PHASE I
WATERSHED ASSESSMENT FINAL REPORT
AND TMDL

SCHOOL LAKE
DEUEL COUNTY, SOUTH DAKOTA

South Dakota Watershed Protection Program
Division of Financial and Technical Assistance
South Dakota Department of Environment and Natural Resources
Steven M. Pirner, Secretary

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Project Sponsor and Prepared By

East Dakota Water Development District

State of South Dakota
Mike Rounds, Governor

August 2005

This project was conducted in cooperation with the State of South Dakota and the United States Environmental Protection Agency, Region 8.

EPA Grant # BG 99860101-08

EXECUTIVE SUMMARY

PROJECT TITLE: School Lake Watershed Assessment

START DATE: March 01, 2003	**COMPLETION DATE:** 12/31/04
FUNDING:	**TOTAL BUDGET:** $106,010 (projected)
TOTAL EPA GRANT:	$81,980
TOTAL EXPENDITURES OF EPA FUNDS:	$50,113.35 (through 6/30/05)
TOTAL SECTION 319 MATCH ACCRUED:	$18,758.73 (through 6/30/05)
BUDGET REVISIONS:	None
TOTAL EXPENDITURES:	$68,872.08 (through 6/30/05)

SUMMARY ACCOMPLISHMENTS

The School Lake watershed assessment project began in March of 2003 and lasted through August of 2005, when data analysis and compilation into a final report was completed. The assessment was conducted as a result of being placed on both the 2002 South Dakota Report to Congress 305(b) Water Quality Assessment and the 2002 South Dakota 303(d) Waterbody list for being hypereutrophic and not supporting of its designated uses. The lake was listed again in the 2004 Integrated Report. The project met all of its milestones in a timely manner, with the exception of completing the final report. This was delayed while completion of an additional report (Central Big Sioux River Watershed Assessment, South Dakota) was completed.

An EPA section 106 grant provided a majority of the funding for this project. The Department of Environment and Natural Resources and East Dakota Water Development District provided matching funds for the project.

Water quality monitoring and watershed modeling resulted in the identification of total phosphorus impairment as related to TSI trend. The sources of impairment may be addressed through best management practices (BMPs) such as shoreline buffers and riparian management.

The long term goal for this project was to locate and document sources of non-point source pollution in the School Lake watershed and provide feasible restoration alternatives for the improvement of water quality. Through identification of sources of impairment in the watershed, this goal was accomplished.

ACKNOWLEDGEMENTS

The cooperation of the following organizations and individuals is gratefully appreciated. The assessment of the School Lake watershed could not have been completed without the cooperation of the landowners in the study area - their cooperation is greatly appreciated.

Deuel County Conservation District
South Dakota Department of Environment and Natural Resources
South Dakota Department of Game, Fish and Parks
South Dakota State Health Lab
South Dakota State University, Department of Wildlife and Fisheries, GAP Analysis Lab
South Dakota State University, Animal Science Laboratory
United States Department of Agriculture, Natural Resource Conservation Service
United States Fish and Wildlife Service
United States Geological Survey

East Dakota Water Development staff that contributed to the development of this report:
Technical Staff: Deb Springman, Becky Banks, Mark Hanson,
Summer Assistants: Sam Kezar, Kate Vanderwahl

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Abbreviations

AFOs	Animal Feeding Operations – *facility where animals are confined, fed, or maintained for a total of 45 days in any 12 month period, and where vegetation is not sustained in the normal growing season over any portion of the lot or facility*
AGNPS	Agricultural Non-Point Source – *an event-based, watershed-scale model developed to simulate runoff, sediment, chemical oxygen demand, and nutrient transport in surface runoff from ungaged agricultural watersheds*
AnnAGNPS	Annualized Agricultural Non-Point Source – *models the current condition of a watershed, simulating the transport of water, sediments, and nutrients and compares the effects of implementing various conservation practices over time*
BMP	Best Management Practice – *an agricultural practice that has been determined to be an effective, practical means of preventing or reducing nonpoint source pollution*
BSR	Big Sioux River
CFU	Colony Forming Units
CV	Coefficient of Variance – *a statistical term used to describe the amount of variation within a set of measurements for a particular test*
DO	Dissolved Oxygen
EDWDD	East Dakota Water Development District
EPA	Environmental Protection Agency
MOS	Margin of Safety – *an index indicating the amount beyond the minimum necessary*
MPN	Most Probable Number
NGP	Northern Glaciated Plains
NPDES	National Pollution Discharge Elimination System
NPS	Nonpoint Source
NTU	Nephelometric Turbidity Units – *measure of the concentration of size of suspended particles (cloudiness) based on the scattering of light transmitted or reflected by the medium*
SD	South Dakota
SDDENR	South Dakota Department of Environment and Natural Resources
SDGFP	South Dakota Department of Game Fish & Parks
SDGS	South Dakota Geological Survey
SDSU	South Dakota State University
su	Standard Units
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load – *a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of the amount to the pollutant's sources*
TSI	Trophic State Index – *a measure of the eutrophic state of a waterbody*
TSS	Total Suspended Solids
µmhos/cm	microhmos/centimeter – *unit of measurement for conductivity*
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
WQ	Water Quality – *term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose*

INTRODUCTION

PURPOSE

The purpose of this assessment is to determine the sources of impairment and develop restoration alternatives for School Lake in northwestern Deuel County, South Dakota. The watershed is a small portion of the larger north-central Big Sioux River watershed, which is listed in the 1998 South Dakota 305(b) Water Quality Assessment Report as a Category I in need of restoration (Table 1) and is also listed in the current 2004 South Dakota Integrated Report.

Table 1. Description of the 303(d) Listing of School Lake Not Meeting Water Quality Criteria

Lake	Coinciding EDWDD Sites	Basis	Cause	Trophic Status	Source
School Lake	L6, L7	Lake Assessment	Nutrients, Siltation, Noxious Aquatic Plants, TSS, Turbidity	Hypereutrophic	Agriculture

Direct runoff into the lake, as well as intermittent tributaries, contribute loadings of sediment and nutrients primarily related to seasonal snow melt or rainfall events. In the 2000 South Dakota Report to Congress 305(b) Water Quality Assessment, the 2002 South Dakota 303(d) Waterbody List, and the 2004 Integrated Report, School Lake was listed as not supporting its designated uses (Table 2). Excess nutrients, siltation, and noxious aquatic plants are the primary problems. Through water quality monitoring (chemical and biological), stream gaging, and land use analysis, sources of impairment can be determined and feasible alternatives for restoration efforts can be developed.

The 2002 South Dakota 303(d) Waterbody List identifies this lake as a priority for the development of a Total Maximum Daily Load (TMDL) listing TSI as the pollutant of concern. This final TMDL assessment report will serve as the foundation for restoration projects that can be developed and implemented to meet the designated uses and water quality standards of School Lake and its watershed. This project is one of several Big Sioux River watershed-wide restoration implementation projects.

Table 2. Designated Beneficial Uses for School Lake and WQ Concerns

	Designated Beneficial Use	Concerned With:
(6)	Warmwater Marginal Fish Life Propagation	Unionized Ammonia, Dissolved Oxygen, pH, Water Temperature
(7)	Immersion Recreation	Dissolved Oxygen, Fecal Coliform Bacteria
(8)	Limited Contact Recreation	Dissolved Oxygen, Fecal Coliform Bacteria
(9)	Fish & Wildlife Propagation, Recreation, and Stock Watering	Alkalinity, Total Dissolved Solids, Conductivity, Nitrates, pH

It should also be noted that Bullhead Lake was originally listed in the 1998 South Dakota Report to Congress 305(b) Water Quality Assessment as partially supporting of its beneficial uses, due to nutrients, siltation, and noxious aquatic plants. However, subsequent assessments showed Bullhead Lake to be fully supporting of it beneficial uses.

GENERAL WATERSHED DESCRIPTION

The School Lake watershed is approximately 22,152 acres (8,965 hectares) in size and lies within the Big Sioux River Basin (Figure 1), and includes School Lake, Round Lake, Bullhead Lake, and Wigdale Lake. The watershed is located in northwestern Deuel County (Figure 2) and extends from just north of Round Lake to just southeast of the community of Goodwin. School Lake is a naturally occurring lake that is part of a series of lakes at the headwaters of Willow Creek, which is a tributary to the Big Sioux River. This river is a primary water source for the eastern South Dakota region. There are also intermittent tributaries which only carry water during spring snowmelt or rainfall events. The river and the tributaries recharge shallow aquifers which are the principal source of drinking water for the residents of the Big Sioux River watershed.

