Water Quality Improvement Plan
for

Blue Lake

Monona County, Iowa

Total Maximum Daily Load
for Algae and Turbidity

Iowa Department of Natural Resources
Watershed Improvement Section
2008

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General Report Summary

What is the purpose of this report?

This report has two purposes. First, it is a resource to be used by watershed planners, water quality improvement groups, individual citizens, and local, county and state government staff. This document can serve as a guide to help these groups understand and identify how excessive algae and lack of clarity cause Blue Lake's water quality problems. Second, this report satisfies the Federal Clean Water Act requirement to establish a Total Maximum Daily Load (TMDL) for waterbodies on the impaired waters list.

What is wrong with Blue Lake?

Blue Lake is impaired by excessive growth of algae, a lack of clarity caused by this algal growth, and non-algal turbidity. These problems combine to reduce the recreational use of the lake.

What is causing the problem?

The nuisance algae growth is caused by excessive nutrients, mostly phosphorus, which is delivered to the lake from nonpoint sources in the watershed. Phosphorus is the limiting nutrient for algal growth in Blue Lake. Much of the phosphorus comes from geese, septic tanks, row-crop land use, groundwater pumping that supplements lake inflow and helps maintain water level, and internal recycling of sediment stirred up by carp and waves.

What can be done to improve Blue Lake?

The number of geese at Blue Lake needs to be reduced and septic tanks need to be inspected and repaired as necessary. The recycling of phosphorus from lake bottom sediment by carp and wave turbulence should be minimized. Agricultural practices need to be modified to minimize erosion and the phosphorus content of eroded soil.

Who is responsible for a cleaner Blue Lake Water Quality?

There is not a sole source of the phosphorus causing the algae and clarity problems in Blue Lake. IDNR and other state and federal agency staff are collaborating to understand pollutant sources and searching for solutions to these water quality problems. However, everyone that lives, works, and recreates in the watershed is responsible for correcting the problem. When unregulated sources are the major contributors, water quality improvements happen when concerned citizens and landowners adopt voluntary changes to contributing sources.

Required Elements of the TMDL

This TMDL 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:	Blue Lake, located in west central Monona County, 3 miles west of Onawa, Latitude: 42.0463094 Longitude: -96.1576176 T84N R46W S35
Use designation classes:	Class A1 Primary Contact Recreation Class B (LW) Aquatic Life
Impaired beneficial uses:	Primary Contact Recreation (A1)
Identification of the pollutants and applicable water quality standards:	Class A1 Primary Recreational use has been assessed as not supported due to aesthetically objectionable conditions caused by algae and turbidity. The TMDL target is a Carlson's Trophic State Index (TSI) of less than 65 for both chlorophyll a and Secchi depth. These TSI values are equivalent to a chlorophyll concentration of 33 µg/l and a Secchi depth of 0.7 meters. The total phosphorus (TP) concentration target of 58 µg/l has been related to chlorophyll and Secchi depth by BATHTUB lake nutrient modeling.
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	The cause of the nuisance algal blooms is excessive TP. The mass of phosphorus that can be delivered to the lake and still maintain water quality is 1,126 lbs/year. The maximum allowable daily load is 24.1 lbs/day.
Quantification of the amount or degree by which the current pollutant loads in the waterbody, including the pollutants from upstream sources that are being accounted for as background loading, deviate from the pollutant loads needed to attain and maintain water quality standards:	The existing mean values for Secchi depth, chlorophyll and total phosphorus, based on 2000 to 2006 sampling, are 0.4 meters, 46 µg/l and 98 µg/l, respectively. A minimum in-lake increase in Secchi transparency of 75% and minimum in-lake reductions of 25% for chlorophyll a and 41% for TP are required to achieve and maintain water quality goals and protect for beneficial uses. The estimated existing annual TP load to Blue Lake from all sources is 2,661 lbs/year. Based on watershed and lake modeling load capacity is 1,126 lbs/yr. The required total load reduction is 1,535 lbs/year for TP sources.

Identification of pollution source categories:	Nonpoint TP loads have been identified as the cause of impairment to Blue Lake.
Wasteload allocations for pollutants from point sources:	There are not any permitted point sources in the watershed so the WLA is zero.
Load allocations for pollutants from nonpoint sources:	The annual TP load allocation is 1069.9 lbs/yr. The daily TP load allocation is 21.7 lbs/day.
A margin of safety:	The margin of safety for annual and daily maximum loading is an explicit 10 percent of the modeled allowable loads.
Consideration of seasonal variation:	TMDL development is based on an annual phosphorus loading that will result in attainment of TSI targets for the growing season (May through September).
Allowance for reasonably foreseeable increases in pollutant loads:	An allowance for increased phosphorus loading was not included in this TMDL. The Iowa Department of Natural Resources owns and maintains the entire shoreline around Blue Lake. Much of the watershed is in forest, grass and wetlands (39%) and most of the rest is in agricultural production, with row-crop predominating. A significant change in watershed land use is unlikely.
Implementation plan:	Section 4 of this document is a general implementation plan intended to guide local citizens, government agencies, and water quality improvement 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. Waters that do not meet the Iowa Water Quality Standards criteria are identified from this report and placed on the 303(d) Impaired Waters List. A pollutant Total Maximum Daily Load (TMDL) must be calculated and a report written for each water body on the impaired waters list.

A TMDL is a calculation of the 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 includes an allowance for a margin of safety to account for uncertainty in the TMDL calculation.

This TMDL report is for Blue Lake in Monona County, Iowa. Blue Lake is on the 2004 impaired waters list for algae and turbidity problems resulting from excess phosphorus triggering algal blooms and inorganic suspended solids. Phosphorus is the nutrient that limits excess algal growth.

There are two primary purposes of this report: 1) to satisfy federal requirements of a Total Maximum Daily Load for impaired waters, and 2) to serve as a resource for guiding water quality projects in the Blue Lake watershed addressing algae and turbidity problems. Local citizens, water quality groups, and government agencies will find it a useful description of the causes and solutions to Blue 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.

2. **Description and History of Blue Lake**

Blue Lake is a Missouri River oxbow lake located in western Monona County three miles west of Onawa and three miles east of the Missouri River. The lake was an active channel of the Missouri River in 1804 when the Lewis and Clark expedition went through the area. The lake shoreline is now part of Lewis and Clark State Park, which includes a campground with modern restrooms and showers and a swimming beach.

The meander loop that is Blue Lake was cut off some time between 1804 and 1852 when a survey showed the river channel west of what is now Blue Lake. It is most likely that Blue Lake was cutoff around 1833. The Missouri River had changed by 1879 from a single meandering channel to a semi-braided stream with a channel bed elevation and flood plain lower and narrower than the older broader flood plain of the meandered river. The difference in elevation between the older flood plain and the more recent one is 10 to 12 feet.

Table 2. Blue Lake Information

Waterbody Name	Blue Lake
8 Digit Hydrologic Unit Code (HUC):	10230001Missouri River-Soldier River
12 Digit (HUC)IA:	596
IDNR Waterbody ID	IA 06-WEM-00445-L
Location	Monona County
Latitude	42.0463094
Longitude	-96.1576176
Water Quality Standard Designated Uses	Class A1 Recreational Class B (LW) Aquatic Life
Tributaries	Oxbow Lake
Receiving Waterbody	Oxbow Lake
Lake Surface Area	264 acres
Maximum Depth	9.8 feet
Mean Depth	4.6 feet
Volume	1215 acre-feet
Length of Shoreline	10.4 miles
Watershed Area (with lake)	5291 acres (5,027 without the lake)
Watershed/Lake Area Ratio	19:1
Lake Detention Time[1]	0.32 years (117 days) from watershed model, pumping, ditch
Lake Detention Time[1]	0.30 year (110 days) at outlet, regression model

1. There is no obvious outlet for Blue Lake. Inflow from the watershed and pumping is lost mostly through seepage and evaporation.

2.1. Blue Lake

Blue Lake was studied in some detail in the 1970s and early 1980s and a major restoration effort was undertaken beginning in 1980. This effort included dredging, pumping of supplemental water from groundwater not connected hydraulically to the lake, and the introduction of grass carp (White Amur) to control aquatic vegetation.

Blue Lake has been dredged twice, first in 1951 and then again in 1980. Both times the dredging deepened the lake but did not increase its surface area. The 1951 dredging removed 413,000 cubic yards of material over an area of 77 acres. The 1980 dredging removed 370,000 cubic yards from a 50-acre area.

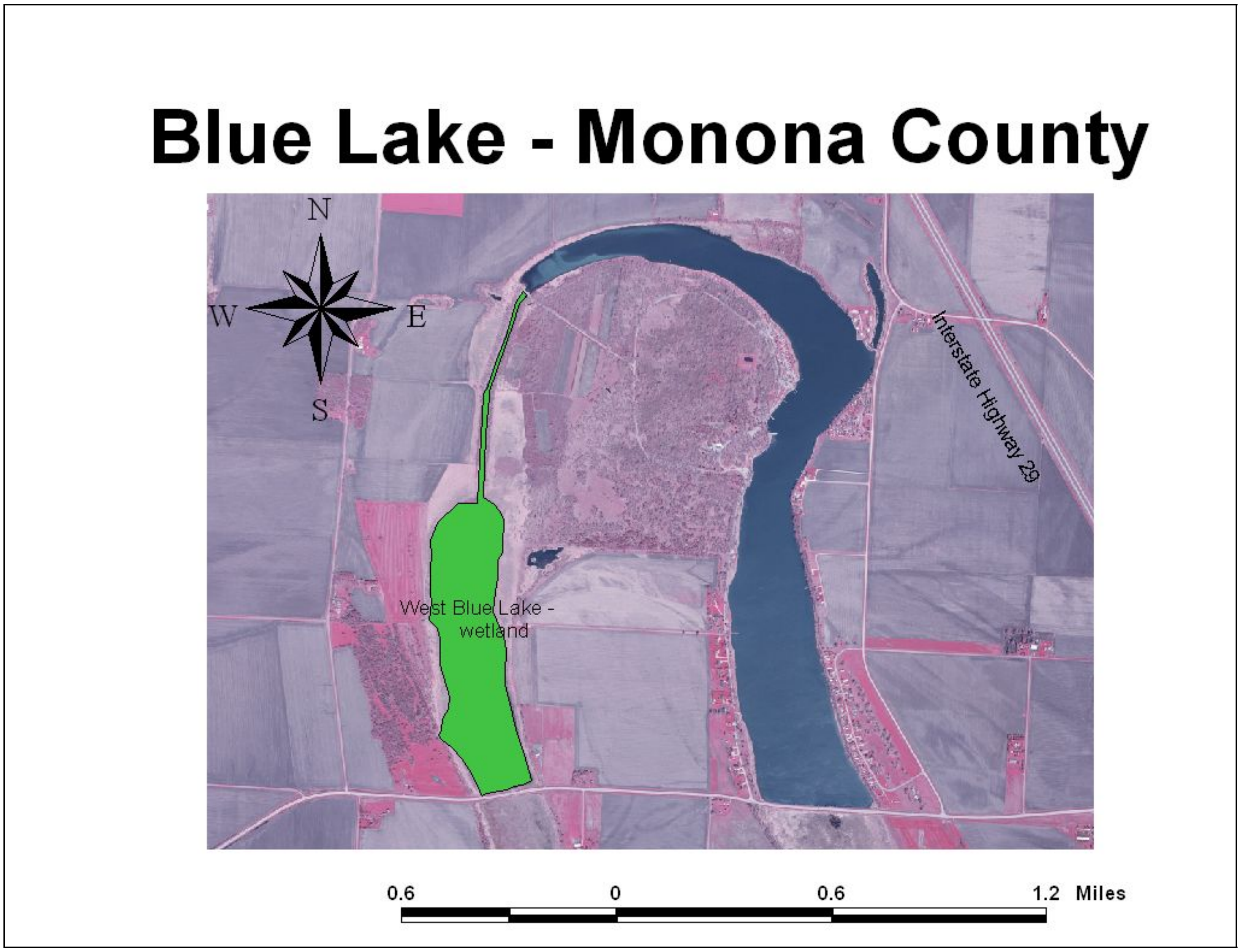

Figure 1 Blue Lake - 2002 photo

Morphology and Hydrology.
Blue Lake is an oxbow that in the past (150 years ago) was the main channel of the Missouri River. Today it is a hook shaped water body (see Figure 1) with relatively impermeable bottom materials in the north and more permeable bottom materials to the south.

Because Blue Lake is perched above the water table during dry periods and experiences significant seepage loss, there is often not enough flow from groundwater, direct precipitation, or surface runoff to maintain desired lake water levels. The water table has been affected over the years by the degradation of the Missouri River channel and withdrawals for irrigation.

There is not a direct surface lake outlet. There are sand point bars at the south side of the place where the lake bends around from a west-east to a north-south alignment. These point bars are where most outflow seepage occurs. The dilemma with keeping the lake at the desired level (1041 feet MSL) is that as the water surface rises above 1039 feet MSL, more and more of the bottom becomes leaky sand.

The bottom of Blue Lake consists of silt and clay layers varying in thickness from nine feet to a few inches. The south and west shorelines are point bar sands that are 70 feet thick. The northern shore of the lake is silts and clays 20 feet deep and extending 1200 feet wide. The thick silt and clay lake bottom in the north also prevents recharge from groundwater seepage when the water table is elevated. The more permeable lake bottom in the south allows recharge into the lake when the water table is high and seepage out of the lake when the water table is low.

A review of the pumping records for the groundwater well used to supplement the lake inflow shows that pumping is unnecessary in wet years to maintain the desired water surface elevation of 1041 feet MSL. In years of average precipitation, it is possible to maintain an elevation of 1041 feet with the supplemental pumping. In dry and drought years, even with supplementary pumping, a maximum water surface of only 1038 or 1039 feet is possible.

Water Quality.
One of the most striking observations related to Blue Lake water quality occurred in the 1970s and early 1980s when the water quality as measured by algae, transparency and nutrient concentration was comparable to high quality lakes in Iowa. Table 3 shows Blue Lake water quality data from 1977 compared to that recently sampled.

Table 3 Comparison of 1977 and current water quality

Year	1977 annual mean	2000-2006 mean
Chlorophyll, µg/l	4.8	44
Secchi depth, meters	1.5	0.41
Total phosphorus, µg/l	26	87

There are two important differences between the 1977 and 2006 lake conditions. These are the loss of aquatic plants through the introduction of grass carp and the presence today of large numbers of geese. The aquatic plants would have taken up much of the available phosphorus, thus limiting the growth of algae and improving water clarity.

2.2. The Blue Lake Watershed

The estimated Blue Lake watershed consists of 5,027 acres. However, since the lake is in the historic floodplain of the Missouri River and most of the drainage in the surrounding region has been controlled and significantly altered for various purposes, the actual area that drains into the lake as defined by basin "divides" varies. This variation depends on how the basin is delineated and the assumptions made. The watershed and lake area also fluctuate as the water surface elevation goes up and down. Figure 2 shows the basin boundary assumed for this report. A section of the modern Missouri River channel is shown in the lower left corner of the map.

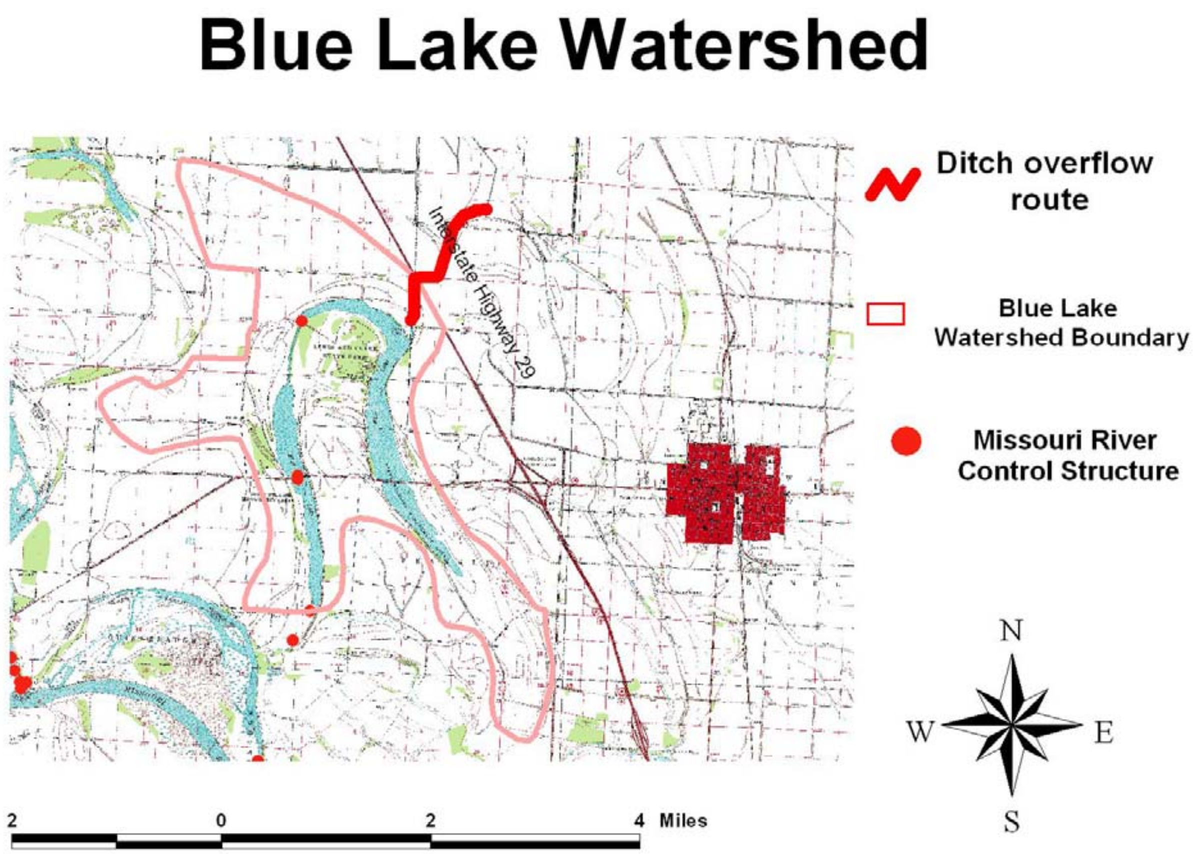

Figure 2 The Blue Lake watershed and showing I-29 and the City of Onawa

The water shown to the west of Blue Lake in Figure 2 is called West Blue Lake, but it has become a wetland even in the wettest conditions. It is not considered a source or outlet in this report, although there is a hydraulic connection to Blue Lake.

