerical criteria used to assess water bodies for support of their aquatic life, recreational, and drinking water uses. There are different criteria for different waterbodies depending on their designated uses. All waterbodies must support the general use criteria.

General Use Segments

A general use water body does not have perennial flow or permanent pools of water in most years, i.e. ephemeral or intermittent waterways. General use water bodies are defined in IAC 567-61.3(1) and 61.3(2). General use waters are protected for livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses.

Designated Use Segments

Designated use water bodies maintain year-round flow or pools of water sufficient to support a viable aquatic community. In addition to being protected for general use, perennial waters are protected for three specific uses, primary contact recreation (Class A), aquatic life (Class B), and drinking water supply (Class C). Within these categories there are thirteen designated use classes as shown in Table B1. Water bodies can have more than one designated use. The designated uses are found in IAC 567-61.3(1).

Table B1 Designated use classes for Iowa water bodies.

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

Appendix C --- Union Grove Lake Water Quality Data

The following tables contain the monitoring data most relevant to lake eutrophication modeling from the Iowa State University Lakes Study and the IDNR/UHL sampling. The means and coefficients of variation from the UHL table were used as the observed inputs for the BATHTUB water quality modeling.

Table C1 ISU Lake Study monitoring data, 2000 to 2007

Sample Date	Total Phos. ug/l	Chlor-a, ug/l	Secchi Depth, m	Total Nitr., mg/l	Inorganic Suspended Solids, mg/l	Volatile Suspended Solids, mg/l	Total Suspended Solids, mg/l
07/07/00	269.0	87.2	0.38	3.44	28	14	42
08/02/00	183.7	31.8	0.37	4.54	20	21	40
09/05/00	185.6	8.5	1.03	0.98	6	3	9
06/07/01	51.3	14.7	1.00	12.45	14	3	18
07/12/01	81.3	11.4	0.95	8.40	8	6	14
08/09/01	185.2	44.8	0.60	4.27	7	10	17
06/13/02	72.6	32.9	0.45	2.31	13	6	19
07/17/02	151.6	57.3	0.40	3.83	12	11	22
08/14/02	187.2	61.8	0.30	1.12	19	13	33
06/11/03	52.9	25.5	0.88	8.39	7	10	17
07/17/03	61.5	15.6	0.80	4.95	9	9	19
08/14/03	81.7	37.5	0.55	2.07	17	4	21
06/09/04	64.0	72.3	0.70	2.58	8	6	14
07/15/04	70.6	39.3	0.80	4.97	2	9	11
08/11/04	163.5	71.5	0.35	2.35	21	14	35
06/16/05	70.0	59.1	0.60	4.89	15	7	22
07/20/05	70.7	126.4	0.60	5.50	9	9	19
08/09/05	125.5	230.9	0.40	2.23	5	16	21
06/14/06	41.08	20.10	1.25	4.81	4	4	9
07/19/06	162.54	124.24	0.32	1.97	10	15	26
08/16/06	242.27	92.32	0.37	1.68	11	14	24
06/12/07	27.66	30.00	0.80	10.71	8	9	17
07/18/07	121.29	79.72	0.47	4.94	4	3	9
08/09/07	178.86	200.32	0.35	2.48	5	14	19
Mean	120.9	65.6	0.614	4.4	11	10	21
Median	101.5	51.0	0.575	4.0	9	9.5	18.9

The UHL data in Table C2 was used for BATHTUB input of observed data. Only the data from 2006 to 2008 was actually used so that the BATHTUB model was using the same set as the WASP model.

Table C2 UHL/IDNR lake monitoring data, 2005 to 2008

Sample Date	Total Phos., µg/l	Chlor.-a, µg/l	Secchi Depth, m	Total Nitrogen, mg/l	Inorganic Suspended Solids, mg/l	Volatile Suspended Solids, mg/l	Total Suspended Solids, mg/l
05/26/05	80.00	34.00	0.40	7.22	16.00	9.00	25.00
08/25/05	280.00	67.00	0.40	2.50	8.00	11.00	19.00
10/17/05	90.00	52.00	0.70	1.10	9.00	9.00	18.00
05/16/06	80.00	48.00	0.80	7.00	11.00	5.00	16.00
06/12/06	110.00	73.00	0.50	5.20	12.00	9.00	21.00
07/17/06	160.00	200.00	0.30	2.65	5.00	27.00	32.00
08/21/06	260.00	38.00	0.30	2.35	6.00	22.00	28.00
05/10/07	40.00	27.00	1.30	10.50	5.00	3.00	8.00
07/10/07	170.00	69.00	0.90	7.30	3.00	6.00	9.00
08/22/07	260.00	100.00	0.50	2.15	3.00	14.00	17.00
05/12/08	110.00	61.00	0.40	8.90	21.00	8.00	29.00
07/17/08	60.00	11.00	1.40	5.50	3.00	4.00	7.00
Mean	141.7	65.0	0.7	5.2	8.5	10.58	19.08
Median	110.0	56.5	0.5	5.4	7.0	9.0	18.5

The data in Table C3 has been used to help parameterize the WASP lake model. It is from three different locations in the lake that are different depths.

Table C3 Watershed 319 project in lake monitoring data, 2008

Collection Site	Date Collected	Chlorophyll A (ug/L)	Ortho Phosphate as P (mg/L)	Total Phosphorus as P (mg/L)	Secchi depth (m)
maximum depth	06/02/08	8	0.210	0.390	0.13
maximum depth	06/16/08	2	0.130	0.300	0.10
maximum depth	06/30/08	54	0.100	0.070	0.42
maximum depth	07/14/08	11	0.100	0.080	0.63
maximum depth	07/28/08	28	0.100	0.090	0.94
mid depth	06/02/08	3	0.200	0.370	0.11
mid depth	06/16/08	3	0.120	0.330	0.11
mid depth	06/30/08	58	0.100	0.100	0.41
mid depth	07/14/08	8	0.100	0.080	0.62
mid depth	07/28/08	22	0.100	0.080	0.90
shallow depth	06/02/08	3	0.190	0.360	0.11
shallow depth	06/16/08	5	0.120	0.320	0.11
shallow depth	06/30/08	55	0.100	0.100	0.38
shallow depth	07/14/08	1	0.100	0.040	0.77
shallow depth	07/28/08	20	0.100	0.100	0.68
average		**19**	**0.1247**	**0.1873**	**0.4280**

Table C4 Watershed 319 project Deer Creek monitoring data, 2008

Collection Site	Date Collected	*E.coli* /100 ml	Nitrate - N (mg/L)	Ortho P (mg/L)	TP (mg/L)	TSS (mg/L)	VSS (mg/L)	Secchi depth (m)
200th st.	06/02/08	20	16	0.04	0.06	13	2	>0.6
200th st.	06/16/08	190	15	0.04	0.05	16	2	>0.6
200th st.	06/30/08	170	16	<0.02	0.04	4	1	>0.6
200th st.	07/14/08	160	16	<0.02	0.04	6	2	>0.6
200th st.	07/28/08	50	13	0.03	0.03	6	1	>0.6
b ave.	06/02/08	230	14	0.05	0.07	28	4	0.43
b ave.	06/16/08	140	13	0.05	0.07	25	3	0.51
b ave.	06/30/08	460	13	<0.02	0.05	5	1	>0.6
b ave.	07/14/08	170	14	<0.02	0.05	NA	NA	>0.6
b ave.	07/28/08	320	12	0.03	0.04	7	2	>0.6
	average	191	14.2	0.04	0.05	12.22	2	0.47

Appendix D --- Watershed Hydrology, Water Quality Analysis, and Modeling

An array of spreadsheets and watershed and water quality models were used to evaluate available data and perform watershed and in-lake water quality modeling for Union Grove Lake. The watershed-loading model used was BasinSims/Generalized Watershed Loading Function (GWLF) model. Two different water quality models were used to evaluate the algae impairment. The first is BATHTUB, an empirical mass balance eutrophication model. The second is WASP, a dynamic mechanistic model run with its eutrophication module.

Table D1 Descriptions of the models used for Union Grove Lake

Model	Type and purpose	Time frame	Description
BasinSims/GWLF	Watershed model used to estimate erosion and TP loads	Annual, monthly, daily	Inputs daily rain and temperature, land use, and nutrients. Uses USLE to estimate erosion and phosphorus. Provides estimates of average annual flow and watershed TP loading for BATHTUB model and daily flow and nutrients for WASP model.
BasinSims/GWLF	Watershed model used to simulate hydrology	Annual, monthly, daily	Provides estimates of daily flow calibrated to outflow measured at the lake discharge weir. Furnishes daily flow for the WASP model and recurrence intervals for duration curves.
BATHTUB	Lake water quality empirical model	Annual	Inputs loads from watershed and internal recycle. Inputs multi-year monitoring data annual average to estimate algal and Secchi depth load response. Generates average annual existing and maximum target loads.
WASP	Lake water quality dynamic mechanistic model	Daily, hourly	Incorporates a more detailed and segmented lake representation. Inputs daily load and flow from three separate subbasins. Generates hourly to daily predictions for all variables including flow through the lake. The hourly predictions can be used to calibrate the model to observed diurnal swings in DO, pH, and chlorophyll. Daily predictions can be used to calibrate the model to weekly trends for variables through the growing season. Gives a clearer picture of the important role that internal phosphorus recycle has.
Flow and load duration curve	Multi-year flow and load analysis for *E. coli*	Multi-year	Transforms daily flow to recurrence flow intervals. Inputs monitored bacteria concentrations to calculate loads to evaluate pollutant source contributions and critical flow intervals.

EPA accepts these models for TMDL development and all can be freely downloaded from internet web sites. Adequate Union Grove Lake water quality, weather and watershed data is available to use with these models and get reasonable results. Besides the three models, several spreadsheets were developed for the following purposes:

- Analyze in-lake data,
- Create weather, transport, and nutrient files for BasinSims/GWLF,
- Calibrate BasinSims/GWLF flow to measured lake discharge,
- Transform BasinSims/GWLF output for use in BATHTUB WASP,
- Transform BasinSims/GWLF output for use in WASP,
- Evaluate and interpret WASP and BasinSims/GWLF output,
- Construct flow and load duration curves for E. coli load.

Watershed Modeling – BasinSims/GWLF

The BasinSims/GWLF watershed model uses precipitation and temperature data from the nearby Marshalltown National Weather Service COOP station (IA5198), land use information from a DNR GIS coverage created from 2002 infrared photography and a watershed assessment done in 2004. The factors used for erosion estimates are from IDNR GIS coverages and the GWLF user manual. Soil information is from an IDNR GIS coverage based on SURGO data.

Watershed Modeling Procedures.
The procedures used to evaluate TP loads to Union Grove Lake are diagrammed in Figure D1 and consist of:

- Estimates of the delivered loads from watershed non-point sources, including geese feces and septic tanks, using BasinSims/GWLF modeling.
- Estimates of the daily TP load to Union Grove Lake based on measured in-lake TP concentrations and BATHTUB model response.
- Estimates of the allowable TP loads at the target chlorophyll and transparency values using BATHTUB modeling.

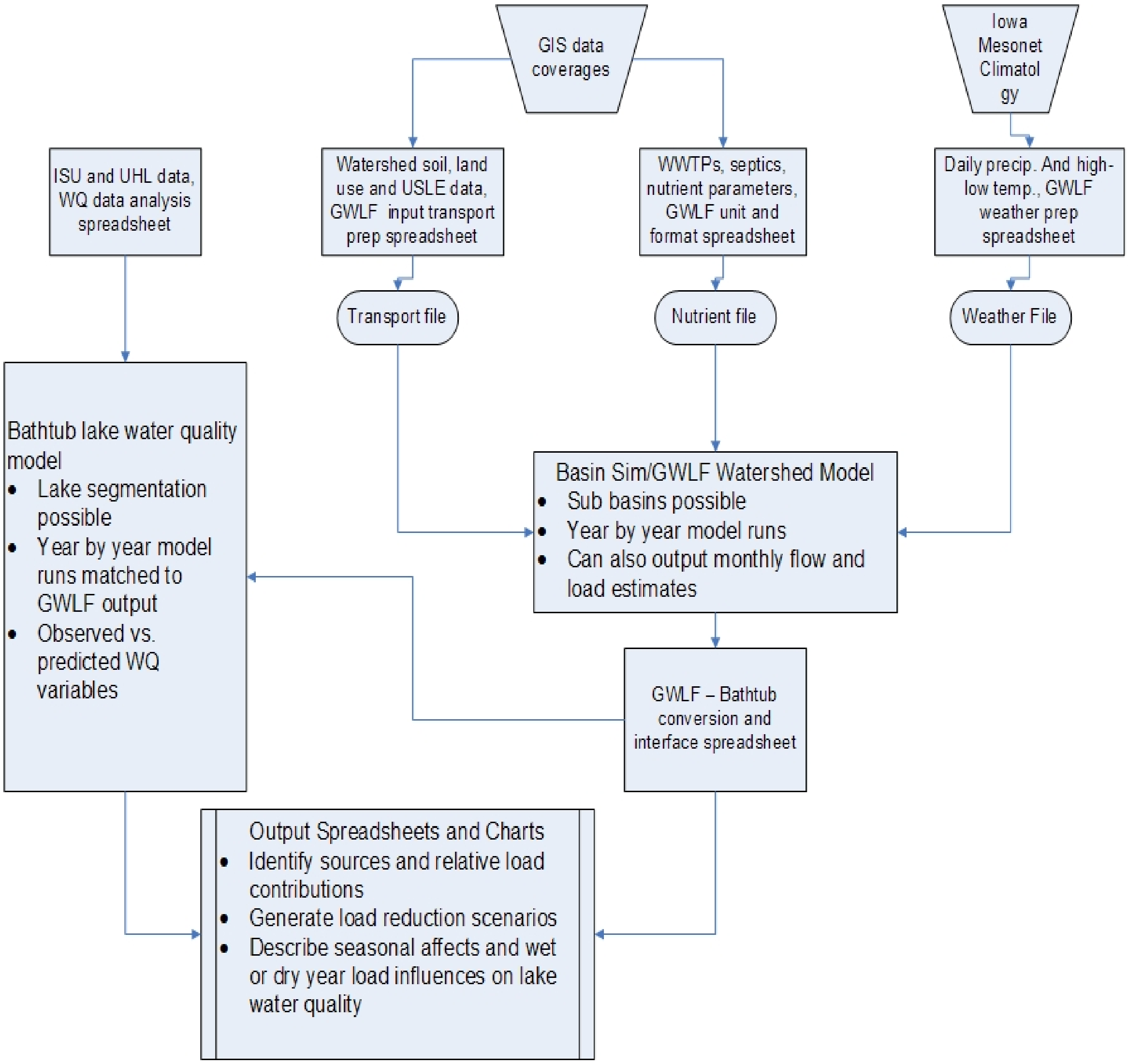


Figure D1 BasinSims/GWLF and BATHTUB lake water quality modeling flowchart

Three configurations of the BasinSims/GWLF watershed model shown in Table D2 were developed based on the seven subbasins shown in Figure D2. These watershed model configurations were used to generate input for the eutrophication water quality models and the flow and load duration curves. The subbasins were delineated to accommodate watershed spatial variations with the following characteristics:

- differences in ecoregion,
- dissimilar load sources such as row crop land use, livestock, septic tanks and geese,
- major sediment control structures, and
- flow into the lake from different tributaries.

Table D2 BasinSims/GWLF model configurations

Configuration	Weather file	Transport file	Nutrient file	Purpose
One basin	Marshalltown data from 4/1/06 to10/31/08	One basin file with recession coef. = 0.11 and SDR = 0.1	One basin file, includes septic tanks	Calibrated hydrologic model
One basin	Marshalltown data from 4/1/06 to 10/31/08	One basin file with recession coef. = 0.11 and SDR = 0.1	One basin file, includes septic tanks	Develop flows for duration curves for bacteria
Seven subbasins	All subbasins use the same Marshalltown data weather file, running from 4/1/06 to 10/31/08	Seven basin files, all recession coef. = 0.11, Different USLE factors and SDR for each subbasin	Two nutrient files have been used, one for the subbasin that includes the septic tank and geese feces loads and one for the six subbasins without these loads.	Flow and phosphorus loading for BATHTUB and WASP

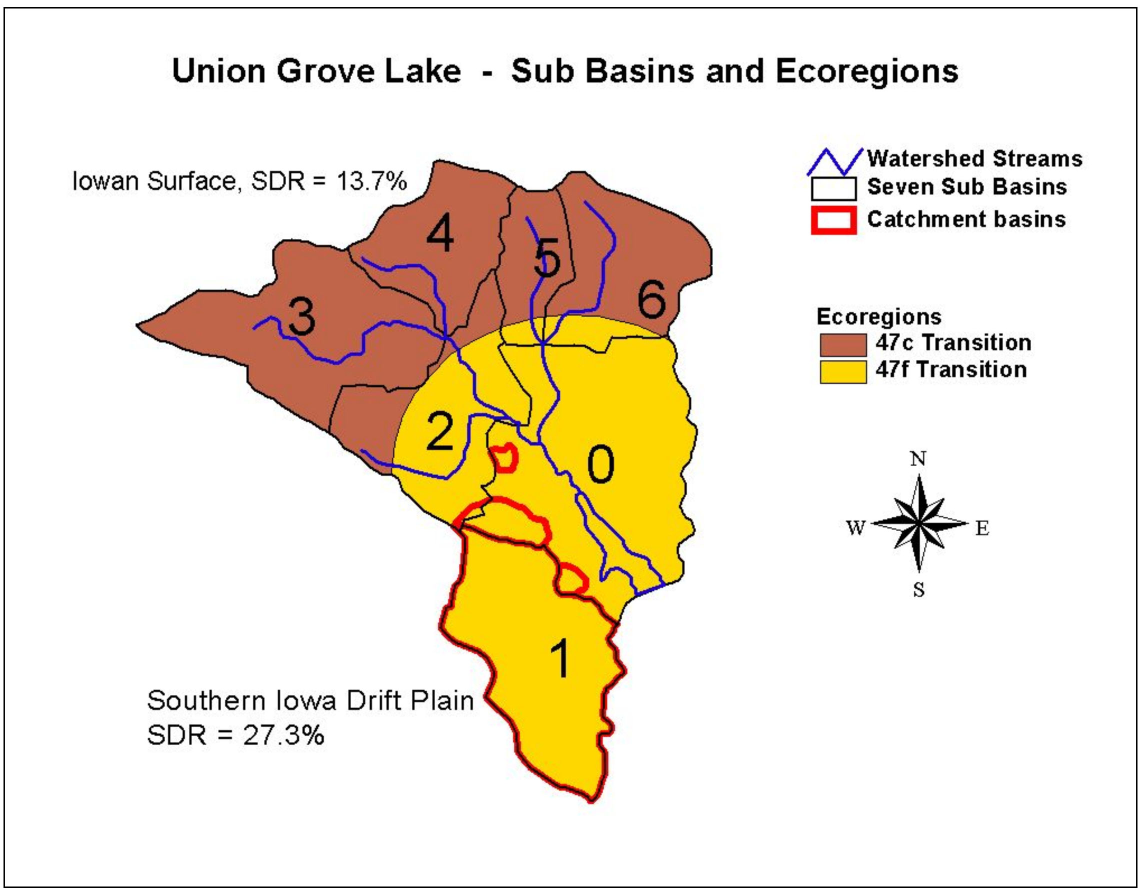


Figure D2 Watershed model subbasin layout

BasinSims/GWLF Model Construction, Assumptions and Parameterization
The watershed load estimates are based on BasinSims/GWLF watershed modeling using temperature and precipitation data from a weather station in the City of Marshalltown, nine miles southwest of Union Grove Lake. The period used as weather input to the model was April 1, 2006 to November 1, 2008.

The watershed has been divided into seven subbasins as shown in Figure D2. The subbasin divisions were made based on drainages for the upstream tributaries, the tributary that drains into the lake from the southwest, and the more directly draining areas adjacent to the lake. The loads from the waterfowl and the septic tanks are included in the directly draining subbasin (Subbasin 0).

Another benefit to the use of several subbasins is that load reductions from BMPs implemented in specific locations of the watershed can be incorporated into the model and pollutant reductions predicted or evaluated.

Three sediment delivery ratios were used for the Union Grove Lake watershed based on ecoregion and proximity to the lake, watershed size, topography, and local knowledge. A sediment delivery ratio (SDR) of 13.7 percent was used for the Subbasins 3, 4, 5, and 6 in the Iowan Surface ecoregion. These subbasins are in the headwaters and upstream reaches of Deer Creek and its tributaries. The Subbasin 2 sediment delivery ration is 20 percent because it is split nearly evenly between the two ecoregions.

The subbasins nearer the lake in the Southern Iowa Drift Plain, Subbasins 0 and 1, have a higher estimated SDR of 27.3 percent. Ameliorating sediment delivery from Subbasin 1 is a large sediment detention pond assumed to reduce delivery from the entirety of Subbasin 1 by ninety percent. There are also three smaller sediment detention ponds in Subbasin 0 that are assumed to reduce delivery by ninety percent for the areas that drain to them.

The numbers of geese and the seasonal population fluctuation were obtained from IDNR wildlife staff and entered into the point source compartment of the model on a monthly basis. The development of the Transport and Nutrient files for the subbasin watershed models were developed separately for each and are detailed below.

Transport and Nutrient Files
The GWLF model factors K, LS, C, and P used in the seven transport files were taken from the IDNR RUSLE erosion model shapefile data table as shown in the spreadsheet nb *GWLF klscp and CN.xls*. The IDNR RUSLE erosion model has been used extensively by the department and is implemented through Arc View. There is coverage for the entire state of Iowa based on 2002 satellite imagery for land use and SURGO soils data for the K and LS factors. The C factor is also based on the 2002 imagery. The P factor is assumed worst case except when there are known conservation practices applied in the watershed.

In some areas, a local agency or project coordinator performs watershed assessments. These assessments are used to improve the accuracy of the factors used in analysis and modeling. An assessment was done in 2004 for Union Grove Lake. The BasinSims/GWLF modeling created for this TMDL incorporates this assessment as well as the 2002 satellite information. The information from the assessment has been incorporated into the GIS coverages for the Union Grove Lake erosion model and exported into the *GWLF klscp and CN.xls* spreadsheet. There it has been sorted by land use and soil hydrologic group. Based on the tables in the GWLF User Manual, a curve number is assigned to each land use and soil hydrologic group.