Figure 1. Location of the Big Sioux River Basin

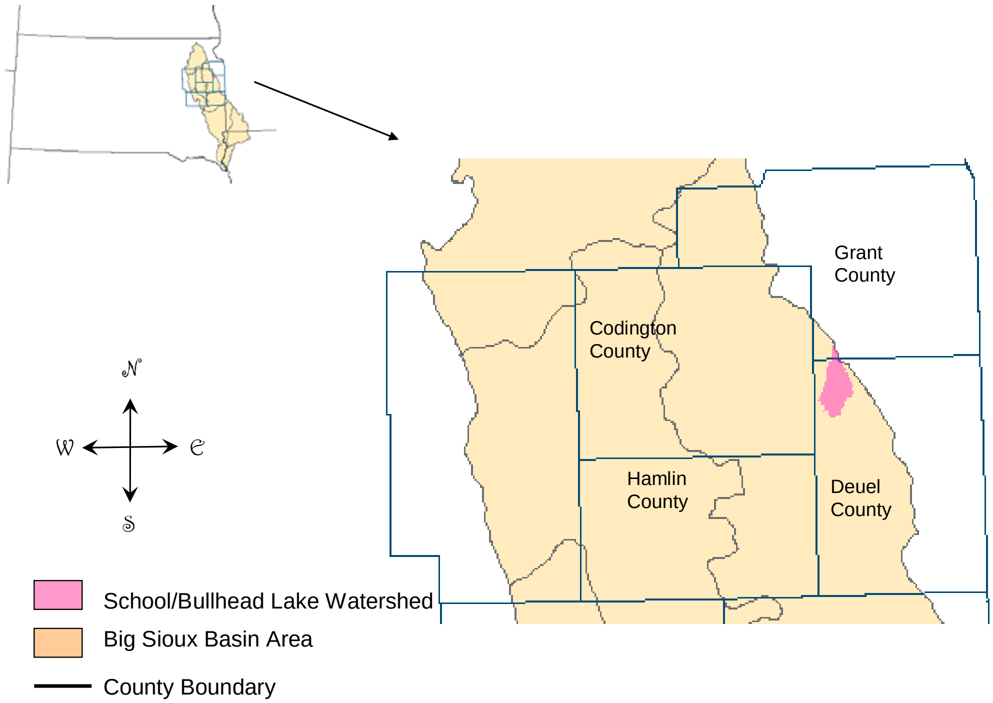


Figure 2. Location of the Watershed in Deuel County, South Dakota

Geology and Soils

Based on the relative age of the landscape, the surficial character of the watershed can be divided into two parts. The landscape to the south and west of School and Wigdale Lakes, including the major tributaries, exhibits a well-developed drainage pattern. Un-drained depressions are rare. The land surface is underlain by glacial till. To the east of these lakes, including the entire Bullhead Lake watershed and much of the Round Lake watershed, drainage is poor, and there are many small potholes and sloughs. Glacial outwash is found around and also east of the lakes. Shallow wells in the saturated sand and gravel (aquifer) are the source of local drinking water. Discharge from the aquifer maintains lake levels during dry periods. The relief in the area is moderate. Land elevation ranges from just over 2,000 feet above mean sea level (MSL) in the southwestern part of the study area to about 1,860 feet (MSL) where School and Bullhead Lakes drain into Round Lake.

The bedrock in the area is the Late Cretaceous Pierre Shale, although no exposures are present. Cretaceous period formations which underlain the shale include Niobrara Chalk, Carlile Shale, Greenhorn Limestone, Granerous Shale, and Dakota Sandstone.

The Cretaceous formations are covered by glacial drift which is physically divided into till and outwash. The glacial till is the predominant drift and it consists of a heterogeneous mixture of silt, sand, and large rock fragments in a matrix of clay. The outwash is commonly found in the valleys and plains of the area and consists of gravel, sand, and some silt. It ranges in thickness from a few feet to almost 70 feet

(Schroeder 1976). Recent alluvial deposits of clay, silt, and sand with some gravel occur along the inlet (T51) to School Lake and are usually 3 to 12 feet in thickness (Beissel and Gilbertson 1987).

Soils within the watershed area are derived from a variety of parent materials. Upland soils are relatively fine-grained, and have developed over glacial till, often with a thin loess (wind-blown silt) cover. Coarse-grained soils are found around the lakes in the area east of the lakes, and are derived from glacial outwash or alluvial sediments.

Climate

The average annual precipitation in the School Lake watershed is 21.9 inches, of which 76 percent typically falls during the growing season of April through September (See Figures 3 and 4). The nearest weather station, located 25 miles west, recorded the average monthly rainfall occurring in 2003 (Table 3). Tornadoes and severe thunderstorms strike occasionally. These storms are often of only local extent and duration, and occasionally produce heavy rainfall events. The annual average snowfall is 35 inches per year. Average temperature between April and September is 48˚F for the low to 72˚F for the high (SDSU 2003).

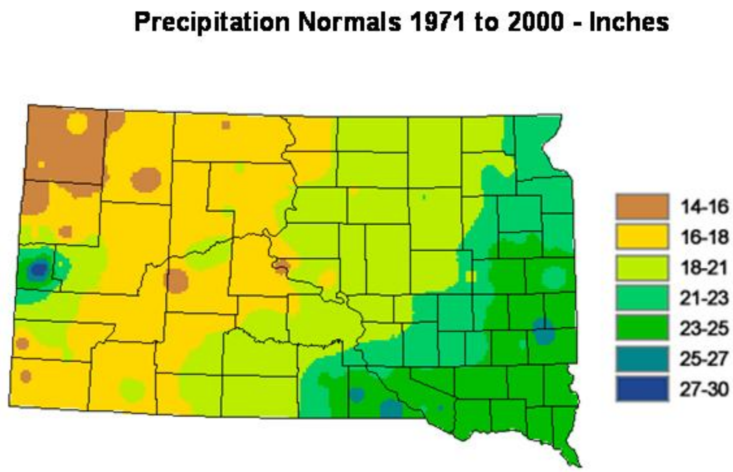


Figure 3. South Dakota Precipitation Normals in Inches from 1971 to 2000

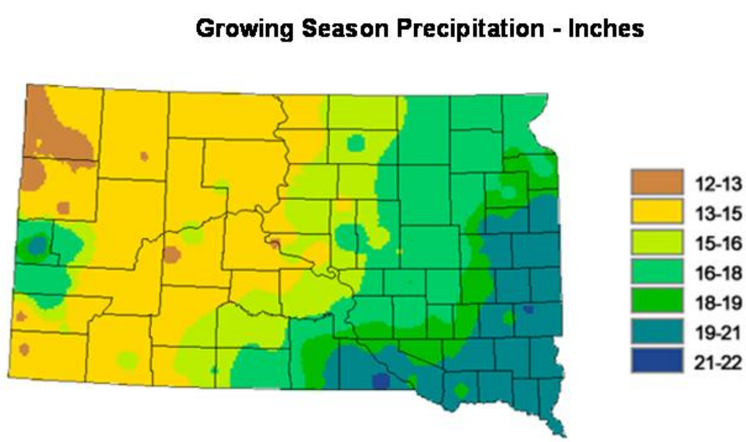


Figure 4. South Dakota Growing Season Precipitation in Inches from 1971 to 2000

Table 3. Monthly Rainfall Averages During the Study Period

WATERTOWN MUNICIPAL AP													
Element	Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TOTAL MONTHLY PRECIPITATION	2003	0.27	1.13	0.39	1.68	2.61	4.16	2.32	1.82	1.49	1.05	0.93	0.29

Land Use

Land use in the watershed is predominantly agricultural (Figure 5). Significant tracts are in grass and/or pasture land, with a limited amount of row crops (corn and soybeans) and small grains. Approximately 48 percent of the area is cropland, such as corn and soybeans, and 32 percent is grassland and pastureland. Sparsely scattered animal feeding operations are located in the watershed, of which five were visited and evaluated. Approximately 520 animals were documented. Of this number, 80 percent were beef cattle. Residential development is limited to the small town of Goodwin and scattered farm dwellings and a few seasonal homes on Bullhead Lake.

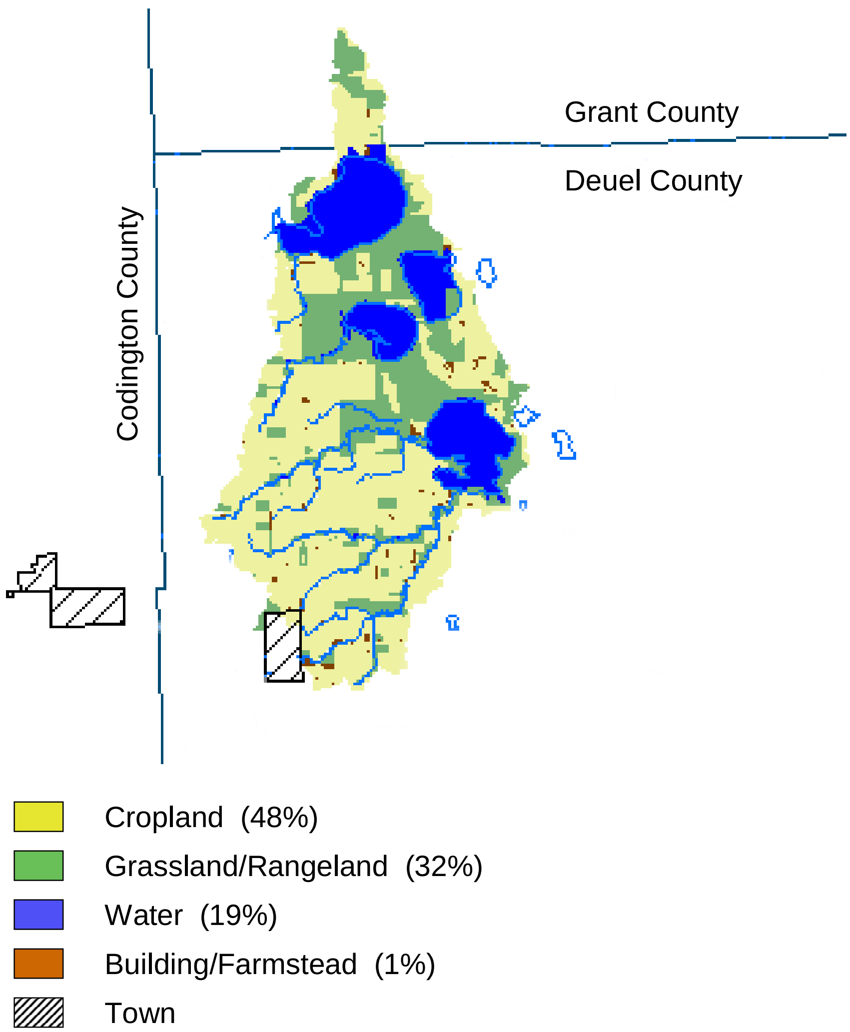


Figure 5. Landuse in the School Lake Watershed

Population

A majority of the population in the School Lake study area lives in the Town of Goodwin in north-central Goodwin Township. The population of Goodwin, based on the 2000 Census, is 160 people. The majority of the watershed lies within Rome Township, with 46 housing units and a population of 99 people.