Figure 3 West Blue Lake, now a wetland, looking north at Highway 175 (Photo by Ed Weiner, IDNR)

One of the important sources of lake inflow occurs when there is significant regional rainfall. This can cause one of the major drainages, the McCandless-Cleghorn Ditch, to exceed its drainage capacity. When this happens, the ditch backs up into its tributaries causing them to rise. Eventually the water surface rises high enough to cause the Blue Lake inflow seen in Figures 4 and 5.

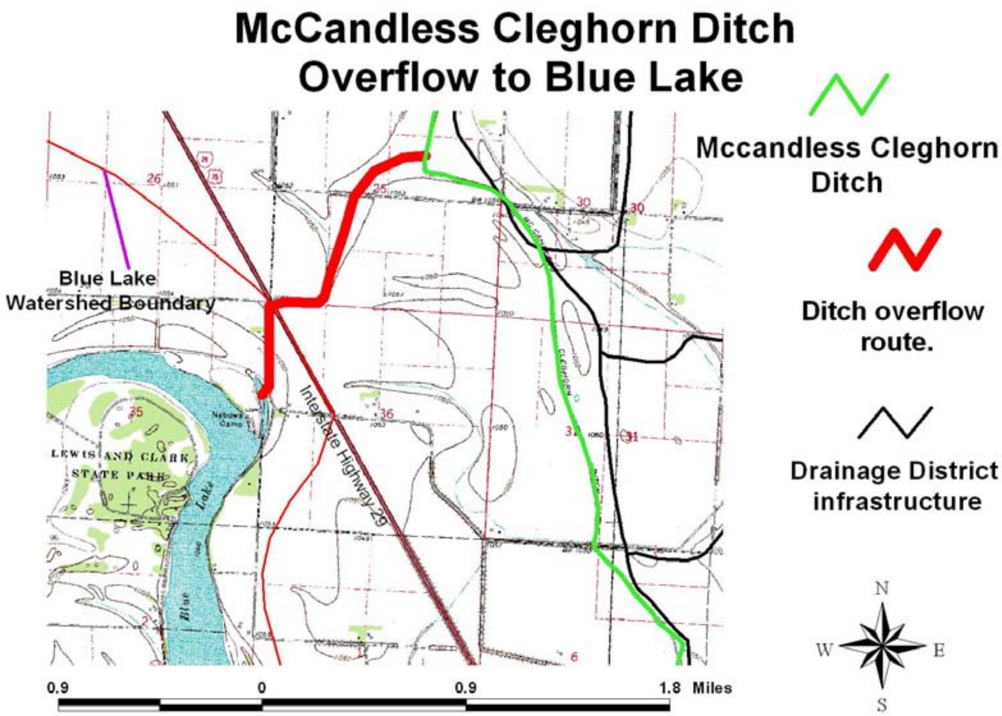

Figure 4 Route of McCandless Cleghorn Ditch overflow to Blue Lake

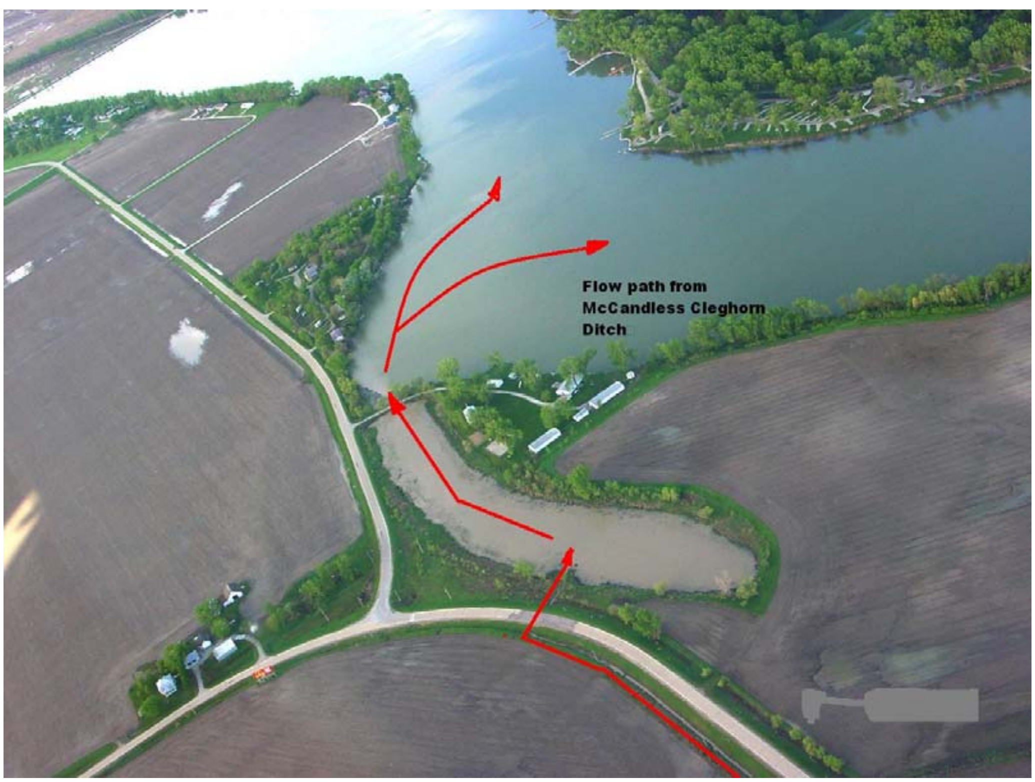

Figure 5 Photo taken in 2001 of McCandless Cleghorn Ditch backing up into Blue Lake (Photo by Ed Weiner, IDNR)

Land Use.
Land uses in the Blue Lake watershed are shown in Table 4. Slightly over half of the immediate watershed is in row crops. These land uses have been incorporated into the GWLF/BasinSims watershed model. The residential land use is made up of homes immediately adjacent to the lake.

Table 4. Land use in the Blue Lake Watershed

Land Uses from Assessment[1]	Area, acres	Percent of total
Water	488	9%
Forest	362	7%
Ungrazed grassland and CRP	1,192	23%
Grazed grassland	258	5%
Alfalfa	56	1%
Corn	1,509	29%
Soybeans and other row crops	1,242	23%
Roads	103	2%
Residential	80	2%
Total	**5,290**	**100%**

1. These nine land uses have been consolidated from the fifteen in the 2002 assessment.

Climate, topography, and soils.
The mean annual air temperature is 49 degrees F (10 degrees C) and the mean annual precipitation is 29 inches (889 millimeters). The elevation change from the highest area of the watershed in the northwest (1055 feet MSL) to the lake surface is about 15 feet over a length of 1.2 miles for an average slope of 0.2 percent. This is very flat topography typical of river floodplains. Much of the elevation drop occurs in the 1000 feet closest to the lake.

The soils and geology of Blue Lake and its watershed have been described in the 1977 document prepared by Greg Ludvigson of the Iowa Geological Survey, *Report of Investigation –Hydrogeology of Blue Lake –Monona County, Iowa*.

> *As is the case in most alluvial systems, the Missouri River alluvium consists of a vertical column of unconsolidated earth materials that generally become progressively coarser grained downward. Fine grained silts and clays comprise the upper portion of this sequence. Their thickness varies from 0 to 25 feet. Beneath the silts and clays are coarse to fine grained sands. Where no silts and clays are present at the surface, these sands are the surficial materials. At the base of the sequence, at depths ranging from 60 to 200 feet, are gravels, which are interstratified with coarse to fine grained sands. These deposits are related to certain alluvial environments. The gravels and coarse sands are channel lag deposits. They are remnant sediments where finer grained materials have been winnowed by currents in active scouring channels. The relatively uniform coarse to fine sands are accretion or bar deposits. They are deposited in areas of slower moving water in an active channel. The silts and clays can either be overbank flood deposits or channel fill deposits. In the latter case, they represent the*

materials that are deposited in cutoff meanders or oxbow lakes or other types of remnant channels.

This vertical sequence of deposits have been obliterated by erosion and redeposited countless times within the active meander belt of the Missouri River. Although variations of tens of feet exist locally, the silts and clays, sands, and gravels and sands may be regarded as sheet-like deposits layered in an orderly sequence.

At Blue Lake, this sequence has been modified by the relatively recent channel that cut the Blue Lake basin. Comparisons of old maps and the present land surface configuration…indicate that this channel was active before 1804 and cut-off between 1804 and 1852. Sedimentation of the lake basin has been an active process since that time. Oxbow lakes are generally ephemeral features, and as such, Blue Lake is considered quite long-lived. Eutrophication and lakebed siltation are natural processes that will eventually fill Blue Lake.

The cut-bank scarps, which are remnant-eroded banks, show the maximum extent of outward cutting in the former meandering channel, which was cut off to form Blue Lake. Bar sands are exposed at the surface as sandy soils. These materials were deposited by accretion on the inside edge of the curving channel. Where the sands are exposed at the surface, they are continuous in the subsurface downward to the top of the basal gravels. Within the Blue Lake meander, the basal gravels are encountered at a generally higher stratigraphic level than gravels outside of the meander. These gravels were probably deposited by the migrating channel that cut the Blue Lake basin. Silts and clays comprise the surficial materials over most of the Blue Lake area. In most places, they form a relatively thin veneer of overbank flood deposits. Locally they thicken where they have filled former channels.

Within the Blue Lake basin, the thickness of the channel fill silts and clays appears to vary gradationally from north to south. At the north end of the lake basin, most distant from the meander cutoff, the silts and clays appear to attain their maximum thickness, about 25 feet. At the south end of the basin , that portion closest to the cutoff site, the silts and clays thin to as little as 6 feet. At an intermediate site immediately south of the Highway 175 embankment, the maximum thickness measured was 9 feet. …the thickness of the silts and clays beneath the lake increase from about 10 feet at the Highway 175 embankment to 20 feet at the north end of the lake. Locally, where the bar sands are exposed along the lake shoreline, there are no silts and clays beneath the lake.

The Iowa State University Engineering Research Institute also did work on the geology and hydrology of Blue Lake in 1977 in conjunction with the Iowa Geological Survey (Lohnes et al, 1977). The geomorphic cross sections of the lake are in Appendix F.

A significant part of the Blue Lake watershed consists of point bar sands that have a high infiltration rate as shown in Figure 6. This reduces the runoff during dry periods so that flows to the lake decrease. It is at these dry times that the supplemental pumping of groundwater to the lake becomes important for maintaining lake level. Other factors influencing runoff as well as the water table elevation are irrigation in the watershed and drainage district infrastructure. Flooding from the Missouri River that inundates Blue Lake has not occurred since 1952. It is unlikely to occur again because of dams built upstream and the Missouri River bed's continued degradation.

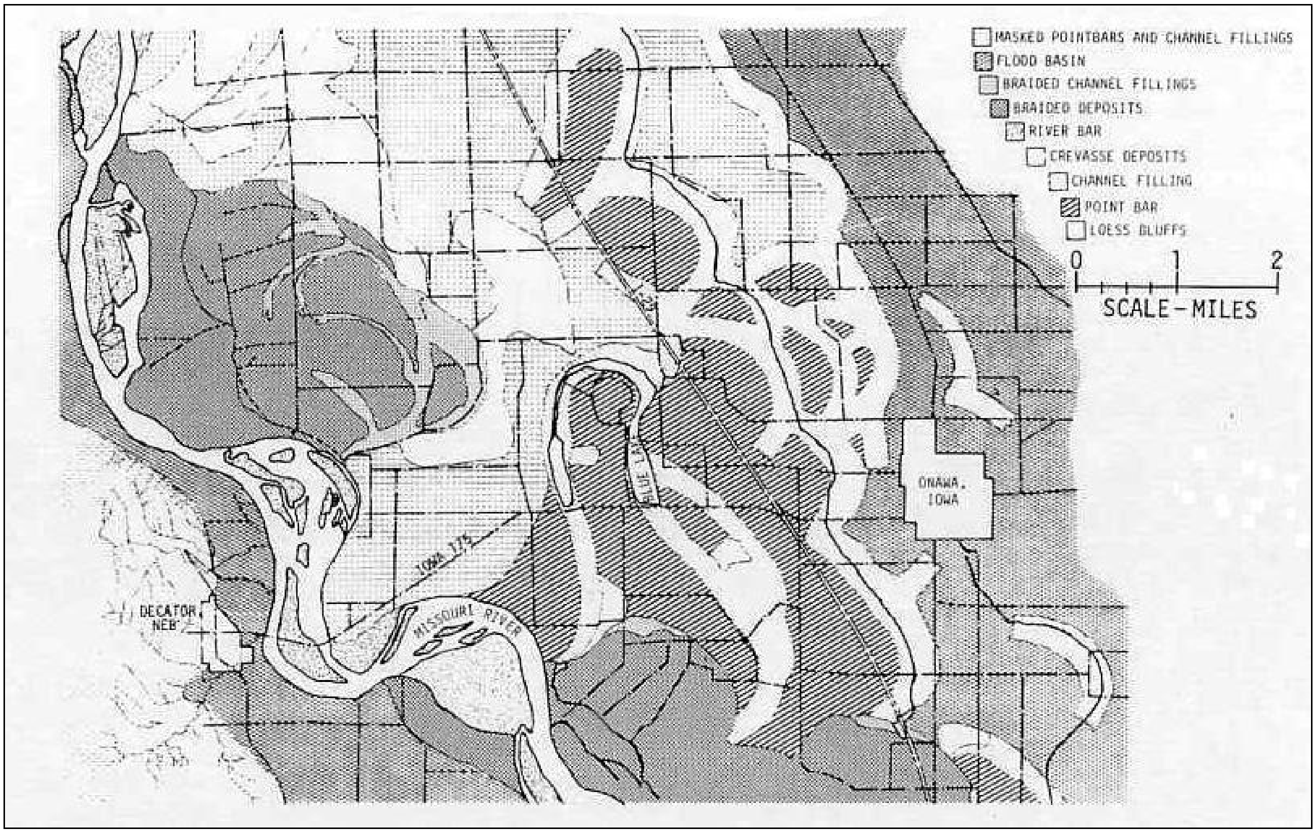

Figure 6 Alluvial geomorphology of the Missouri River floodplain near Blue Lake (Hanson, 1983)

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

A Total Maximum Daily Load (TMDL) is required for Blue Lake by the Federal Clean Water Act since it is on the State of Iowa Impaired Waters List (303d). The impairment is for algae as well as for the turbidity the algae and ISS causes. It has been determined 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 the difference between them, i.e., the needed reductions.

3.1. Problem Identification

Applicable water quality standards.
The Iowa Water Quality Standards (IAC 567-61) list the designated uses for Blue Lake as Primary Contact Recreational Use (Class A1) and Aquatic Life (Class B(LW)). The Blue Lake Primary Contact Recreational use has been assessed as not supported using narrative criteria for aesthetically objectionable conditions caused by algae and turbidity.

Problem statement.
The following paragraphs are from the 2006 305(b) water quality assessment for Blue Lake and describe the reason that the recreational use is assessed as not supported.

> *SUMMARY: The Class A (primary contact recreation) uses are assessed (monitored) as "not supporting" due to aesthetically objectionable conditions related primarily to high levels of inorganic turbidity and secondarily to blooms of suspended algae. Results of IDNR beach monitoring during the 2002-04 period do not suggest impairment of the Class A uses* (from pathogen indicators*) at this lake. The Class B(LW) aquatic life uses remain assessed (evaluated) as "fully supporting". Fish consumption uses remain "not assessed" due to the lack of recent fish contaminant monitoring. The sources of data for this assessment include (1) the results of the IDNR-UHL beach monitoring program in summers of 2002, 2003, and 2004, (2) results from ISU lake surveys from 2000 through 2004, (3) ISU reports on plankton communities at Iowa lakes from 2000 through 2004, and (4) information from the IDNR Fisheries Bureau.*
>
> *EXPLANATION: Results of IDNR beach monitoring at Blue Lake from 2002 through 2004 suggest that the Class A uses should be assessed (evaluated) as "partially supported." Levels of indicator bacteria were monitored once per week during the primary contact recreation seasons (May through September) of 2002 (30 samples), 2003 (29 samples), and 2004 (16 samples) as part of the IDNR beach monitoring program. According to IDNR's assessment methodology, two conditions need to be met for results of beach monitoring to indicate "full support" of the Class A (primary contact recreation) uses: (1) all 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 A uses should be assessed as "not supported". Also, if more than 10% of the samples in any one of the three recreation seasons exceed Iowa's single-sample maximum value of 235 E. coli orgs/100 ml, the Class A uses should be assessed as "partially supported". This assessment approach is based on U.S. EPA guidelines (see pgs 3-33 to 3-35of U.S. EPA 1997b).