The land uses are then weighted and a curve number is assigned to each. The assessment land uses are correlated to the 2002 land use imagery and the KLSCP and curve numbers for these land uses (shown in the spreadsheet *GWLF parameters.xls*) are put into the transport file in the GWLF model. The factors in the evapotranspiration tab of the transport file are from the tables in the GWLF User Manual and are typical for Iowa.

Table D3 Basin 0 land use erosion factors K, LS, C, and P

BASIN 0 land use, SDR = 0.229	Area, hectares	Area weighted KLSCP
Camp, Park, Recreation	4.45	0.00122
Confined Animal Feeding Operation	2.40	0.00391
Corn/Soybeans, Conventional	26.57	0.08036
Corn/Soybeans, Mulch, Good	206.34	0.02241
Corn/Soybeans, No-Till Beans, Mulch Till Corn	159.93	0.01990
CRP, Grass, Good	40.60	0.00080
Farmstead	8.01	0.00378
Forested, Not Grazed	84.07	0.01014
Grassed Field Border	1.95	0.00309
Hay land	11.80	0.00184
Lake/Pond	45.33	0.00000
Pasture, Good Management	61.34	0.00643
Residential	21.84	0.01814
Road	9.45	0.00000
Wetland, Not Cropped	15.07	0.00000
Wildlife Area, Abandoned Land	40.53	0.00323
Basin 0 total	**739.68**	

Table D4 Basin 1 land use erosion factors K, LS, C, and P

BASIN 1 land use, SDR = 0.026	Area, hectares	Area weighted KLSCP
Corn/Soybeans, Conventional	37.8	0.08789
Corn/Soybeans, Mulch, Good	229.6	0.02917
Corn/Soybeans, No-Till Beans, Mulch Till Corn	66.4	0.01456
CRP, Grass, Good	6.6	0.00191
Farmstead	7.9	0.00310
Grassed Field Border	0.5	0.00503
Hayland	2.0	0.00200
Lake/Pond	6.4	0.00000
Pasture, Good Management	12.3	0.00728
Pasture, Poor Management	44.4	0.01693
Road	5.2	0.00000
Wildlife Area, Abandoned Land	44.8	0.00668
Basin 1 total	**463.8**	

Table D5 Basin 2 land use erosion factors K, LS, C, and P

BASIN 2 land use, SDR = 0.200	Area, hectares	Area weighted KLSCP
Corn/Soybeans, Mulch, Good	146.8	0.03455
Corn/Soybeans, No-Till Beans, Mulch Till Corn	161.2	0.02002
Farmstead	6.6	0.00235
Farmstead, Abandoned	1.8	0.01160
Grassed Field Border	1.8	0.00206
Hayland	22.1	0.00162
Pasture, Good Management	32.4	0.00447
Road	4.0	0.00000
Wildlife Area, Abandoned Land	13.0	0.00227
Basin 2 total	**389.7**	

Table D6 Basin 3 land use erosion factors K, LS, C, and P

BASIN 3 land use, SDR = 0.135	Area, hectares	Area weighted KLSCP
Confined Animal Feeding Operation	1.7	0.00326
Corn/Soybeans, Conventional	24.6	0.08817
Corn/Soybeans, Mulch, Good	268.2	0.01785
Corn/Soybeans, No-Till Beans, Mulch Till Corn	130.1	0.01285
Farmstead	8.4	0.00344
Forested, Not Grazed	3.0	0.00395
Grassed Field Border	1.5	0.00310
Hayland	25.8	0.00177
Pasture, Good Management	5.8	0.00480
Road	4.6	0.00000
Tree Planting	1.4	0.00493
Wildlife Area, Abandoned Land	13.1	0.00264
Basin 3 total	**488.3**	

Table D7 Basin 4 land use erosion factors K, LS, C, and P

BASIN 4 land use, SDR = 0.135	Area, hectares	Area weighted KLSCP
Corn/Soybeans, Conventional	45.0	0.02350
Corn/Soybeans, Mulch, Good	104.2	0.01883
Corn/Soybeans, No-Till Beans, Mulch Till Corn	99.1	0.00949
Farmstead, Abandoned	4.2	0.00155
Grassed Field Border	0.8	0.00168
Pasture, Good Management	9.8	0.00245
Road	3.0	0.00000
Wildlife Area, Abandoned Land	0.1	0.00078
Basin 4 total	**266.2**	

Table D8 Basin 5 land use erosion factors K, LS, C, and P

BASIN 5 land use, SDR = 0.135	Area, hectares	Area weighted KLSCP
Corn/Soybeans, Conventional	1.9	0.01941
Corn/Soybeans, Mulch, Good	63.5	0.02007
Corn/Soybeans, No-Till Beans, Mulch Till Corn	76.2	0.01359
CRP, Grass, Good	0.0	0.00018
Farmstead	4.6	0.00349
Grassed Field Border	0.6	0.00231
Hayland	0.7	0.00090
Pasture, Good Management	2.2	0.00227
Road	0.7	0.00000
Basin 5 total	**150.3**	

Table D9 Basin 6 land use erosion factors K, LS, C, and P

BASIN 6 land use, SDR = 0.135	Area, hectares	Area weighted KLSCP
Confined Animal Feeding Operation	0.3	0.00285
Corn/Soybeans, Mulch, Good	86.7	0.01074
Corn/Soybeans, No-Till Beans, Mulch Till Corn	224.4	0.01055
CRP, Grass, Good	3.0	0.00038
Farmstead	2.8	0.00232
Farmstead, Abandoned	0.1	0.00139
Grassed Field Border	1.8	0.00371
Road	3.6	0.00000
Basin 6 total	**322.7**	

Table D10 Monthly GWLF parameters for all subbasins

Month	Cover coefficient	Day length	Growing season (1 = yes)	Erosivity coefficient	Geese feces TP, kg/month
Apr	0.45	13.3	0	0.17	0.34
May	0.95	14.5	1	0.25	0.33
Jun	0.95	15.1	1	0.25	0.22
Jul	0.95	14.8	1	0.25	0.23
Aug	0.75	13.7	1	0.25	0.21
Sep	0.50	12.3	1	0.25	0.51
Oct	0.50	10.7	1	0.17	0.69
Nov	0.45	9.5	0	0.17	0.88
Dec	0.45	8.9	0	0.17	1.04
Jan	0.45	9.2	0	0.17	0.34
Feb	0.45	10.3	0	0.17	0.17
Mar	0.45	11.7	0	0.17	0.79

Table D11 Land use parameters for all basins

Land use	Curve number	Runoff TN, mg/l i	Runoff TP, ug/l
Park	74	2	30
Confined animal feeding operation	89	4	100
Corn/Soy, conventional	79	6	100
Corn/Soy, mulch, good	70	4	70
Corn/Soy, no-till beans, mulch till corn	71	4	70
CRP and grass, good	59	2	30
Farmstead	74	2	30
Farmstead (abandoned)	56	2	30
Forested	55	2	30
Grassed field border	58	1	30
Hayland	58	2	40
Pond	100	0	50
Pasture, good management	68	6	100
Pasture, poor management	74	7	100
Residential	74	4	100
Road	89	0	50
Trees	57	1	30
Wetland	100	0	50
Wildlife land	62	2	30

All of the BasinSims/GWLF models for the seven subbasins have the same nutrient file except for Subbasin 0, which includes the septic tank and geese loads. The geese loads were estimated from detailed information provided by the IDNR Wildlife Bureau. An average month by month estimate of the numbers of geese at the lake is provided in the spreadsheet UGL*geese.xls*. The monthly TP load from geese is entered in the Point Sources tab as kg TP/month.

The sediment attached TP value of 750 mg/kg in the general tab is derived from typical soil values in the Iowa Phosphorus Index and other references. It is calculated using a soil value of 575 mg/kg and multiplying it by an enrichment ratio of 1.3. The enrichment ratio accounts for the smaller particle size in runoff sediment and its higher TP content due to greater surface area. The groundwater phosphorus and nitrogen concentrations were estimated from tributary samples during low flow conditions that are assumed to originate from groundwater.

The number of septic tanks was determined by counting houses in the immediate watershed. The information on the condition of the onsite systems in the residential area adjacent to the lake was obtained from the local lake association. The per capita TP loads are found in the GWLF User Manual. Surveys done in rural Iowa indicate that the fraction of failed septic tank systems is quite high and ranges from 50 to 92 percent statewide. For the Union Grove Lake watershed GWLF model the septic systems have been categorized as short-circuited since most of them are located near the lake.

BasinSims/GWLF Watershed load estimates

There are two forms of output from the BasinSims/GWLF modeling that developed the watershed loads. The first is a summary for the years modeled and is used to develop the input for the BATHTUB model. This output averages the years for which the model is run and this is then converted into TN and TP loads. The annual average flows and loads for each of the subbasins are in Table D12.

Table D12 BasinSims/GWLF output in BATHTUB input form

Subbasin number	Spreadsheet name	Total flow, hm^3/year	TN conc., mg/l	TP conc. ug/l	TN load, lbs/year	TP load, lbs/year
0	basin0sum.xls	3.957	11.5	254	99,972	2,215
1	basin1sum.xls	2.455	12.5	73	67,842	397
2	basin2sum.xls	2.059	13.5	287	61,349	1,300
3	basin3sum.xls	2.580	13.2	177	74,897	1,003
4	basin4sum.xls	1.407	13.0	152	40,305	473
5	basin5sum.xls	0.811	13.0	155	23,254	277
6	basin6sum.xls	1.709	13.0	46	48,808	428
Total		**14.98**	**NA**	**NA**	**416,427**	**6,093**

The other form of output is a daily estimate of flow, separated into groundwater and runoff, and daily DN, TN, DP and TP loads. This BasinSims/GWLF output has been employed in three elements of this report:

1. Maximum daily TP loads were developed in a procedure detailed in Section 3.5 that uses two year recurrence storms and the TP loads associated with those events.
2. Daily flow output was used to produce the calibrated hydrologic model described in the next section.
3. Flow and load duration curves were constructed for the E. coli TMDL in Section 4. For the bacteria load analysis, twelve years of precipitation and temperature

data (1996 to 2008) were incorporated and only the hydrologic output was utilized.

4. The WASP model daily flow and watershed load input was generated from it. The BasinSims/GWLF model was run for three years and the loads generated from May 28, 2008 to October 2, 2008 were used as boundary loads and flows.

The BasinSims/GWLF hydrologic output used for the flow and load duration curves used single transport and nutrient files that represented the entire watershed. The overall watershed K, LS, C, and P erosion factors in the transport file are shown in Table D13 and the derivation from GIS tables can be found in the spreadsheet *allbasinsklscp.xls* in the Support Documentation folder. The overall watershed nutrient file is the same one used for Basin 0 since all nutrient files used for all basins are the same with the exception of the septic tank and geese feces loads.

Table D13 Watershed combined land use K, LS, C, and P erosion factors

Watershed land use, SDR = 0.1	Area, hectares	Area weighted cover KLSCP
Camp, Park, Recreation	4.5	0.00123
Confined Animal Feeding Operation	4.5	0.00358
Corn/Soybeans, Conventional	136.0	0.06417
Corn/Soybeans, Mulch, Good	1105.8	0.02293
Corn/Soybeans, No-Till Beans, Mulch Till Corn	917.6	0.01460
CRP, Grass, Good	50.2	0.00092
Farmstead	42.0	0.00302
Farmstead (abandoned)	2.4	0.00930
Forested, Not Grazed	87.1	0.00993
Grassed Field Border	8.9	0.00292
Hay land	62.5	0.00173
Lake/Pond	51.7	0.00000
Pasture, Good Management	123.9	0.00554
Pasture, Poor Management	44.4	0.01693
Residential	21.9	0.01814
Road	30.5	0.00000
Tree Planting	1.4	0.00494
Wetland, Not Cropped	15.1	0.00000
Wildlife Area, Abandoned Land	111.6	0.00443

Hydrology

The hydrology parameters in the Transport file for the Initialization tab have been calibrated using lake discharge data obtained from a temporary USGS gage at the 70 foot wide weir. The flow over this weir discharges to the original Deer Creek streambed. The gage was operated from September 17, 2007 to November 7, 2007 and from May 28, 2008 to October 2, 2008. The summer/fall 2008 period was used to calibrate the BasinSims/GWLF hydrologic model to the measured lake discharge. The precipitation data comes from the Marshalltown weather station. USGS staff developed the rating curve for the discharge weir. Figure D3 is a photo of the Union Grove Lake gage installation.

During this time there were very high flows as well as the typically low late summer flows. The lake discharge flows increase with the increase in rainfall as would be expected and the visual correlation is acceptable. Figure D4 shows the measured lake discharge plotted with the Marshalltown precipitation data. The three nearest weather stations are in Marshalltown, Grundy Center and Toledo. Marshalltown is the nearest station to 99.5 percent of the Union Grove Lake watershed.

Figure D3 Union Grove Lake USGS gage station

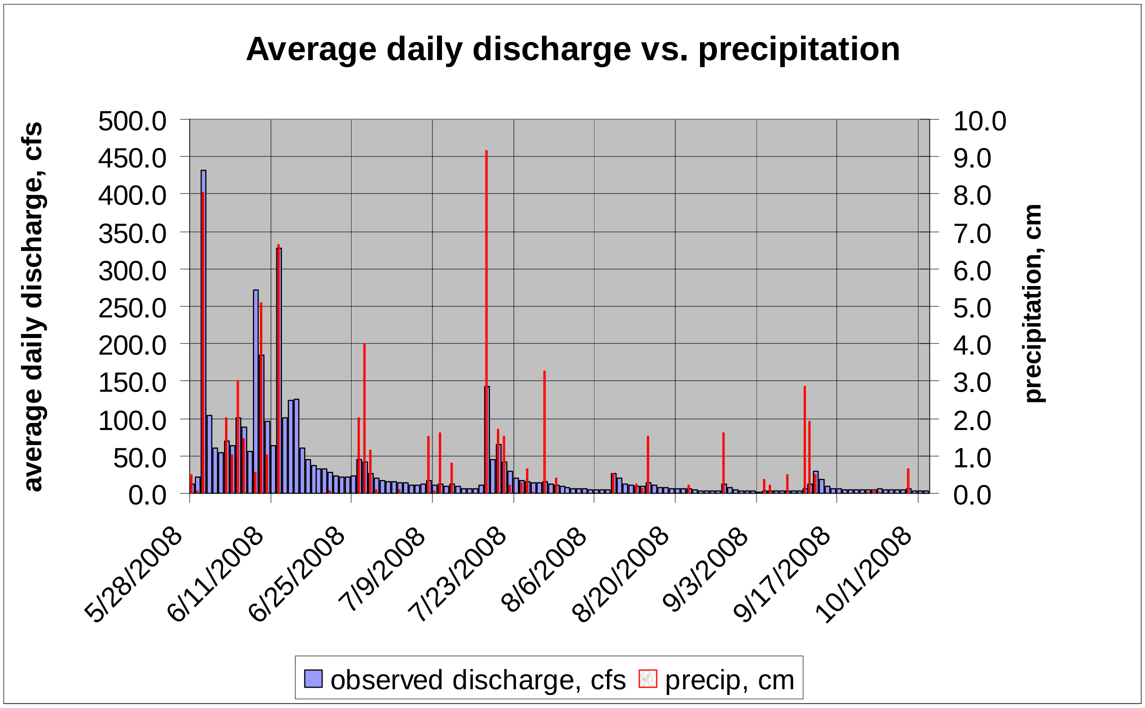


Figure D4 Union Grove Lake measured discharge and Marshall town rainfall

The measured lake discharge was evaluated and a recession coefficient calculated and applied to the watershed model. The recession coefficient was then adjusted to optimize the fit of the modeled recession curve to that of the measured flow. It was also necessary to add a continuous groundwater flow of 3.5 cfs to the lake in order to provide a better correlation at low flow during the dry period at the end of the summer. There are known areas of seepage and bedrock fracture underneath and next to the lake. These conditions have been sources of additional flow from outside of the watershed. A chart plotting the average daily measured flow with the BasinSims/GWLF model flow is shown in Figure D5.

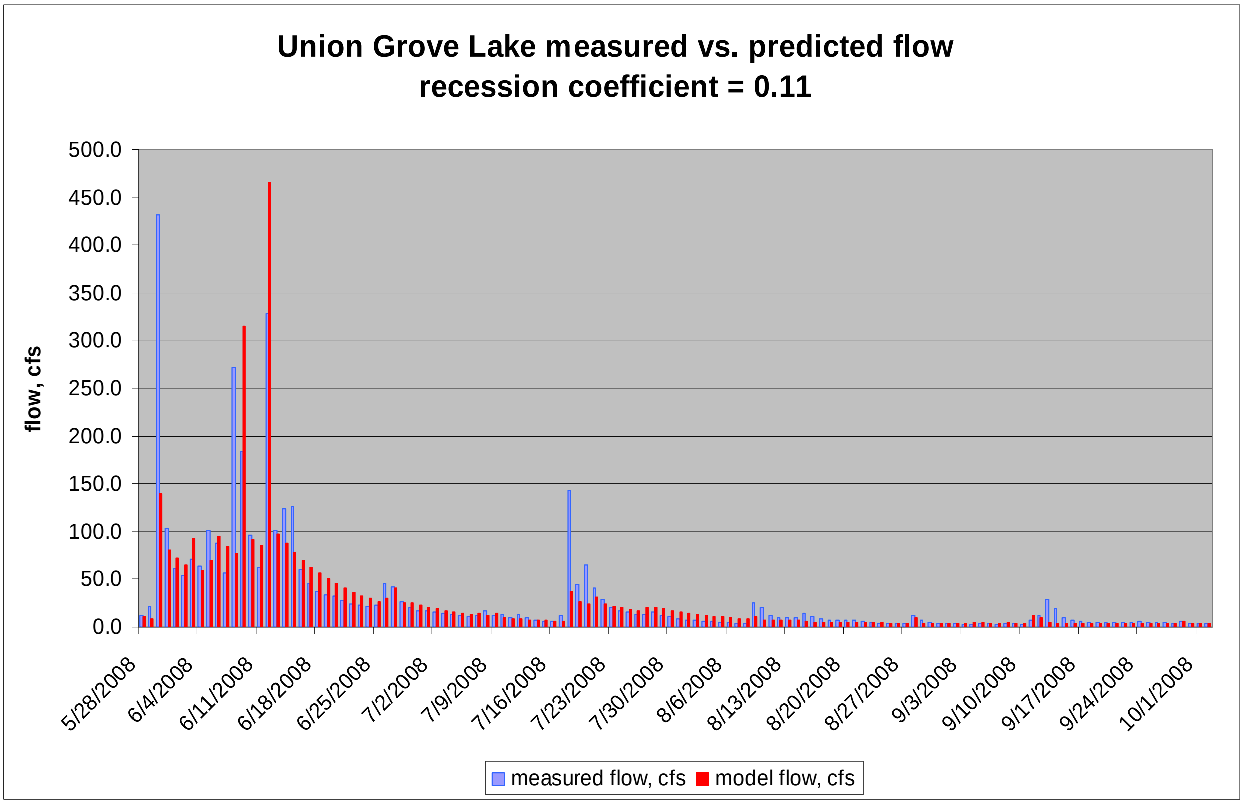


Figure D5 Measured flow plotted with predicted lake discharge flow

It can be seen that there is poorer correlation between the measured and predicted values when flows are peaking. That is because most very intense rainfalls are local. As noted, Marshalltown, the closest weather station is nine miles from Union Grove Lake. A statistical regression evaluated the correlation between the observed and predicted flows. The results are shown in Figure D6.

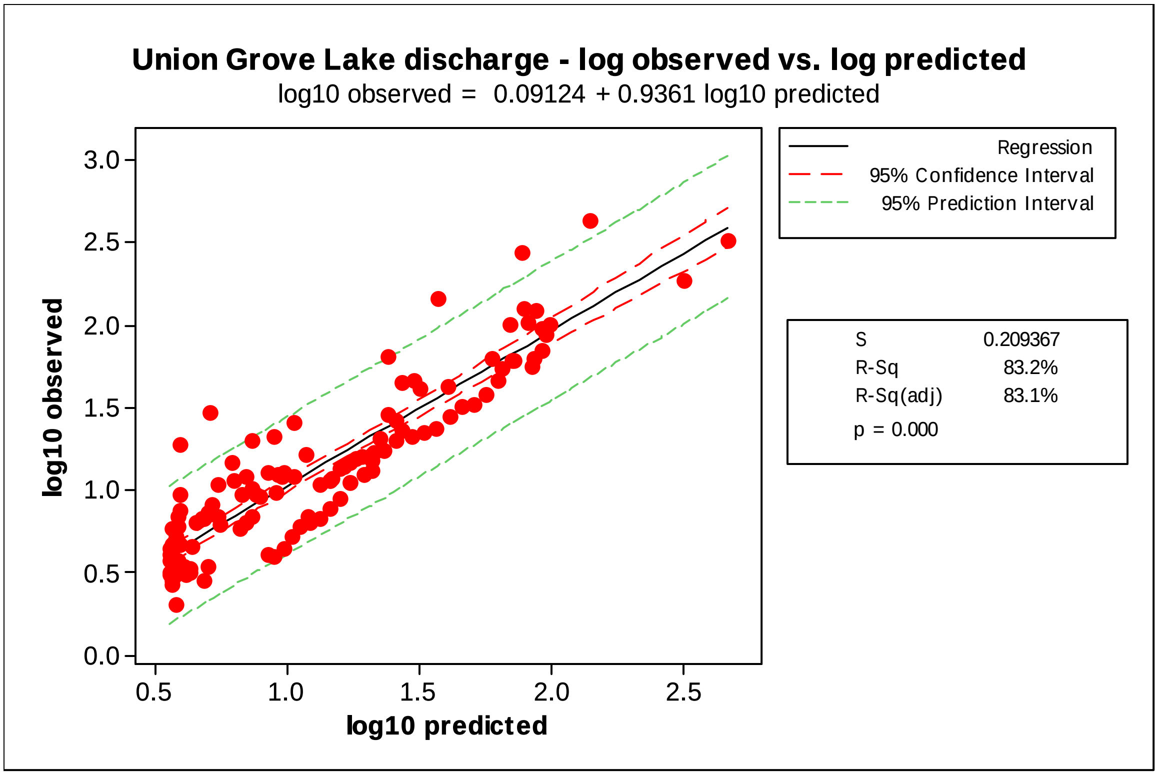


Figure D6 Regression of log observed vs. log predicted

A log transformation has been used to reduce the influence of peak flows. This has been done because:

- The peak flows are orders of magnitude higher than flow on most days, especially during dry periods when base flow dominates.
- The distance between Union Grove Lake and the Marshalltown station makes correlation between the biggest events at the two locations less likely to occur at the same time or even on the same day as can be seen in Figure D5.