History

The School Lake Watershed, like most watersheds across the Midwest, have been converted from a range of tallgrass prairie and deciduous hardwoods to a matrix of intensive agricultural uses with areas of urban/residential sprawl. This conversion has resulted in large-scale alterations to watershed level processes. Primarily, the alteration has been an increase in overland flow of energy and material resources resulting from a decrease in ground-water infiltration/subsurface recharge. An increase in surface runoff has associated increases in the non-point source transport of sediment, nutrient, agricultural and residential chemicals, and feedlot runoff.

The area near and around these lakes was known to be occupied by the Sisseton Dakota Indians in the 1800s. These lakes were part of an Indian trail running from Lac qui Parle (Minnesota River) to Fort Pierre (Missouri River). In the late 1800s, Wigdale Lake was named for the pioneer who settled on the shore of the lake. Before this time, it was known as Two Woods Lake. It was known to be dry in 1854, marked by a boulder on the lake bed. The nickname for Wigdale Lake was Mud Lake, School Lake was named for the township school located on the same section, Round Lake was named for its shape, and Bullhead Lake was named for its fish (Leroy Stohr, Deuel County Conservation District, pers.comm).

PROJECT DESCRIPTION

School Lake is a naturally occurring lake located in the northwest corner of Deuel County. The lake is part of a chain of lakes at the headwaters of Willow Creek, which is a tributary of the Big Sioux River. The Big Sioux River, located in eastern South Dakota, is a primary water source for the region. The other lakes within this chain include Round Lake, Bullhead Lake, and Wigdale Lake (See Table 4).

Table 4. Location Description of the Lakes in the Study Area

Lake	Location
Round Lake	T117, R50, Sec 3,4,5,8,9,10
Bullhead Lake	T117, R50, Sec 10. 11, 14, 15, 22, 23
School Lake	T117, R50, Sec 22
Wigdale Lake	T117, R50, Sec 22, 23, 26, 27

The boundaries of the School Lake watershed study area are defined by the watershed boundaries of the chain of lakes. This 22,152 acre area lies within the Northern Glaciated Plains (NGP), Level III, ecoregion. Within the NGP, one of the 15 level IV ecoregions, the Prairie Coteau, is represented in the assessment area (Figure 6). A description of the Prairie Coteau ecoregion is provided in Table 5. Of the ten monitoring sites, seven located within the four lakes and the remaining three were setup to monitor existing inlets/outlets crucial to the study (Figure 7).

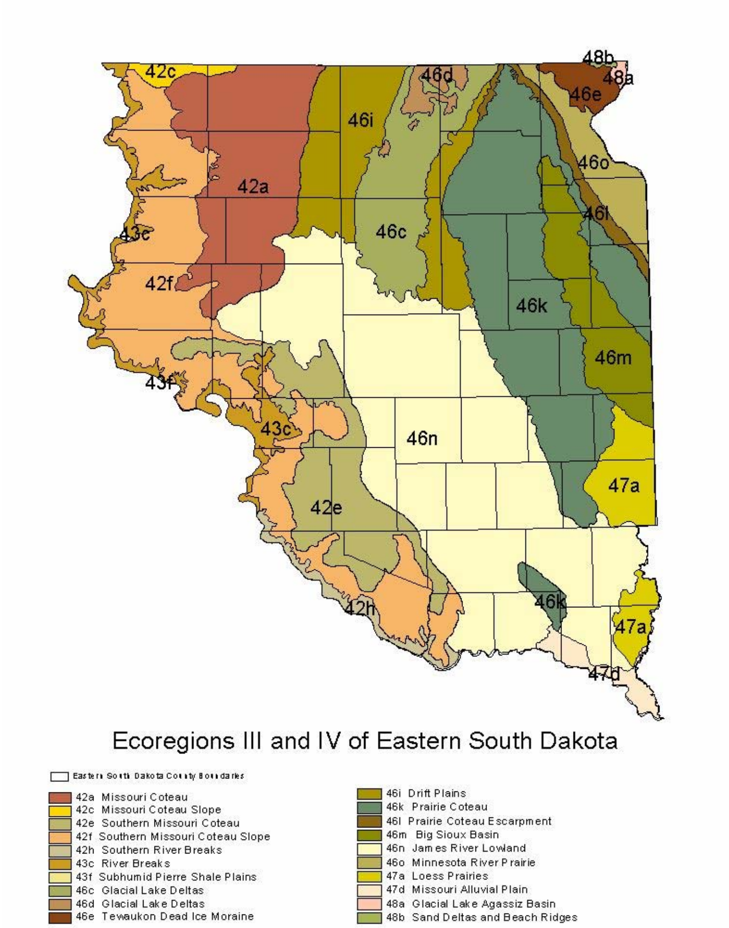


Figure 6. Ecoregions III and IV of Eastern South Dakota

Table 5. Description of the Level IV Ecoregion *Within* the School Lake Watershed (Omernik et al. 1987)

Ecoregion	Physiography	Potential Natural Vegetation	Land Use and Land Cover	Climate	Soil Order
Northern Glaciated Plains					
Prairie Coteau	Surficial geology of glacial till. Hummocky, rolling landscape with high concentration of lakes and wetlands and poorly defined stream network.	Big bluestem, little bluestem, switchgrass, indiangrass, and blue gramma.	Rolling portions of landscape primarily in pastureland. Flatter portions of landscape in row crop, primarily of corn and soybeans. Some small grain and alfalfa.	Mean annual rainfall of 20-22 inches. Frost-free from 110-140 free days.	Mollisols

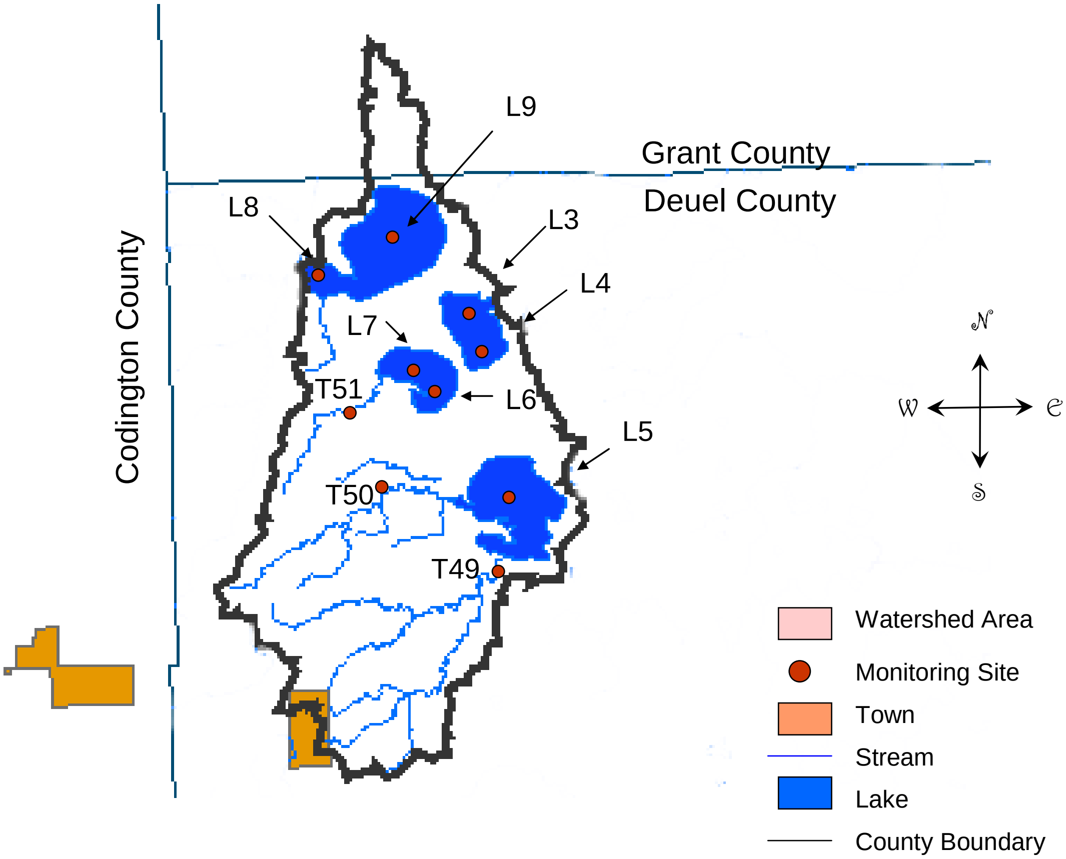


Figure 7. Location of the Monitoring Sites in the School Lake Watershed

BENEFICIAL USES

The State of South Dakota has assigned all of the water bodies that are situated within its borders a set of beneficial uses. Beneficial use means the purpose or benefit to be derived from a water body. Under state and federal law, the beneficial use of water is to be protected from degradation. One of the eleven beneficial uses, (9) fish and wildlife propagation, is assigned to all lakes in South Dakota, and two of the eleven beneficial uses, (9) fish and wildlife propagation and (10) irrigation, are assigned to all the streams in South Dakota. A set of standards is applied to the lakes and streams of this area to maintain the beneficial uses of each waterbody. According to the 1998 and 2000 South Dakota 305(b) water quality assessment, several designated beneficial uses of School Lake are impaired by excess nutrients, siltation, and noxious aquatic plants. Probable sources of these problems are identified in the report as agricultural related. School Lake is classified as hypereutrophic with problems associated with nutrients, siltation, suspended sediment, turbidity, and noxious aquatic plants. In addition, Bullhead Lake, which is a lake within the School Lake watershed, was identified in the past as having excessive nutrients, siltation, and noxious aquatic plants. Designated beneficial uses and numeric water quality standards not to be exceeded for these uses are listed in Table 6 for the School Lake watershed.