At Blue Lake beach, the geometric means of all 63 thirty-day periods during the summer recreation seasons of 2002, 2003 and 2004 were below the Iowa water quality standard of 126 E. coli orgs/100 ml. These results suggest generally very low levels of indicator bacteria at this lake. None of the 59 samples collected during recreational seasons of 2002 and 2003 exceeded Iowa's single-sample maximum criterion of 235 orgs/100 ml. During the 2004 recreational season, 2 of 16 samples exceeded this criterion. Based on IDNR's assessment methodology, however, the results for the 2004 recreational season do not suggest that significantly more than 10 percent of the samples exceed Iowa's single-sample maximum criteria, Thus, these results do not suggest an impairment of the Class A uses of Blue Lake.

Results from the ISU statewide survey of Iowa lakes suggest that high levels of turbidity related primarily to and inorganic suspended solids impair the Class A uses of Blue Lake. Using the overall median values from this survey from 2000 through 2004 (approximately 15 samples), Carlson's (1977) trophic state indices for total phosphorus, chlorophyll-a, and Secchi depth are 68, 65, and 73, respectively. According to Carlson (1977), the index values for total phosphorus and chlorophyll-a place this lake in the range between eutrophic and hyper-eutrophic lakes; the index value for Secchi depth places this lake in the lower range of hyper-eutrophic lakes. These index values suggests moderately high levels of phosphorus in the water column, moderately high levels chlorophyll-a, and very poor water transparency.

According to Carlson (1991), the occurrence of a low chlorophyll-a TSI value relative to those for total phosphorus and Secchi depth indicate non-algal particles or color dominate light attenuation. The ISU lake data suggest that non-algal particles do likely limit algal production at Blue Lake. The median level of inorganic suspended solids in the 131 lakes sampled for the ISU lake survey from 2000 through 2004 was 5.2 mg/l. Of 131 lakes sampled, Blue Lake had the ninth highest median level of inorganic suspended solids (21.0 mg/l), thus suggesting that non-algal turbidity limits the production of algae. These conditions suggest an ongoing impairment to the Class A (primary contact) uses primarily due to presence of high levels of inorganic turbidity that violate Iowa's narrative water quality standard protecting against aesthetically objectionable conditions. The TSI value for chlorophyll-a (65) is on the border of impairment; the lake also had the 22nd highest TSI value for chlorophyll-a. These results suggest that suspended algae also contributes to aesthetically objectionable conditions at Blue

Lake. The IDNR Fisheries Bureau concurs that turbidity-related impairments exist at this lake. Other factors may limit algal production at Blue lake. Based on median values from ISU sampling from 2000-04, the ratio of total nitrogen to total phosphorus for this lake is 12; this ratio suggests the possibility that algal production at this lake may be limited by nitrogen availability.

Nuisance aquatic (algal) species (i.e., bluegreen algae) do not appear to be a problem at Blue Lake. Data from the ISU survey from 2000-04 suggest that bluegreen algae (Cyanophyta) comprise a relatively small portion (approximately 10%) of the summertime phytoplankton community of this lake. The average per sample mass (biovolume) of bluegreen algae in summers of 2000 through 2004 at this lake (3.6 mg/l) was the 17th lowest of the 131 lakes sampled. These conditions do not suggest any impairments due to presence of nuisance aquatic (e.g., algal) species.

The Class B(LW) aquatic life uses of this lake are assessed (evaluated) as "fully supported " based on information from the DNR Fisheries Bureau and DNR Wildlife Bureau. Also, the ISU lake survey data show no violations of the Class B(LW) criteria for dissolved oxygen in the 14 samples collected, or for pH in the 15 samples collected, during summers of 2000 through 2004. These results suggest good chemical/physical water quality at Blue Lake.

Data sources.
The data used to develop the BATHTUB water quality and the GWLF/BasinSims watershed models are described in the following two sub-sections.

Lake Water Quality Data: The primary in-lake data used to assess Blue Lake water quality and to develop this TMDL are from the Iowa State University Lake Study. Data were collected from 2000 to 2006 three times per season, usually in June, July, and August. The samples were analyzed for water quality variables including total and volatile suspended solids, Secchi depth, chlorophyll, phosphorus, and nitrogen. Samples were also examined for phytoplankton and zooplankton composition. The ISU Lake Study data can be found in Appendix C, Table C-1.

In 2005 and 2006, additional data were collected by the University of Iowa Hygienic Lab (UHL) using a protocol similar to that used by ISU. However, the dates that data were collected were expanded to include some in May, September and October. This data can be found in Appendix C, Table C-2. Historic water quality data used in TMDL development was mostly obtained from sources cited in *Section 7 – References*.

Watershed loading model data: The GWLF/BasinSims watershed model uses the precipitation and temperature data from the nearby Onawa National Weather Service COOP station (IA6243). Land use data comes from the 2002 IDNR GIS coverage. The factors used as input to the USLE based GWLF erosion model are from GIS soil and slope coverages. As with the water quality data, a lot of information used to develop model input, such as phosphorus concentrations in the supplemental pumped groundwater, runoff, and overflow from the McCandless Cleghorn Ditch, was taken from the Blue Lake specific references listed in *Section 7 - References*.

Interpreting Blue Lake data.
Most Blue Lake data from the ISU Lake Study has been averaged for the nutrient related variables and suspended solids. One sampling irregularity is the missing chlorophyll values in the ISU data set. Chlorophyll data for four sampling dates, three of them consecutive, are missing although all other sampling variables, i.e., phosphorous, nitrogen, suspended solids, and Secchi depth are available.

The missing chlorophyll data occurs at the same time that the two highest total phosphorous values were measured during the monitoring period. The seven-year average ISU total phosphorus concentration is 98 μg/l when all of the samples are included. Excluding the TP values for dates when there is not any chlorophyll data, the mean TP is 87 μg/l. This skews the key relationship between phosphorus and algae blooms when evaluating water quality nutrient impacts. It is reasonable to assume that mean chlorophyll concentration for the monitoring period would be higher if the chlorophyll data for the four dates were available.

The total nitrogen to total phosphorus ratio can often suggest which of these two nutrients limits algae growth. Based on values from ISU sampling from 2000 to 2006, the mean and median ratios of total nitrogen to total phosphorus are both 12. This ratio is in the range that indicates phosphorus is the limiting nutrient for almost all lake conditions.

Another limitation to algal growth is light reduction caused by algal (volatile) and inorganic suspended solids (ISS). ISS represent the fraction of turbidity not caused by algae. It consists mostly of eroded silt and clay particles that do not quickly settle out in the lake. The data from the ISU sampling shows there has been noteworthy inorganic suspended solids concentrations; Blue Lake has the ninth highest annual average ISS concentration (20 mg/l) of the 131 lakes (5.2 mg/l) in the study.

For the years 2005 and 2006 data were collected during the growing season by both ISU and UHL. These data were combined in the Figure 7 chart. (Note that the mg/l concentrations for ISS have been multiplied by 10 so that the values can be shown on the same scale as TP and chlorophyll.) Figure 7 also shows daily precipitation. The averages for the data displayed in Figure 7 are shown in Table 5. The averages of the TP and chlorophyll data show a relationship different from that predicted by TSI equations. This difference is driven in part by the very low value of the October 2006 chlorophyll concentration as well as the influence of ISS light limitation. There are two other interesting observations that can be made from the figure and table:

- The chlorophyll is higher in 2005 when ISS is lower and lower in 2006 when the ISS is higher.
- The total suspended solids and Secchi depth are not significantly different in 2005 and 2006.

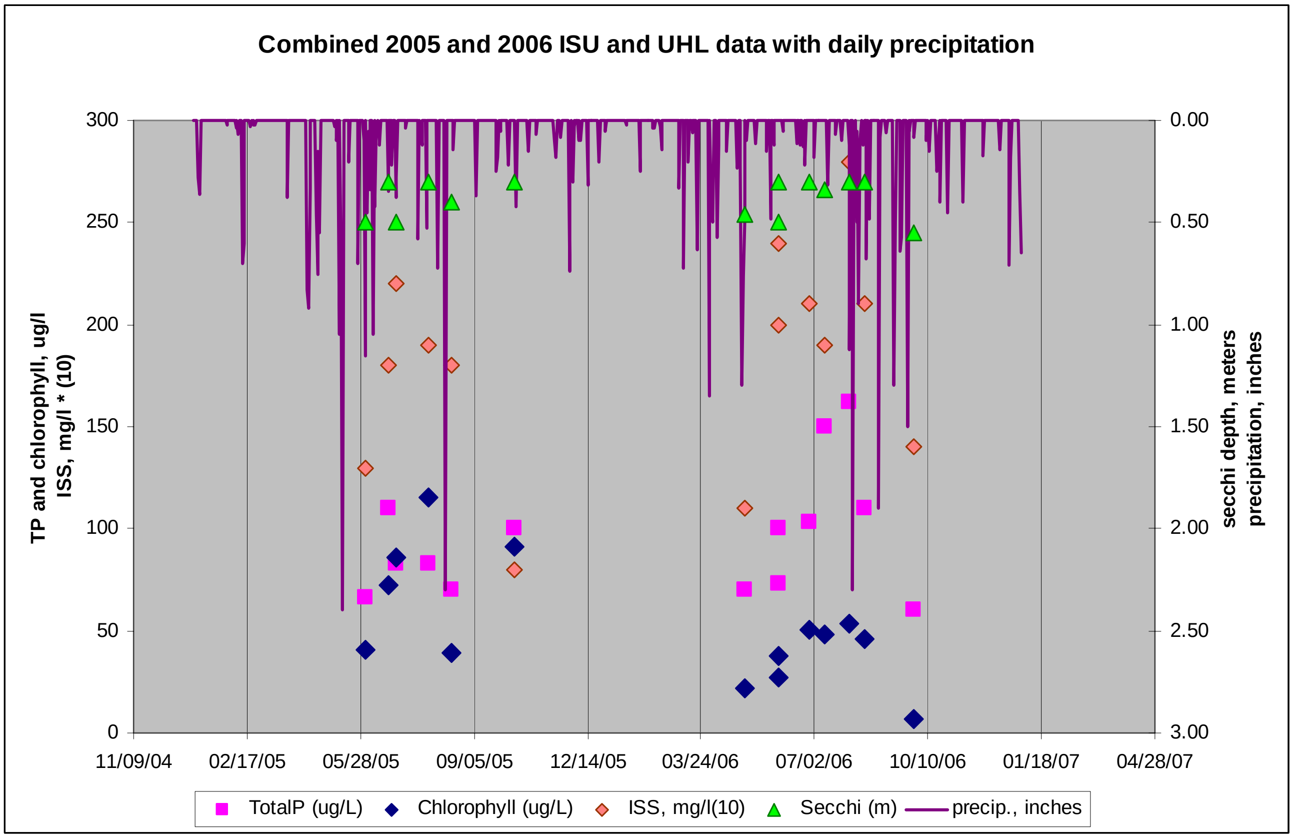

Figure 7 Combined ISU and UHL 2005 and 2006 Blue Lake data

Table 5 Means of ISU and UHL data for 2005 and 2006

	TotalP (µg/l)	Chlorophyll (µg/l)	Secchi (m)	Total N, mg/l - N	VSS, mg/l	ISS, mg/l
2005 mean	85	74	0.38	1.11	22	16
2006 mean	110	41	0.36	1.31	21	21

<u>Carlson's Trophic State Index</u>: Carlson's trophic state index (TSI) can be used to relate algae, as measured by chlorophyll, transparency, and total phosphorus to one another. It can also be used as a guide to establish water quality improvement targets.

If the TSI values for the three variables are the same, the relationships between TP and algae and transparency are strong. TP TSI values that are higher than the chlorophyll values indicate there are limitations to algae growth besides phosphorus.

Figure 8 shows a comparison of the Blue Lake TSI values for chlorophyll, Secchi depth and total phosphorus for the ISU data. The chlorophyll values generally chart below both TP and Secchi depth. The higher Secchi depth values are the result of the ISS, in addition to algal suspended solids, limiting light penetration for algal photosynthesis. TSI values for the ISU monitoring data are in Appendix C, Table C-3. Further explanation of TSI procedures and their use in lake assessments can be found in Appendix E.

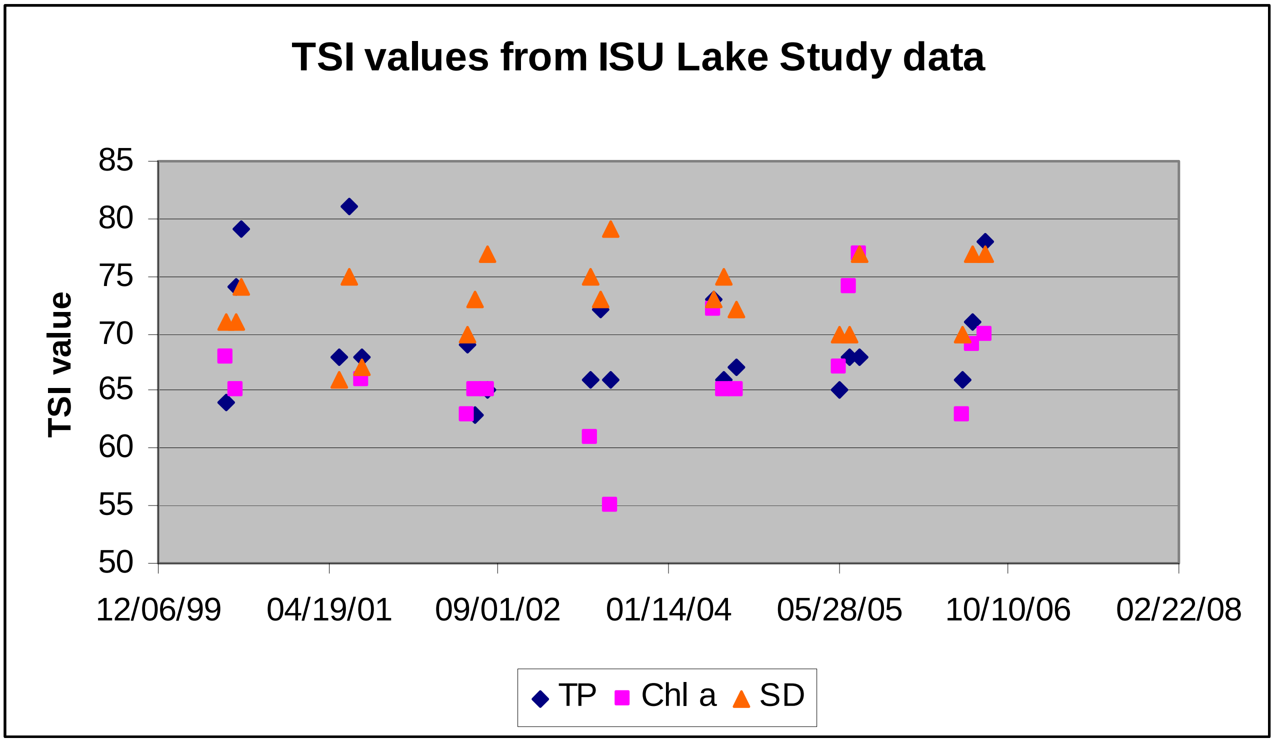

Figure 8 Blue Lake TSI values for ISU Study data, 2000 to 2006

Charts that compare the three TSI variables and interpret the differences are shown in Figure 9. The left hand chart plots the differences between TP, chlorophyll, and Secchi depth in one of four quadrants. If the three TSI values are identical they plot in the center, or zero-zero. The Blue Lake system plots in the lower left hand quadrant just below the X-axis. The right-hand chart interprets what the Blue Lake plotted point location suggests. The point location indicates the potential for a slight surplus of phosphorus and appears to indicate that smaller particles, clay grading to small silt, are causing some light limitation. This would point to inorganic suspended solids that are small and slow to settle particles.