The R-squared statistic is 83 percent.

The fit between the measured and predicted flow values has also been evaluated using the Nash-Sutcliffe model efficiency coefficient to test the hydrologic model. This is a commonly used method for evaluating hydrologic models. The Nash-Sutcliffe model (N-S) efficiency coefficient assesses predictive efficiency of hydrological models. The equation used to calculate it is:

$$E = 1 - \frac{\sum_{t=1}^{T}(Q_o^t - Q_m^t)^2}{\sum_{t=1}^{T}(Q_o^t - \overline{Q_o})^2}$$

Where E = N-S efficiency coefficient
Q_o^t = observed discharge at time t

Q_m^t = modeled discharge at time t

$\overline{Q_o}$ = mean of the observed values

For the hydrologic model the log values were used to reduce the influence of the peak discharge and emphasize the low flow conditions when the algae problem is at its worst. The daily average lake discharge was measured from May 28, 2008 to October 2, 2008 and was used and compared to the daily modeled flow. The results are shown in Table D14.

Table D14 Calculation of the Nash-Sutcliffe efficiency coefficient

Term	Value
Log numerator (log of the sum of the squared difference between observed and predicted flow)	5.707
Log denominator (log of the sum of the squared difference between observed and mean observed flow)	34.227
Nash-Suttcliffe efficiency coefficient (One minus the division of the numerator by the denominator as a percentage)	83.3 %

The log transformed Nash-Sutcliffe efficiency coefficient is less sensitive to extreme peaks such as those seen in May and June and is better at predicting lower flows. For the most part, the results of the model evaluations are reasonable and the hydrologic model is acceptable for the purposes of this report.

Water Quality Modeling 1– BATHTUB Eutrophication Models

BATHTUB Model Assumptions and Parameterization

The procedures used to evaluate TP loads to Union Grove Lake with the BATHTUB model consist of:

- Evaluation of the delivered loads from watershed nonpoint sources using GWLF/BasinSims modeling including geese feces and septic tanks.
- Evaluation of the annual TP load to Union Grove Lake using observed lake phosphorus concentrations, estimated hydraulic detention time, and mean depth as observed inputs for the BATHTUB modeling,
- Evaluation of the allowable TP loads at the target concentration (TP=56 ug/l) for the lake, using BATHTUB modeling.

The predicted values from the BATHTUB model for total phosphorus, chlorophyll and Secchi depth are compared to the observed values from the in-lake monitoring data in the BATHTUB model output spreadsheet called *UGL EXISTINGBTB.xls.*

These loads include the watershed loads generated by GWLF/BasinSims modeling for the three subbasins shown in Figure 9 (p 28), atmospheric deposition, and internal resuspension and recycling. A small lake with large numbers of carp, Union Grove Lake has a considerable recycled TP load component.

The model has been calibrated to account for the systemic differences between Union Grove Lake monitoring data and the model equations describing the relationship between phosphorus, chlorophyll, and Secchi depth.

The internal load has been adjusted so that it makes up for the difference between the watershed model loads and the predicted load from the lake response model. It is based on phosphorus recycled per unit area of lake surface and is estimated to be 10 mg/m^2/day. Multiplying the areal loads by the lake area in square meters and converting the resulting values from milligrams to pounds gives the annual internal load of 3739 lbs/year, 37 percent of the total annual load. The following tables show the BATHTUB input for existing and target loading models. Both the existing and target load models use the same variables shown in Tables D15 to D17.

Table D15 Global variables for BATHTUB model

Global variable	Value
Averaging period (years)	1
Precipitation (meters)	0.864
Evaporation (meters)	0.853
Atmospheric TP (mg/m^2/year)	30

Table D16 Calibration and internal load for BATHTUB

Model variable	Value
Chlorophyll calibration factor	1.3
Secchi depth calibration factor	1.2
Internal load (mg/m^2/day)	10

Table D17 Union Grove Lake morphometry for BATHTUB model

Morphometric variable	Value
Lake surface area (km^2)	0.465
Mean depth (meters)	1.86
Lake length (kilometers)	1.656
Mixed layer depth (meters)	1.86

The BATHTUB model for existing conditions is calibrated to the averaged observed data for TP, chlorophyll, and Secchi depth. Non-algal turbidity is estimated by the model from the chlorophyll and Secchi depth values. These input values are shown in Table D18.

Table D18 Observed water quality data

Observed data variable	Value
Total phosphorus (µg/l)	139
Total nitrogen (µg/l)	5700
Chlorophyll (µg/l)	70
Secchi depth (meters)	0.7
Non-algal turbidity (1/m)	0.1

There are four tributaries in the Union Grove Lake BATHTUB model. Three of these tributaries are subbasins of the watershed (Figure 9 page 28) that have been described earlier. The largest of these is Deer Creek and includes the summed BasinSims/GWLF output from five subbasins (2 through 6). The other two are Subbasin 0 and Subbasin 1. Subbasin 0 is the area immediately adjacent to the lake and includes the geese feces and septic tank loads. Subbasin 1 is the tributary that discharges to the southwest corner of the lake from a large sedimentation basin. The output for these two subbasins comes from individual BasinSims/GWLF models and is the input for these two tributaries in the BATHTUB model. The input for the tributaries is shown in Table D19. There is also a component of the inflow called groundwater seepage that is input into BATHTUB as a separate tributary.

Table D19 BATHTUB tributary input from BasinSims/GWLF modeling

Tributary	Deer Creek	Basin 0	Basin 1	Groundwater seepage
Subbasin area (km^2)	16.209	7.4	4.639	NA
Flow rate (hm^3/year)	8.566	3.957	2.455	3.13
Total P conc. (µg/l)	177	254	73	65
Ortho P conc. (µg/l)	31	46	34	50
Total N conc. (µg/l)	11826	11472	12547	NA
Inorganic N conc. (µg/l)	11439	10916	12442	NA

The BATHTUB model for target conditions operates by using chlorophyll and Secchi depth targets to establish the TP target. Total phosphorus load is reduced incrementally and the model is run repeatedly until both the chlorophyll and Secchi depth targets are achieved. The BATHTUB model that achieves the target chlorophyll and Secchi depth requires an annual average TP concentration of 56 µg/l. At this concentration the chlorophyll achieves the target of 33 µg/l and the Secchi depth is one meter and exceeds the target depth of 0.8 meters.

Table D20 shows the tributary model inputs that achieve the targets. Subbasin area and annual average flow rate are the same as for the existing conditions BATHTUB model. Nitrogen concentration is assumed to be unchanged since 97 percent is dissolved and little of it will be removed using watershed BMPs since it is not sediment attached. It is also assumed that the fraction of TP that is orthophosphate increases since the sediment attached fraction is the what is removed with watershed BMPs.

Table D20 BATHTUB tributary input at target conditions

Tributary	Deer Creek	Basin 0	Basin 1	Groundwater seepage
Total P conc. (µg/l)	60	80	60	65
Ortho P conc. (µg/l)	40	60	40	50

The output from the two BATHTUB models can be found in two spreadsheets, UGL_EXISTING.xls and UGL_TMDL2.xls that are in the Support Documentation folder. In addition, these spreadsheets contain the detailed BATHTUB model assumptions, statistics, and input. The overall balances from the two BATHTUB models are shown in Tables D21 and D22. The flows for both models are the same.

Table D21 BATHTUB model output for existing conditions

Flow and load source	Flow (hm^3/yr)	TP load (kg/yr)	Fraction of total load (%)	TP concentration (µg/l)
Deer Creek	8.6	1516.2	32.8	177
Basin 0	4.0	1005.1	21.8	254
Basin 1	2.5	179.2	3.9	73
Seepage GW	3.1	203.5	4.4	65
Total trib. inflow	18.1	2,904.0	62.9	160
Atmospheric	0.4	13.9	0.3	35
Internal recycle load	NA	1,698.4	36.8	NA
Total inflow	18.5	4,616.3	100	249

Table D22 BATHTUB model output for target conditions

Flow and load source	Flow (hm^3/yr)	TP load (kg/yr)	Fraction of total load (%)	TP concentration (µg/l)
Deer Creek	8.6	514.0	37.7	60
Basin 0	4.0	316.6	23.2	80
Basin 1	2.5	147.3	10.8	60
Seepage GW	3.1	203.5	14.9	65
Total trib. inflow	18.1	1181.4	86.6	65
Atmospheric	0.4	13.9	1.0	35
Internal recycle load	NA	169.8	12.4	NA
Total inflow	18.5	1365.1	100	**56** [1]

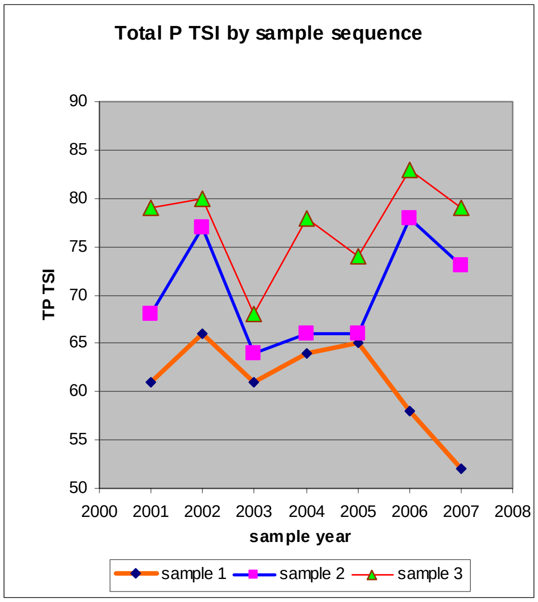
1. Note that this is the target TP concentration to achieve the chlorophyll and Secchi depth targets.

Water Quality Modeling 2– WASP Eutrophication Model

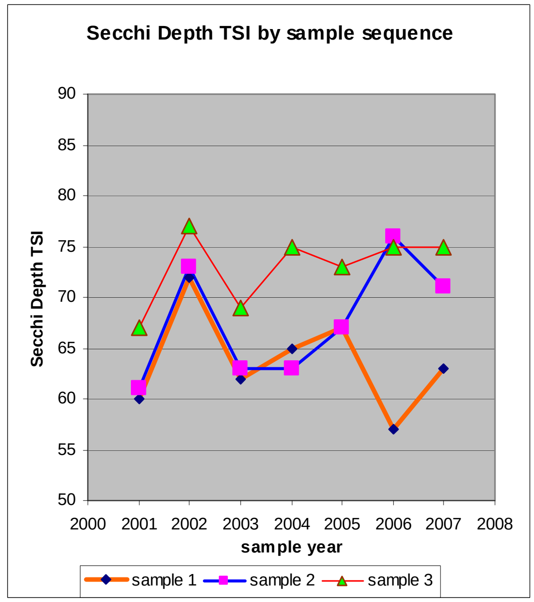
A discussion of the in lake processes that cause algal blooms and the sources of the nutrients that drive them is just beginning with the implementation of empirical models that relate TP, chlorophyll, and transparency. This approach depends on averaging all monitoring data collected during the growing season and can miss important variations between years and in individual years through the summer into the fall. Important information is averaged out or there simply is not enough of it to provide sufficient resolution except on an annual basis. Union Grove Lake ISU data provides an example of this.

Sequencing the ISU monitoring data shows consistent increases in total phosphorus and decreases in transparency as the summer progresses. This pattern is consistent year to year as shown as TSI values in Figure D7 (a) and (b). Chlorophyll shows the same pattern of increase through the summer into fall, though not as consistently as for phosphorus and transparency, as shown in Figure D7 (c). Generally, Sample 1 was collected in June, Sample 2 was collected in July, and Sample 3 was collected in August. This increase in TSI for phosphorus and chlorophyll through the growing season is predicted in the WASP modeling.

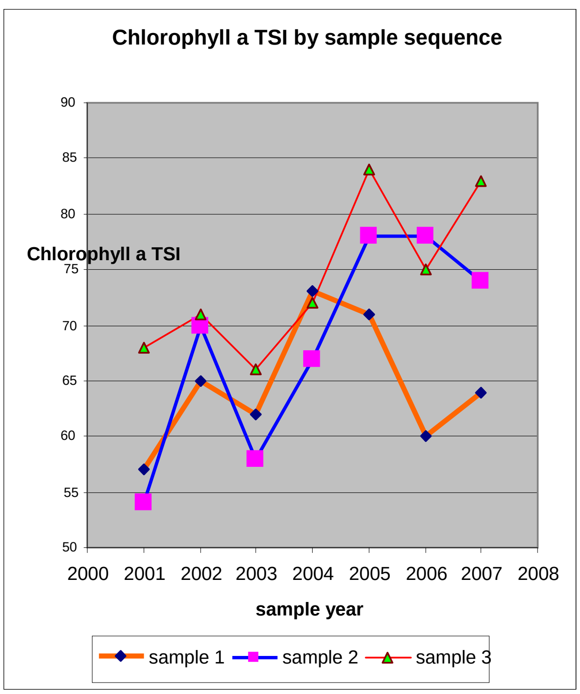
The other important aspect of the long term averaging problem is that the lake condition is not the same year to year. This is usually the result of the amount of rainfall there is in any given year as well as the time during the growing season when it occurs. In 2003, TSI values for TP, chlorophyll and Secchi depth all were lower in June, July and August than in previous and subsequent years. This is an example of the annual variability that can occur.



(a) TP TSI values by month



(b) Secchi depth TSI values by month



(c) Chlorophyll TSI values by month

Figure D7 ISU Lake Study data for June, July and August of each year.

The significance of the increase in TP and chlorophyll concentrations as the growing season progresses is that algal blooms are peaking when precipitation transported loads are delivered at a low frequency and intensity. This is also reflected in the WASP modeling. In other words, watershed loads play a relatively small role at the time the algae problem is most significant. The sediment attached phosphorus must be delivered months or years before it is available for algal growth.

The data and WASP modeling also show that a high flushing rate, that most likely will occur in May, June and early July, can inhibit the development of major algal blooms caused by internal recycling by limiting the hydraulic and solids detention time.

These two factors, the indirect and delayed delivery of watershed loads and the high flushing rate in spring and early summer, show the importance of a mechanistic lake model for understanding lake water quality and internal phosphorus recycling. IDNR Fisheries staff has said that there are large numbers of carp in the lake and estimate that there are 200 pounds per acre. Feeding carp suck in silt and other lake bottom debris and then expel it through their gills in a cloud of suspended material. This is the mechanism by which the high internal recycling loads necessary for the lake models are attained.

As hydraulic and solids detention time grow longer due to a decreasing flushing rate, the impact of recycling intensifies and the system is to some extent self sustaining. As shown in Figure D7, the inventory of algae and phosphorus tends to increase as summer progresses. This is due in part to the continuing resuspension of silt and phosphorus, but also because previously resuspended phosphorus remains in the water column incorporated into the algae and suspended algal detritus. As algae dies and the detritus settles towards the bottom, a significant fraction of the disintegrating cell material is soluble. This material, including soluble phosphorus, is available for algal growth.

Later in the season, nitrogen can become limiting if there is no resupply from the watershed. Previously abundant soluble inorganic nitrogen, mostly nitrate, is continuously transformed to organic nitrogen in the form of insoluble algal detritus. This form of nitrogen is not immediately available for algal metabolism. This is a condition that can select for blue green algae since they are capable of fixing abundant atmospheric nitrogen.

WASP model development

In order to provide a clearer picture of what is going on in Union Grove Lake, a monitoring program was designed to collect continuous dissolved oxygen, temperature, pH, and lake discharge. The data collected has been used to construct a model incorporating more detail and a mechanistic understanding of lake processes. The water quality model used is the Water Quality Analysis Simulation Program (WASP). It is a dynamic mechanistic model developed by EPA to evaluate a broad range of water quality problems and conditions in streams and lakes and is widely used for the development of water quality improvement plans.

The latest version, WASP 7.31, has been used to simulate conditions in the lake. WASP is well documented and supported by EPA and can be obtained from an EPA website for free. The model consists of a basic framework and several modules that can be selected from and operated within the basic model framework. These include the eutrophication module that has been used to evaluate Union Grove Lake. In addition to the type of module, there are four options for hydrodynamic input. The approach used for Union Grove Lake is the one-dimensional kinematic wave. This is a mid-range representation of hydrodynamics falling between net or gross flows and the output from a separate hydrodynamic model. Figure D8 shows a schematic of the WASP modeling.

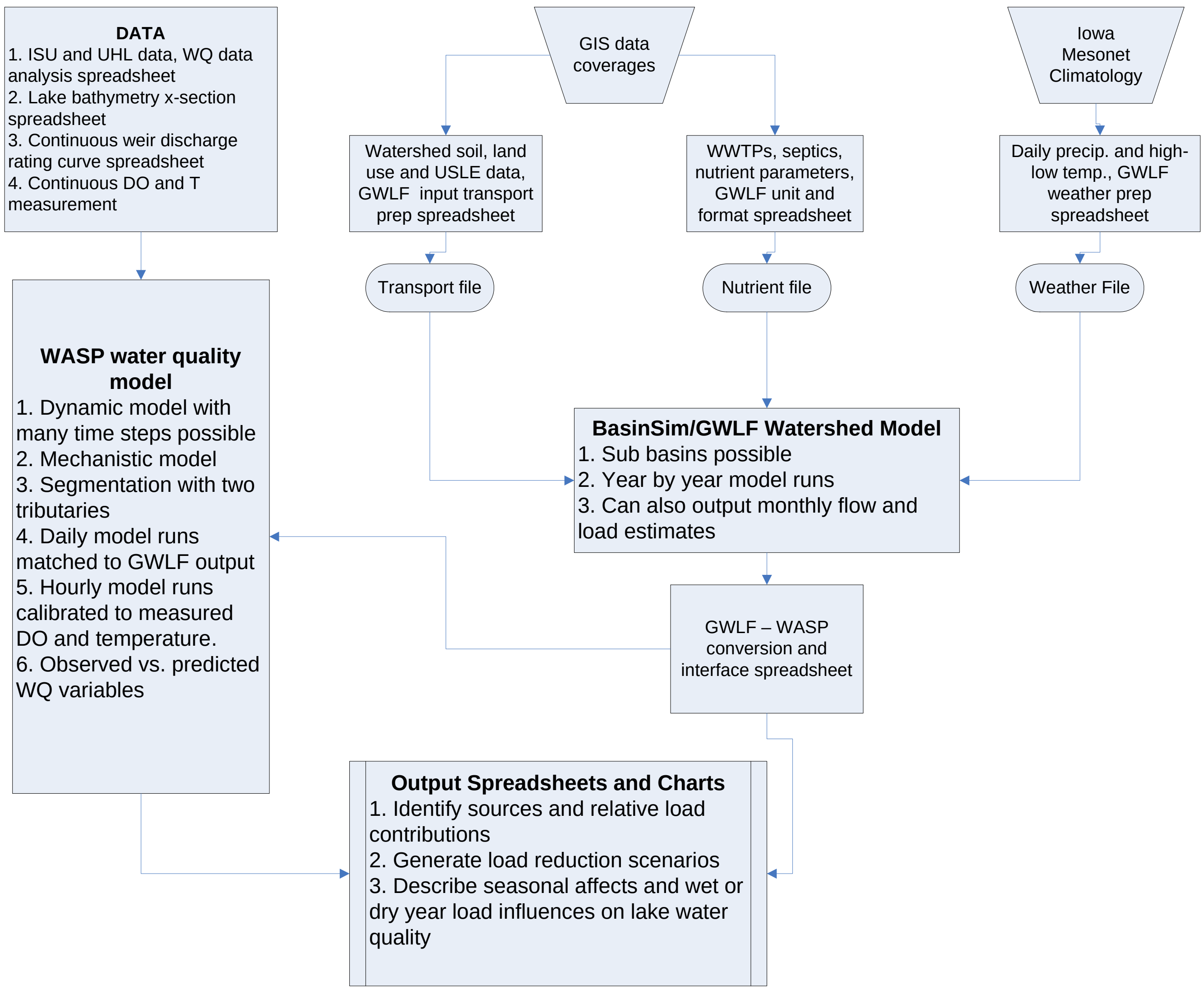


Figure D8 WASP Union Grove Lake modeling flowchart

For the WASP model, Union Grove Lake is divided into five main segments and three smaller input segments. The main segments are listed in Table D23 and shown in Figure D9.

Table D23 Lake segments for WASP model

Segment Name	Length (m)	Width (m)	Volume (m3)	Surface Area (m2)	Travel Time (days) *	Velocity, (m/s) *
Deer Creek	767	2.8	704	2,132	0.01	0.94414
Sediment basin	175	158.9	13,900	27,800	0.19	0.01090
Segment1	550	260.5	238,109	143,281	3.18	0.00200
Segment2	694	304.5	488,917	211,314	6.53	0.00123
Dam outlet	267	173.4	135,216	46,287	1.81	0.00171
Total	**2,453**	**NA**	**876,845**	**430,814**	**11.72**	**NA**

*Travel time and velocity have been calculated for the average daily flow of 0.87 m^3/s. The estimated maximum daily flow is 12.2 m^3/s.