All lake sites are assigned beneficial use nine. In addition, School and Round Lakes were assigned beneficial uses six, seven, eight and nine, and Bullhead Lake was assigned five, seven, eight, and nine. The tributary sites were all assigned beneficial uses nine and ten. See Table 7 for a listing of monitored sites and their beneficial use classification.

Table 6. Numeric Criteria Assigned to Beneficial Uses of Surface Waters for the School Lake Watershed

Parameters (mg/L) except where noted	**5** Warmwater semipermanent fish life propagation	**6** Warmwater marginal fish life propagation	**7** Immersion recreation	**8** Limited contact recreation	**9** Fish & wildlife propagation, recreation & stock watering	**10** Irrigation
Fecal Coliform (per 100 mL) May 1 - Sept. 30			≤ 200 (mean); ≤ 400 (single sample)	≤ 1,000 (mean) ≤ 2,000 (single sample)		
Conductivity (µmhos/cm @ 25° C)					≤ 4,000[1]/≤ 7,000[2]	≤ 2,500[1]/≤ 4,375[2]
Total ammonia nitrogen as N (mg/L)	≤ result of equation[3]	≤ result of equation[3]				
Nitrogen, Nitrates (mg/L) as N					≤ 50[1]/≤ 88[2]	
Dissolved oxygen (mg/L)	≥ 5.0	≥ 4.0	≥ 5.0	≥ 5.0		
pH (standard units)	≥ 6.5 - ≤ 9.0	≥ 6.0 - ≤ 9.0			≥ 6.0 - ≤ 9.5	
Total alkalinity (mg/L)					≤ 750[1]/≤ 1,313[2]	
Suspended solids (mg/L)	≤ 90[1]/≤ 158[2]	≤ 150[1]/≤ 263[2]				
Total dissolved solids					≤ 2,500[1]/≤ 4,375[2]	
Temperature (°F)	≤ 90	≤ 90				

Note: [1] 30-day average [2] daily maximum [3] $(0.411 \div (1+10^{7.204-pH})) + (58.4 \div (1+10^{pH-7.204}))$

Table 7. Monitoring Sites and Their Beneficial Use Classification

Water Body	Site ID	Beneficial Use Classification 5	6	7	8	9	10
Wigdale Lake Tributary	T49					■	■
Wigdale Lake Tributary	T50					■	■
School Lake Tributary	T51					■	■
Bullhead Lake I	L3	■		■	■	■	
Bullhead Lake II	L4	■		■	■	■	
Wigdale Lake	L5					■	
School Lake I	L6		■	■	■	■	
School Lake II	L7		■	■	■	■	
Round Lake I	L8		■	■	■	■	
Round Lake II	L9		■	■	■	■	

RECREATIONAL USE

Recreational activities at and near the lakes include fishing, swimming, boating, picnicking, hiking, and hunting (Table 8). School, Bullhead, and Round Lakes are frequented by fisherman. There is no record of creel surveys for these lakes. However, game fish known to be in Round and School Lake include northern pike, yellow perch, and black bullhead. These species are also found in Bullhead Lake along with walleye. There is no record of the types of fish species found in Wigdale Lake. Round Lake and School Lake regularly winterkill. In fact, in 2000 all the study lakes winterkilled. Due to the problem of winterkill these lakes are occasionally stocked with fish. Table 9 shows the most recent stocking activities (Dave Bartling, Deuel County Conservation Officer, pers. comm.). Due to its depth, Bullhead Lake partially winterkills. There are state game production and walk-in areas, as well as federal waterfowl production areas located throughout the watershed (Figure 8). These areas are frequently used by hunters (SDGFP 2004).

Table 8. Recreational Uses for Each Monitored Lake

Lake	Boat Ramp	Public Dock	Shore Fishing	Public Toilets	Swimming
School	X	X	X		X
Bullhead	X	X	X	X	X
Round	X		X	X	X
Wigdale					

Table 9. Stocking Activities

Lake	Year	Species	# stocked
School	2001	Northern Pike Fry	200,000
Round	2001	Northern Pike Fry	500,000
Bullhead	1997	Walleye Fingerlings	68,000

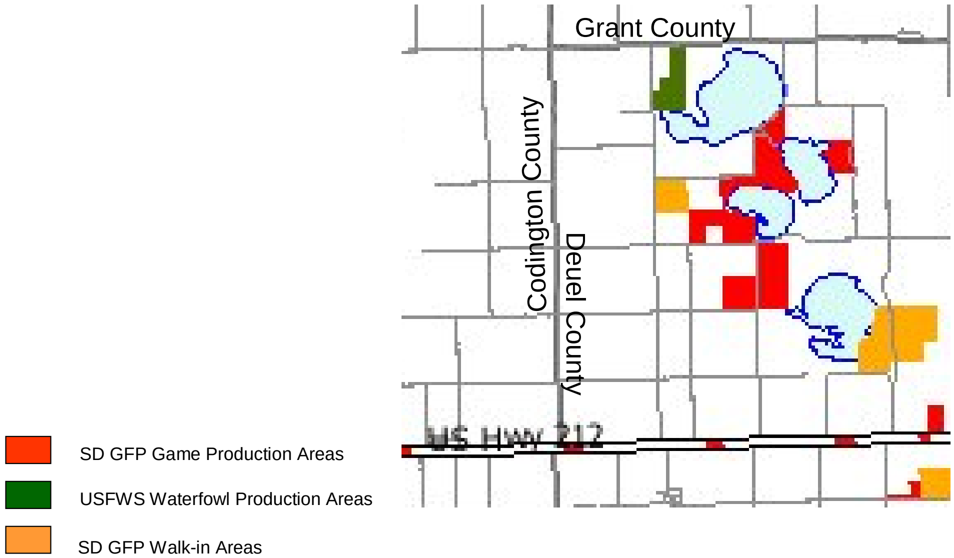


Figure 8. State and Federal Lands Located Within the Watershed

THREATENED AND ENDANGERED SPECIES

Information from South Dakota Game, Fish and Parks (Ashton and Dowd 1991) and the USFWS (2004) were used to construct the following table (Table 10) of the threatened and endangered species that may be found within the School Lake watershed study area. Specie status, within the study area is identified as endangered, threatened, rare, or candidate. The Western Prairie Fringed Orchid was listed by the USFWS as species that have historically been found to occur in Deuel County and could possibly still be in the area. The Bald Eagle, and the Topeka Shiner are listed as species that are known to be found within the area. However, none of these species were encountered during the study.

Table 10. Endangered, Threatened, and Candidate Species of the School Lake Watershed

NAME	SCIENTIFIC NAME	CATEGORY	STATUS FEDERAL	STATUS STATE
Bald Eagle	*Haliaeetus leucocephalus*	Bird	FT	
Topeka Shiner	*Notropis topeka*	Fish	FE	
Banded Killifish	*Fundulus diaphanus*	Fish		SE
Central Mudminnow	*Umbra limi*	Fish		SE
Northern Redbelly Dace	*Phoxinus eos*	Fish		ST
Dakota Skipper	*Hesperia dacotae*	Insect	FC	SR
Regal Fritillary	*Speyeria idalia*	Insect		SR
Western Prairie Fringed Orchid	*Platanthera praeclara*	Plant	FT	
Northern Redbelly Snake	*Storeria occipitomaculata occipitomaculata*	Reptile		ST

KEY TO CODES:

FE = Federal Endangered	SE = State Endangered
FT = Federal Threatened	ST = State Threatened
FC = Federal Candidate	SR = State Rare

PROJECT GOALS, OBJECTIVES, AND MILESTONES

GOALS

The goals of this assessment project are to:

1) Determine and document sources of impairments to the eastern South Dakota
2) Identify feasible restoration alternatives to support watershed implementation projects to improve water quality impairments within the watershed
3) Develop TMDL based on identified pollutants

Impairments cited in the 1998 and the 2000 305(b) Water Quality Assessment Report and the 1998 and 2002 South Dakota 303(d) Waterbody List for this portion of the BSR watershed are excessive nutrients, siltation, and noxious aquatic plants.

Goals were accomplished through the collection of tributary and lake data and aided by the completion of the BATHTUB and the Agricultural Non-Point Source (AGNPS) watershed modeling tools. Through data analysis and modeling, the identification of impairment sources was possible. The identification of these impairment sources will aid the state's nonpoint source (NPS) program by allowing strategic targeting of funds to portions of the watershed that will provide the greatest benefit per expenditure.

OBJECTIVES

Objective 1. Water Quality Assessment

Water sampling of seven in-lake sites and three tributary sites began in April 2003 and lasted through October 2003. Sampling of the tributary sites continued in April 2004 and lasted until June 2004 when the tributaries went dry (See Table 11). Monitoring of the tributaries continued in 2004, due to the automated samplers not being established until June 2003. Spring runoff in 2003 was missed due to the late installation of the automated samplers. Because of this problem, monitoring of the tributaries and automated samplers continued in the spring of 2004.