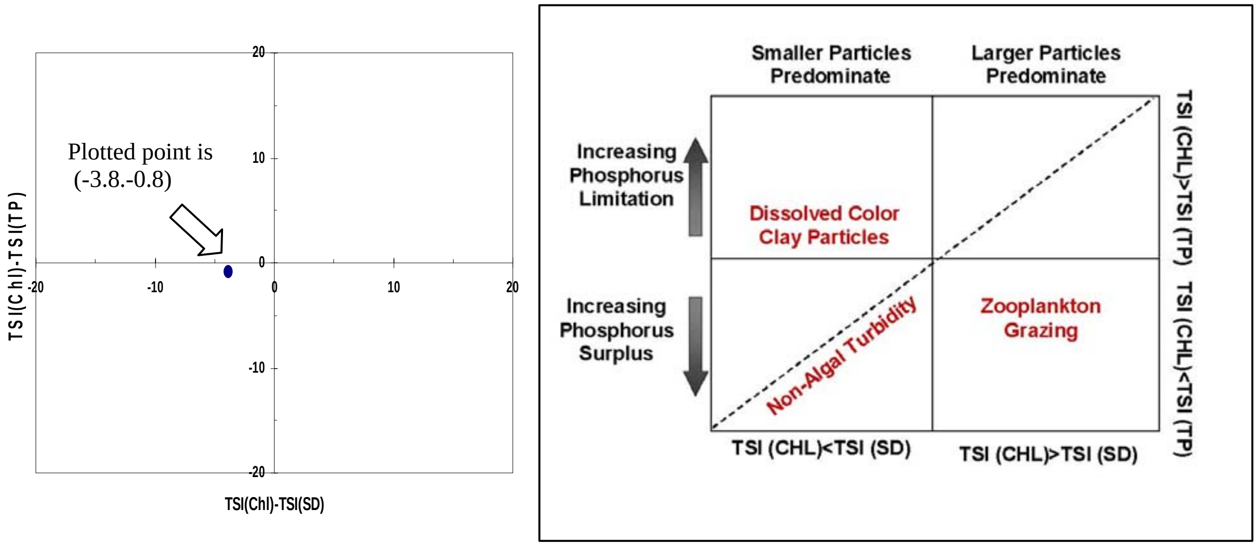

Figure 9. Blue Lake Mean TSI Multivariate Comparison Plot

3.2. TMDL Target

Based on the Iowa 305b assessment protocol that determines if a lake is impaired by algae and turbidity, the targets for this TMDL are a mean TSI value of less than 65 for both chlorophyll and Secchi depth. These values are equivalent to a chlorophyll concentration of 33 µg/l and a Secchi depth of 0.7 meters. Using the BATHTUB model, estimates were developed for Blue Lake, yielding a TP target concentration of 58 µg/l. The existing and target values for concentration and TSI are shown in Table 6.

Table 6. Blue Lake Existing vs. Target TSI Values

Parameter	2000-2006 Mean TSI Value	Existing 2000-2006 Mean Value	Target TSI Value	Target Value	Water quality improvement needed
Chlorophyll a	68	46 µg/l	<65	<33 µg/l	Decrease 28%
Secchi Depth	71	0.4 m	<65	>0.7 m	Increase 75%
Total Phosphorus	NA[1]	98 µg/l	NA	<58b µg/l	Decrease 41%

1. Not applicable

General description of the pollutant.

The TP load causes nuisance summer algal blooms because phosphorus is the limiting nutrient in the Blue Lake system. Although it is not the only factor in algal productivity (light penetration also affects algal growth), excess TP is the primary reason for blooms of algae and resulting volatile suspended solids that cause 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 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 results in achievement of the TSI targets for chlorophyll and Secchi depth.

Selection of environmental conditions.
The critical condition for which the chlorophyll and Secchi depth TSI targets apply is the growing season of April through September. During this period, nuisance algal blooms are prevalent. The existing and target TP concentrations for the lake are expressed as annual averages, as are the TP load estimates calculated for the existing and maximum allowable loads.

Potential pollution sources
There are no permitted point sources in the watershed. The potential nonpoint sources are agricultural activities, inadequate septic tank systems, wildlife, residential runoff, atmospheric deposition, and internal recycling loads. Loads carried in the supplemental pumped well water and resuspended bottom sediment loads are examples of nonpoint sources that adversely affect water quality in Blue Lake.

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 lake model. Based on a review of available literature and the default values used in the BATHTUB model, estimated direct deposition is an annual average areal load of 30 $mg/m^2/yr$ giving a load of 70 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 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 Blue Lake can receive while meeting the chlorophyll and Secchi depth targets. Based on meeting the annual average TP concentration of 58 μg/l estimated by the BATHTUB model, the annual average loading capacity is 1,126 lbs/year.

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

The criteria for assessing lake algae and turbidity impairment are based on TSI scores for chlorophyll and Secchi depth. The 305b assessment impairment thresholds for nuisance conditions are TSI values of 65 for both chlorophyll and Secchi depth, giving a target chlorophyll concentration of 33 µg/l and a target Secchi depth of 0.7 meters. The average annual TP concentration goal for these targets has been estimated using the BATHTUB model and is 58 µg/l. *Appendix E – Carlson's Trophic State Index* contains a more detailed explanation of the TSI and its use in 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

Identification of pollutant sources.
The TMDL approach is to separate pollutant sources into those that are regulated by discharge permits from those that are not. Point sources are those that are permitted and nonpoint sources are those that are not

There are six quantified phosphorus sources for Blue Lake in this TMDL.

- The first of these sources is the phosphorus from the watershed areas draining into the lake. This includes loads from the residential septic tanks adjacent to Blue Lake. Estimates of watershed phosphorus loads are calculated in the GWLF/BasinSims model. Figure 10 shows the contributions of phosphorus from the various watershed land uses.
- The second is the groundwater pumpage into the lake from a well. This is modeled in the BATHTUB water quality model as a tributary inflow.
- The third is the geese. This load is modeled in GWLF as a "point source" that varies monthly with the estimated seasonal change in population.
- The fourth is the periodic flooding from the backed up McCandless-Cleghorn Ditch during heavy rainfall. This is modeled in BATHTUB as a tributary inflow.
- The fifth is the phosphorus recycled from lake sediments. An estimate of the internal recycle phosphorus load is calculated in the BATHTUB model.
- The sixth is natural background atmospheric direct deposition. The direct deposition load is calculated in the BATHTUB model.

<u>Point Sources</u>: There are not any permitted point sources in the Blue Lake watershed.

<u>Nonpoint Sources</u>: The sources modeled with GWLF/BasinSims are shown in Figure 10. These include loads from all land use categories, geese, septic tanks, and groundwater. It does not include the loads from supplementary groundwater pumping, episodic overflow from the McCandless Cleghorn Ditch, or atmospheric deposition.

Well over half of the load is estimated to come from geese. Land use loads are relatively low because the sediment delivery ratio in the flat historic floodplain of the Missouri River is estimated as two percent. Another important factor is the high infiltration rate of the mostly sandy soils in the watershed.

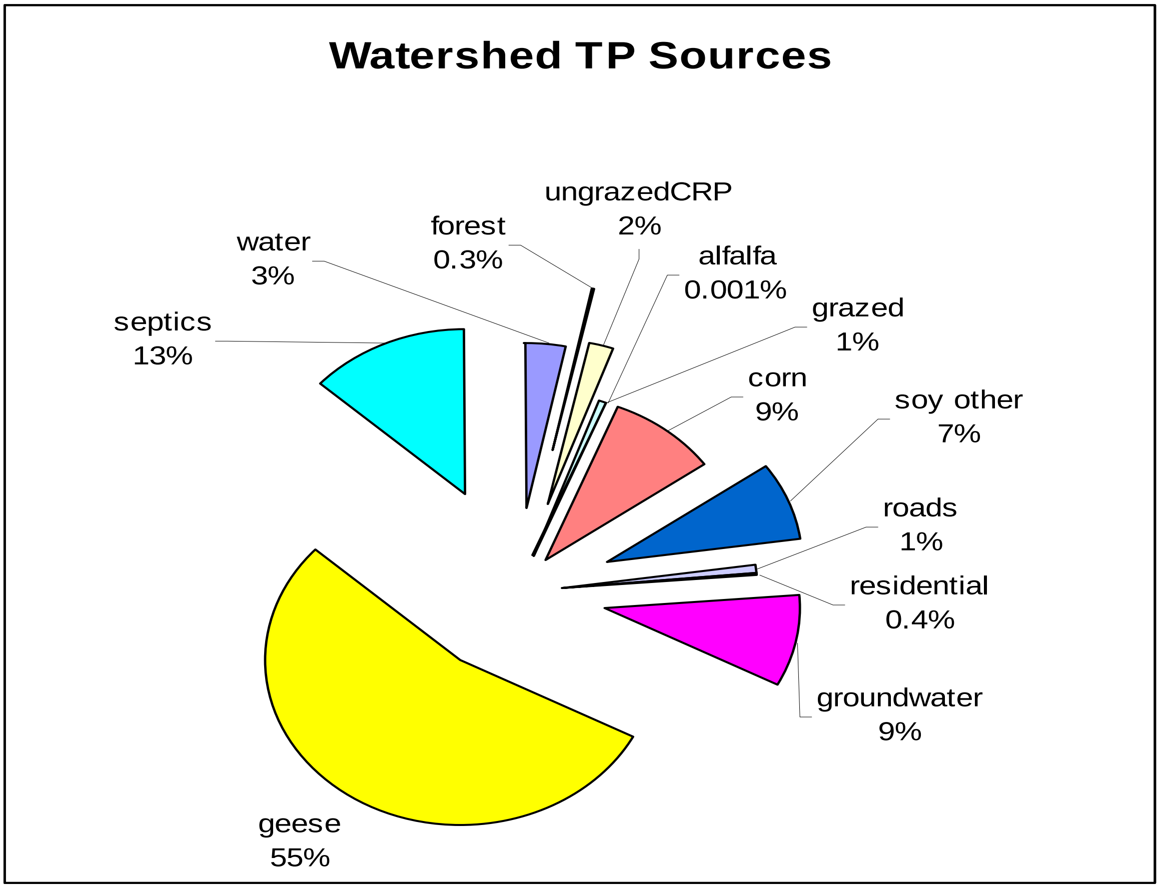

Figure 10 Blue Lake watershed phosphorus sources

The phosphorus sources not included in Figure 10 are estimated using the BATHTUB in-lake water quality model. These include supplementary pumpage, drainage ditch overflow, atmospheric deposition, and internal phosphorus recycling through the resuspension of bottom sediment by carp and waves. Figure 11 shows the watershed loads and these others as a fraction of the total existing loads to Blue Lake.

Existing load

The total annual phosphorus load to Blue Lake is made up of the fractions shown in Figure 11. Table 7 shows the TP mass and fraction of the total for each of these subcategories and the total existing load to Blue Lake. Watershed and lake modeling are described in Appendix D, Analysis and Modeling.

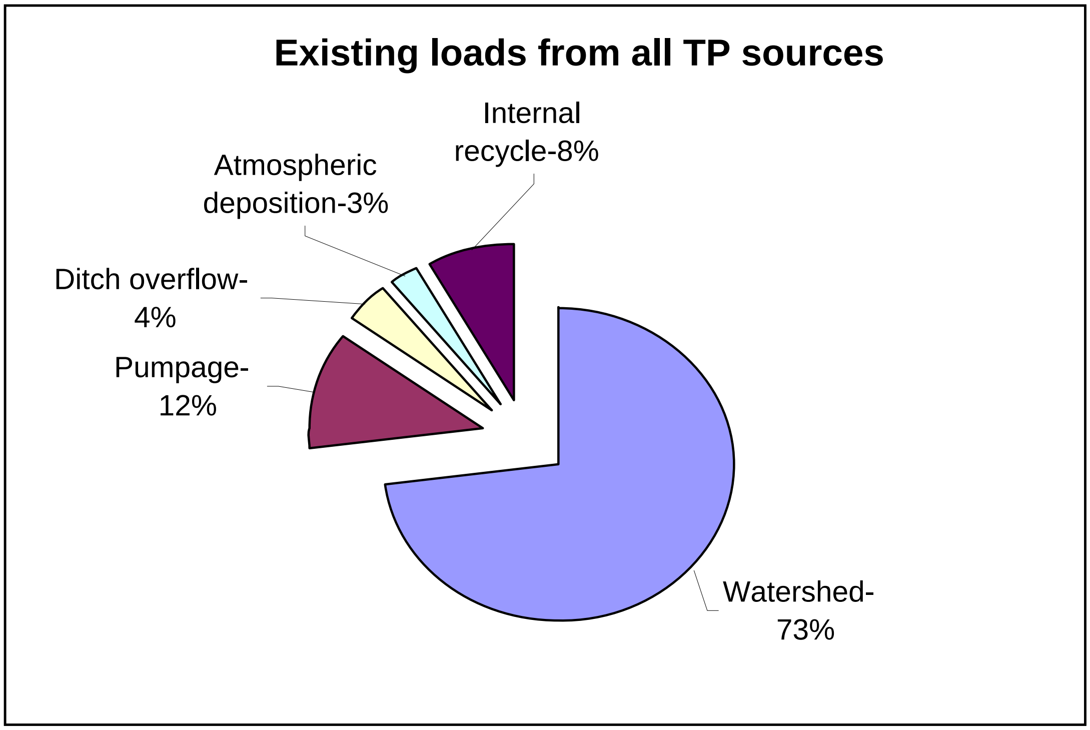

Figure 11 All existing Blue Lake phosphorus loads

Table 7 Existing loads to Blue Lake

Load source	Load, lb/yr	Percent of total
Watershed	1947	73
Pumpage	317	12
Ditch overflow	110	4
Atmospheric deposition	71	3
Internal recycle	216	8
total	**2661**	**100**

Departure from load capacity
The targeted total phosphorus load capacity for Blue Lake is 1,126 lbs/year from all sources. The existing total load estimate is 2,661 lbs/year. The difference between the existing and target loads is 1,535 lbs/year.

Linkage of Sources to Target
The phosphorus load to Blue Lake originates entirely from the sources listed in Table 7, 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 7 have been linked to the nuisance algae condition using the BATHTUB lake nutrient model.

Allowance for pollutant load increase
An allowance for increased phosphorus loading was not included in this TMDL. The Iowa Department of Natural Resources owns and maintains the shoreline around Blue Lake. Much of the 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 very unlikely.

3.4. Pollutant Allocation

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

Load allocation.
As noted, the existing TP load to Blue Lake is 2,661 lbs/year from all sources. The allowable load is 1,126 lbs/year as modeled in BATHTUB to achieve the target TP concentration of 58 µg/l. Evaluating the different load sources for reductions provides a potential allocation scheme involving decreasing loads where success appears to be most likely.

Watershed loads were estimated using the GWLF/BasinSims model as described in Appendix D and in the TMDL Support Documentation. The watershed load allocation was developed using averaged output for nine years (1997 to 2006) from GWLF/BasinSims.

The two most obvious reductions would be for the septic tank and geese loads. Together they are fifty percent of the total load to the lake and are more accessible to remediation than the other more diffuse sources. Limiting the frequency and volume of the overflow from the McCandless Cleghorn Ditch achieves additional reductions in both TP and ISS.

Row cropland makes up 12% of the estimated TP load. This can be decreased by implementing management practices. 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. Table 8 shows a possible distribution of the allowable load to the different sources. The geese, septic tank, and row crop loads and load reductions make up part of the watershed load.

Table 8 Total phosphorus existing loads, load reductions, and target loads

Load source	Existing load, lb/yr	Load reduction, lb/yr	Target load, lb/yr
Watershed	1947	-1382	565
Pumpage	317	0	317
Ditch overflow	110	-44	66
Atmospheric deposition	71	0	71
Internal recycle	216	-109	107
Total	**2661**	**1535**	**1126**

Figure 12 shows the distribution of the target load among the source categories. This figure should be compared to Figure 11. The most notable change between them is the relative reduction in the watershed contribution and the relative increase in the pumpage contribution. The overall reduction between the existing and target loads is 58 percent.

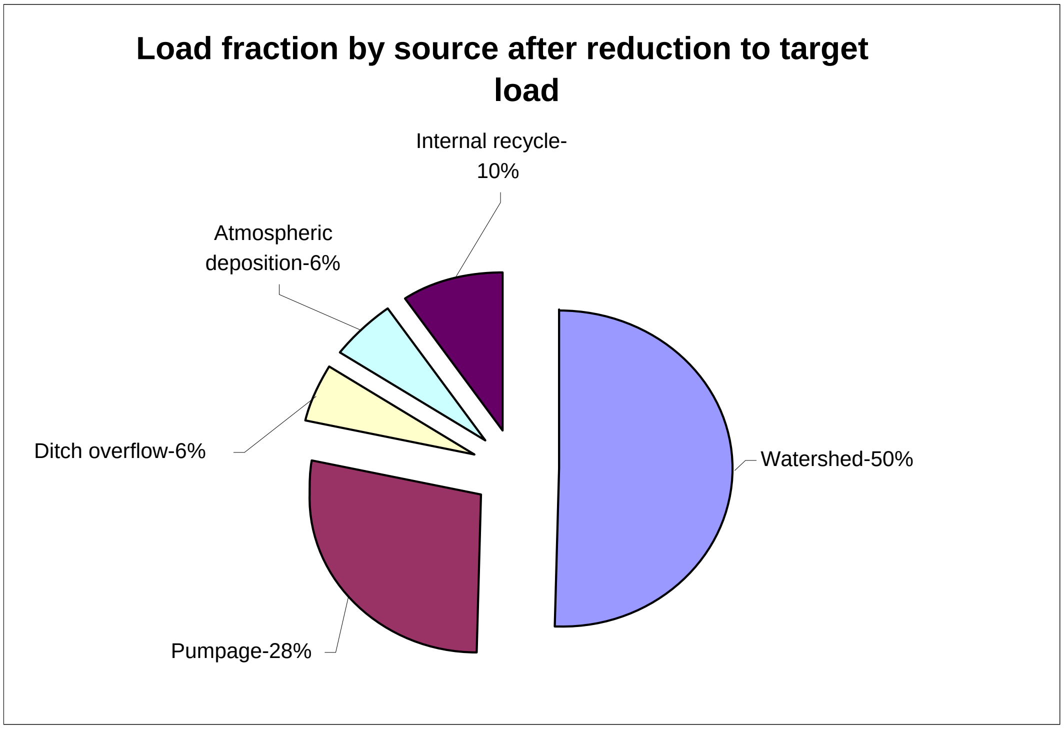

Figure 12 Load fractions by source after load reductions

Even though the algal blooms and turbidity problems occur during the growing season of April through September, the existing load must be distributed through the year due to the large numbers of geese overwintering on the lake. The largest TP reductions may not be in the summer because geese reduction must occur in the winter months when most of the population is on the lake.