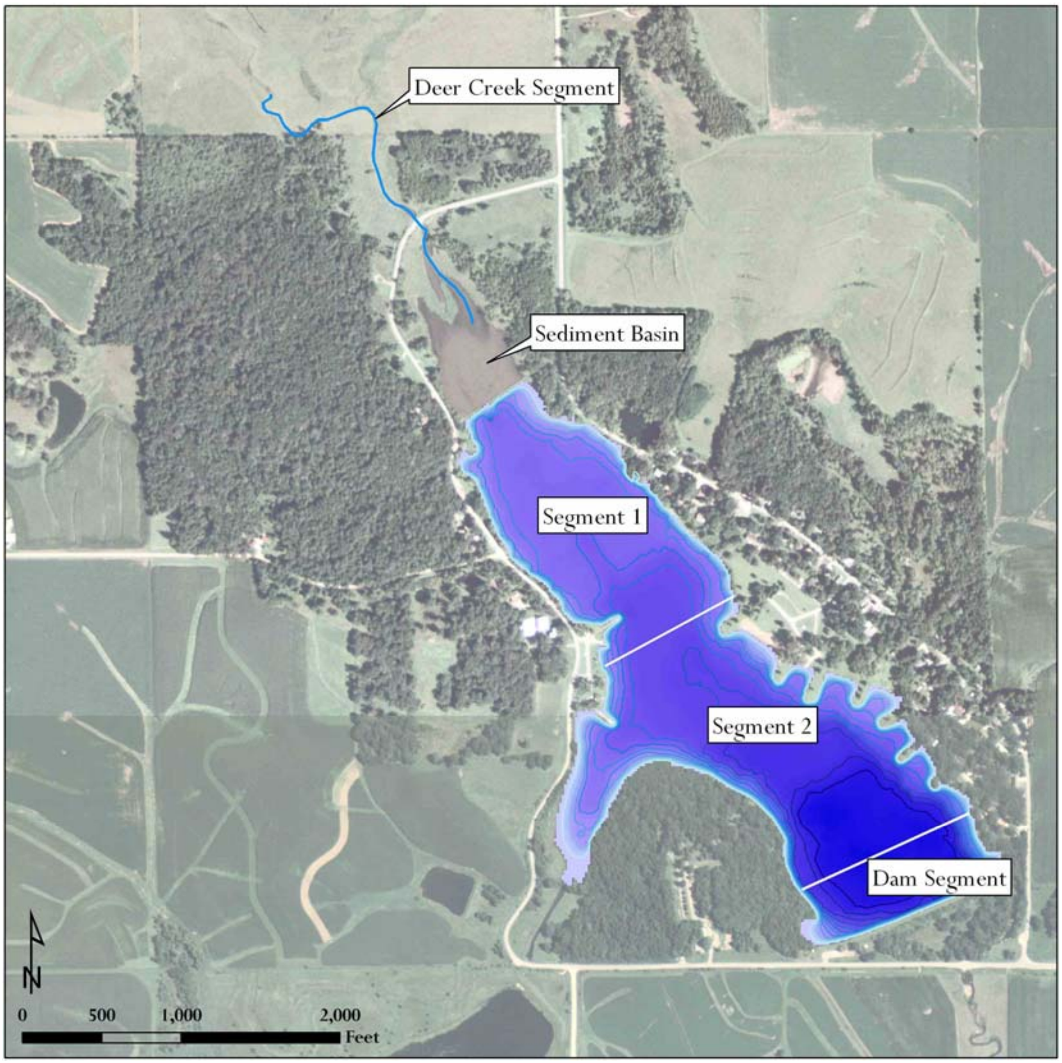


Figure D9 Segmentation of the lake for WASP model

The Deer Creek segment is included to provide a transition from the stream to the lake. Its length is about half a mile and its upstream terminus is at the first 10 foot contour line going up from the lake surface on the Quad map. Deer Creek flows into a relatively shallow part of the lake that has been configured to retain silt. The average width of the creek was estimated from several measurements from aerial photography. The downstream end of this segment passes through a silted in area as shown in Figure D10.

A rock and earth dike that crosses the width of the lake and was constructed in the late 1980's as part of a lake restoration project forms the lake sediment basin. There is a 65 foot wide shallow section in the dike where water flows into the main body of the lake. The sediment basin has been modeled in WASP as a weir controlled segment.

Figure D10 Deer Creek flows into the Union Grove Lake sediment basin, looking south.

Figure D11 Union Grove Lake sediment control dike, looking east

Bathymetry of the lake segments downstream of the sediment basin and the locations of the longitudinal profile and cross-sections used to approximate the lake morphometry for the model are shown in Figure D12. Slopes and depths for the segments were calculated from the profile shown in Figure D13.

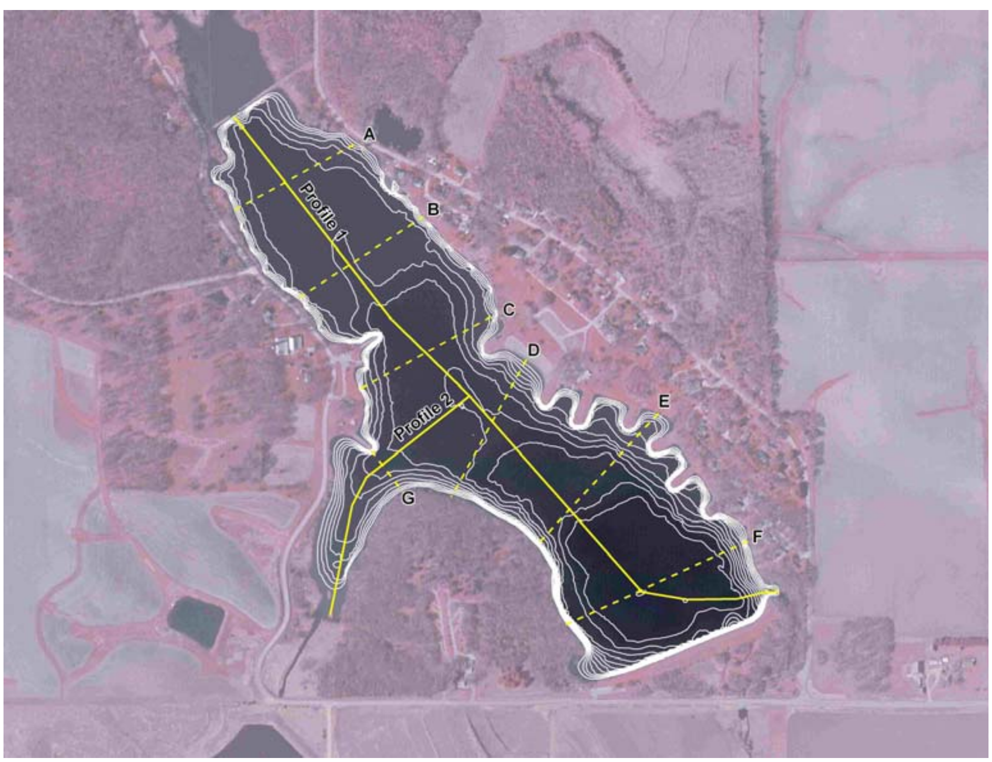


Figure D12 Union Grove Lake showing profile and cross-section alignments

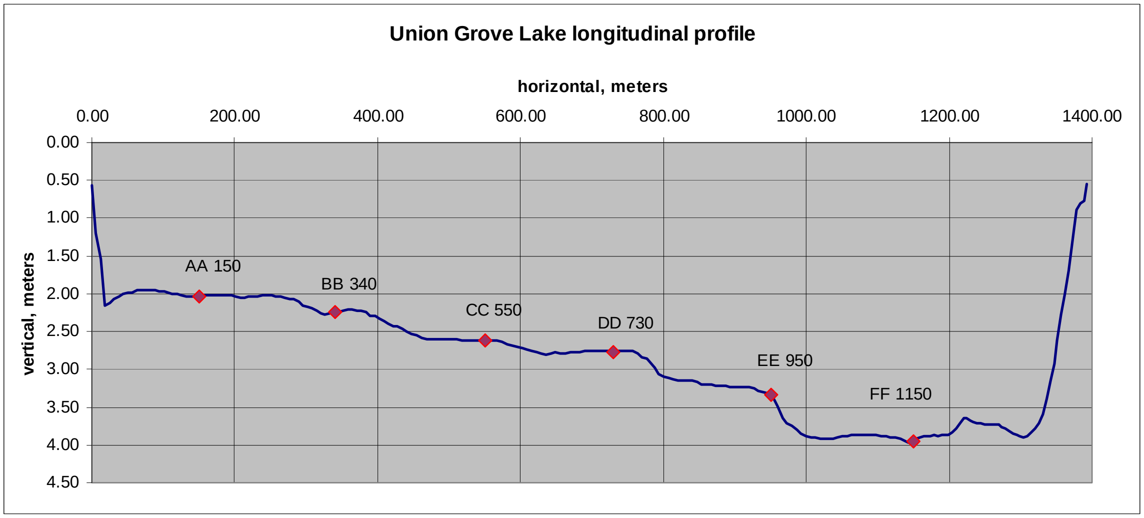


Figure D13 Union Grove Lake longitudinal profile

The model segment boundaries coincide with two of the cross sections shown in Figure D12. Segment 1 runs from the sediment basin to cross-section C. Segment 2 runs from cross-section C to cross section F. The Dam Segment runs from cross-section F to the discharge weir to the east of the dam.

Segment 1 is the shallow end of the lake and receives the flow from the sediment basin through the gap in the sediment basin dike. This is the segment where the groundwater seepage flow and load is input to the model. A recycled load is also added to this segment based on surface area.

Segment 2 slopes down from Segment 1 to the deepest part of the lake. It receives the flow from Segment 1 and two of the watershed subbasins, Subbasin 0 and Subbasin 1 (see Figure D2). Subbasin 0 is the subbasin that surrounds the lake and includes loads from the septic tanks and geese in addition to runoff loads. Subbasin 1 drains the sub-watershed to the southwest of the lake and a separate tributary discharges to a large sediment basin and then to the lake. The trapping efficiency of the sediment basin is estimated to be 90% and this reduction has been accounted for in the Subbasin 1 BasinSims/GWLF watershed model.

The Dam Segment is at the south end of the lake and has the deepest point in the lake. It runs from cross-section F to the discharge weir. This is the segment where most water quality sampling has been done. That monitoring includes the continuous DO, temperature, and pH measurements taken in fall 2007 and summer/fall 2008.

The other three segments are model devices used to represent flows and loads other than the major Deer Creek tributary. These have already been noted above and are the groundwater seepage inflow, the modeled flow from Basin 0, and the Basin 1 modeled flow from the southwest tributary. These are modeled as low volume segments with relatively short length.

Conceptual lake process model
Union Grove Lake is a small shallow impoundment with a large watershed to lake area ratio. Wind mixing and solar heating are important, especially in the later summer and early fall when flow is low and detention time increases. As the detention time increases internal resuspension and recycling of silt and phosphorus become the dominant source of lake turbidity and nuisance algal blooms.

For Union Grove Lake the resuspension and recycling problem is aggravated by the presence of large numbers of carp, at least 200 pounds per acre according to IDNR Fisheries staff. These fish are bottom feeders constantly ingesting bottom sediment and other material and then shooting it out of their gills. This results in turbidity and makes previously settled phosphorus available for algal growth, particularly in shallower parts of the lake. Figure D14 shows the phosphorus cycle.

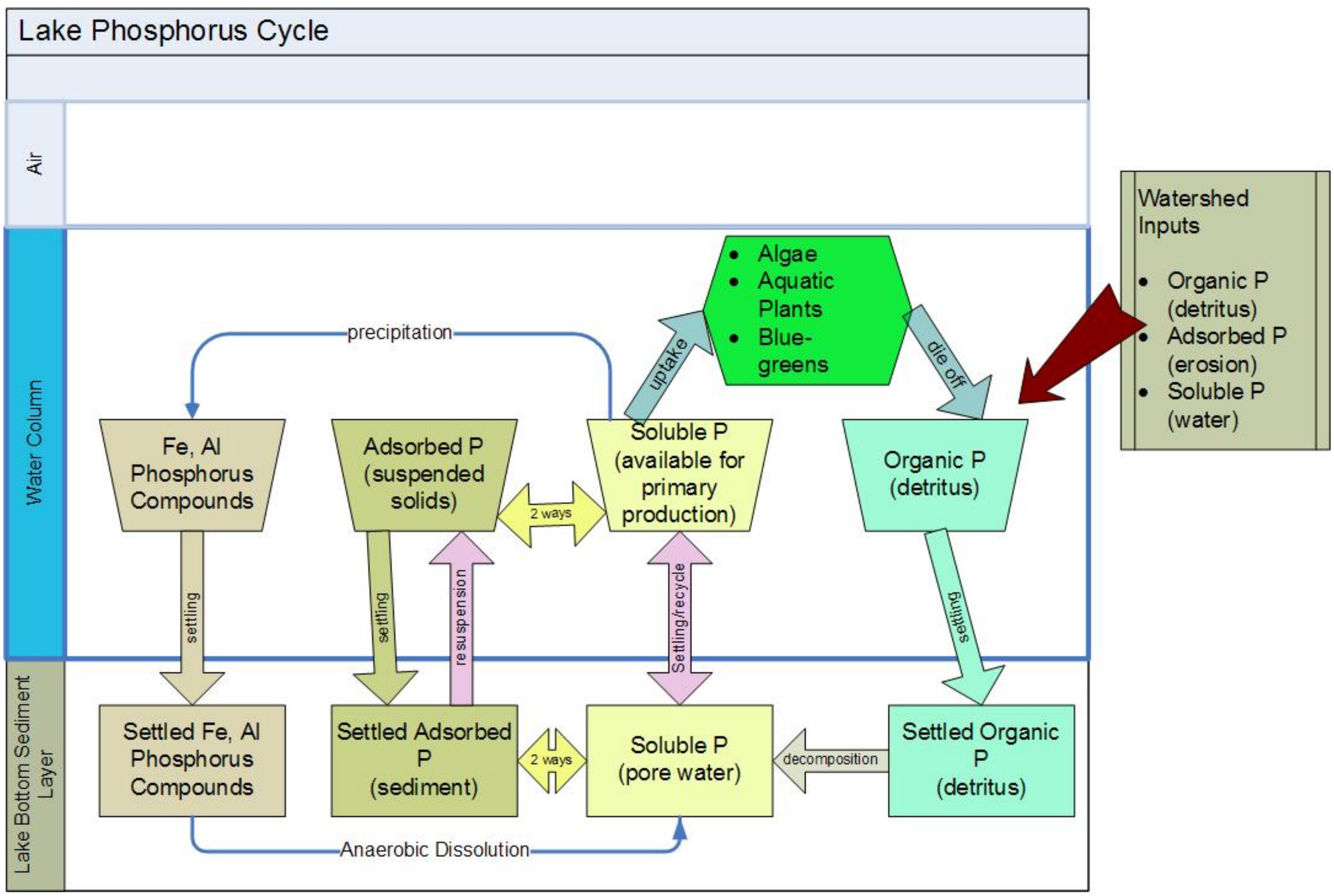


Figure D14 Phosphorus cycle in Union Grove Lake

Union Grove Lake does not develop strong thermal stratification as shown in seven years of water column profiles done during the ISU Lake Study. Typical temperature and dissolved oxygen profiles from 2006 are shown in Figure D15. As can be seen, there is a small drop in temperature from top to bottom in mid-summer. In 2008, UHL did the

Union Grove Lake sampling and profiles. These are shown in Figures D16 and D17. The July 17, 2008 top to bottom two degree temperature difference does not provide stratification significant enough to inhibit mixing in the lake.

Dissolved oxygen profile concentrations differ from the temperature profiles and show a pronounced decline with depth in the 2006 data in a pattern that is mirrored in the July 17, 2008 DO profile. The 2008 DO profiles for May and September show little change in DO concentration with increasing depth indicating rather complete mixing of the water column. There is quite a change in DO with depth in July when the upper DO concentration also is higher than the other months and there is a sudden and significant DO decrease.

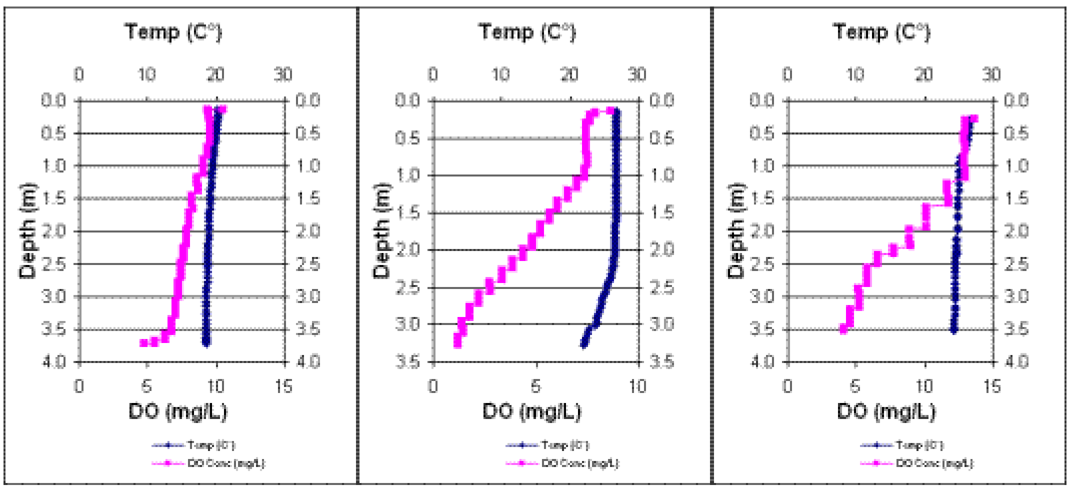


Figure D15 Temperature and DO profiles from 2006 ISU Lake Study, June 14, July 19, and August 16.

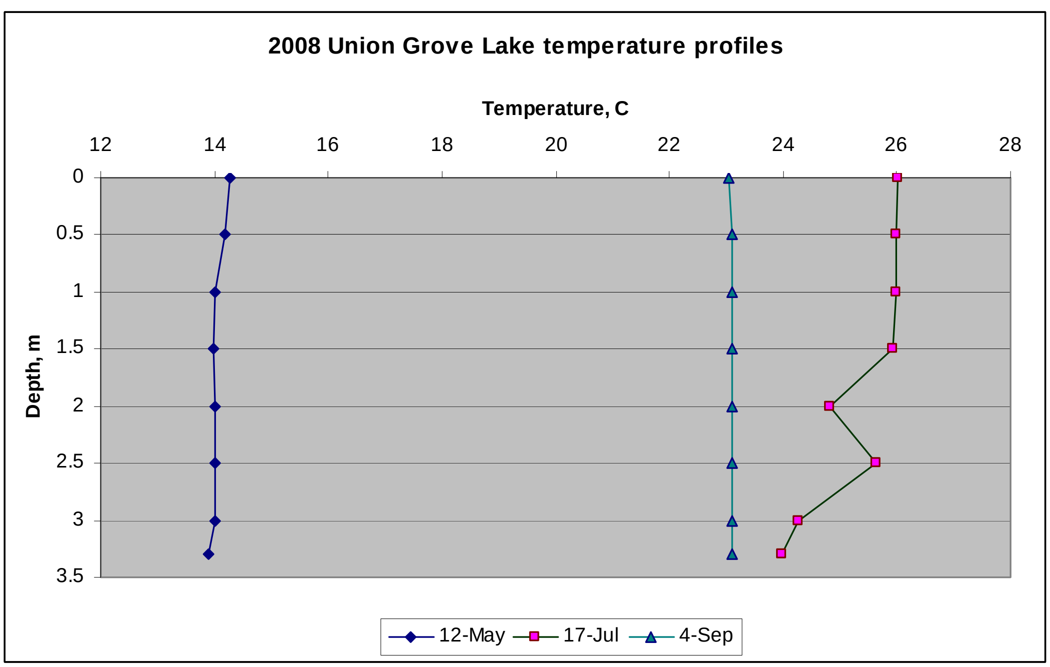


Figure D16 2008 Temperature profile from IDNR/UHL data

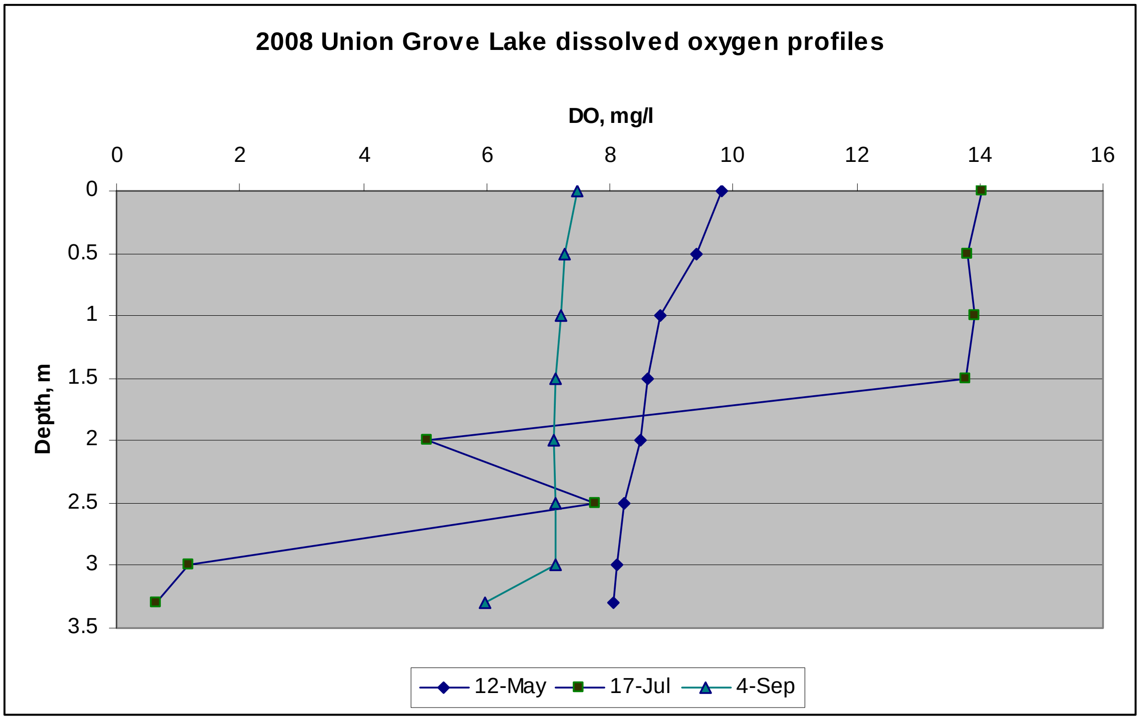


Figure D17 2008 Dissolved oxygen profiles from IDNR/UHL data

Since the profiles were made well after sunup this pattern shows the high productivity of photic zone phytoplankton. The algal turbidity in the upper part of the water column causes the extinction of light with increasing depth and decreasing photosynthetic DO production. Descending down the water column, algae and other microorganisms settle out of the photic zone, respiring and depleting dissolved oxygen.

In 2008 data was collected from two data sensors at fixed depths located in the deepest part of the lake, approximately in the center of the Dam Segment. This is also the location where all of the ISU Lake Study and UHL data is gathered. The sensors were placed at depths of two feet and eleven feet and collected DO, temperature, pH and specific conductivity data every 20 minutes.