Detailed level and flow data were entered into a database that was used to assess the nutrient and solids loadings. ISCO GLS samplers and ISCO 4230 bubbler flow meters were installed at the pre-selected monitoring sites along the tributaries.

Objective 2. Quality Assurance/ Quality Control (QA/QC)

Duplicate and blank samples consisted of ten percent of all samples and were collected during the course of the project to provide defendable proof that sample data were collected in a scientific and reproducible manner. QA/QC data collection began in April of 2003 and was completed on schedule in June of 2004 (See Table 11).

Objective 3. Landuse Assessment

Four models were incorporated into this project to analyze and predict loadings. The FLUX model was used to calculate loadings and concentrations in monthly, yearly, and daily increments for the tributaries (inlets) from sample concentration data and continuous flow records. The BATHTUB model was used to predict changes in water quality parameters related to eutrophication (phosphorus, nitrogen, chlorophyll-*a*, and transparency). Reductions of phosphorus and nitrogen watershed loading were modeled to generate an inlake reduction curve. AGNPS was used to model feedlot runoff loads and to help pinpoint areas of concern. The AGNPS model was used to assess the pollution potential of feedlots in the area based on animal numbers, condition of feedlot, proximity to water, soils, rainfall events, and topography. Model outputs included a feedlot rating, chemical oxygen demand, and phosphorus loadings. The AnnAGNPS model is a more extensive variation of the AGNPS model. It was used to simulate the transport of surface water, sediment, nutrients, and pesticides through the watershed, during various rainfall events. The current condition of the watershed was modeled and used to compare the effects of implementing various conservation alternatives over time (See Table 11).

Objective 4. Information and Outreach

Project updates were provided monthly to the EDWDD Board of Directors. Assessments of the conditions of animal feeding operations located within the project area were conducted by contacting landowners individually (See Table 11).

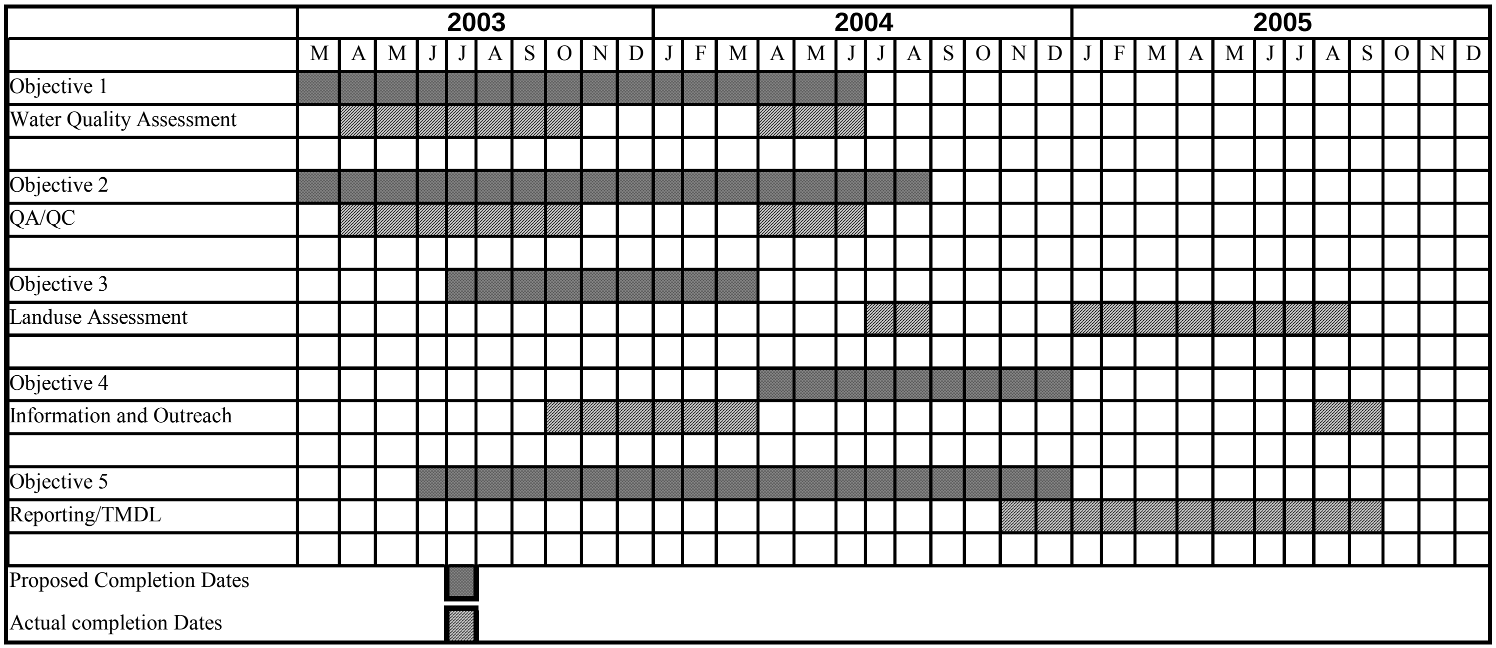
Objective 5. Reporting/TMDL Determination

When a waterbody is listed on a state's 303(d) list, TMDL's must be developed for that waterbody at levels that meet water quality standards that support the designated beneficial uses, shown previously on page 10. A TMDL is a tool or target value that is based on the linkages between water quality conditions and point and non-point sources of pollution. Based upon these linkages, maximum allowable levels of pollution are allocated to the different sources of pollution so that water quality standards are attainable. Sources that exceed maximum allowable levels (or loadings), as shown on Table 6, must be addressed in an implementation plan that calls for management actions that reduce loadings (1998 and 2002 SD 303(d) Waterbody List). Furthermore, an implementation plan can call for protection of areas that are below allowable levels. Identifying the causes and sources of water quality impairments is a continuation of the process that placed the waterbody on the 303(d) list. In the case of School Lake watershed, the hypereutrophic state of the lake which is linked to excess nutrients, siltation and noxious aquatic plants from the probable non-point sources identified in the 305(b) water quality assessment, guided the strategy for this assessment.

MILESTONES

The School Lake Watershed Assessment Project was scheduled to start in March 2003. However, due to the fact that monitoring equipment needed to be purchased and additional staff was hired, water quality monitoring was delayed until April of 1999 and the actual samplers needed to collect runoff were not installed until June 2003. The following table shows the proposed completion dates versus the actual completion dates of the project goals, objectives, and activities.

Table 11. Milestones - Proposed and Actual Objective Completion Dates



METHODS

ENVIRONMENTAL INDICATORS

Water Quality Monitoring

Water samples were collected from seven in-lake sites and three tributary sites. The tributary samples were scheduled for collection to coincide with spring runoff and storm events, and at base flow conditions. A total of 109 samples were collected over a period from April 2003 through June 2004. This included 90 standard samples, 10 blank samples, and 9 duplicate samples.

Field measurements included dissolved oxygen (DO), pH, turbidity, air temperature, water temperature, conductivity, salinity, stage, and general climatic information. A Hanna Instruments 9025 meter was used to measure pH. Salinity, DO, water temperature, and conductivity were measured using a YSI 85 meter. Turbidity was measured using a LaMotte 2020 turbidity meter and a mercury thermometer was used to measure air temperature. Monitoring of the lakes also included Secchi depth measurements.

The State Health Lab in Pierre, South Dakota performed analysis on all samples for alkalinity, total solids, total suspended solids (TSS), volatile total suspended solids, ammonia, nitrate-N, total Kjeldahl nitrogen (TKN), total phosphorus, total dissolved phosphorous, E coli, and fecal coliform bacteria. Appendix A contains all grab sample data for each monitoring site.

Two of the lakes (School Lake and Bullhead Lake) were also monitored by the state of South Dakota as part of the DENR lake assessment monitoring program. Water quality data was incorporated into our reduction prediction database and analyzed in conjunction with our data. The following table (Table 12) depicts the DENR sites that coincided with EDWDD monitoring sites.

Table 12. Project Sites Coinciding with DENR Ambient Monitoring Locations

EDWDD Site	DENR Site	Lake
L6, L7	SWLAZZZ 2319	School
L3, L4	SWLAZZZ 2303	Bullhead

Description of Parameters

Water quality was sampled according to the SD DENR protocols (Stueven et al. 2000). Water quality analyses provided concentrations for a standard suite of parameters (Table 13). The detection limits are set by the State Health lab based on lab equipment sensitivity.

Table 13. Water Quality Parameters Analyzed and Laboratory Detection Limits

Parameter	Units	Lower Detect Limit
Alkalinity-M	mg/L	< 6.0
Alkalinity-P	mg/L	0
Total suspended solids	mg/L	< 1.0
Total solids	mg/L	< 7.0
Volatile Total Suspended Solids	mg/L	< 1.0
Nitrates	mg/L	< 0.1
Ammonia-nitrogen	mg/L	< 0.02
TKN	mg/L	< 0.11
Total phosphorus	mg/L	< 0.002
Total dissolved phosphorus	mg/L	< 0.003
Fecal coliform bacteria	cfu/100 mL	< 10.0
E coli	mpn/100 mL	< 1.0

Alkalinity

Alkalinity is a measure of the buffering capacity of water, or the capacity of water to neutralize acid. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. Alkalinity does not refer to pH, but instead refers to the ability of water to resist change in pH. Waters with low alkalinity are very susceptible to changes in pH. Waters with high alkalinity are able to resist major changes in pH. Lakes with high alkalinity have high pH values while lakes with low alkalinity have low pH values. The hardness of the water is usually determined by the amount of calcium and magnesium salts present in water and is associated with the presence of carbonates. Hard water lakes are generally more productive than soft water lakes and can accept more input of salts, nutrients, and acids to their system without change than can soft water lakes. The range of pH values associated with M-alkalinity (Methyl orange indicator) is 4.2 to 4.5. The range of pH values associated with P-alkalinity (Phenolphthalein indicator) is 8.2 to 8.5.