Total Load Allocation (LA): The total LA for Blue Lake is the sum of the all of the source allocations. The load allocations are the modeled allowable load less the explicit ten percent margin of safety (MOS). These are shown in Table 9.

Table 9. Maximum Annual Average Load Allocations

Source	Annual average allowable TP load	Average annual load allocation (10% MOS)
Watershed LA	565 lbs/year (MOS applied)	565 lbs/year (MOS applied)
Pumpage LA	317 lbs/year	285.3 lbs/year (MOS applied)
Ditch overflow LA	66 lbs/year	59.4 lbs/year (MOS applied)
Atmospheric deposition	71 lbs/year	63.9 lbs/year (MOS applied)
Internal recycle	107 lbs/year	96.3 lbs/year (MOS applied)
Total LA	**1126 lbs/year**	**1069.9 lbs/year**

Federal regulations require that all TMDL reports include a daily maximum load. Table 10 shows the daily TP load allocations for Blue Lake (allowable loads less the ten percent margin of safety). Section 3.5, Total Maximum Daily Load Summary, details the development of the daily load allocations.

Table 10. Maximum Daily Load Allocations

Source	**Daily average allowable TP load**	**Daily Average TP Allocation**
Watershed LA	9.21 lbs/day	8.29 lbs/day (MOS applied)
Pumpage LA (275 day pumping season)	1.2 lbs/day	1.08 lbs/day (MOS applied)
Ditch overflow LA (5 days per year)	13.2 lbs/day	11.88 lbs/day (MOS applied)
Atmospheric deposition	0.2 lbs/day	0.18 lbs/day (MOS applied)
Internal recycle	0.3 lbs/day	0.27 lbs/day (MOS applied)
Total	**24.11 lbs/day**	**21.7 lbs/day**

Margin of safety.
The procedures used to provide the margin of safety (MOS) for the maximum annual average load and maximum daily load are different.

<u>MOS for Maximum Annual Average Load</u>: The explicit numeric margin of safety for this TMDL has two components, one for watershed TP loads, including geese and septic tanks, and one for the supplemental pumping, ditch overflow, atmospheric deposition, and internal recycle loads.

The watershed load MOS is a 10 percent decrease in the allocation for the maximum average annual load. This decrease is accounted for in the allocation spreadsheet calculations (*Blue Lake Allocation2.xls*). The hydrology and total phosphorus loads used in the allocation spreadsheet are generated from the summary GWLF/BasinSims modeling output.

The MOS for supplemental pumping, ditch overflow, atmospheric deposition, and internal recycle loads is an explicit 10% of the allowable TP loads in Table 8. The sum of these allowable loads is 561 lbs/year. The MOS is 56.1 lbs/year. The load allocation after the MOS is applied is 504.9 lbs/year (561-[561*0.1] = 504.9 lbs/year).

<u>MOS for Maximum Daily Load</u>: The margin of safety for the maximum daily allowable load is an explicit 10% reduction in the watershed, supplemental pumping, ditch overflow, and atmospheric deposition loads. The allowable daily maximum load based on an average 2-year return storm is 24.11 lbs/day and the ten percent MOS is 2.41 lbs/day.

3.5. TMDL Summary

Lakes with levels of nutrients that cause algae and turbidity impairments, such as Blue 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 (1069.9 lbs/year) + MOS (56.1 lbs/year) = 1,126 lbs/year

The procedures and information used to calculate these loads have been 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 Blue Lake has two major components:

- The watershed load that consists of TP from precipitation driven erosion, geese, and septic tanks that is estimated using the watershed model.
- The loads that are not included in the watershed model loads. These are supplemental pumping, ditch overflow, atmospheric deposition, and internal recycle.

The watershed load varies considerably over the year, driven by rainfall and variation in the numbers of geese present. The supplemental pumping, ditch overflow, atmospheric deposition, and internal recycle loads are more consistent over time. The allowable daily loads for supplemental pumping, ditch overflow, atmospheric deposition, and internal recycle loads are in Table 10. The sum of these allowable daily loads is 14.9 lbs/day and the load allocation with the ten percent MOS applied is 13.41 lbs/day

Watershed Daily Allowable Load, MOS, LA, and TMDL: The 2-year return 24-hour duration storm is generally accepted as the condition that defines the maximum daily erosion load for TMDL purposes. During precipitation events, nearly all of the delivered TP is attached to sediment. The 2-year return 24-hour duration event in the Blue Lake region is 2.94 -inches. Figure 13 shows the Onawa precipitation from 1997 to 2006. The year 1996 is not used because there was an extremely unusual 9-inch rain over a period of 24 hours in July. During this nine-year period, there were two days when precipitation events were equal to or exceeded 2.94 inches.

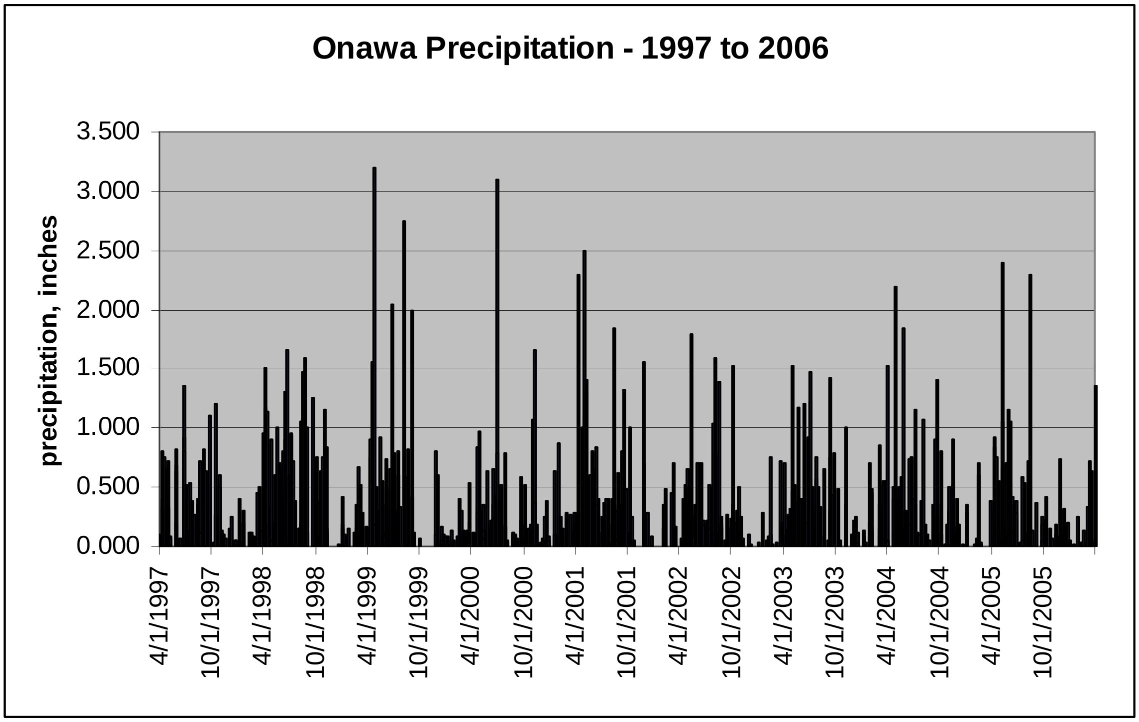

Figure 13. Daily precipitation from 1997 to 2006

Table 11 shows the two 2-year return events, the modeled daily loads, and the allowable maximum daily load. The allowable maximum daily load assumes the same reduction used for the annual maximum load, 71 percent. The values for the two events have been averaged to construct the average maximum daily load for the two 2-year storms. The load allocation is the allowable load less the ten percent MOS; LA = 9.21-0.921 = 8.29 lbs/day.

Table 11. Events and modeled loads used for development of maximum daily loads

Event date	24 hour rainfall, inches	Modeled daily load, lbs/day	Allowable daily load, 71 % reduction, lbs/day
4/22/1999 2 yr event	3.201	31.6	9.164
6/26/2000 2 yr event	3.098	31.9	9.25
Average for 2 yr storms	**3.15**	**31.75**	**9.21**

Total Maximum Daily Load: The equation for the total maximum daily load shows the total phosphorus load capacity. The values used in this equation are from Table 10.

TMDL = WLA (zero lbs/day) + LA (21.7 lbs/day) + MOS (2.41) = 24.11 lbs TP/day

4. Implementation Plan

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

4.1. Implementation Approach

The best way to reduce algae blooms in Blue Lake is to lower the lake phosphorus concentration by systematically reducing watershed TP loads starting with the most significant sources.

The existing watershed loads are shown in Figure 10 and below in Table 12. The watershed contributes 73 percent of the annual TP load as shown in Figure 11. The largest watershed load comes from geese, the second largest from septic tanks, and then row crop agriculture. The greatest reduction can be accomplished by reducing the large numbers of overwintering geese. Table 12 shows an overall watershed load reduction of 70 percent after the suggested reductions are implemented.

Table 12 Targeted reductions based on GWLF/BasinSims summary output[1]

Watershed Source	Area (acres)	Existing TP Load (lb)	Allocated TP Load (lb)	Percent Reduction
Water	489	66	66	0.0%
Forest	361	6	6	0.0%
Ungrazed & CRP grass	1,193	35	35	0.0%
Grazed grass	257	12	12	0.0%
Alfalfa	57	1	1	0.0%
Corn	1,509	181	90	50.0%
Soybean & other crops	1,242	145	73	50.0%
Roads	104	14	14	0.0%
Residential	79	7	7	0.0%
GROUNDWATER[2]	0	172	172	0.0%
GEESE[2]	0	1,053	105	90.0%
SEPTIC SYSTEMS[2]	0	259	26	90.0%
TOTAL	**5,290**	**1,949**	**606**	**68.9%**

1. This table was derived from the allocation spreadsheet model output evaluation.
2. These sources are not associated with a specific land use.

Loads from all sources are shown in Figure 11 and below in Table 13. Besides those originating in the watershed, loads are contributed by the supplemental groundwater-pumping, overflow from McCandless Cleghorn Ditch, internal recycle and atmospheric deposition. Two of these loads, from groundwater pumping and atmospheric deposition are not readily addressed. The watershed loads were enumerated above. The ditch overflow can be reduced by raising the divide elevation somewhere along the route from the ditch to the lake. Internal sediment resuspension load can be reduced by removing carp and encouraging aquatic plants to grow in shallow areas of the lake.

Table 13 Existing loads to Blue Lake

Load source	Load, lb/yr	Percent of total
Watershed	1,947	73
Pumpage	317	12
Ditch overflow	110	4
Atmospheric deposition	71	3
Internal recycle	216	8
total	**2661**	**100**

As shown in Tables 12 and 13 and Figures 10 and 11 (Section 3.3), the largest TP sources are geese, septic tanks, and row crops. The geese, septic tanks, and row crop reductions were incorporated into GWLF/BasinSims output evaluation (shown in Table 12) in the allocation worksheet. The following reductions are suggested for achieving water quality goals. The existing loads and suggested reductions are listed in Table 14. This table shows a suggested distribution of the allowable load to different sources. This scheme of load reduction requires the following:

- A 90 percent reduction in the number of goose days. A goose-day is one goose at Blue Lake for one day. The number of geese at the lake in the fall is estimated by IDNR wildlife biologists to be 5,000 and in the winter to be 4,000. The TP load generated by one goose day is half a gram. The estimated number of goose days for Blue Lake is 975,355. This is an annual phosphorus load of 1,050 pounds.
- A 90 percent reduction in the load from septic tanks. The onsite wastewater treatment effectiveness for nearby residences needs to be evaluated and improved as necessary.
- A 50 percent reduction in row crop loads by implementing best management practices (BMP). The suggested reductions should be managed to achieve the allocated load and be both practical and effective. For example, unit reductions (lbs/acre) for ungrazed grassland cannot be expected to be as great as those that can be achieved for row-cropped land where management of erosion and fertilizer application have a significant impact. 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.
- A 40 percent reduction in the flow and phosphorus load from the McCandless Cleghorn Ditch. This would have the additional benefit of reducing inorganic suspended solids and turbidity. As shown in the Figure 5 photo, this overflow is quite turbid.

- A 50-percent reduction in the resuspension of lake bottom sediment by carp and wind could be implemented through the removal of carp and the establishment of aquatic plants in shallow areas susceptible to waves. Encourage the growth of rooted aquatic plants in shallow areas to stabilize bottom sediments. Water quality data from the late 70s and early 80s shows aquatic plants producing dramatic algae and turbidity reductions in Blue Lake.

Table 14 Existing loads, load reductions, and target loads

Load source	Existing load, lb/yr	Load reduction, lb/yr	Target load, lb/yr
Watershed	1947	-1382	565
Pumpage	317	0	317
Ditch overflow	110	-44	66
Atmospheric deposition	71	0	71
Internal recycle	216	-109	107
Total	**2661**	**1535**	**1126**

4.2 Implementation Timeline

In monitoring, data analysis, and modeling there is always some uncertainty as to how representative sampling and models are of actual conditions and system dynamics. While some natural variability and data gaps are inevitable, it is felt that the procedures used in this report are a reasonable explanation of the pollutant sources and water quality situation. In the TMDL report, uncertainty is dealt with through the application of a margin of safety.

As the stakeholders move to implementation of phosphorus reductions, adaptive management of remediation activities and best practices can be a sensible and efficient way to ensure that these measures are having the desired impact. Adaptive management reduces both watershed and recycled loads by incrementally applying best management practices and monitoring the resulting water quality to see if progress is being made towards achieving goals. Watershed load reduction requires wildlife management, wastewater disposal improvements, and adjustments to agricultural practices. Changes like these require time to implement. For these reasons, the following watershed improvement timetable is recommended.

Table 15 Implementation timeline

Source	Existing loads, lb/year	2012 target loads, lb/year	2016 target loads, lb/year
Geese	1,053	400	105
Septic tanks	259	100	26
Row Crop	326	225	163
Ditch overflow	110	66	66
Resuspension	216	107	107
Total	1964	898	467

5. Future Watershed and Water Quality Monitoring

Watershed and in-lake water quality monitoring are important elements in any plan to improve Blue Lake. It plays a key role in both the analysis and modeling of pollutant sources and water quality. Monitoring is necessary to track the effectiveness of strategies used to improve lake water quality.

5.1. Monitoring to Support Lake System Evaluation

Monitoring similar to that done for the ISU Lake Study and the 2005 and 2006 UHL sampling will continue at Blue Lake. This monitoring, consisting of three to six samples taken in the growing season, provides enough information for 305b assessment purposes. Over time, this data is also sufficient to detect trends when evaluated using the right statistical tools. It is not adequate for a mechanistic understanding of the lake system.

The hydrology of the Blue Lake watershed and the wider historic floodplain region has a large impact on lake water quality. Blue Lake monitoring needs components that describe the most important hydrologic factors such as water table and lake water surface elevations and inflows, i.e., a water balance.

The variability in lake systems from year to year is considerable and averaging available data over a few or many years will likely conceal important responses to shifting hydrology and other factors. Data collection must take place in an analytical framework that accounts for precipitation and can explain observed variability.

Monitoring that will support analysis and modeling should include the following:

- Measurement of the water surface elevation. This can be as simple as putting up an elevation staff in a protected area, and reading and recording from it every day. There do not appear to be any outflow points of concentration that would provide worthwhile discharge information. Determining lake detention time will help calibrate the watershed and lake models and help explain TP and chlorophyll response to hydrologic conditions.
- Measurement of overflows from McCandless Cleghorn Ditch and sampling for total and dissolved phosphorus, turbidity, ISS and TSS needs to be done. This can be sampled at the culvert where the overflow enters the lake. See the photo in Figure 5.
- Keep track of the supplemental groundwater pumping volume and do a monthly analysis of it for phosphorus, suspended solids, dissolved solids, turbidity, and iron.
- Do biweekly sampling of important water quality variables to support a mechanistic representation of the lake system.
- Measure precipitation, wind speed, and temperature near the lake.
- Do continuous monitoring of dissolved oxygen and temperature for improved lake model calibration.

5.2. Monitoring to Support Watershed Improvement Projects

The recommendations for water quality improvement focus on reducing the geese population, improving septic tank wastewater treatment, implementing management practices on agricultural land that will reduce nutrient loss, allowing less overflow to Blue Lake from the McCandless Cleghorn Ditch, removing carp and encouraging aquatic plants in shallow areas of the lake.

Monitoring to see if goals are being met should incorporate each of these:

- Keep a month-by-month estimate of the numbers of geese that are present throughout the year.
- Perform inspections of nearby residential septic tanks with five-year follow-ups.
- Assess agricultural practices and re-assess in five years for BMP implementation.
- Assess changing carp populations and aquatic plant coverage each year.

Modeled watershed scenarios can estimate potential TP reduction as sources are removed and land uses are modified. Improved lake sampling and hydrologic measurement may permit the modeling and evaluation of seasonal changes in algal productivity and the impact of precipitation. Reduced geese and septic tanks loads can be modeled to describe how algal blooms respond to these changes in specific conditions.

6. Public Participation

Public involvement is important in the TMDL process. The landowners, tenants, and citizens who directly manage the land and live in the watershed determine the water quality in Blue Lake. Efforts were made during the development of this TMDL report to ensure that local stakeholders were involved in the decision-making process to agree on achievable goals for the water quality in Blue Lake.