This 2008 data was collected from the Upper sensor from July 21 to October 2. Due to some equipment problems, data was collected from the lower sensor only from August 23 to October 2. Figure D16 shows an hourly summary of this data for both the upper and lower sensors.

The profile data in Figure 16 shows similarities to the dissolved oxygen profile data in that the dissolved oxygen concentration varies with depth. It also shows that often there is an inverse relationship between the upper and lower DO concentrations; as the DO concentration increases at the upper sensor it decreases in the at the lower sensor. This is particularly notable from September 19 to 29. During this period, algal productivity is peaking and the upper layer DO concentration is often supersaturated. The DO concentration in the lower layer decreases as dead and decaying algae settle from the photic zone creating an oxygen demand and living algae that settle below the photic zone respire rather than produce DO.

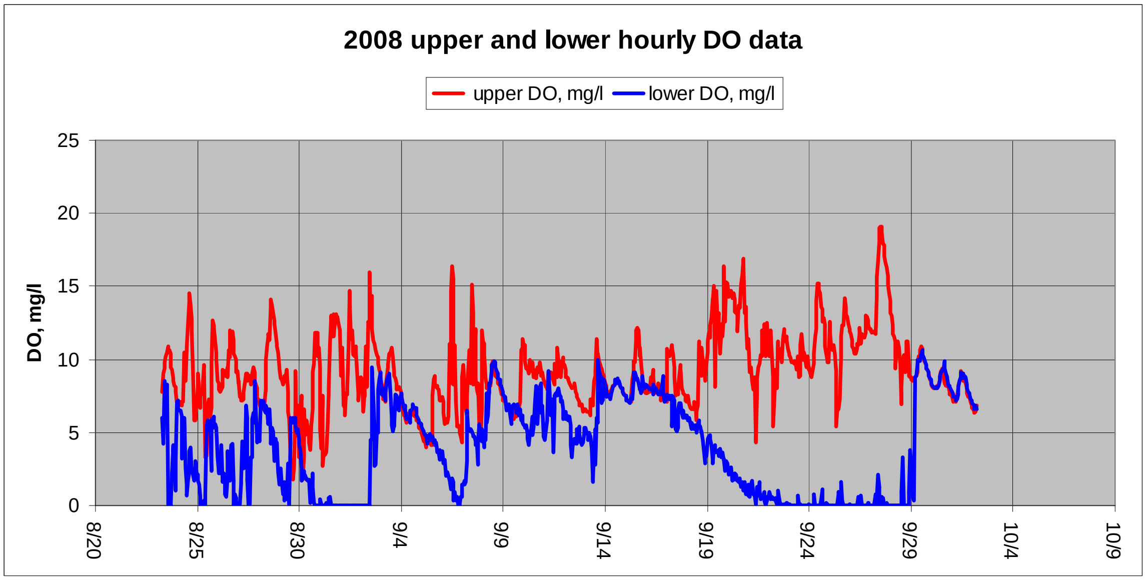


Figure D18 2008 upper and lower sensor hourly DO data

The hourly temperature data starting August 14 and going to October 2 shows that there is not a strong thermal stratification during this period as noted previously. During the September 19 to 29 high productivity interval, the temperature in both the upper and lower layers steadily rises.

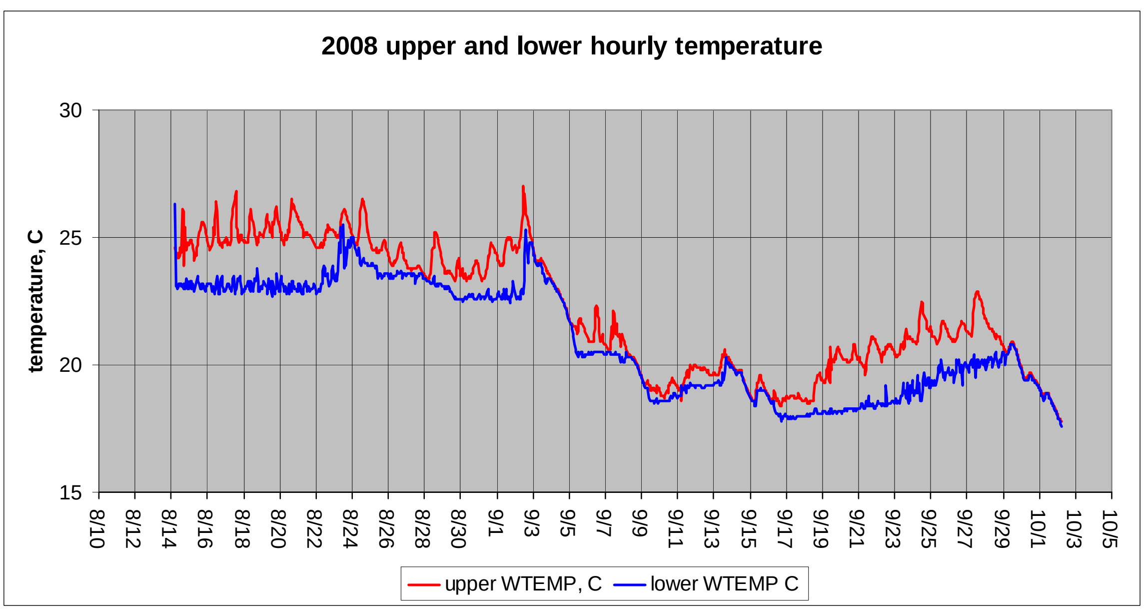


Figure D19 2008 upper and lower hourly temperature data.

These observations prompted the following assumptions for the Union Grove Lake WASP model:

- Each of the segments is mixed and hypolimnion segments are not needed.
- Input of internal phosphorus recycle load is a prescribed benthic phosphate flux to the water column since the recycling is caused by carp. The flux is 10 $mg/m^2/day$ applied to the surface area of the four lake segments and is the same as that used for BATHTUB modeling,
- The sediment basin and dam outlet segments have no slope and are modeled for weir controlled flow.
- Light extinction occurs with increasing depth from algal turbidity and this creates the observed DO gradient.

WASP Parameterization
The WASP model uses BasinSims/GWLF model out put as input for flows and loads. The GWLF model output divides phosphorus loads into soluble and attached fractions. It is assumed that the dissolved fraction represents orthophosphate and that the attached fraction represents the organic/particulate fraction of the TP load.

Included in the GWLF model are the lake geese. These have been input as a monthly point source in the nutrient file and a geese load spreadsheet is in the support documentation folder. These loads are assumed to be soluble phosphorus. Septic tank loads are assumed to be soluble phosphorus. There is limited soluble reactive phosphorus monitoring in the ISU Lake Study data and it assumed that it represents water column orthophosphate in the WASP model. It can be found in the spreadsheet *UGL_all ISU UHL data.xls* in the Support Documentation folder.

Wind Speed and Reaeration and Light
The average daily wind speed was obtained from the same Marshalltown weather station as other meteorological data used in the development of this report. For a lake waterbody with a large surface area and low segment water velocities, wind is the major driver of reaeration at the water surface. The WASP model has incorporated this and the results can be seen in Figure D20. As can been seen from this figure, the average daily wind speed and modeled lake reaeration constant (Ka) are closely associated.

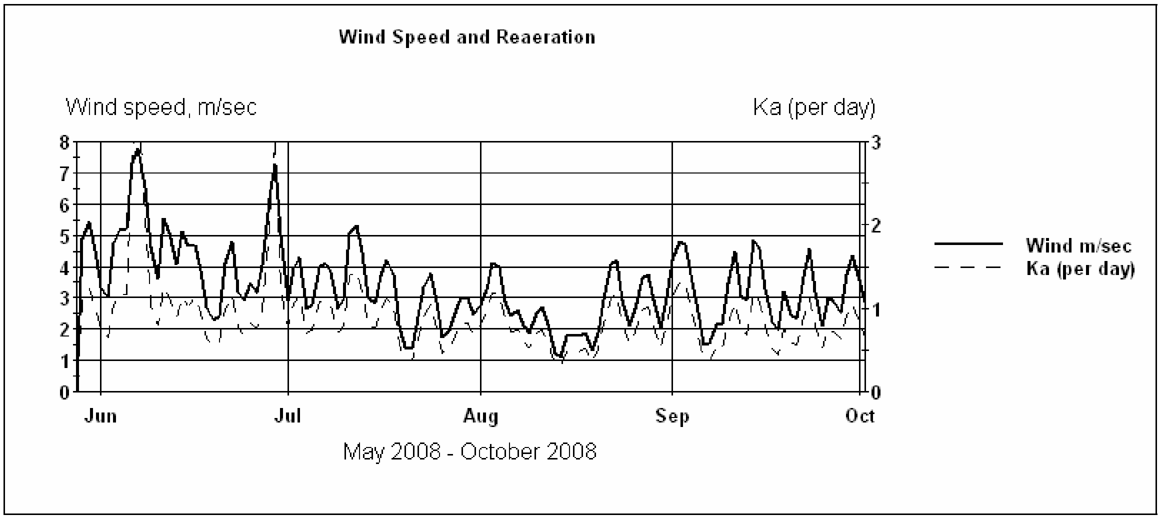


Figure D20 Wind speed and lake reaeration

There have not been any direct measurements of light at the lake but there is data from the Marshalltown weather station on the tenths of the sky covered from sunup to sundown. It is assumed that the available light (1,500 Langleys at noon for latitude) is decreased by the fraction of sky that is covered.

Dissolved Oxygen and Oxygen Demand

The initial BOD concentrations for the WASP segments were estimated from data collected in the summer of 2008 at two tributary locations and three locations in the lake. This data can be found in the spreadsheet *UGL 319 08.xls* and in Appendix C. Ranges of sediment oxygen demand (SOD) have been obtained initially from a table developed by USEPA Region 4 of measured in-situ SOD for different types of waterbodies and bottom conditions. It has also been used as a calibration variable to uniformly raise or lower predicted DO concentration.

The observed DO concentration shows strong diurnal fluctuation with amplitudes as great as 15 mg/l over twelve hours (see Figure 18). This result of phytoplankton metabolism controls lake oxygen dynamics in the summer and fall. Furthermore, it drives the diurnal pH swings caused by the uptake of carbon dioxide during photosynthesis and causes the pH impairment.

Time Steps and WASP Output

The Dam Segment is used for comparison to observed data for calibration because it is the location where the observed data was collected. Just as in the observed data, there is a strong diurnal fluctuation in predicted DO concentrations generated by the WASP model for existing conditions for the Dam Segment. The flow data from the calibrated BasinSims/GWLF model output is the daily average flow. The WASP model flow output can be adjusted to a wide range of time steps, from minutes to days to weeks. For the

Union Grove Lake model two time step intervals have been used; an average daily time step and an average hourly time step.

The average daily time step matches the daily BasinSims/GWLF watershed model output. This is also the time step used to try to match the predicted to the observed DO through the manipulation of the eutrophication parameters in the WASP model. An average daily time step does not show the diurnal changes in DO but reflects changes in flow and loads into the lake. Many of the WASP model inputs, such as inflow, light, reaeration, internal phosphorus load, watershed phosphorus and nitrogen loads, sediment oxygen demand (SOD), and watershed biological oxygen demand (BOD), are daily averages.

Figure D21 shows the observed average daily DO plotted with the predicted average daily DO through the time the continuous observations were made in the Dam Segment. The daily averaging of the observed and predicted values removes the diurnal effects allowing for a better view of the impacts changes in the variables input as daily averages. Figure D21 also shows the DO saturation concentration as a point of reference.

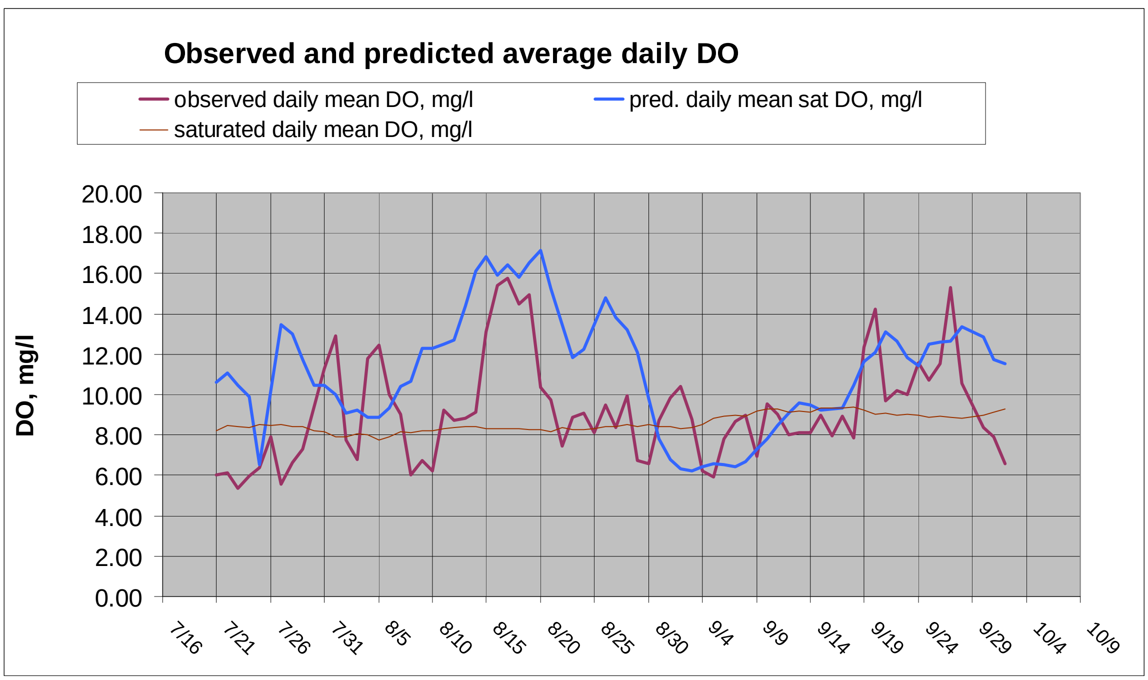


Figure D21 WASP predicted daily DO

As can be seen in this figure, the predicted DO concentration follows the observed data in a general visual way, but the 73 individual days do not. This is the consequence of having limited input variable data that does not include daily values. The observed values also tend to be more variable than the predicted values since some factors such as specific local weather conditions are not always accounted for in the model.

Daily data is particularly important for variables such as BOD that have an impact on DO not associated with algal photosynthesis and respiration. Beginning on July 21, 2008, the initial observed data show DO concentrations that are lower than predicted because of an oxygen demand not included in the model. Daily BOD load data is not available. Figure D22 shows the average daily output from the WASP model for DO and chlorophyll for August and September 2008.

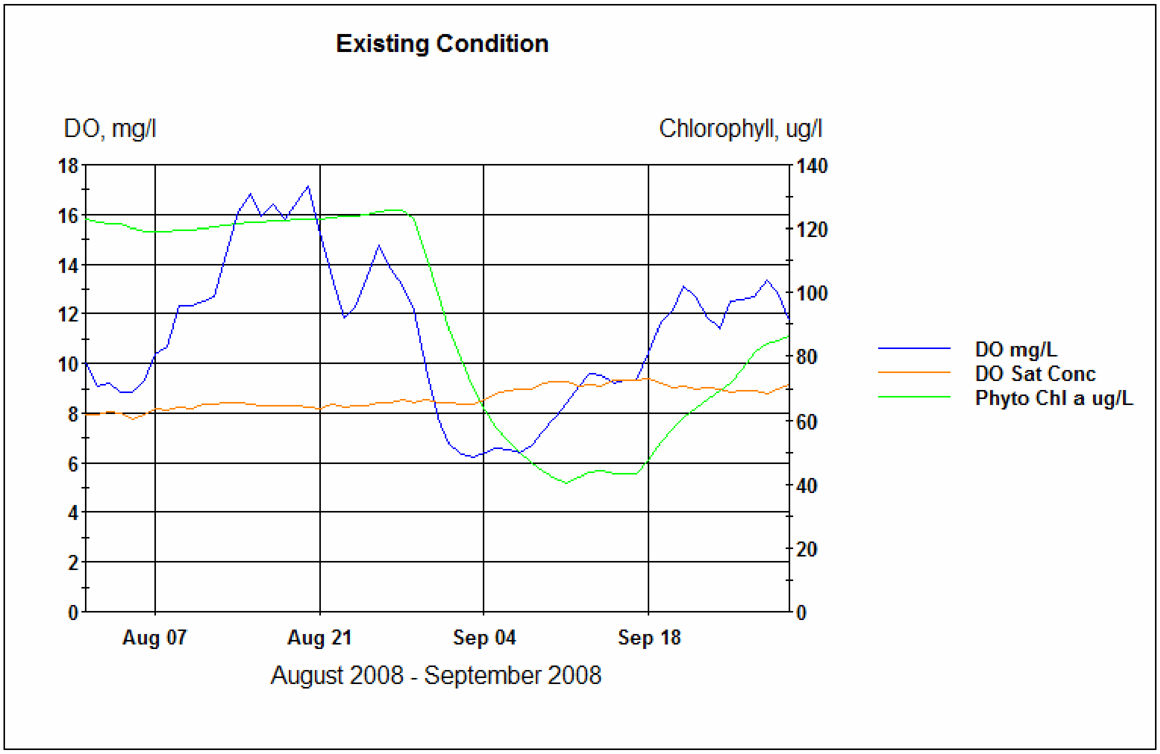


Figure D22 WASP generated average daily DO and chlorophyll concentrations

Figure 23 shows the hourly observed and predicted DO concentrations plotted together. The observed DO is less regular than the predicted data because of variations in weather and loads noted above in the discussion of average daily observed and predicted DO concentrations.

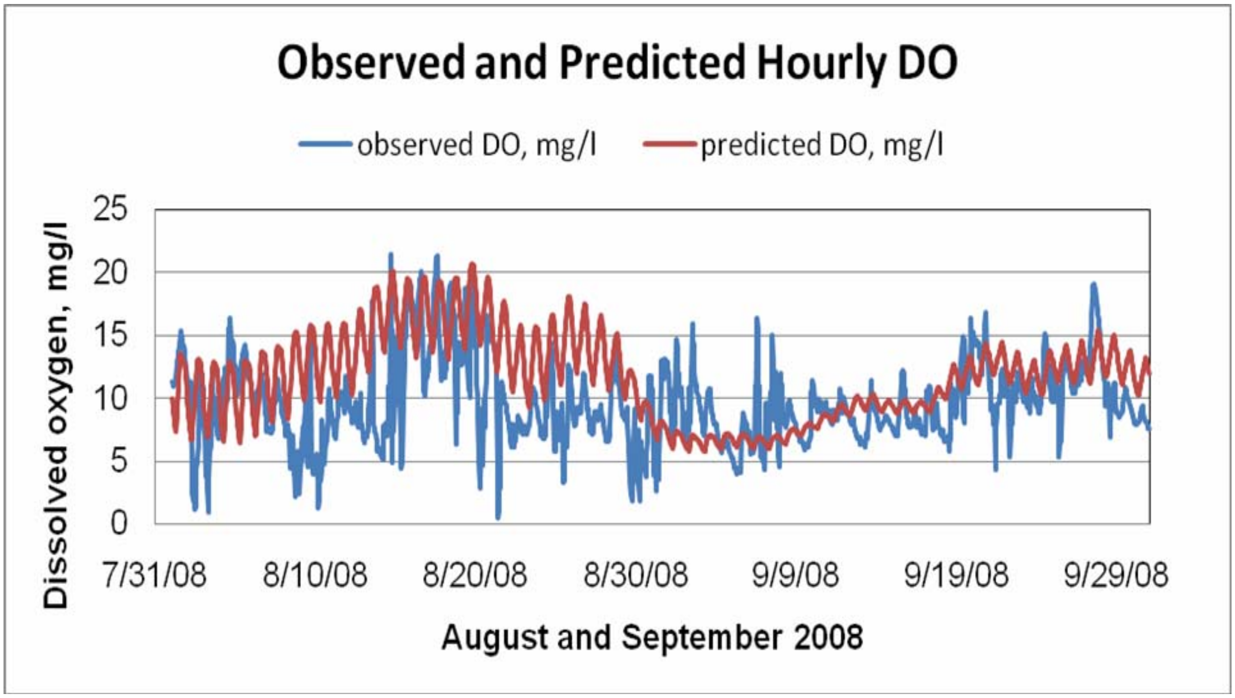


Figure D23 Observed and predicted hourly DO showing the diurnal fluctuations resulting from algal photosynthesis and respiration

The WASP model was run with an hourly time step to link the diurnal pH variation to the corresponding observed diurnal DO variation as discussed previously in Section 3. The model then links phosphorus to algal DO productivity. The hourly DO and chlorophyll concentrations for the modeled existing condition are shown in Figure D24. There is a diurnal affect on the chlorophyll concentration that reflects daytime algal growth.

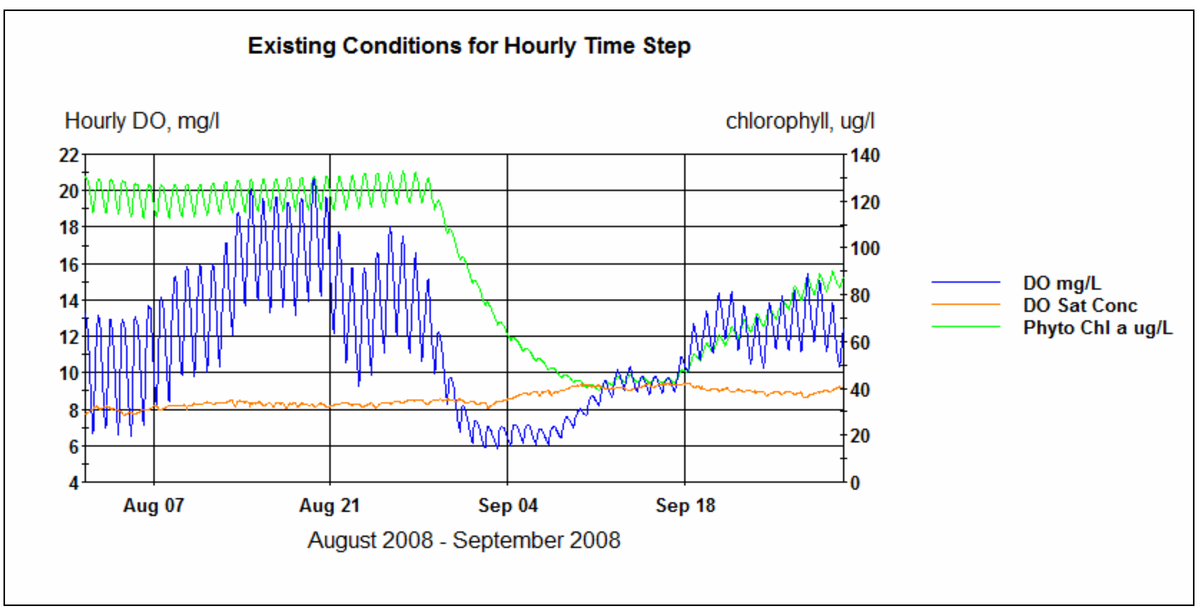


Figure D24 WASP modeled hourly DO and chlorophyll output at existing internal recycle TP concentrations

Figure D25 shows algal oxygen dynamics as an hourly rate of DO production or respiration. Productivity shows a strong diurnal effect peaking mid day and going to nothing at night. The area under the productivity curve is the mass of DO produced. Respiration shows only slight diurnal changes since algae respire night and day. As noted previously, increasing the DO concentration through photosynthesis produces a corresponding decrease in carbon dioxide concentration that in turn causes a rise in pH.