Total Suspended Solids

Total Suspended Solids (TSS) is the portion of total solids that are suspended in solution, whereas dissolved solids make up the rest of the total. Suspended solids include silt and clay particles, plankton, algae, fine organic debris, and other particulate matter. Higher TSS can increase surface water temperature and decrease water clarity. Suspended solids are the materials that do not pass through a filter, e.g. sediment and algae. Subtracting suspended solids from total solids derives total dissolved solids concentrations. Suspended volatile solids are that portion of suspended solids that are organic (organic matter that burns in a 500^{o} C muffle furnace).

Total Solids

Total Solids are materials, suspended or dissolved, present in natural water. Sources of total solids include industrial discharges, sewage, fertilizers, road runoff, and soil erosion.

Volatile Total Suspended Solids

Volatile solids are those solids lost on ignition (heating to 500 degrees C.) They are useful to the treatment plant operator because they give a rough approximation of the amount of organic matter present in the solid fraction of wastewater, activated sludge and industrial wastes. Volatile solids measure the sediments which are able to be burned off of a dried sediment sample. They are useful because they give a rough approximation of the amount of organic matter present in the water sample. ‘‘Fixed solids’’ is the term applied to the residue of total, suspended, or dissolved solids after heating to dryness for a specified time at a specified temperature. The weight loss on ignition is called ‘‘volatile solids.’’

Nitrate-Nitrite

Nitrate and nitrite are inorganic forms of nitrogen easily assimilated by algae and other macrophytes. Sources of nitrate and nitrite can be from agricultural practices and direct input from septic tanks, precipitation, groundwater, and from decaying organic matter. Nitrate-nitrite can also be converted from ammonia through denitrification by bacteria. The process increases with increasing temperature and decreasing pH.

Ammonia

Ammonia is the nitrogen product of bacterial decomposition of organic matter and is the form of nitrogen most readily available to plants for uptake and growth. Sources of ammonia in the watershed may come from animal feeding areas, decaying organic matter, bacterial conversion of other nitrogen compounds, or industrial and municipal surface water discharges.

Un-Ionized Ammonia

Un-ionized ammonia is the fraction of ammonia that is toxic to aquatic organisms. The concentration of un-ionized ammonia is calculated and dependent on temperature and pH. As temperature and pH increase so does the percent of ammonia which is toxic to aquatic organisms. Since pH, temperature and ammonia concentrations are constantly changing, un-ionized ammonia is calculated instantaneously (by sample) to determine compliance with tributary water quality standards rather than from a loading basis.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is used to calculate organic nitrogen. TKN minus ammonia derives organic nitrogen. Sources of organic nitrogen can include release from dead or decaying organic matter, septic systems or agricultural waste. Organic nitrogen is broken down to more usable ammonia and other forms of inorganic nitrogen by bacteria.

Total Nitrogen

Total nitrogen is the sum of nitrate-nitrite and TKN concentrations. Total nitrogen is used mostly in determining the limiting nutrient, either nitrogen or phosphorus. Nitrogen was analyzed in four forms: nitrate/ nitrite, ammonia, and Total Kjeldahl Nitrogen (TKN). From these four forms, total, organic, and inorganic nitrogen may be calculated. Nitrate and nitrite levels are usually caused from fertilizer application runoff. High ammonia concentrations are directly related to sewage and fecal runoff. Nitrogen is difficult to manage because it is highly soluble and very mobile in water.

Total Phosphorus

Phosphorus differs from nitrogen in that is not as water-soluble and will attach to fine sediments and other substrates. Once attached, it is less available for uptake and utilization. Phosphorus can be natural from geology and soil, from decaying organic matter, waste from septic tanks or agricultural runoff. Nutrients such as phosphorus and nitrogen tend to accumulate during low flows because they are associated with fine particles whose transport is dependent upon discharge (Allan 1995). These nutrients are also retained and released on stream banks and floodplains within the watershed. Phosphorus will remain in the sediments unless released by increased stage, discharge, or current.

Total Dissolved Phosphorus

Total dissolved phosphorus is the fraction of total phosphorus that is readily available for use by algae. Dissolved phosphorus will attach to suspended materials if they are present in the water column and if they are not already saturated with phosphorus. Dissolved phosphorus is readily available to algae for uptake and growth.

Fecal Coliform Bacteria

Fecal coliform are bacteria that are found in the environment and are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. They indicate the possible presence of pathogenic bacteria, viruses, and protozoans that also live in human and animal digestive systems. These bacteria can enter the river and tributaries by runoff from feedlots, pastures, sewage treatment plants, and seepage from septic tanks.

E. Coli

Escherichia coli is a type of fecal coliform bacteria that is found in the intestines of humans and animals. The presence of *E. coli* in water is a strong indication of recent sewage or animal waste contamination, which may contain disease causing organisms.

Dissolved Oxygen

Dissolved oxygen is important for the growth and reproduction of fish and other aquatic life. Solubility of oxygen generally increases as temperature decreases, and decreases with lowing atmospheric pressure. Stream morphology, turbulence, and flow can also have an affect on oxygen concentrations. Dissolved oxygen concentrations are not uniform within or between stream reaches. A stream with running water will contain more dissolved oxygen than still water. Cold water holds more oxygen than warm water. Dissolved oxygen levels of at least 4-5 mg/L are needed to support a wide variety of aquatic life. Very few species can exist at levels below 3 mg/L.

pH

pH is based on a scale from 0 to 14. On this scale, 0 is the most acidic value, 14 is the most alkaline value, and 7 represents neutral. A change of 1 pH unit represents a 10-fold change in acidity or alkalinity. The range of freshwater is 2-12. pH is a measure of hydrogen ion activity, the more free hydrogen ions (more acidic), the lower the pH in water. Values outside the standard (pH 6.0 – 9.5) do not meet water quality standards.

Water Temperature

Water temperature affects aquatic productivity and water chemistry, including the levels of DO and un-ionized ammonia. Temperature extremes are especially important in determining productivity of aquatic life from algae to fish.

Conductivity

Conductivity is the measurement of the conductive material in the sample without regard to temperature. In streams and rivers, conductivity is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity, and areas with clay soils tend to have higher conductivity. In lakes, geology of the watershed establishes the ranges of conductivity. In general, a higher conductivity indicates that more material is dissolved material, which <u>may</u> contain more contaminants.

Specific Conductivity

Also known as temperature compensated conductivity which automatically adjusts the reading to a calculated value which would have been read if the sample had been at 25^{o} C. The ability of water to conduct an electrical current, which is the measure of the quantity of ions in the water. It is determined by the presence of inorganic dissolved solids, such as salts. Specific conductivity is generally found to be a good measure of the concentration of total dissolved solids (TDS) and salinity.

Salinity

Salinity is the natural concentration of salts in water. This is influenced by the geologic formations underlying the area. Salinity is lower in areas underlain by igneous formations and higher in areas underlain by sedimentary formations.

Turbidity (NTU)

Turbidity or water clarity is a measure of how much the passage of light is restricted by suspended particles. Turbidity is measured in nephelometric turbidity units (NTUs). High NTU levels may increase temperatures; lower dissolved oxygen levels, and reduce photosynthesis. High NTU can clog fish gills, which lowers growth rate and resistance to disease; and it can smother fish eggs and macro invertebrates. Sources of turbidity include soil erosion, waste discharge, urban runoff, eroding stream banks, and excessive algae growth.

Secchi Disk

A 20 cm Secchi disk is flat, with black and white alternating quadrants that used to measure the transparency of water. The disk is lowered into water by a rope until the pattern on the disk is no longer visible. The deeper the measurement, the clearer the water.

Sampling

Tributary

Water quality samples were collected between the spring of 2003 and the summer of 2004, during base flows and storm events. Samples were collected using the State of South Dakota standard operating procedures for field sampling. Water samples were then filtered, preserved, and packed in ice for delivery to the State Health lab in Pierre, South Dakota. Stream, climatic, and weather conditions were also recorded at the time of sampling. See Appendix B for water quality field data sheets.

Inlake

Water quality samples were collected once per month, April through October 2003. During the months of June, July, and August additional samples were collected during the chlorophyll-*a* sampling. Samples were collected using the State of South Dakota standard operating procedures for field sampling. Water samples were then filtered, preserved, and packed in ice for delivery to the State Health lab in Pierre, South Dakota. Lake, climatic, and weather conditions were also recorded at the time of sampling. See Appendix B for water quality field data sheets.

Biological Monitoring

Algae Sampling

Algae were sampled once in mid-June and once in mid-August 2003, at each of the four lakes, during the regularly scheduled water quality sampling. A surface water sample was collected at a depth of approximately one meter at three different locations on the lake, including the established monitoring sites. The three samples were equally combined into one overall sample, and then preserved with Lugol's iodine. Samples from each of the four lakes were collected and shipped to the DENR for analysis. Algae were sampled according to the SD DENR protocols (Stueven et al. 2000). Two of the lakes (School Lake and Bullhead Lake) were also monitored by the state of South Dakota as part of the DENR assessment monitoring program, once in June 2003 and once in July 2003.