6.1. Public Meetings

A preliminary meeting with stakeholders and agency staff was held on December 13, 2007 at the USDA Service Center in Onawa. IDNR WIS staff toured the state park and the watershed and obtained important information for the development of this report. The State of Iowa owns and operates the state park and immediate lakeshore.

An announced public meeting was held on May 7, 2008 in Onawa, Iowa. This meeting took place during the April 17, 2008 to May 19, 2008 public comment period. Notes from this meeting and the list of attendees are included here.

Subject: May 7, 2008 Public Meeting - Blue Lake Water Quality Improvement Plan
Location: Onawa Community Center

Meeting Outline:

- IDNR Water Quality Improvement Plan (TMDL) Presentation – Bill Graham
- IDNR Fisheries background information on carp removal and McCandless Cleghorn Ditch overflow. Lannie Miller
- IDNR Wildlife comments on potential development projects and water quality improvement. Ed Weiner
- IDNR Lake Restoration Program comments and funding options – George Antoniou
- Discussion – All Attendees

Narrative
IDNR presented an evaluation of the Blue Lake water quality problems explaining that phosphorous was the factor causing the lake algal blooms and that the most significant phosphorus sources were geese, septic tanks, watershed runoff, sediment resuspension by carp, and groundwater pumpage into the lake. Small particles (clay and silt size) also cause significant turbidity and originates in watershed runoff and overflow from the McCandless Cleghorn Ditch.

Recommendations are to eliminate overwintering by geese, evaluate specific septic tank impacts, and measure flows and phosphorus concentrations in watershed runoff.

Lannie Miller spoke to the carp problem in the lake and explained what happened in 2007. The carp were completely eradicated but returned when a heavy rain caused the Ditch to overflow into the lake bringing in a new batch of carp. Some residents and lake users were surprised to learn why the carp came back so quickly. It was observed that modifications had been done to cause drainage from the Ditch to Blue Lake. Lannie does not want to invest in carp removal until the ditch overflow situation is fixed.

Ed Weiner talked about potential methods for reducing the overwintering geese. Lake bottom aerators are often used in the winter to provide oxygen and reduce the potential for fish kills. Lake aeration will be more carefully managed since this is what draws the large numbers of overwintering geese. Ed also talked about components of a development project that would include phosphorus monitoring of pumpage, runoff and Ditch overflow as well as an estimate of Ditch overflow frequency and volume. Ed suggested that there may be a way to increase flow to the lake with higher quality water.

George Antoniou said that Blue Lake was on the IDNR Lake Restoration Program priority list for attention and funding. He outlined procedures for local stakeholders to arrange to meet with lake restoration staff about plans to improve Blue Lake water quality. He described the program and available funding.

The open discussion with stakeholders touched on the issues of dredging, geese, carp, Ditch overflow, replacing septic tank systems with sewers and wastewater treatment, groundwater pump maintenance and operation, fishing quality, and aquatic vegetation.

Blue Lake Public Meeting Sign in Sheet

Name	Affiliation	Email Address	Telephone	Address
Larry and Kathy Bonnos	Live on Blue Lake	L+K@onawave.net	712 423 2205	22622 Dogwood Loop, Onawa, IA
Ted and Karen Hayden	Live on Blue Lake	Not available	712 423 2375	22862 Dogwood Loop, Onawa
Mike and Diane Kelly	Lake user	Not available	712 423 1445	25399 Hickory Ave., Onawa
Jamie Murray	Land owner/Lake user	mmfeeds@yahoo.com	712 423 2273	21094 CTY HWY K-42
Bob Waters	IDALS	bob.waters@ia.nadcnet.net Bob.Waters@Iowaagriculture.gov	515 306 7012	C/O NRCS, Box 475, Atlantic, IA 50022
Kathy Schneider	NRCS (Monona County DC)	Kathy.Schneider@ia.usda.gov	712 423 2624	607 10th Street, Onawa
Ed Weiner	IDNR Wildlife	Ed.Weiner@idnr.iowa.gov	712 423 2426	607 10th Street, Onawa
Lannie Miller	IDNR Fisheries	Lannie.Miller@dnr.iowa.gov	712 652 2638	Black Hawk District Office, Box 619, Lakeview, IA 51450

Name	Affiliation	Email Address	Telephone	Address
Scott Dykstra	IDNR, Lewis and Clark SP Ranger	Scott.Dykstra@dnr.iowa.gov	712 423 2825	21914 Park Loop, Onawa, IA
Kathy Koskovich	IDNR	Katherine.koskovich@dnr.iowa.gov	712 330 6932	Correctionville, IA
George Antoniou	IDNR Lake Restoration Program	George.antoniou@dnr.iowa.gov	515 281 8042	IDNR, Wallace State Office Building, Des Moines, IA 50319
Allen Plath	NRCS	Allen.Plath@ia.usda.gov	712 423 2624	Onawa, IA
June DeLashmutt	Monona County Public and Environmental Health	mcphjune@longlines.com	712 433 1773	Monona County Courthouse, Onawa, IA
Rob Greiner	resident	lakeside@onawave.net	712 423 9803	Onawa, IA
Charles Ikenberry	IDNR Watershed Improvement	Charles.ikenberry@dnr.iowa.gov	515 281	IDNR, Wallace State Office Building, Des Moines, IA 50319
William Graham	IDNR Watershed Improvement	William.graham@dnr.iowa.gov	515 281 5917	IDNR, Wallace State Office Building, Des Moines, IA 50319

6.2. Written Comments

The Iowa Department of Natural Resources did not receive any written comments on the draft Blue Lake TMDL Water Quality Improvement Plan.

7. References

There are two reference categories in this section. Section 1 includes those that are specific to Blue Lake consisting of the several studies and reports done for this water body. Section 2 includes general technical and lake management references.

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8. 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 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 to 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.
FSA:	Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.
General use(s):	Refer to narrative water quality criteria that all public 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.

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 B-1. Designated use classes for Iowa water bodies.

Class prefix	Class	Designated use	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 1	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 --- Water Quality Data

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

Table C-1. ISU Lake Study monitoring data, 2000 to 2006

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
06/22/00	64.3	46.1	0.48	1.03	25.2	10.0	35.2
07/20/00	123.9	32.5	0.47	1.30	15.4	8.3	23.7
08/09/00	179.5	No data	0.37	1.41	21.0	14.3	35.2
05/24/01	84.8	No data	0.65	1.07	29.4	12.3	41.6
06/21/01	202.6	No data	0.35	1.47	18.8	23.6	42.4
07/25/01	84.1	35.2	0.60	1.06	11.5	7.4	18.9
05/30/02	88.5	27.5	0.50	0.82	23.3	9.0	32.3
06/26/02	61.2	32.5	0.40	0.97	5.7	13.5	19.2
07/31/02	69.4	34.1	0.30	0.90	25.1	6.5	31.6
05/29/03	72.8	23.0	0.35	0.84	31.5	4.0	35.5
06/25/03	108.5	No data	0.40	0.91	21.5	11.5	33.0
07/31/03	74.3	12.0	0.28	1.03	12.1	17.9	30.0
05/26/04	117.1	64.9	0.40	1.08	37.0	20.0	57.0
06/23/04	75.2	33.6	0.35	1.14	10.9	17.6	28.5
07/28/04	76.7	34.3	0.45	0.92	16.7	17.4	34.1
06/02/05	66	40.9	0.5	0.78	13.0	9.0	22.0
06/29/05	83	85.8	0.5	0.99	22.0	20.0	42.0
07/27/05	83	115	0.3	1.14	19.0	23.0	42.0
05/31/06	73	27.3	0.5	1.26	24.0	10.0	34.0
06/27/06	103	50.4	0.3	1.32	21.0	21.0	42.0
08/02/06	162	53.6	0.3	1.3	28.0	42.0	70.0
Mean	97.8	44.0	0.4	1.1	20.3	15.15	35.73
Median	83.0	34.3	0.4	1.1	21.0	13.5	34.1
Std. Dev.	39.30	25.04	0.10	0.20	7.61	8.41	11.92
Coef. Of Var.	0.40	0.57	0.25	0.18	0.37	0.55	0.33

Table C-2. UHL/IDNR lake monitoring data, 2005 and 2006

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
06/21/05	110	72	0.3	1.04	18	25	43
08/16/05	70	39	0.4	1.55	18	17	35
10/11/05	100	91	0.3	1.15	8	36	44
05/02/06	70	22	0.46	1.05	11	9	20
05/31/06	100	38	0.3	1.25	20	22	42
07/11/06	150	48	0.34	1.45	19	19	38
08/15/06	110	46	0.3	1.55	21	24	45
09/27/06	60	7	0.55	1.05	14	6	19
Mean	96.3	45.4	0.4	1.3	16.1	19.8	35.8
Median	100.0	42.5	0.3	1.2	18.0	20.5	40.0
Std. Dev.	29.25	26.49	0.09	0.22	4.64	9.47	10.55
Coef. Of Var.	0.30	0.58	0.25	0.18	0.29	0.48	0.30

Table C-3. Blue Lake TSI Values based on ISU Lake Study data

Sample Date	TSI (TP)	TSI (CHL)	TSI (SD)
06/22/00	64	68	71
07/20/00	74	65	71
08/09/00	79	No data	74
05/24/01	68	No data	66
06/21/01	81	No data	75
07/25/01	68	66	67
05/30/02	69	63	70
06/26/02	63	65	73
07/31/02	65	65	77
05/29/03	66	61	75
06/25/03	72	No data	73
07/31/03	66	55	79
05/26/04	73	72	73
06/23/04	66	65	75
07/28/04	67	65	72
06/02/05	65	67	70
06/29/05	68	74	70
07/27/05	68	77	77
05/31/06	66	63	70
06/27/06	71	69	77
08/02/06	78	70	77

Appendix D - Analysis and Modeling

A set of models and spreadsheets were used to evaluate available data and perform watershed and in-lake water quality modeling for Blue Lake. The watershed-loading model used was GWLF/BasinSims. The in-lake water quality model used was BATHTUB, a model developed by the U.S. Army Corps of Engineers to evaluate eutrophication dynamics in reservoirs and lakes. Generally, EPA accepts these two models for TMDL development and both can be freely downloaded from internet web sites. Adequate Blue Lake water quality, weather, and watershed data is available to use with these models and get reasonable results.

The GWLF/BasinSims watershed model uses the precipitation and temperature data from the nearby Onawa National Weather Service COOP station (IA6243). Land use information was obtained from a DNR GIS coverage created from 2002 infrared photography. 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.

Besides the two models, several spreadsheets were developed for the following purposes:

- Analyze in-lake data,
- Create weather, transport, and nutrient files for GWLF/BasinSims,
- Transform GWLF/BasinSims output for use in BATHTUB,
- Evaluate and interpret BATHTUB and GWLF/BasinSims output.

The lake data from the ISU Lake Study and more recently from IDNR/UHL monitoring has been analyzed in a spreadsheet set up to calculate means, medians, standard deviations, and coefficients of variance. These values are used as BATHTUB model input. This spreadsheet also includes statistical analyses and charts used to evaluate and display results. The mean of all ISU Lake Study data was used as the observed data input to the BATHTUB model. Mean GWLF/BasinSims output for the years matching the ISU data, 2000 to 2006, was used as the BATHTUB model tributary input.

Mean GWLF/BasinSims output is based on the weather information for the years of existing lake data, from 2000 to 2006. Both models can run for the individual years allowing for the changes in annual precipitation and nutrient loading to be evaluated against in-lake water quality impacts. The BATHTUB model output spreadsheet compares the predicted and observed water quality variables.

Modeling Procedures

The procedures used to evaluate TP loads to Blue Lake consist of:

- Estimates of the delivered loads from watershed non-point sources using GWLF/BasinSims modeling including wildlife and septic tanks.
- Estimates of the annual TP load to Blue Lake using measured in-lake phosphorus concentrations, estimated hydraulic detention time, and mean depth as inputs for the BATHTUB modeling,

- Estimates of the allowable TP loads at the target concentration (TP=58 µg/l) for the lake, using BATHTUB modeling.

The following flow chart outlines these procedures.

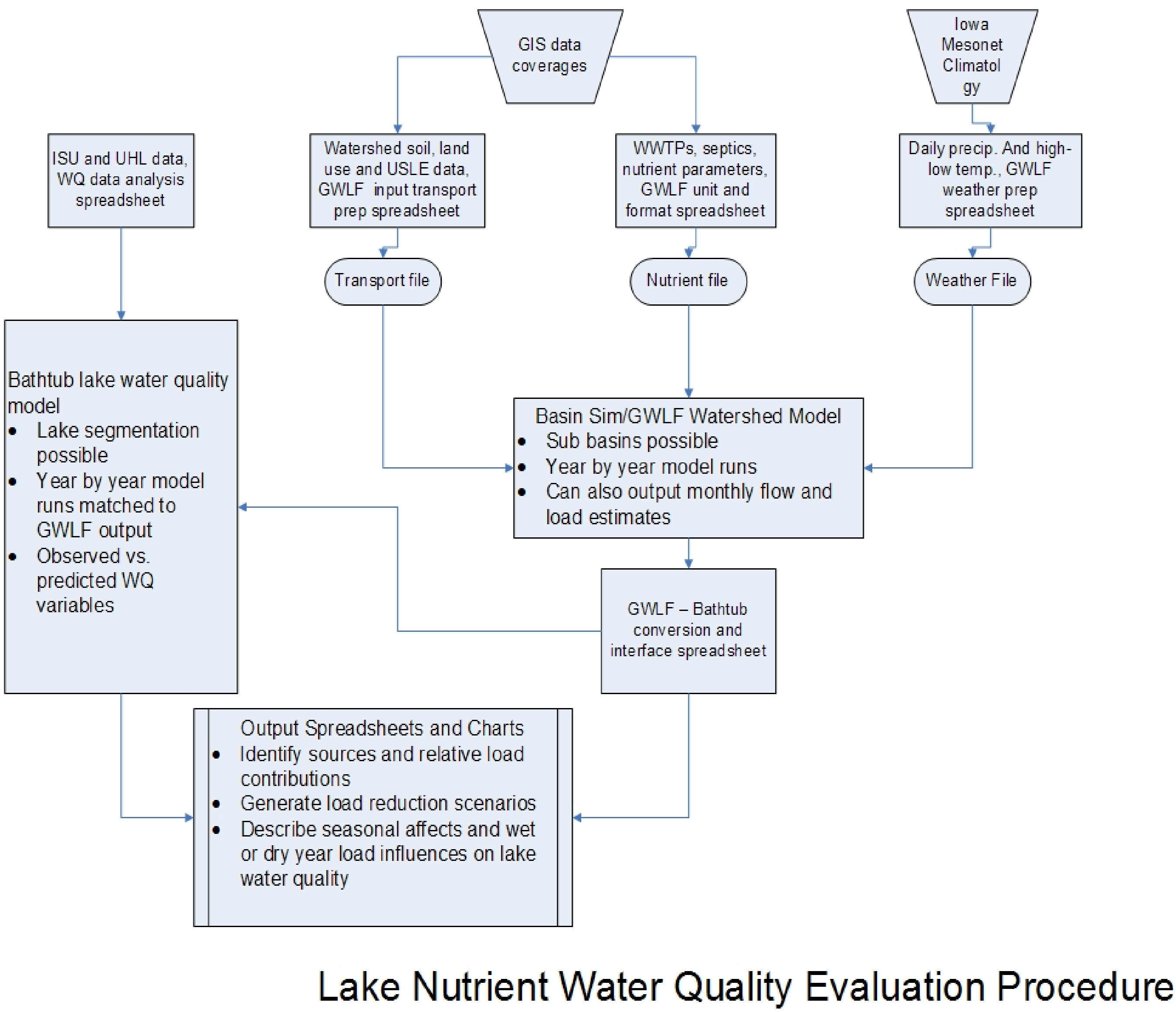

Figure 14. Blue Lake modeling flowchart

GWLF/BasinSims Watershed load estimates

The watershed load estimates are based on GWLF/BasinSims watershed modeling using temperature and precipitation data from a weather station in the City of Onawa, three miles east of Blue Lake. The period used as weather input to the model was April 1, 1997 to March 30, 2006. The sediment delivery ratio for Blue Lake is 2% based on the watershed size, floodplain topography, local knowledge, and ecoregion.

The numbers of geese and the seasonal population fluctuation were obtained from local IDNR wildlife staff and entered into the model on a monthly basis. Septic tank numbers were obtained by counting the number of houses in aerial photography in the immediate vicinity of the lake.

BATHTUB model load response
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 *bathtub_output_existing2.xls.*

These loads include the watershed loads generated by GWLF/BasinSims modeling, supplemental groundwater pumping, overflow from McCandless Cleghorn Ditch, atmospheric deposition, and internal recycling. A small lake with large numbers of geese and some rough fish such as carp, Blue Lake has a considerable wildlife and some recycled TP load components.

The model has been calibrated to account for the refractory nature and lack of availability for some of the measured total phosphorus. The internal load has been adjusted to the watershed model loads and is estimated to be 0.25 $mg/m^2/day$. 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 215 lbs/year.

Analysis and Model Documentation

The data analysis and modeling specifics for the Blue Lake TMDL are contained in the spreadsheet files listed below in Table D-1. These spreadsheets are located in the folder *TMDL support documentation*.