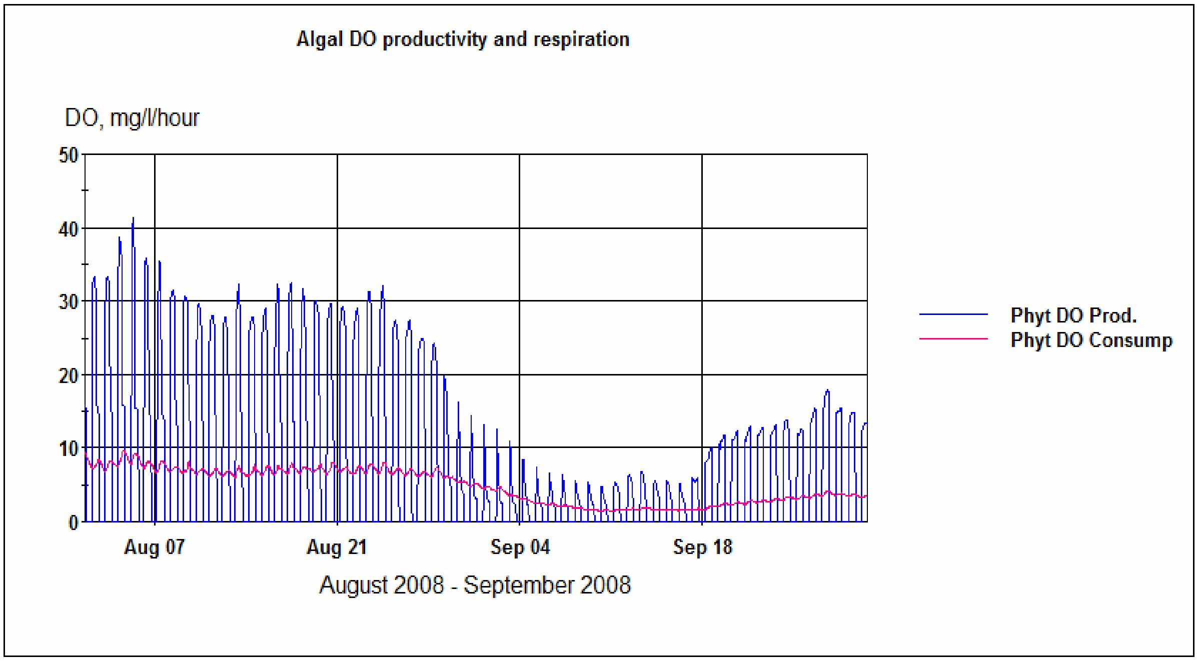


Figure D25 Modeled existing phytoplankton productivity and consumption

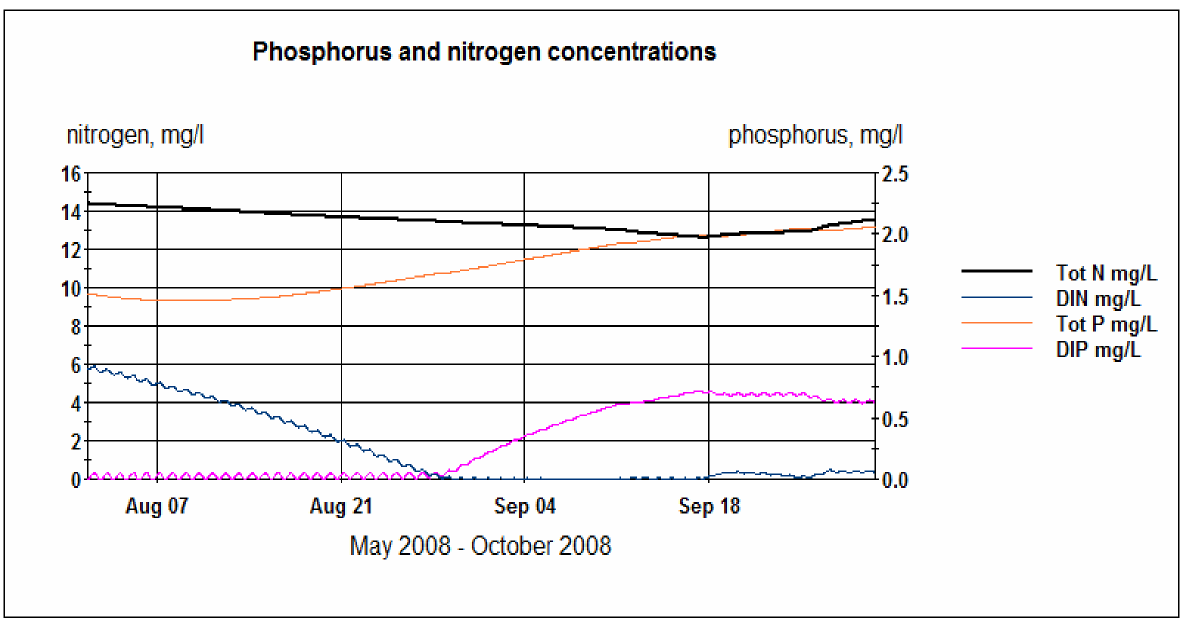


Figure D26 Modeled existing phosphorus and nitrogen concentrations

Figure 26 shows the modeled changes in the concentrations of total phosphorus and total nitrogen through the summer. The total concentrations do not vary that much but the amounts of nitrogen and phosphorus available for immediate algal uptake, dissolved inorganic phosphorus (DIP) and dissolved inorganic nitrogen (DIN), do vary considerably, sometimes dropping to fairly low concentrations that could be limiting.

To evaluate the impact that reducing the internal recycle TP load by 90 percent would have the WASP model was run with the prescribed benthic phosphorus flux reduced to 10 percent of the existing areal load. The results are shown in Figures D27 through D29. These figures correspond to Figures D24 through D26 that show existing conditions for the same variables but without internal recycle phosphorus reduction.

It can be seen that the chlorophyll is not always below the target concentration of 33 ug/l but an average might be depending on the time step used to do the averaging. Based on the phytoplankton productivity and respiration at the target condition, the diurnal pH value will always be below the maximum allowed by the water quality standards. It can also be seen that by reducing the internal resuspension and recycle of phosphorus, water quality improvement will approach target expectations.

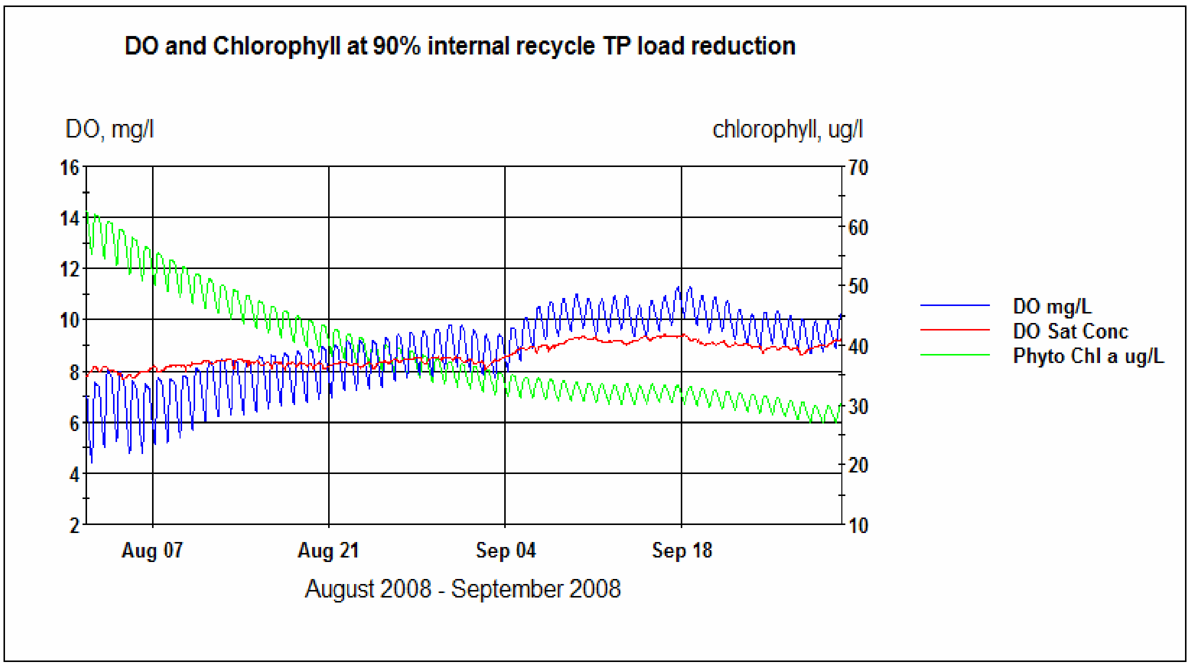


Figure D27 WASP hourly DO and chlorophyll output – internal recycle TP reduced 90 percent to TMDL target

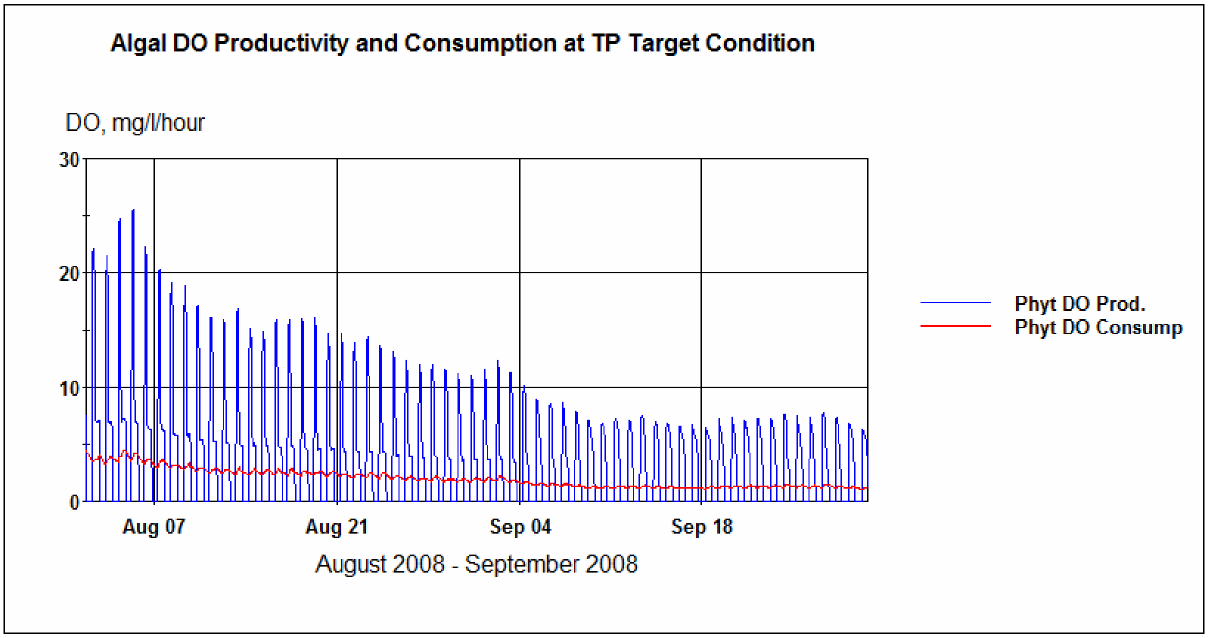


Figure D28 Algal productivity and consumption at the target internal recycle TP load

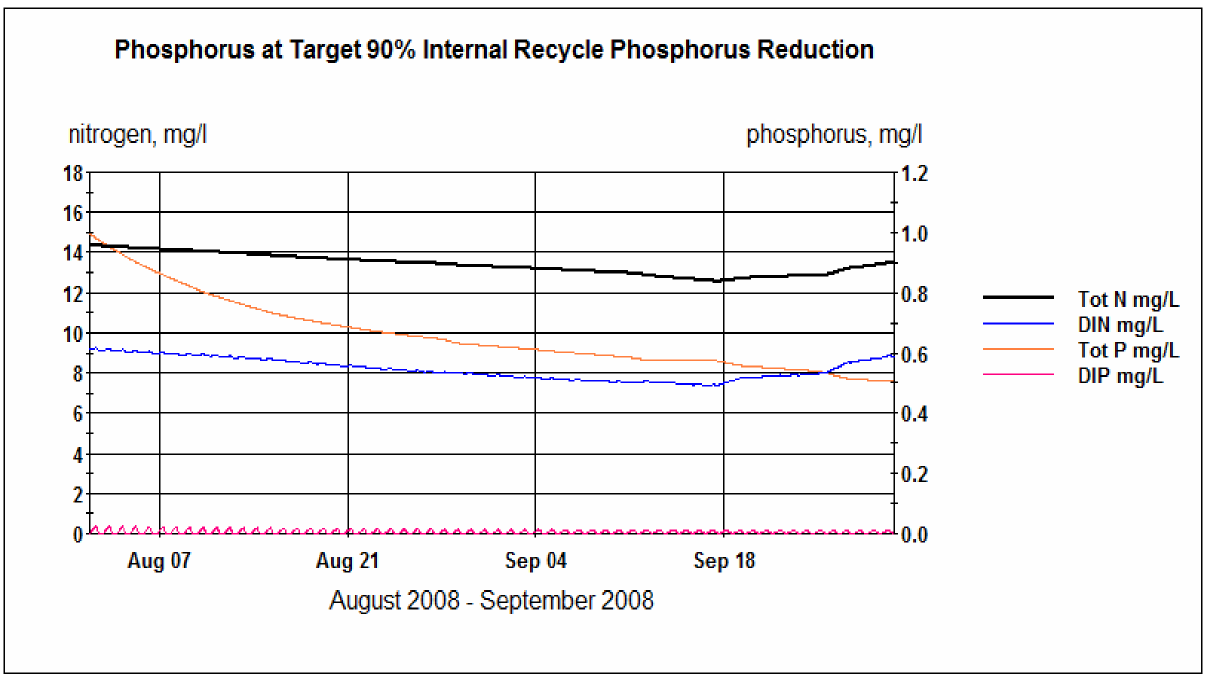


Figure D29 TP and dissolved inorganic phosphorus (DIN) and total nitrogen and dissolved inorganic nitrogen (DIN) concentrations after a 90 percent reduction in internally recycled phosphorus.

Pathogen Indicator Analysis and Modeling

This section includes additional details for the development of the *E. coli* TMDL not included in the main body of the report. Some of the load source assumptions and references for the BIT model bacteria load delivery are in the first section and a discussion of the of the four flow conditions is in the second section. The third section discusses bacteria die-off.

EPA Bacteria Indicator Tool
The EPA Bacteria Indicator Tool was used to estimate nonpoint source bacteria loadings for this TMDL. The BIT estimates the monthly accumulation rate of fecal coliform bacteria on four land uses (crop land, forest and ungrazed pastureland, built-up, and pastureland), as well as the upper limit for the accumulation that occurs when it does not rain and there is no wash off.

The BIT used the following assumptions for estimates of livestock and wildlife bacteria contributions:

- Dairy cattle are confined in feedlots and their waste is applied as manure.
- Access to pastureland for grazing cattle varies during the year. According to researchers at Iowa State University (Russell, Jim. Dept. of Animal Science, Iowa State University. Ames, IA 50011. December 2005. Personal communication) cattle are:
  - 80 percent confined from January through March.
  - During the spring and summer months (April through October) they spend 100% of their time grazing.
  - In November and December, they have slightly reduced access and spend approximately 80 percent of their time grazing.
- The grazing schedule for sheep is similar to cattle except that sheep are usually confined from January through March.

Flow condition analysis
This section elaborates on the section (page 43) in the main body of the report called Linkage of E. coli Sources to the Lake, Flow and Load Analysis.

At the zero to ten percent flow condition, the existing load is 2.26 E+12 *E. coli* organisms. The estimated total load available for wash off from all land uses is 3.70 E+13. The fraction of delivered *E. coli* during the runoff condition is 6 percent ((2.26 E+12) ÷ (3.70 E +13) = 0.06 = 6 percent). There are not any sample violations between the 6 percent and 34 percent recurrence levels. All of the samples that exceeded the *E. coli* criteria had an associated flow recurrence of less than six percent, meaning that excess loads occur primarily during peak runoff conditions.

The recurrence interval between 30 and 80 percent has an estimated delivered *E. coli* load of 3.43 E+10. The time of travel for *E. coli* loads from cattle in the stream, two days, was estimated from the WASP model velocities for Deer Creek and the lake segments during a July low flow period

The estimated continuous load exceeds the delivered load by 8.17 E+10, or 70 percent. Therefore, the available fraction found in the lake at the 30 to 80 percent recurrence interval is 30 percent. The reasons that the available and delivered loads are different are:

- Loads will always be higher when there is a shorter travel time from the source to the lake's beach where the *E. coli* is measured meaning that travel time is considerably shortened during precipitation driven high flows. This is particularly true of bacteria loads from cattle in the stream where the sources are some distance from the lake. On the other hand, during dry periods when stream and lake velocities are reduced, the longer travel time to the beach allows for significant die-off due to exposure to sunlight and predation. A bacteria decay coefficient of two has been selected to incorporate zooplankton predation.
- Septic tanks have less impact during lower flow drier periods since a greater fraction of the discharge percolates through the soil and does not get to the lake as interflow.
- The loads from geese are less affected by low flow conditions during dry periods since a large fraction of this load is delivered directly to the lake.

In the 80 to 100 percent recurrence interval, flows in and out of the lake decrease even more than at the 30 to 80 percent interval. Loads delivered from the watershed, including cattle in the stream, are minimal or non-existent. The estimated delivered loads and the measured lake concentration may not reflect all of the impacts of geese and adjacent septic tanks. As the lake inflow approaches zero, its load carrying capacity becomes very small as well. A significant number of the criteria violations occur in these low flow conditions when the hydraulic detention time increases and flushing is not occurring.

Calculating bacteria die-off
Bacteria die-off from the source to the monitored location in the lake is estimated using the following procedure.

The BIT estimate for cattle in the stream *E. coli* load is 1.01 E+12 organisms. Die-off between the watershed source and the Union Grove Lake Beach was estimated using the two day time of travel and a decay coefficient of two in the standard exponential equation used for this purpose. The equation is:

$$C_x = C_o \div e^{kt} = 1.01E{+}12 \div e^{(2*2)} = 1.84\ E{+}10\ \textit{E. coli}\ \text{organisms}$$

Where: **Co** = Initial bacteria count, as a concentration of organisms per 100 milliliters or liters or as a daily load, organisms per day at the source.
C_x = Concentration or daily load at a point distance "x" downstream of the discharge.
K = first order decay coefficient, 1/day = 2
The decay coefficient of 0.96 has generally been used for Iowa stream TMDL development and also for some lakes. This value comes from Chapter 8 (pages 434 and 435) of the EPA Rates, Constants and Kinetics Manual (EPA/600/3-85/040). It is the median of all of the measured values for a wide variety of waterbodies and conditions found Table 8-2 of the manual. Union Grove Lake is more like the lakes and lagoons

(decay range of 1 to 9.6) in the table than the streams or estuaries. In general, the table's lakes have higher bacteria decay rates than streams. Assuming that bacteria from the watershed, mostly loads from sources like cattle in the stream, travel through the lake before reaching the beach area where sampling is done, the decay rate will be higher in the lake. For this reason, a decay coefficient of two has been applied to the watershed sources that are important during low flow conditions.

T = time of travel, days = 2 days

This form of the equation is used to estimate the delivered bacteria loads. The septic tank *E. coli* loads are not decayed since there is not any significant travel time between the residential area and the adjacent beach where the weekly bacteria monitoring is done. The same is true of the bacteria loads from geese whose preferred hangouts are the shoreline lawns.

The available *E. coli* load from the continuous sources is:

Cattle in streams	= 1.84 E+10 org/day (k=2, time of travel=2d)
Septic tanks	= 2.00 E+10 org/day
Geese	= 7.80 E+10 org/day
Total	**1.16 E+11 org/day**

Analysis and Model Documentation

The data analysis and modeling for the Union Grove Lake TMDL are contained in the spreadsheet and model input files listed below in Tables D24 to D30. These folders, spreadsheets, and model input files are located in the folder S*upport Documentation 2*. The spreadsheets contain the data and information used to develop this water quality improvement plan, the model input and output files, and the model files for the BasinSims/GWLF watershed modeling and the BATHTUB and WASP eutrophication modeling. The three models and related documentation can be downloaded from the internet. The model files can be directly loaded into the downloaded model software.