Chlorophyll-*a* Sampling

Chlorophyll-*a* was sampled at each monitoring location on each of the four lakes. Sampling occurred once per month in April, May and September, and twice per month (every other week) in June, July, and August, during the regularly scheduled water quality sampling. However, the sampling in June, July, and August that did not correspond with regular water quality sampling, and only included chlorophyll-*a*, total phosphorus, total dissolved phosphorus, water temperature, Secchi depth, turbidity, pH, dissolved oxygen, salinity, conductivity, and air temperature. At each location, a column sampler was used to collect the sample, which was stored in a light impenetrable brown bottle. The sample was filtered using a 1.0 micron glass fiber filter with the volume of sample annotated. The filter was wrapped in aluminum foil, placed on ice, and shipped to the DENR in Pierre, South Dakota for analysis. Chlorophyll-*a* was sampled according to the SD DENR protocols (Stueven et al. 2000). Two of the four lakes (School and Bullhead Lakes) were also monitored for chlorophyll-*a* by the state of South Dakota as part of the DENR assessment monitoring program. The DENR sampled School Lake twice in July 2003 and Bullhead Lake once in June 2003 and twice in July 2003.

Aquatic Plant Sampling

Aquatic plants were surveyed in School Lake between 22 July and 5 August 2003. The shoreline was divided into 19 transects (Figure 9). A buoy attached to a 100 m floating rope, marked in 10 m increments, was used to sample each transect. One end of the rope was staked to the shoreline, and the other end attached to a buoy and an anchor which was positioned perpendicular to the shoreline. Lake depth was annotated at the buoy and also at each 10 m increment that was sampled. Starting at the 10 m increment closest to the shoreline, a vegetation rake was cast from the boat in four directions and dragged in to the boat. After each cast, vegetation caught in the tines was recorded. This process was repeated at successive 10 m increments until no vegetation in any of the four directions was documented. Other data recorded included GPS coordinates, identifying transect features on map, date, time, bank stability, shoreline vegetation, riparian zone width, and Secchi depth.

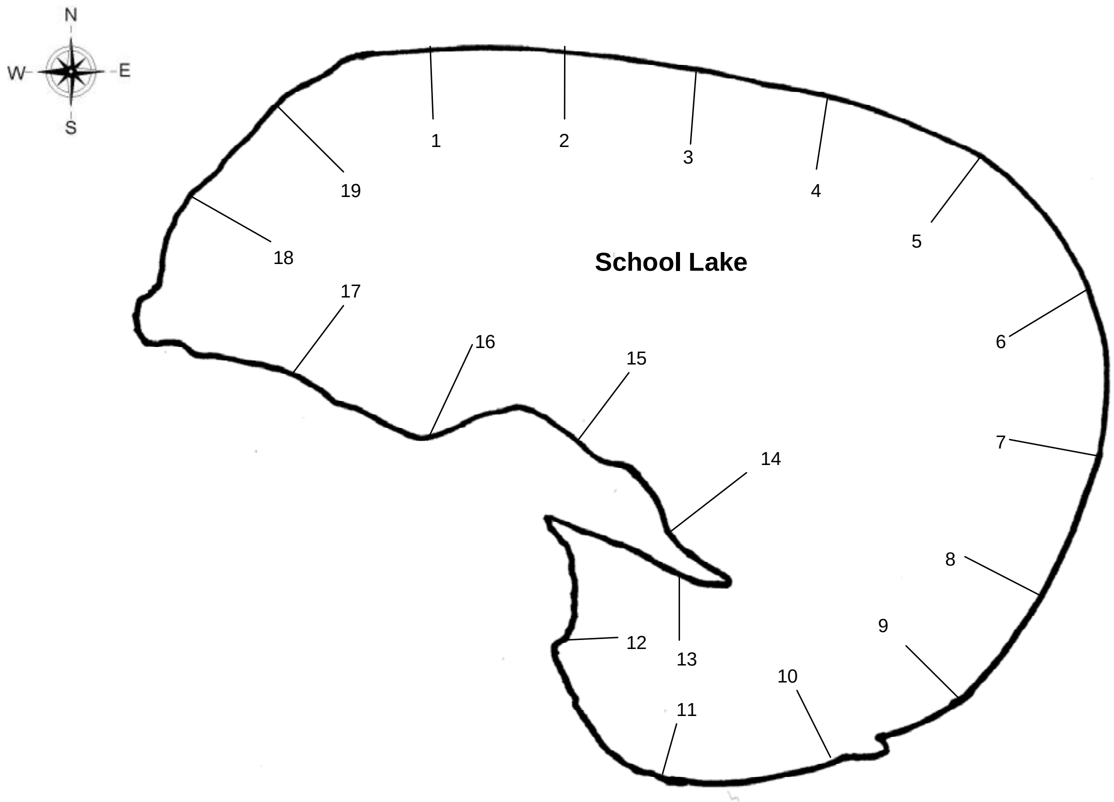


Figure 9. Diagram of the School Lake Vegetation Sampling Transects

Hydrologic Monitoring

Tributary

Three tributary monitoring sites were selected among the inlets and outlets of the lakes in the watershed and continuous stream flow records were collected using flow meters. The sites were selected to determine which portions of the watershed were contributing the greatest amount of nutrient and sediment load to School Lake. Each tributary site was equipped with automated ISCO GLS samplers and ISCO 4230 bubbler flow meters. Water stages were monitored and recorded to the nearest 1/100th of a foot for each of the sites. A USGS top setting wading rod with a pygmy current meter and a CMD 9000 digimeter were used to determine flows at various stages. Each tributary site was also installed with USGS Style C staff gauge as a quality control check for the installed meters. Recorded stages and flows were used to create stage-discharge tables and curves for each tributary (Gordon et al. 1992). Stage-discharge tables, curves, and equations can be found in Appendix C.

Inlake

Hydrologic monitoring of each lake consisted of tracking lake levels using existing benchmarks belonging to the DENR, Water Rights Program. A location description of each benchmark is shown in Table 14.

Table 14. Benchmark Locations for School Lake, Bullhead Lake, Round Lake, and Wigdale Lake

Waterbody	Location
Round Lake	Located in the SW NW Section 10-T117N-R50W, SE side of the lake at the public picnic area, find a 4" diameter cottonwood tree, nail painted red in the base of the cottonwood tree 1.5' above the ground
Bullhead Lake	Located in the NE SW Section 10-T117N-R50W, NW end of the lake at the boat ramp, 62' S-SW along trail from the boat ramp area, 10' W of the centerline of the trail, blue sign indicating the benchmark is a DENR with the round metal cover
School Lake	Located at the boat ramp on the N shore of the lake, take trail to the SW from the NE corner of Section 16-T117N-R48W, trail ends at the boat ramp, 20' W of boat ramp, nail painted orange in the base of a box alder tree 1.5' above the ground
Wigdale Lake	0.20 miles from the NE corner of Section 26 along section line fence between Sections 23 and 26, 1' S of fence, all in T117N-R48W, blue sign indicating the benchmark is a DENR with the round metal cover

Hydrologic Budgets

The hydrologic budget estimates how much water entered and left the lake during the study period. All inputs of water must equal all outputs of water in a hydrologic cycle. However monitoring all possible inputs of water to a lake is very difficult. Thus, an estimate of water load to the lake is necessary to balance the equation.

The hydrologic inputs to Round Lake, School Lake, Bullhead Lake, and Wigdale Lake come from sources such as precipitation, tributary runoff, ungauged runoff, and groundwater. Water Quality data was collected from April 22, 2003 to October 22, 2003. Tributary runoff was calculated using the FLUX model. Rainfall data for the year 2003 was collected from the Watertown, South Dakota field station and used to calculate precipitation inputs. The following equations were used to determine the inputs of the hydrologic budget:

Precipitation:

Amount of precipitation (feet) × Surface area of the lake = Precipitation input

Ungauged Runoff:

Flow coefficients were figured by the following:

Wigdale Lake’s tributaries flow ÷ Tributary drainage area = Coefficients for flow

Ungaged runoff was determined by:

Coefficients for flow × Watershed area = Ungauged runoff

Groundwater:

Outputs – Inputs = Groundwater input

The hydrologic outputs come from sources such as evaporation, advective flow, and change in storage. Advective flow was calculated by the BATHTUB model. Evaporation data was measured from the nearest weather station which is located two miles north of Brookings, South Dakota. The following equations were used to find the outputs of the hydrologic budget:

Evaporation:

Amount of evaporation (feet) × Surface area of the lake = Evaporation Input

Change In Storage:

Benchmark reading in October 2003 – Benchmark reading in April 2003 = Change in storage

Change in storage × Surface area of the lake = Change in storage input

TSI COMPUTATION

Carlson's (1977) Trophic State Index is a comparison index that uses total phosphorus, Chlorophyll-*a*, and Secchi transparency to measure the relative eutrophic state of a waterbody. The concentrations and measurements of these parameters were adjusted to fit an index scale 0 to 100. Inlake data for these three parameters was applied to Carlson's equations. The formulas used are below:

TSI (Total Phophorus) = 10 (6- (LN (48/TP) / LN2)

TSI (Secchi Disk) = (6 – (LN SD / LN2))

TSI (Chlorophyll-*a*) = 10 × (6 – ((2.04 – (0.68 (LN (CHL))) / (LN (2)))

TP = Total phosphorus in μg/L
SD = Secchi depth in meters
CHL = Chlorophyll-*a* in mg/m^3

The mean TSI was calculated by averaging the TSI values for total phosphorus, Secchi depth, and chlorophyll-*a*.

QUALITY ASSURANCE AND DATA MANAGEMENT

Quality Assurance/Quality Control (QA/QC) samples were collected for at least 10% of the samples taken. A total of 109 water samples were collected from 10 monitoring sites. Total QA/QC samples were 19, with nine being duplicates and 10 being blanks.