Table D-1. List of Analysis and Model Documentation Spreadsheets

Spreadsheet file name	Description of contents
20 yr rain and T BL.xls	Temperature and precipitation data from the Onawa weather station.
ISU Study Data BL2.xls	Original water quality data from the ISU Lake Study.
Data Evaluation BL4.xls	Analysis and evaluation of all ISU Lake Study and UHL water quality data, 2000 to 2006.
2005_2006 AND 2007 PRECIP.xls	Weather data from the Onawa weather station for 2005 to 2007
BL3monthly.xls	GWLF/BasinSims output by month, source, and an averaged summary of all years output.
BL daily flow1.xls	GWLF/BasinSims daily output.
Bathtub_output_existing2.xls	BATHTUB output for existing lake water quality conditions.
Bathtub_output_TMDL2.xls	BATHTUB output for TMDL lake water quality conditions
Blue Lake Allocations2.xls	Watershed nonpoint source allocations made using the GWLF/BasinSims output summary

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:

$$TSI\ (TP) = 14.42 \ln(TP) + 4.15$$
$$TSI\ (CHL) = 9.81 \ln(CHL) + 30.6$$
$$TSI\ (SD) = 60 – 14.41 \ln(SD)$$

where

TP = in-lake total phosphorus concentration, µg/l
CHL = in-lake chlorophyll-a concentration, µg/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 E-1. Changes in temperate lake attributes according to trophic state (modified from U.S. EPA 2000, Carlson and Simpson 1995, and Oglesby et al. 1987).

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

Table E-2. 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 (µg/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 E-3. 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 (µg/l)	Chlorophyll-a levels (µg/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.

Appendix F --- Maps

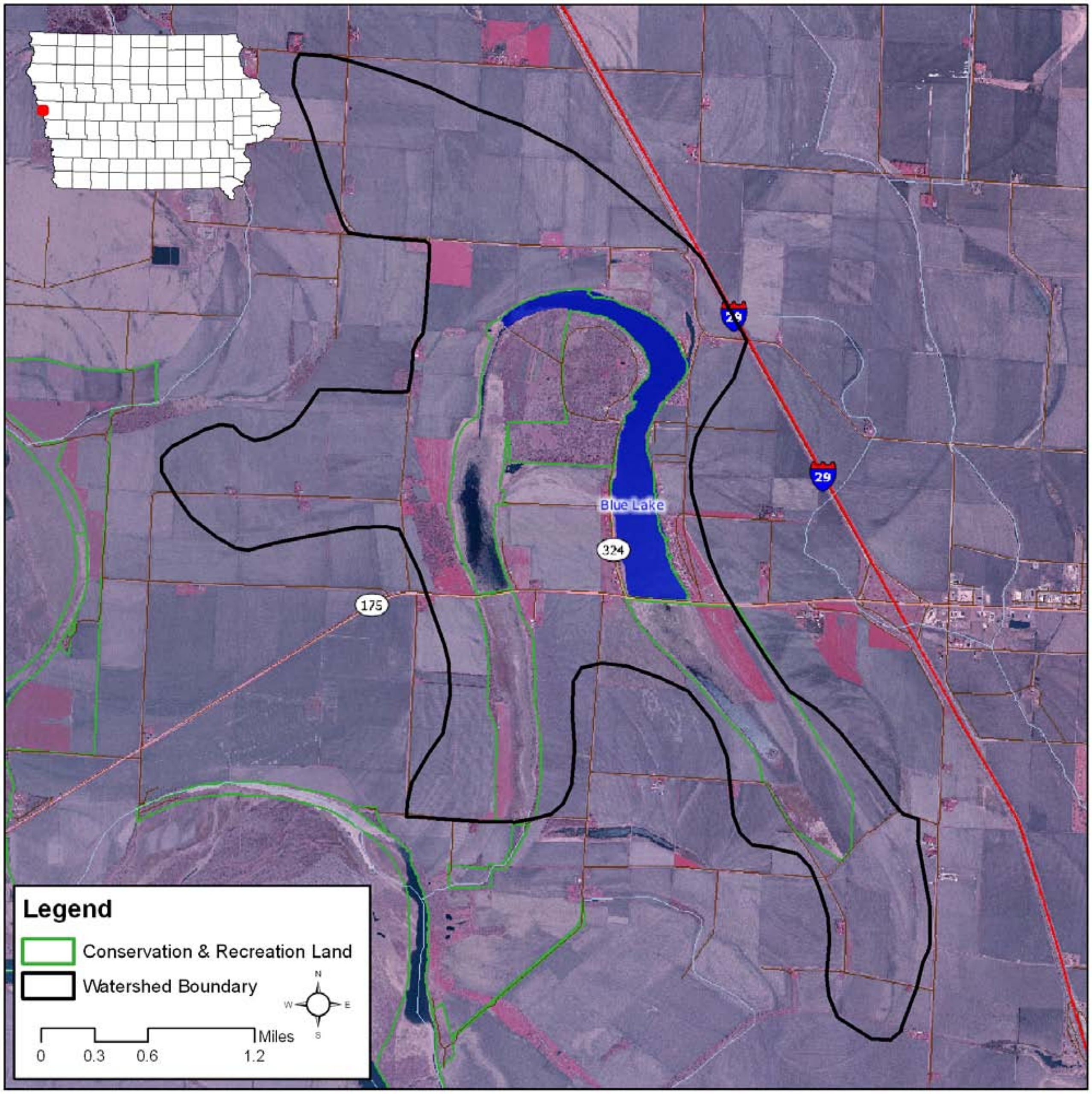

Figure 15. Blue Lake and its watershed, 2002 photography

Blue Lake Geological Cross Sections
The following figures show the cross sections through Blue Lake done from borings that were done in the late 1970's. The only change that has occurred since these borings were made is the dredging done in 1980. This dredging removed material from the area where the lake bends from an east-west alignment to the north south alignment. This is approximately from section M-M to section Q-Q. The maximum depth of the dredging was 1032 feet MSL. The dredging was done in areas near the shore where the clay and silt depths were greatest and there was minimal chance of increasing seepage. The volume dredged was 374,000 cubic yards. (Lohnes, 1982) The cross sections show the areas where the point sand bars surface and most seepage occurs.