Table D24 Data and analysis spreadsheets

Folder and file name	Description of contents
Data (folder)	**Data and analysis spreadsheets**
10 yr rain and T GWLF form.xls	Temperature and precipitation data from the Marshalltown weather station.
ugl noaa weather.xls	Additional Marshalltown weather data used in WASP model, wind, clouds etc.
precip 4_06 to 11_08.xls	Additional years of weather data used in GWLF and WASP models
ISU Study Data UGL.xls	Original data from the ISU Lake Study.
Waterfowl nutrients in UGL.xls	IDNR Wildlife staff estimates of geese at Union Grove Lake
UGL ISU UHL data and TSI charts.xls	Analysis and evaluation of all ISU Lake Study and UHL water quality data, 2000 to 2008, TSI charts for data. .
UGL2008 319 Monitoring.xls	Contains 2008 data from two tributary and three lake sites.
profile data (subfolder)	Lake water column profile data files for 2005 to 2008 are in this folder.
Union Grove Lake (date and year).xls	Spreadsheet files with water column profile data for 2005 to 2008.
ug_discharge (subfolder)	Continuous lake stage data and rating curve development, fall 2007 and summer/fall of 2008.
discharge day conversions.xls	Conversions of flow from cfs to meters cubed per day.
discharge calibration.xls	Contains the predicted and observed average daily flow values and calibration, N-S coefficient and MAPE calculations.
ug_rating_(shift number).xls	Spreadsheet files used by USGS to develop the rating curve for the lake discharge weir.
YSI continuous data (subfolder)	Continuous lake DO, temperature, and pH. collected fall 2007 and summer/fall 2008.
ug_upper2008 fixed2.xls	Continuous values for DO, temperature, and pH for the upper sensor from 7/21/2008 to 10/2/2008.
ug_lower2008.xls	Continuous values for DO, temperature, and pH for the upper sensor from 8/14/2008 to 10/2/2008.
upper and lower charts 2008.xls	Upper and lower sensor data analyzed and plotted together.
uniongr upper.xls	Upper sensor data for DO and pH, plotted by each day.

Table D25 BasinSims/GWLF seven subbasins model folders and files

Folder and file name	Description of contents
GWLF 7 subbasins (folder)	Contains subbasin GWLF model development, input and output folders.
Model input development (subfolder)	. Development of GWLF KLSCP factors and curve numbers for each of the seven subbasins.
2002 and 04 Land Cover Summary.xls	Land cover information from the 2002 GIS coverage and the 2004 field assessment.
KLSCP by subbasin.xls	Development of GWLF KLSCP factors and curve numbers for each of the seven subbasins.
LandCover_HydroGroupCode.xls	Curve number derivation for consolidated land use by soil hydrologic group.
UGL GWLF subbasin 2 (subfolder)	
Input (sub-subfolder)	All GWLF transport, nutrient, and weather files for each of the seven subbasins are here.
Basin (number) WASP Input.prj	Files with the prj extension are GWLF project files. There is one for each of the seven subbasins. Project files load the input files into the model.
UGLWASPweather.dat	The weather file is the same for all seven subbasins.
basin(number)transport.dat	GWLF transport files. There is one for each of the seven subbasins.
Basin(number)nutrient.dat	GWLF nutrient files. There is one for each of the seven subbasins.
Output (sub-subfolder)	GWLF output files from each of the seven subbasins are here as well spreadsheets that combine the results from the seven subbasins.
Results_basin(number).dat	The monthly mean results for each year of the in this GWLF model
Summary_basin(number).dat	The summarized mean results for years of weather data used in GWLF model.
Basin(number) (sub-sub-subfolder)	Spreadsheets containing daily and monthly flow, erosion, and nutrient output.
Basin(number)_ForStream.xls	Daily output
Basin(number)_SumMonth.xls	Monthly summary output
Combined basins (sub-sub-subfolder)	Sums the flow, erosion, and nutrient output for subbasins 2 to 6 as Deer Creek discharge to the lake.
combined basins 2 to 6 SP and SN.xls	Sums the sediment attached phosphorus and nitrogen for subbasins 2 to 6.
combined basins 2 to 6 DP and DN.xls	Sums the dissolved phosphorus and nitrogen for subbasins 2 to 6.
Output in BATHTUB form (sub-subfolder)	All GWLF transport, nutrient, and weather files for each of the seven subbasins are here.
Basin(number)sum.xls	GWLF output converted for BATHTUB input for each of the seven subbasins.
combined basins 2 to 6 for btb.xls	Sum of subbasins 2 to 6 for input to BATHTUB as Deer Creek discharge to lake.

Table D26 BasinSims/GWLF one basin watershed model folders and files

Folder and file name	Description of contents
GWLF bacteria (folder)	GWLF model files used for bacteria model and duration curves, consolidates all subbasins.
Input (subfolder)	The GWLF transport, nutrient, and weather files for each of the one basin model are here
UGL bacteria.prj	Files with the prj extension are GWLF project files. There is one for each of the seven subbasins. Project files load the input files into the model.
weatherUGL2.dat	The 12 year GWLF weather file used for the one basin model.
uglTransportRec3ETchange.dat	The GWLF transport file for the one basin model.
uglnutrient2old.dat	The GWLF nutrient file for the one basin model.
Output (subfolder)	The GWLF transport, nutrient, and weather files for each of the one basin model are here
Resultsbacteria1.dat	The monthly mean results for each year of the 12 used in this GWLF model
Summarybacteria1.dat	The summarized mean results for the 12 years of weather data used in this GWLF model.
BacteriaForStream2.xls	This spreadsheet contains the daily flow and runoff output from the GWLF model.

Table D27 Data and analysis spreadsheets for *E. coli*

Folder and file name	Description of contents
Bacteria (folder)	**Spreadsheet files with data, data analysis and modeling for bacteria**
bacteria beach UGL.xls	Original *E. coli* data
2000 to 2008 beach EC.xls	Modified *E. coli* data.
geese and bacteria.xls	Estimates of *E. coli* loads for BIT and GWLF
Union Grove BIT.xls	Bacteria Indicator Tool used to evaluate watershed sources of bacteria.
bacteria source evaluation.xls	Evaluation and charting of the BIT output
LDC for GWLF2.xls	Flow and load duration curves using calibrated GWLF hydrology and E. coli data
LDC existing load.xls	Load duration curves relating BIT output to existing E. coli loads

Table D28 BATHTUB eutrophication model folders and files

Folder or file name	Description of contents
BATHTUB (folder)	
UGL_TMDL.btb	BATHTUB model with watershed and internal recycle TP loads reduced to meet TMDL targets for chlorophyll and Secchi depth.
UGL_EXISTING.btb	BATHTUB model calibrated to existing observed conditions.
output for bathtub (folder)	Contains output from GWLF for input to the BATHTUB model.
UGL EXISTINGBTB.xls	Contains the direct output from the BATHTUB model for existing conditions.
UGL_TMDLBTB.xls	Contains the direct output from the BATHTUB model for target TMDL conditions.

Table D29 WASP eutrophication model folders and files

Folder or file name	Description of contents
WASP (folder)	
WASP input development 4_2.xls	This file has the lake morphometric and parameterization data used to develop the WASP model.
UG_CrossSections 2.xls	Contains the cross-sections and profiles of the lake developed from the 2006 lake bathymetry and used to design the WASP lake segments.
daily calibrations6.xls	Contains worksheets and charts for making daily averages out of the hourly averages for observed and predicted values.
hourly calibration2.xls	Contains worksheets and charts for hourly averages for observed and predicted values.
existing day step.OUT	Lists daily time step WASP model inputs for segmentation, coefficients, parameters, and time functions for existing conditions
existing hour step.OUT	Lists hourly time step WASP model inputs for segmentation, coefficients, parameters, and time functions for existing conditions
target hour step.OUT	Lists hourly time step WASP model inputs for segmentation, coefficients, parameters, and time functions for target 90% reductions in internal recycle TP load.
existing day step.wif	WASP daily time step model for existing TP loads.
existing hour step.wif	WASP hourly time step model for existing TP loads.
target hour step.wif	WASP hourly time step model for target 90% reductions for internal recycle TP load.
existing day step.BMD	WASP output for daily time step model for existing conditions.
existing hour step.BMD	WASP output for hourly time step model for existing conditions.
target hour step.BMD	WASP output for hourly time step model for target 90% reductions in internal recycle TP load

Table D30 Load chart spreadsheet files

Folder or file name	Description of contents
daily load rain events.xls	Precipitation data and chart for daily load estimate
load category chart corrected.xls	Data and chart quantifying all load sources
UGLwatershedsummarytotal 2.xls	Data and chart quantifying watershed load sources

Appendix E --- Carlson's Trophic State Index

Carlson's Trophic State Index is a numeric indicator of the continuum of the biomass of suspended algae in lakes and thus reflects a lake's nutrient condition and water transparency. The level of plant biomass is estimated by calculating the TSI value for chlorophyll-a. TSI values for total phosphorus and Secchi depth serve as surrogate measures of the TSI value for chlorophyll.

The TSI equations for total phosphorus, chlorophyll and Secchi depth are:

$$TSI\ (TP) = 14.42\ \ln(TP) + 4.15$$

$$TSI\ (CHL) = 9.81\ \ln(CHL) + 30.6$$

$$TSI\ (SD) = 60 - 14.41\ \ln(SD)$$

TP = in-lake total phosphorus concentration, ug/L

CHL = in-lake chlorophyll-a concentration, ug/L

SD = lake Secchi depth, meters

The three index variables are related by linear regression models and *should* produce the same index value for a given combination of variable values. Therefore, any of the three variables can theoretically be used to classify a waterbody.

Table E1 Changes in temperate lake attributes according to trophic state.

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

(modified from U.S. EPA 2000, Carlson and Simpson 1995, and Oglesby et al. 1987)

Table E2 Summary of ranges of TSI values and measurements for chlorophyll-a and Secchi depth used to define Section 305(b) use support categories for the 2004 reporting cycle.

Level of Support	TSI value	Chlorophyll-a (ug/l)	Secchi Depth (m)
fully supported	<=55	*<=12*	*>1.4*
fully supported / threatened	55 → 65	*12 → 33*	*1.4 → 0.7*
partially supported (evaluated: in need of further investigation)	65 → 70	*33 → 55*	*0.7 → 0.5*
partially supported (monitored: candidates for Section 303(d) listing)	65-70	*33 → 55*	*0.7→ 0. 5*
not supported (monitored or evaluated: candidates for Section 303(d) listing)	>70	*>55*	*<0.5*

Table E3 Descriptions of TSI ranges for Secchi depth, phosphorus, and chlorophyll-a for Iowa lakes.

TSI value	Secchi description	Secchi depth (m)	Phosphorus & Chlorophyll-a description	Phosphorus levels (ug/l)	Chlorophyll-a levels (ug/l)
> 75	extremely poor	< 0.35	extremely high	> 136	> 92
70-75	very poor	0.5 – 0.35	very high	96 - 136	55 – 92
65-70	poor	0.71 – 0.5	high	68 – 96	33 – 55
60-65	moderately poor	1.0 – 0.71	moderately high	48 – 68	20 – 33
55-60	relatively good	1.41 – 1.0	relatively low	34 – 48	12 – 20
50-55	very good	2.0 – 1.41	low	24 – 34	7 – 12
< 50	exceptional	> 2.0	extremely low	< 24	< 7

The relationship between TSI variables can be used to identify potential causal relationships. For example, TSI values for chlorophyll that are consistently well below those for total phosphorus suggest that something other than phosphorus limits algal growth. The TSI values can be plotted to show potential relationships as shown in Figure E1.

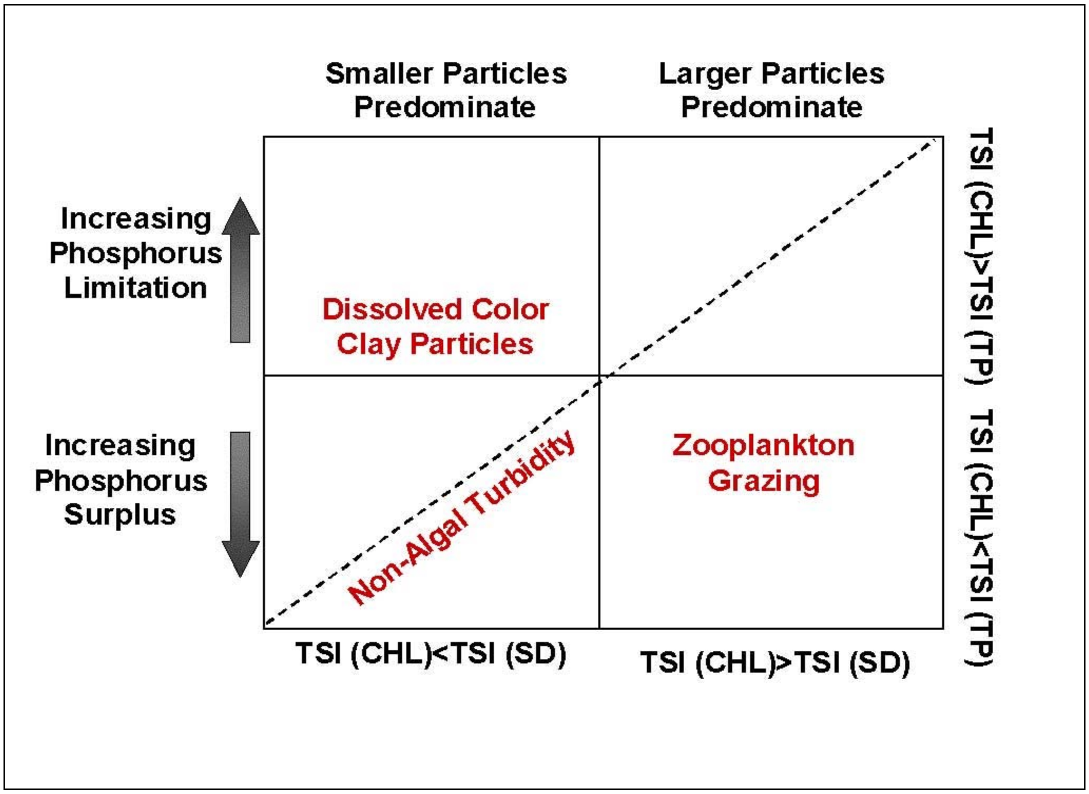


Figure E1 Multivariate TSI Comparison Chart (Carlson)

Appendix F --- Maps

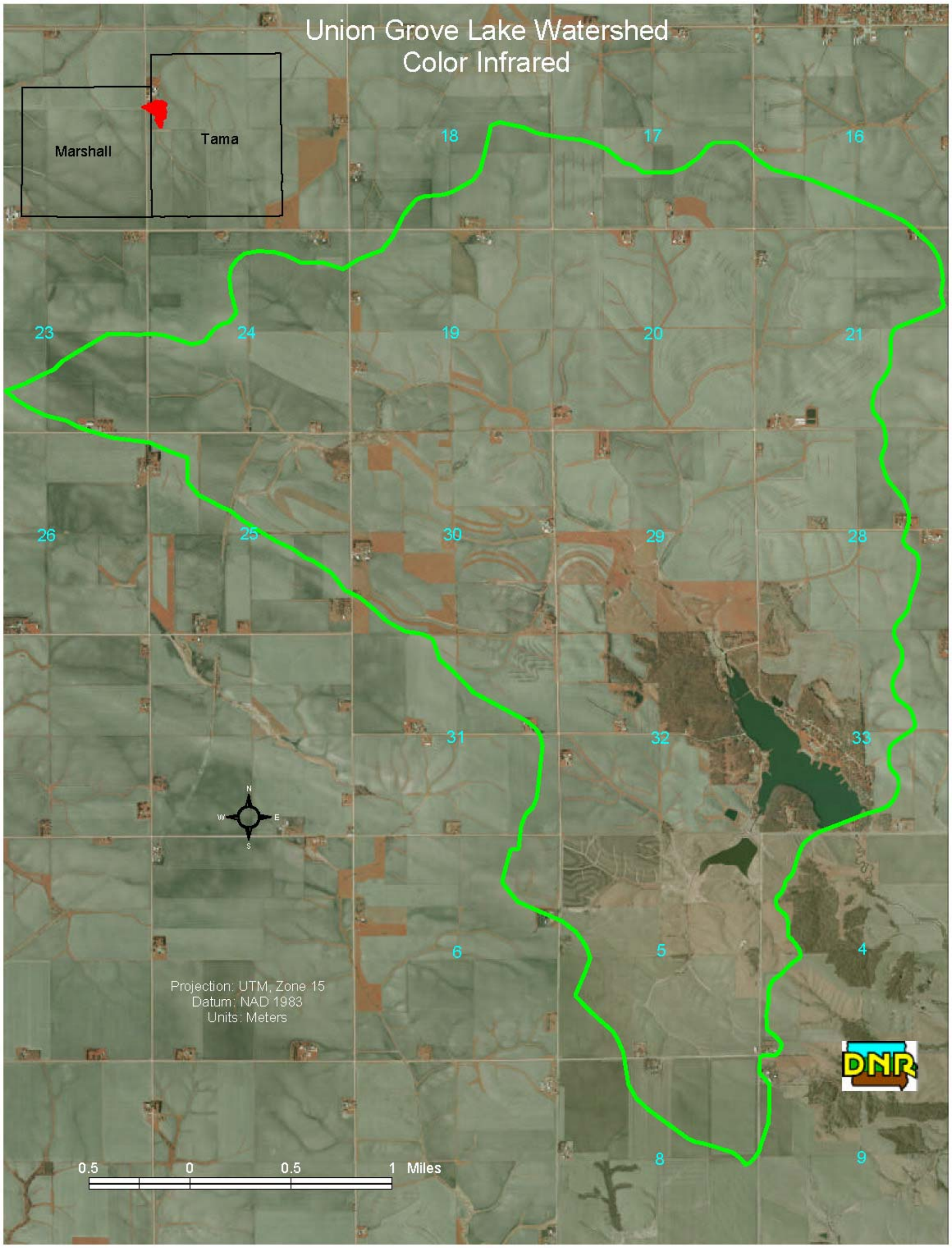


Figure F1 Union Grove Lake watershed in infrared photography

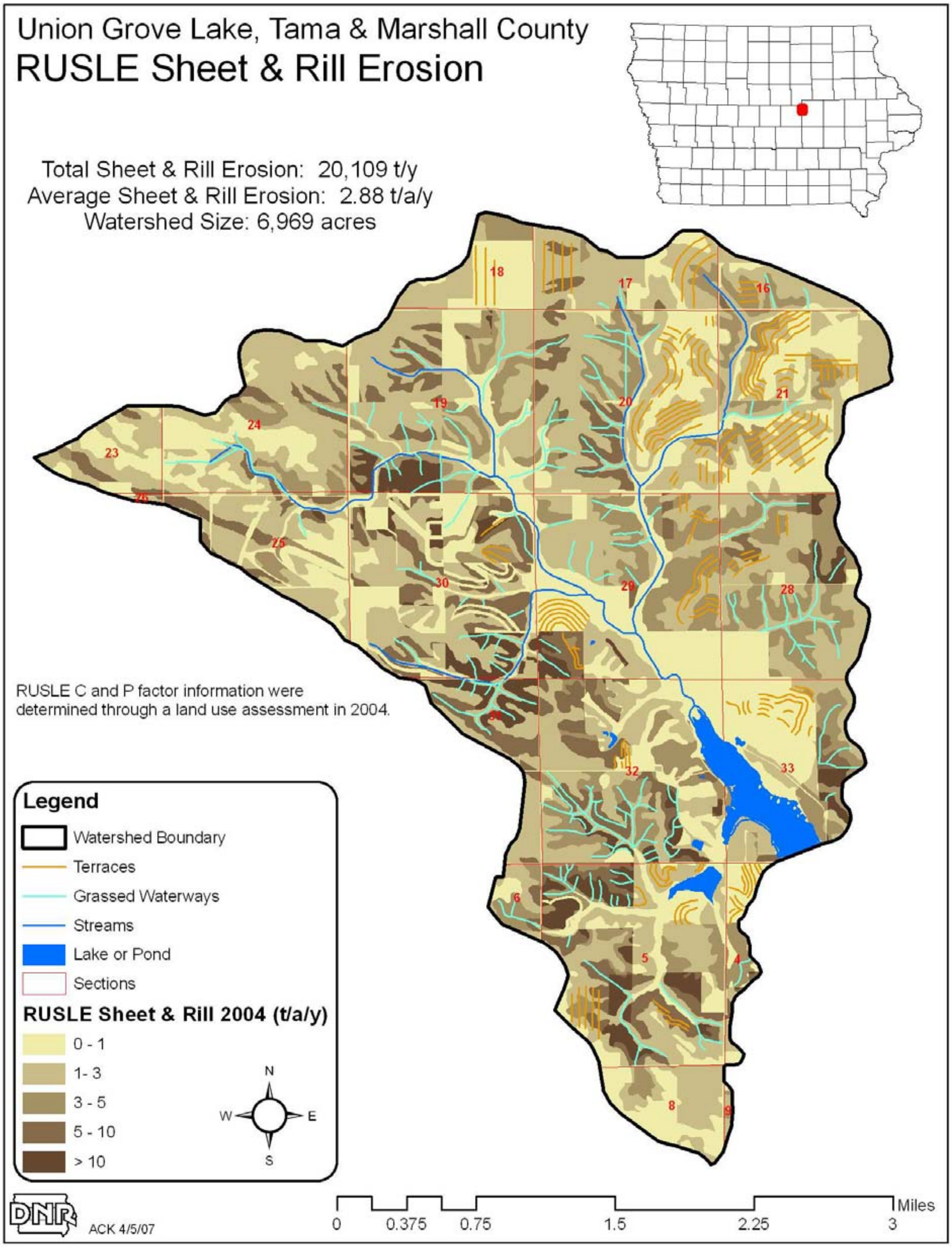


Figure F2 Union Grove Lake watershed sheet and rill erosion

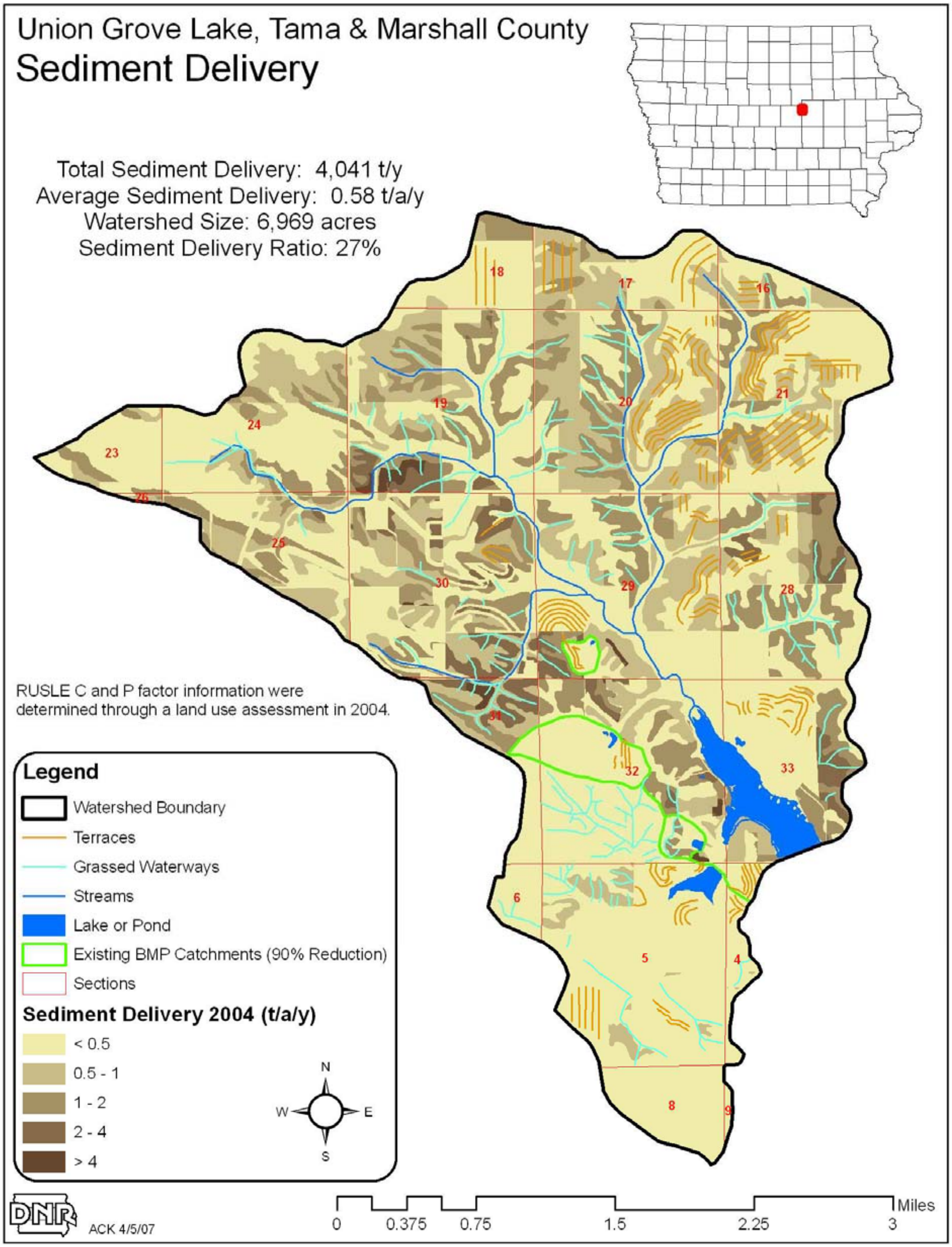


Figure F3 Union Grove Lake watershed average annual sediment delivery

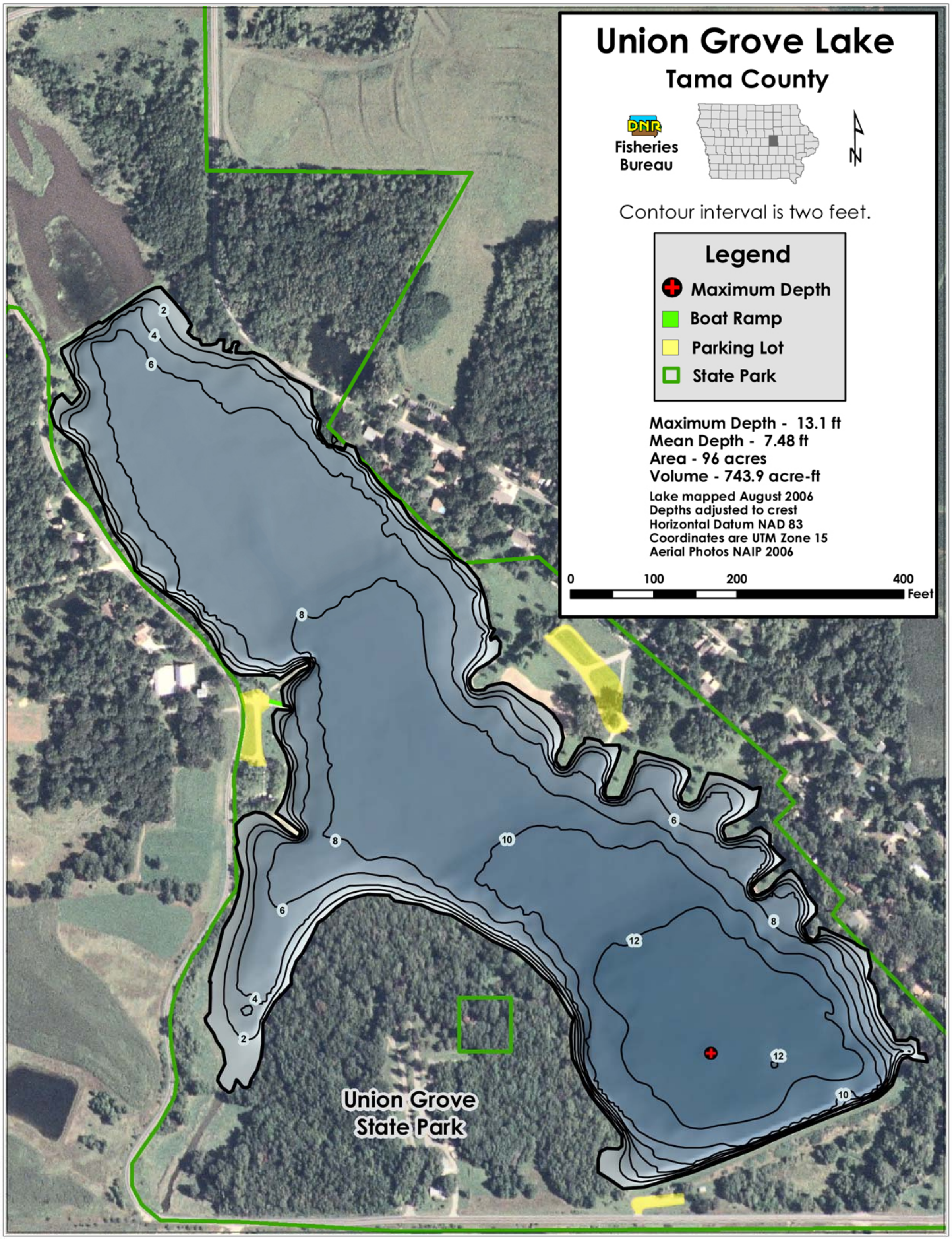


Figure F4 Union Grove Lake bathymetric map

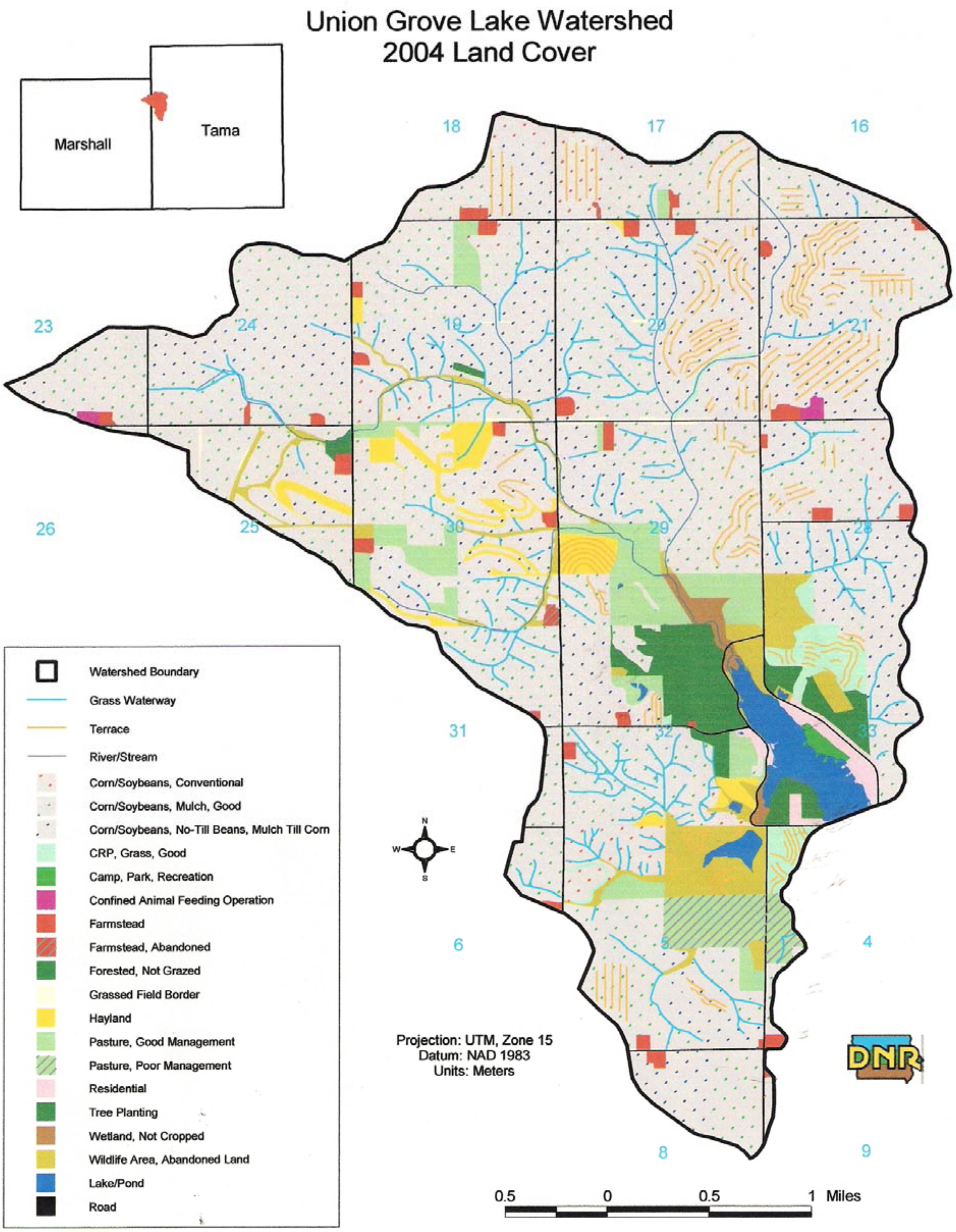


Figure F5 2004 watershed assessment land use map

Appendix G --- Water Quality Assessments – 2008 305(b) Report

The 2008 305(b) water quality assessments for Union Grove Lake are found below. They describe the rationales behind the finding that the primary contact recreation and aquatic life uses are not fully supported. There are separate assessments for the algae/turbidity and pathogen indicator impairments.

Algae/turbidity 305(b) Assessment

Results from the ISU and UHL lake surveys suggest that the Class A1 uses at Union Grove Lake are "not supported." Using the median values from these surveys from 2002 through 2006 (approximately 22 samples), Carlson's (1977) trophic state indices for Secchi depth, chlorophyll a, and total phosphorus were 71, 70, and 68 respectively for Union Grove Lake. According to Carlson (1977) the Secchi depth and chlorophyll a values place Union Grove Lake in the hypereutrophic category, while the total phosphorus value places Union Grove Lake in between the eutrophic and hypereutrophic categories. These values suggest very high levels of chlorophyll a and suspended algae in the water, very poor water transparency, and high levels of phosphorus in the water column.

The level of inorganic suspended solids is very high at Union Grove Lake and suggests that non-algal turbidity contributes to the impairment. The median inorganic suspended solids concentration at Union Grove Lake was 9.4 mg/L, which was the 24th highest of the 132 monitored lakes.

Data from the 2002-2006 ISU and UHL surveys suggest a moderately large population of cyanobacteria exists at Union Grove Lake that also may contribute to the impairment at this lake. These data show that cyanobacteria comprised 79% of the phytoplankton wet mass at this lake. The median cyanobacteria wet mass (32.9 mg/L) was also the 35th highest of the 132 lakes sampled.

The Class B(LW) (aquatic life) uses are assessed (monitored) as "partially supported" due to violations of the state's criterion for pH. High levels of algae and inorganic turbidity also remain water quality concerns at this lake. Data from the ISU and UHL lake surveys show that during 2002-2006 there was one violation of the Class B(LW) criterion for ammonia in 15 samples. Based on IDNR's assessment methodology, a single violation of the ammonia criterion does not suggest impairment of the Class B(LW) uses. There was one violation of the Class B(LW) criterion for dissolved oxygen in 22 samples (5%). Based on IDNR's assessment methodology this violation is not significantly greater than 10% of the samples and therefore does not suggest impairment of the Class B(LW) uses. There were, however, 5 violations of the pH criterion in 22 samples (23%). These violations are significantly greater than 10% of the samples and therefore do *indicate an impairment (partial support/monitored) of the Class A1 and Class B(LW) uses at Union Grove Lake.*

Physical/chemical data from the IDNR-UHL beach monitoring program also indicate that the Class B(LW) uses at Union Grove Lake should be assessed "partially supported" due to violations of the pH criterion. Using beach monitoring data from 2004, 2005, and 2006, there was one violation of the Class B(LW) criterion for dissolved oxygen in 69 samples (1%), and 12 violations of the pH criterion in 69 samples (18%). The violations of the pH criterion are significantly greater than 10% of the samples and therefore suggest impairment (partial support/monitored) of the Class A1 and Class B(LW) uses at Union Grove Lake.

Pathogen Indicator (E. coli) 305(b) Assessment

The Class A1 (primary contact recreation) uses are assessed (monitored) as "not supported" due levels of indicator bacteria that exceed the state water quality criteria, violations of the state's pH criterion, and also due to poor water transparency and nuisance algae blooms that violate Iowa's narrative water quality standard protecting against aesthetically objectionable conditions. The Class B(LW) (aquatic life) uses are assessed (monitored) as "partially supported" due to violations of the state's criterion for pH. The high levels of algae and inorganic turbidity remain water quality concerns at this lake. Fish consumption uses are "not assessed" due to lake of fish tissue monitoring at this lake. Sources of data for this assessment include (1) results of the statewide survey of Iowa lakes conducted from 2002 through 2006 by Iowa State University (ISU), (2) results of the statewide ambient lake monitoring program conducted from 2005 through 2006 by University Hygienic Laboratory (UHL), (3) information from the IDNR Fisheries Bureau, and (4) results from the IDNR-UHL beach monitoring program in 2004, 2005, and 2006.

Results of IDNR beach monitoring from 2004 through 2006 suggest that the Class A1 uses are "not supported." Levels of indicator bacteria at Union Grove Lake beach were monitored once per week during the primary contact recreation seasons (May through September) of 2004 (22 samples), 2005 (23 samples), and 2006 (28 samples) as part of the IDNR beach monitoring program. According to IDNR's assessment methodology, two conditions need to be met for results of beach monitoring to indicate "full support" of the Class A1 (primary contact recreation) uses: (1) all thirty-day geometric means for the three-year assessment period are less than the state's geometric mean criterion of 126 E. coli orgs/100 ml and (2) not more than 10 % of the samples during any one recreation season exceeds the state's single-sample maximum value of 235 E. coli orgs/100 ml. If a 5-sample, 30-day geometric mean exceeds the state criterion of 126 orgs/100 ml during the three-year assessment period, the Class A1 uses should be assessed as "not supported". Also, if significantly more than 10% of the samples in any one of the three recreation seasons exceed Iowa's single-sample maximum value of 235

E. coli orgs/100 ml, the Class A1 uses should be assessed as "partially supported." This assessment approach is based on U.S. EPA guidelines (see pgs 3-33 to 3-35 of U.S. EPA 1997b).

At Union Grove Lake beach, the geometric means of 17 thirty-day periods during the summer recreation seasons of 2004, 2005 and 2006 exceeded the Iowa water quality standard of 126 E. coli orgs/100 ml: 15 of 18 geometric means violated in 2004, 2 of 19 geometric means violated in 2005, and 0 of 24 geometric means violated in 2006. Also, the percentage of samples exceeding Iowa's single-sample maximum criterion (235 E. coli orgs/100 ml) was significantly greater than 10% in 2004: 55%. The percentage of samples exceeding the single-sample maximum criterion was not significantly greater than 10% in 2005 (13%) or 2006 (7%). According to IDNR's assessment methodology and U.S. EPA guidelines, these results suggest impairment (nonsupport) of the Class A1 (primary contact recreation) uses.

Union Grove Lake was sampled as part of IDNR's Safe Lakes Program, which aims to identify sources of bacteria to selected beaches where bacteria levels have consistently violated the state water quality criteria. The Safe Lakes Program was not able to identify the sources of bacteria to Union Grove Lake. However, a "beach groomer" was purchased and used at this lake to remove goose droppings. This new procedure is expected to decrease bacteria levels at this beach in the future.

Appendix H --- Public Comments

IDNR received one public comment during the public comment period for the Union Grove Lake TMDL.

Berckes, Jeff [DNR]

From: Bro, Melody - Toledo, IA [melody.bro@ia.nacdnet.net]
Sent: Monday, June 29, 2009 3:25 PM
To: Berckes, Jeff [DNR]
Cc: kasal@netins.net; mjsnider@traer.net; jbruene@iowatelecom.net; mckenna4@fctc.coop; Jones, Larry.E - Toledo, IA
Subject: Union Grove TMDL

Follow Up Flag: Follow up
Flag Status: Completed

Drawing from farm visits with nearly all of the watershed's owners or operators, here are my comments:

Figure 8: There are NO row crops grown in the watershed with conventional tillage.

Figure 8: Does "conservation till" incorporate both minimum tillage and no-till? I can come up with exact figures if you need them, but the vast majority of row crops in the watershed are no-tilled.

Table 16: Having made contact with all of the cattle producers in the watershed, I believe a generous beef head number is actually less than 300, not nearly 400.

Table 16: There are no dairy cattle in the watershed.

Thanks for coming on the 15th to enlighten us. You did a nice job!

Melody A.C. Bro
Union Grove Lake Watershed Coordinator
Tama SWCD
102 Hwy 30 West Toledo, IA 52342
641/484-2702, ext. 120 melody.bro@ia.nacdnet.net
www.iowadnr.gov/water/watershed/uniongrove/

Berckes, Jeff [DNR]

From: Bro, Melody - Toledo, IA [melody.bro@ia.nacdnet.net]
Sent: Monday, June 29, 2009 3:36 PM
To: Berckes, Jeff [DNR]
Cc: kasal@netins.net; mjsnider@traer.net; jbruene@iowatelecom.net; mckenna4@fctc.coop; Jones, Larry.E - Toledo, IA
Subject: Union Grove TMDL

Follow Up Flag: Follow up
Flag Status: Completed

Jeff:

I forgot one other comment re: the beef cattle, many of them are in the watershed for only a few months of the year. Also, at least one producer hauls his lot manure outside of the watershed to spread it on his fields.

Melody A.C. Bro
Union Grove Lake Watershed Coordinator
Tama SWCD
102 Hwy 30 West Toledo, IA 52342
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www.iowadnr.gov/water/watershed/uniongrove/

July 7, 2009

Mel Bro
Union Grove Lake Watershed Coordinator
Tama SWCD
102 Hwy 30 West
Toledo, IA 52342
641-484-2702 ext. 120

Dear Ms. Bro:

The following is a response to comments received via e-mail on June 29, 2009:

Drawing from farm visits with nearly all of the watershed's owners or operators, here are my comments:

> *Figure 8: There are NO row crops grown in the watershed with conventional tillage.*
>
> *Figure 8: Does "conservation till" incorporate both minimum tillage and no-till? I can come up with exact figures if you need them, but the vast majority of row crops in the watershed are no-tilled.*
>
> *Table 16: Having made contact with all of the cattle producers in the watershed, I believe a generous beef head number is actually less than 300, not nearly 400.*
>
> *Table 16: There are no dairy cattle in the watershed.*
>
> *(subsequent e-mail) I forgot one other comment re: the beef cattle, many of them are in the watershed for only a few months of the year. Also, at least one producer hauls his lot manure outside of the watershed to spread it on his fields.*

IDNR Response

We appreciate your comments and excellent work towards improving Union Grove Lake water quality. It sounds as though practices in the watershed are moving in the right direction thanks to your efforts.

Cropping practices and the numbers of livestock in the watershed are a moving target, often changing year to year and month to month. We do the best we can with the data available at the time. The differences you mention would have a minor impact on the conclusions of the TMDL and numbers and practices might be different next year as watershed conditions change. The following are more specific responses to your comments.

The tillage practices used for the modeling were obtained from a 2004 field assessment done by Charlie Kiepe, a former NRCS employee.

The watershed modeling was done in 2007 based on the Kiepe assessment. The department assumes that tillage practices change over time with different rotations as does land use. Both may be different two or three years from now. In Figure 8 the conventional tillage represents only 18 percent of the row crop phosphorus load and 8 percent of the entire phosphorus load to the lake. Were this to be no till, all other factors being equal, the change in phosphorus load would be a reduction of from 1 to 4 percent depending on which of the seven subbasins the row crop was in.

One of the big advantages of developing separate subbasin GWLF models was the capability of using different sediment delivery ratios (SDR) for each based on ecoregion and other factors rather than a single SDR for the whole watershed. This has a much more significant impact on modeling results than tillage practices since the SDR ranges from 13 to 27 percent rather than the straight 27 percent used for the RUSLE modeling.

For the bacteria modeling, the livestock counts are entered as a combination of manure applied to simplified landuses at different times of the year and the fraction of time grazing cattle spend in pasture, confined, and in the stream. Bacteria delivery to the lake is similar in concept to soil loss in that only a fraction of the organisms available for washoff from pasture and cropland are delivered to the lake.

The livestock numbers used were estimates from Cal Wolter of the IDNR GIS section and are based on his evaluation of county agricultural statistics and aerial coverages of watershed buildings and landuse. Livestock numbers can easily fluctuate 20 or 30 percent year to year and for modeling we tend to lean towards more conservative figures, i.e., using the larger annual average estimates. The difference noted in overall numbers of livestock would have a minor impact on bacteria delivered to the lake during the recreation season since it is assumed that most manure is applied to fields in the late fall. Due to your information regarding cattle numbers, we have removed the dairy cattle estimates from our calculations and added the same number to beef cattle. The information can be found listed in Table 16 on page 42.

Thank you again for your comments. If you have further questions, I can be reached at 515-281-5917.

Sincerely,

William Graham, TMDL Project Manager
Watershed Improvement Section