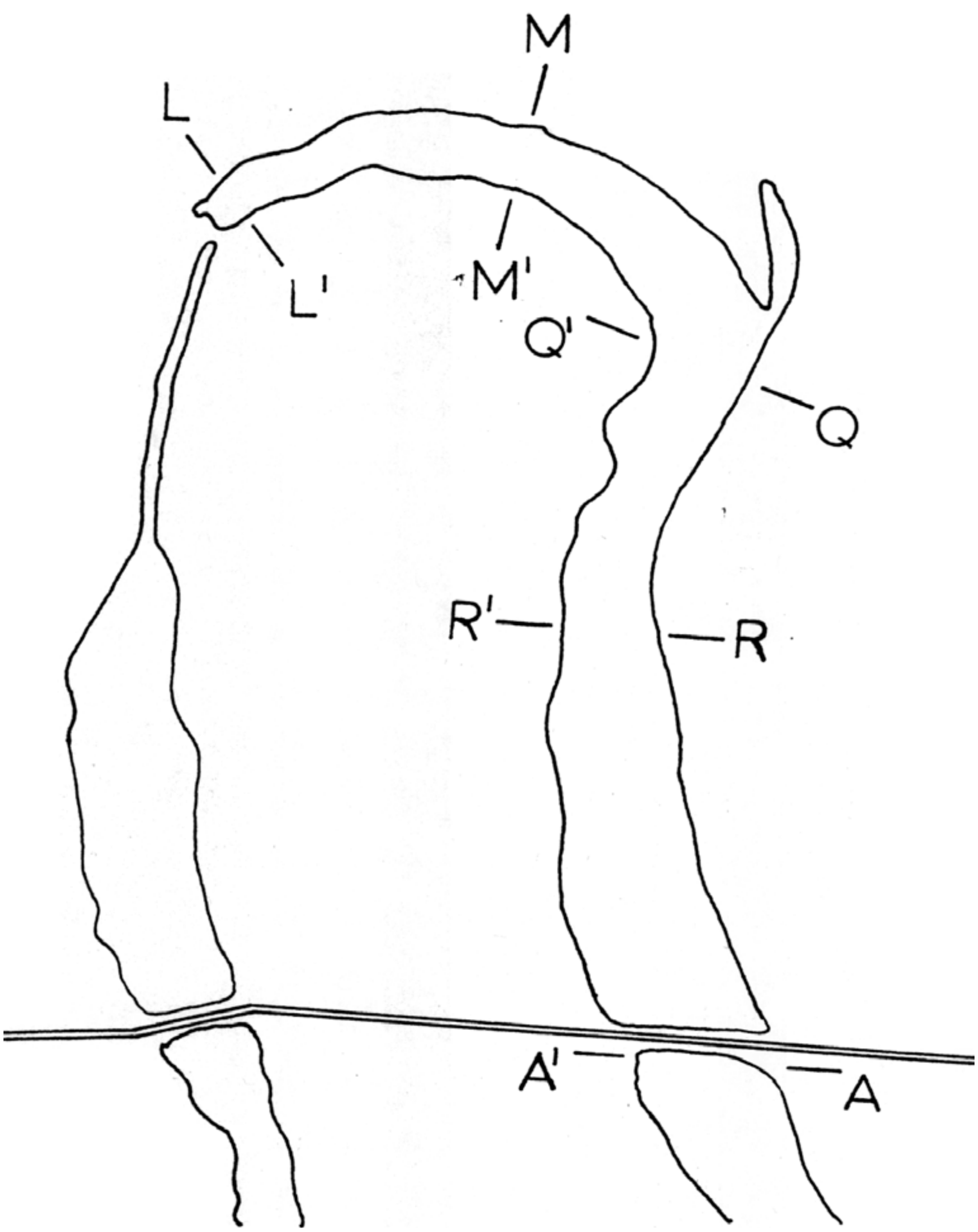

Figure 16 Cross Section locations

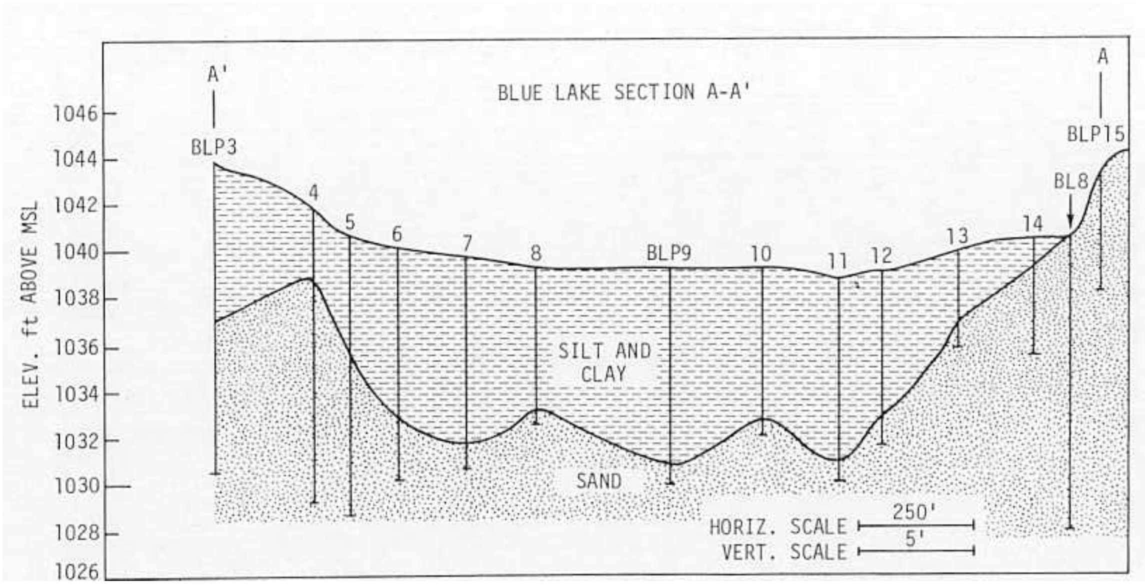

Figure 17 Cross section A-A in the marsh south of Highway 175 and Blue Lake

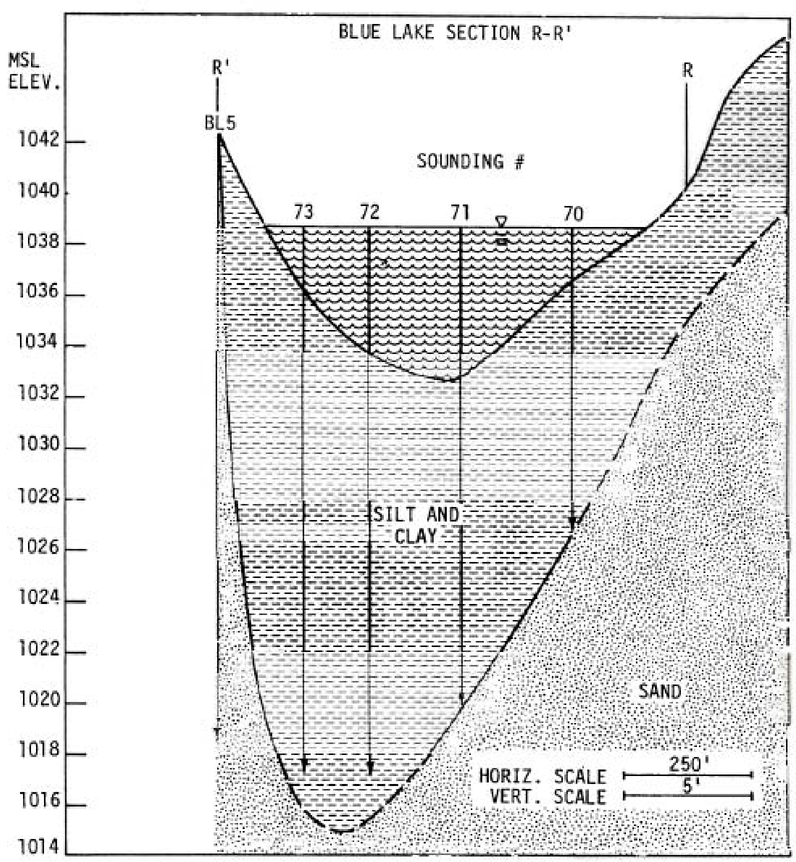

Figure 18 Cross section R-R in the middle of the north-south segment

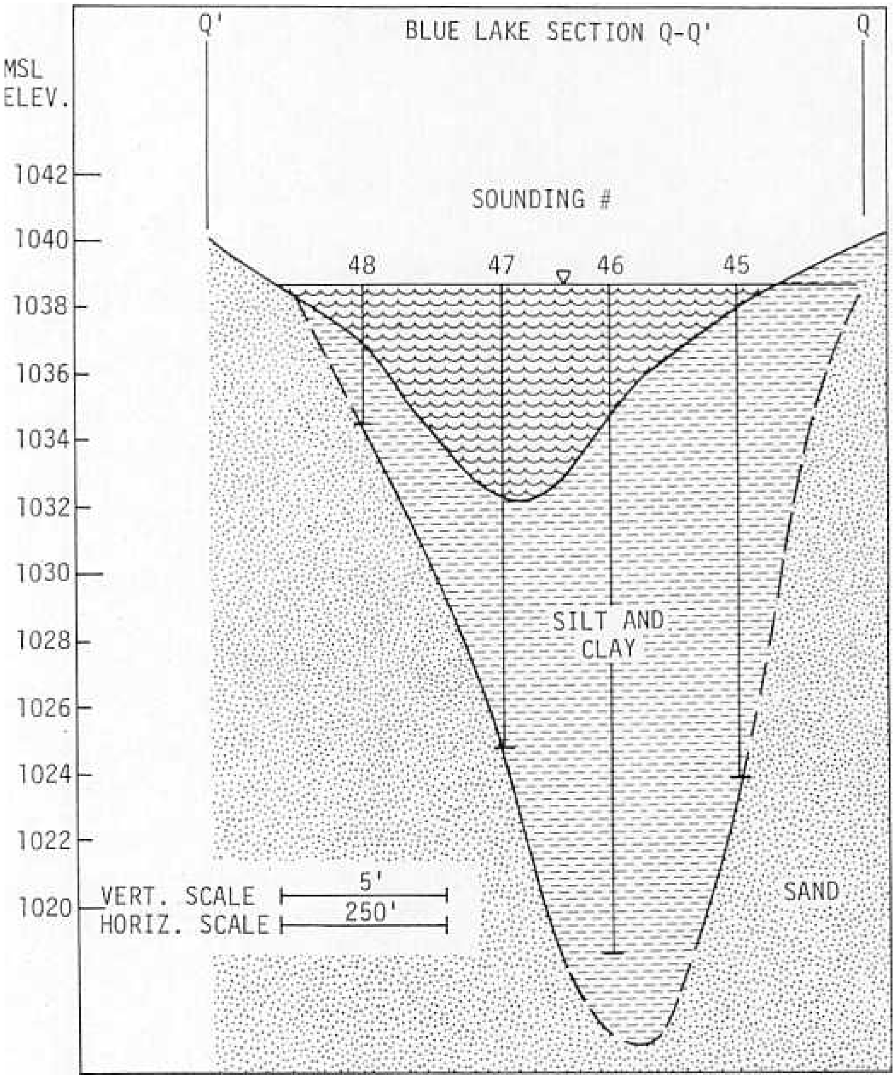

Figure 19 Cross section Q-Q at the north end of the north-south segment

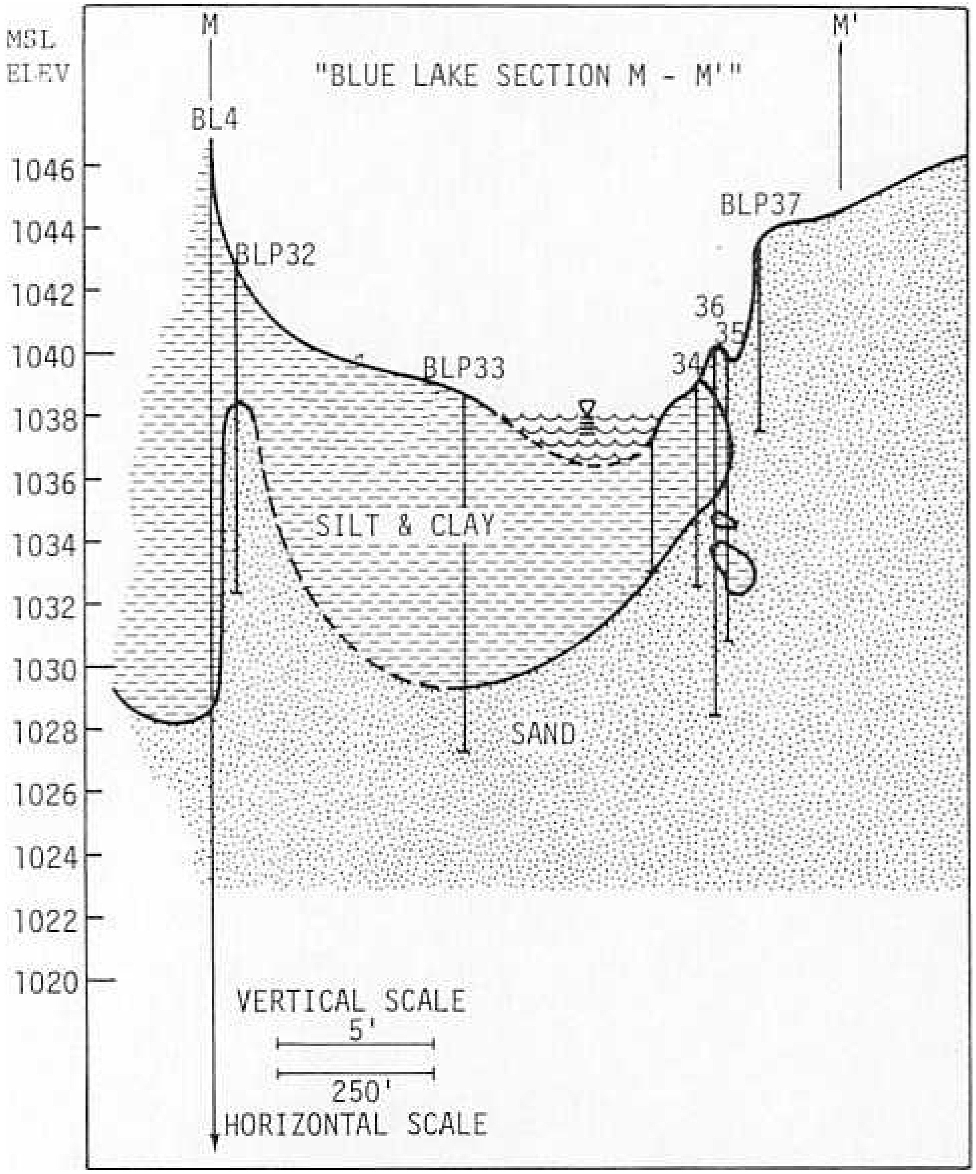

Figure 20 Cross section M-M at the mid section of the east-west segment

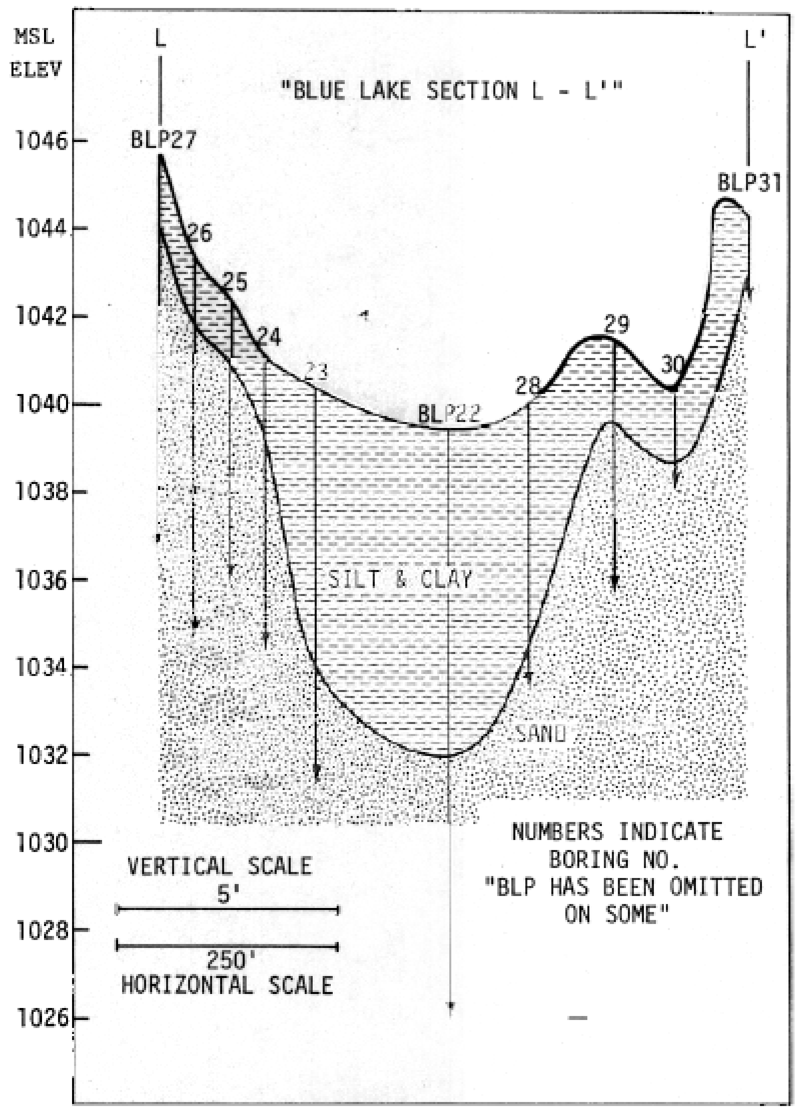

Figure 21 Cross section L-L at the west end of the east-west segment

The cross section N-N was not included in the same report as those above. Its location is shown in Figure 21. Cross section N-N is shown in Figure 22. It is one of the most revealing since it shows sand exposed below 1038 feet MSL elevation as well as the bottom elevation of the depression where the McCandless Cleghorn Ditch overflow enters the lake system at about 1040 feet MSL.

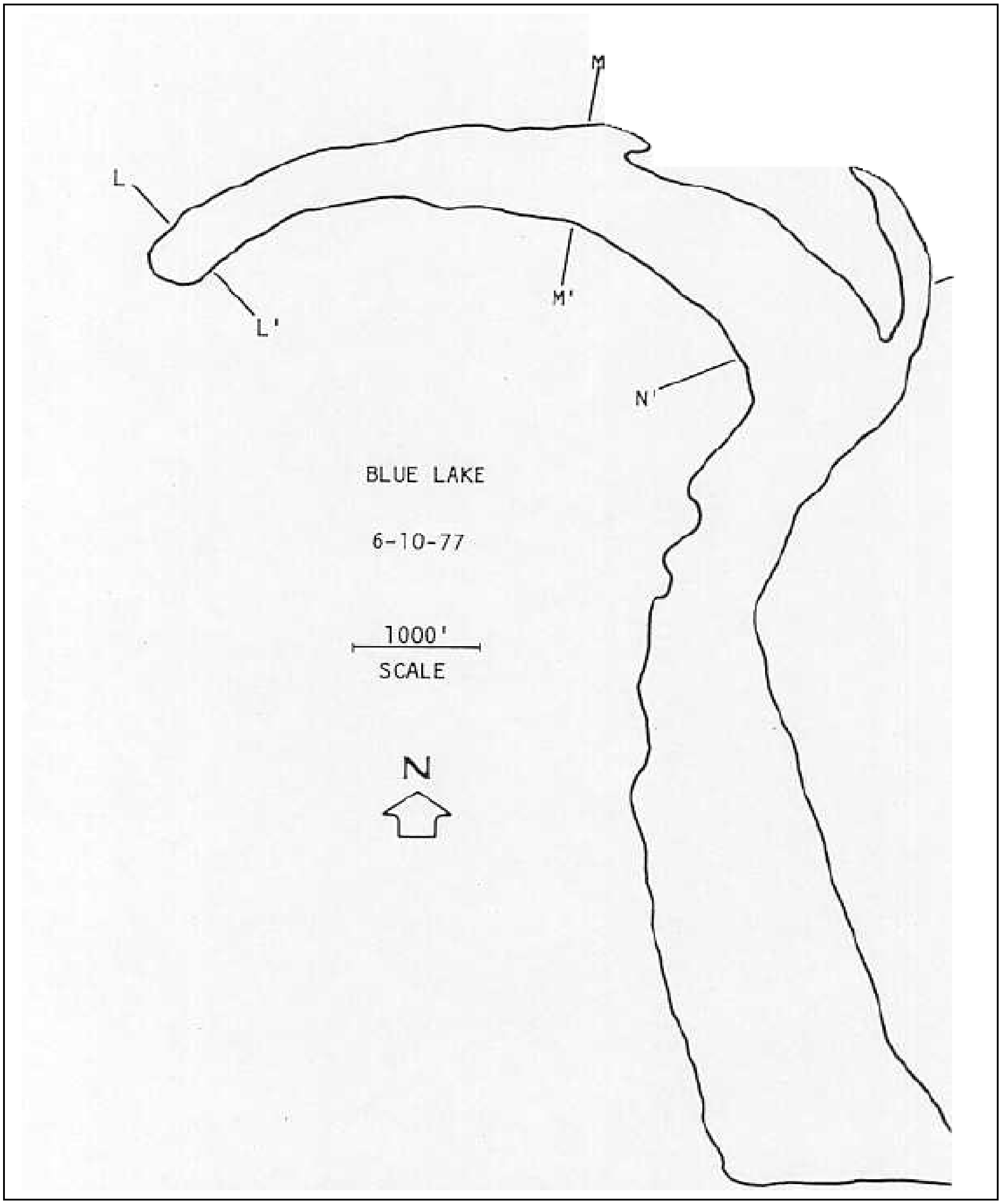

Figure 22 Cross section locations

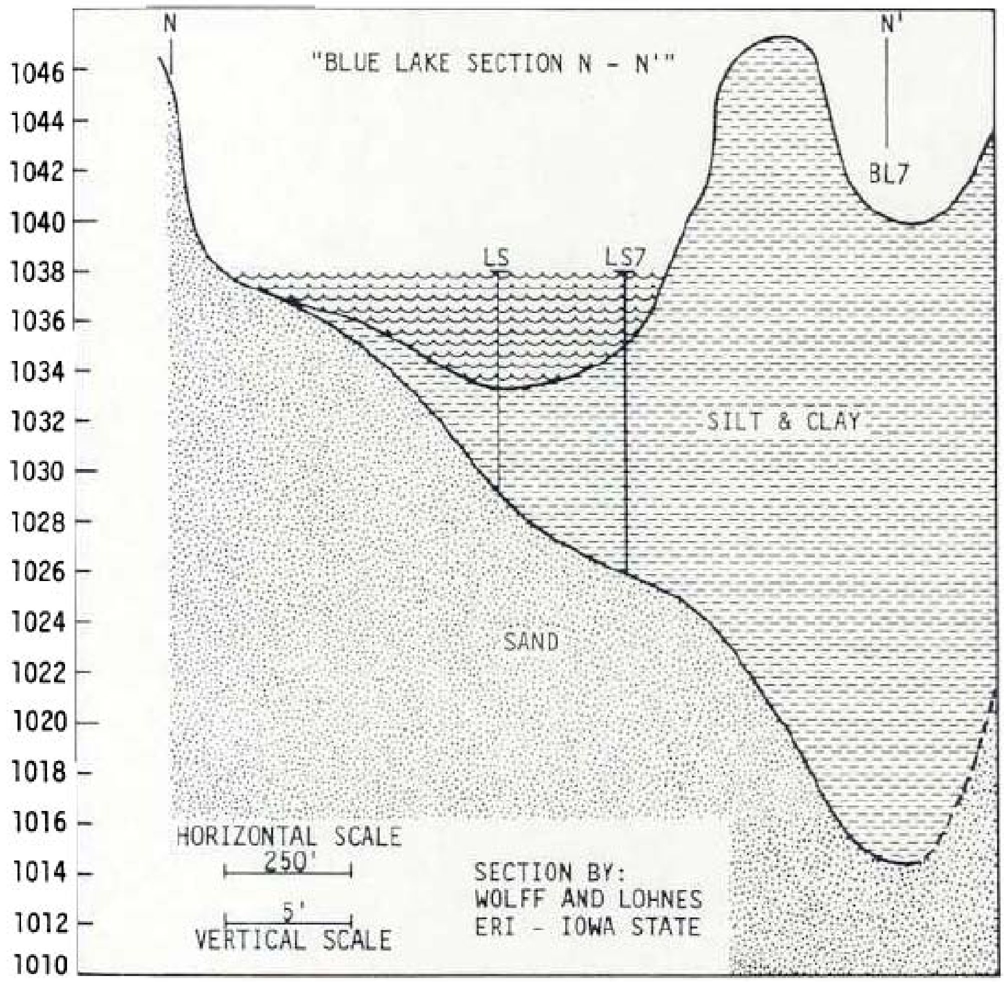

Figure 23 Cross section through NN

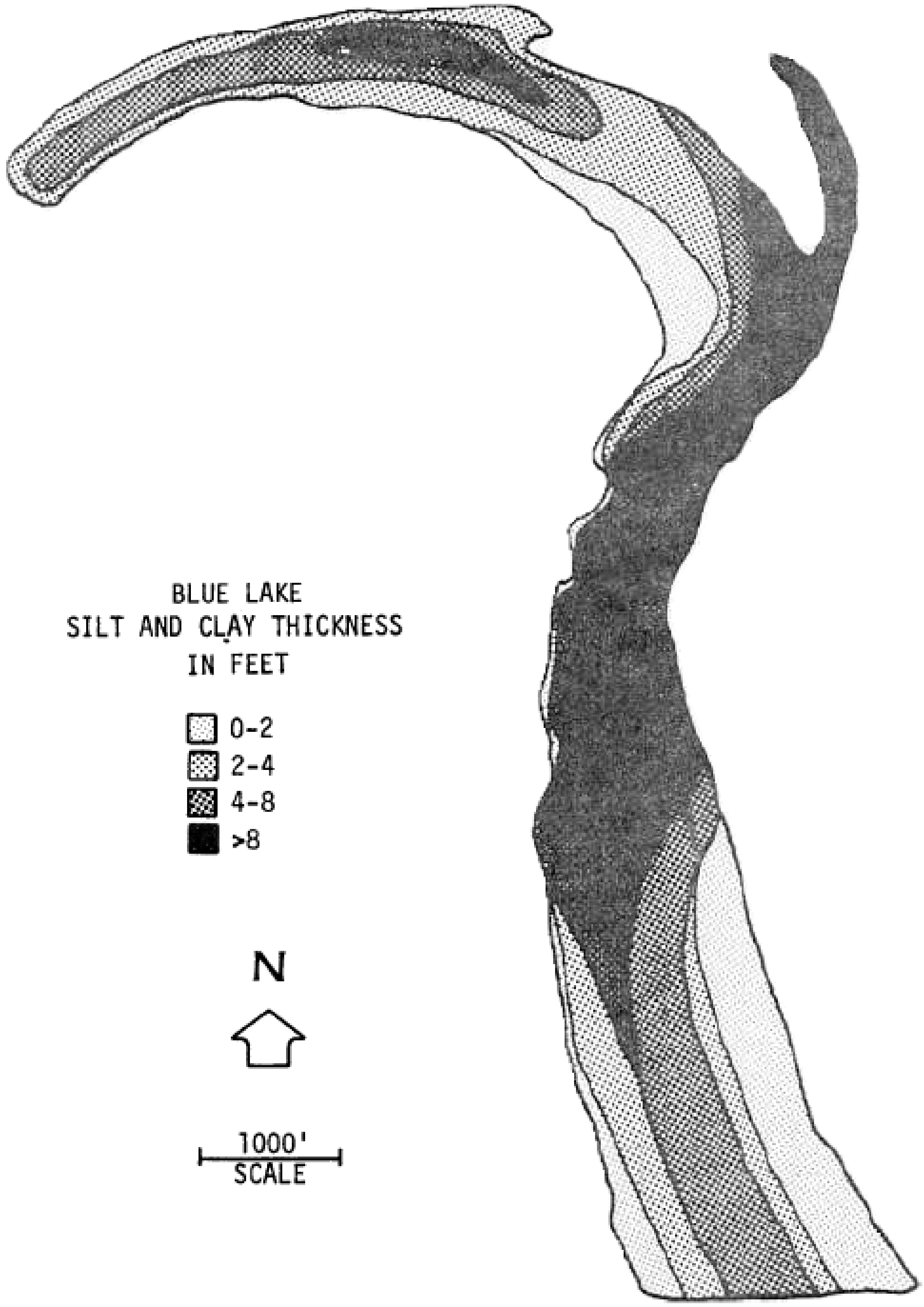

Figure 24 Blue Lake silt and clay thickness