QA/QC results were entered into a computer database and screened for data errors. Overall, the duplicates produced very similar results to the sample itself, with the exception of fecal coliform and e coli counts.

Field blanks frequently registered detectable limits of nutrients. Total phosphorus and total dissolved phosphorus detects were probably due to the quality of rinsing water and the quality of the acid preserve used with the total dissolved phosphorus. See Appendix D for field duplicates and blanks.

ASSESSMENT OF SOURCES

Point Sources

Wastewater Treatment Facilities (NPDES)

The City of Goodwin is the only NPDES facility located within this watershed. This is a no discharge facility.

Non Point Sources

Urban Stormwater Runoff

Due to the limitations of the monitoring data, it was not feasible to assess stormwater impacts for the City of Goodwin. The City of Goodwin is a small rural town within five miles of the School Lake Watershed. The impact of the City of Goodwin would be minimal since a vast amount of grassland area lies between the town and this watershed.

Agricultural Runoff

Agricultural runoff was taken into account when the BATHTUB and AnnAGNPS models calculated land use scenarios for TSS reductions, and when AGNPS was used to perform ratings on the feedlots in the study area. This information was then incorporated in the process of prioritizing watershed areas for fecal reduction.

Background Wildlife Contribution

As part of the background contribution of fecal coliform bacteria, wildlife was considered. A general estimate of wildlife fecal coliform bacteria loading was derived from assessing total deer contributions. Deer are the largest of the wild animals occupying the study area and factual information was readily available about this animal. Using 2002 SD Game Report, estimations of the amount of deer per square mile was calculated for Deuel County. Watershed areas for each of the four lakes were combined and used to calculate the wildlife contribution (See the Results Section). The following equations were used in the calculation.

The average deer per acre was multiplied by the acres within the watershed:

$$\text{deer/acre} \times \text{watershed acres} = \text{deer/watershed}$$

Then the number of deer per watershed was multiplied by the number of days monitored and then multiplied by the CFU/deer/day (MPCA 2002) to calculate total CFU's per watershed from deer.

$$\text{deer/watershed} \times \text{\# monitoring days} \times \text{CFU/deer/day} = \text{CFU's per watershed (from deer)}$$

Failing Septic Systems Contribution

As part of the background contribution from fecal coliform bacteria, rural households were not considered for their contribution of the total fecal concentration in the watershed. This watershed is not heavily populated and few housing units are located in close vicinity to the lakes. The possible contribution from housing units for fecal coliform bacteria is considered negligible.

Modeling

The strategy for selecting modeling and assessment techniques was based on the need to:

1) balance the cost of modeling intensity with the need to cover a broad geographic area in a timely manner,
2) link the transport of total suspended solids (TSS) with watershed processes and land uses,
3) link the transport of fecal coliform bacteria with feedlot density, proximity, and ratings, and land uses,
4) link the transport of nutrients (phosphorus and nitrates) with watershed processes and land uses, and thus
5) generate key information that integrates the relationship of cumulative effects and watershed health (indices of biological integrity) with the choices and consequences of human decisions in watershed protection and restoration.

These needs conform to the advantages of performing an assessment on a large scale (Barbour et al. 1999). Specific advantages include being able to address cumulative effects by accounting for large-scale watershed processes and how this ability can be used to guide management approaches. Four basic modeling and assessment techniques that were used are described below. Each technique generates an independent set of information (Table 15). This section will focus on the four models used to assess water quality in the study area.

Table 15. Modeling and Assessment Techniques and Outputs Used for the SBLWAP

Modeling Technique	Outputs
FLUX Model	Loadings for WQ Parameters Concentrations for WQ Parameters
BATHTUB Model	Trophic State Index (TSI) Values Reduction Response Model
AGNPS	Total Phosphorus and Nitrogen Chemical Oxygen Demand (COD) Feedlot Rating
AnnAGNPS	Phosphorus (attatched & soluable), Nitrogen (attached & soluable), sediment yield

FLUX Model

Total nutrient and sediment loads of the three inlets were calculated using the Army Corps of Engineers Eutrophication Model known as FLUX (Walker 1999). FLUX uses individual sample data in correlation with daily discharges to develop six loading calculations. For each monitoring site, loadings of total suspended solids, as well as water quality parameters not identified as impairing water quality, were calculated with the model. The FLUX model uses data obtained from 1) grab-sample water quality concentrations with an instantaneous flow and 2) continuous flow records. Loadings and concentrations were calculated by month. Coefficients of variation (CV) were used to determine what method of calculation was appropriate for each parameter at each site (See Appendix E). However, due to the daily flow records including a significant amount of zero flow days, either method 2 (flow-weighted- mean concentration applied to mean flow) or method 3 (flow-weighted- mean concentration applied to mean flow with a bias adjustment factor) were applied. Each water quality parameter was saved by site as daily, monthly and yearly concentrations and loadings.

Water quality, sampled according to Stueven et al. (2000), was analyzed by the State Health Laboratory. Water quality analyses provided concentrations for a standard suite of parameters previously mentioned. Continuous streamflow records for tributary sites were derived using stage records and stage-discharge curves (See Appendix C).

BATHTUB Model

The BATHTUB was used as a model that predicts in-lake responses to tributary loadings. Input data for the model consists of general lake morphology, tributary loading data, and current inlake water quality. Tributary loading data is calculated for the inlets of the lake using the FLUX model.

The BATHTUB model is predictive in that it will assess impacts of changes in water and/or nutrient loadings. The BATHTUB assumes if nutrient concentrations were reduced, the overall TSI values for total phosphorus, Chlorophyll-*a*, and Secchi disk would be reduced, indicating improvement in water quality. Existing tributary nutrient concentrations were reduced by 10 percent successively (10 percent increments) and modeled to create an inlake reduction curve. An example of the reduction curve is shown in Figure 10.

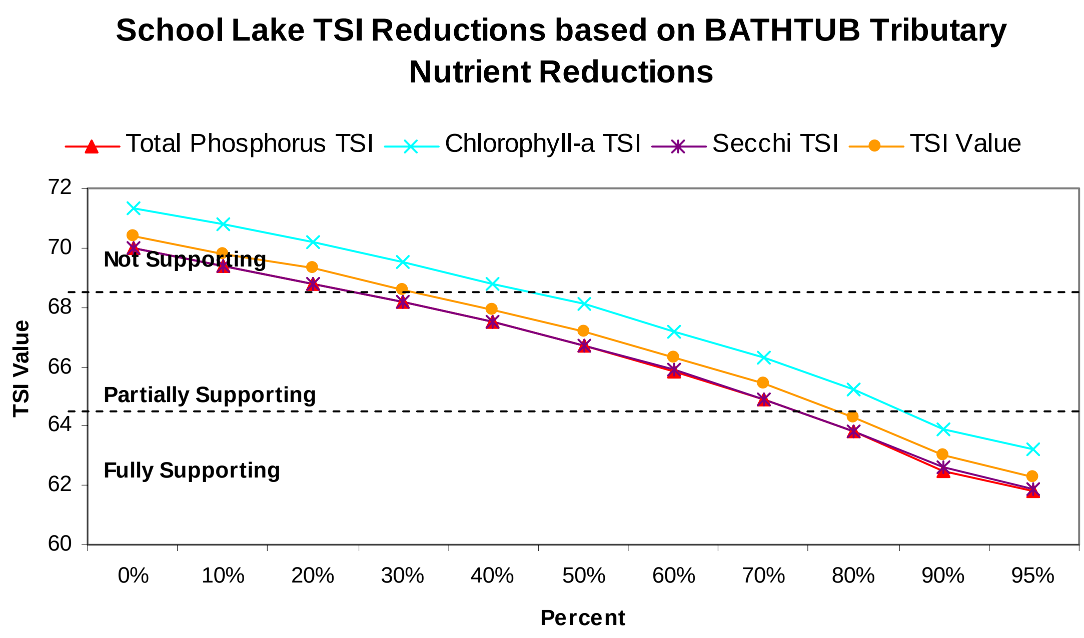


Figure 10. Predicted Trophic State Index (TSI) Reductions Using the BATHTUB Reduction Model

AGNPS Feedlot Model

The Agricultural Non-Point Source Pollution (AGNPS) model is a GIS-integrated water quality model that predicts non-point source pollutant loadings within agricultural watersheds. ArcView GIS software was used to spatially analyze feedlots and their pollution potential.

Watersheds dominated by agricultural land uses, pasturing cattle in stream drainages, runoff from manure application, and runoff from concentrated animal feeding operations can influence fecal coliform bacteria concentrations. The AGNPS feedlot assessment assumed the probable sources of fecal coliform bacteria loadings were related to agricultural land use (upland and riparian), use of streams for stock watering, and animal feeding operations.

Density of feedlots in a watershed upstream from a monitoring site provided a measure of source frequency. A mean of individual feedlot scores weighted by proximity to receiving water monitoring site provided an indicator of potential input from all feedlots. Upland and riparian land uses provide an indicator of the degree of potential land surface sources available to pasturing of livestock. A complete methodology report can be found in Appendix F.

AnnAGNPS Landuse Model

The AnnAGNPS model expands the capabilities of the AGNPS model described above. This model is intended to be used as a tool to evaluate non-point source pollution from agricultural watersheds ranging in size up to 740,000 acres. With this model the watershed is divided up into homogenous land areas or cells based on soil type, land use and land management. AnnAGNPS simulates the transport of surface water, sediment, nutrients, and pesticides through the watershed. The current condition of the watershed can be modeled and used to compare the effects of implementing various conservation alternatives over time within the watershed. The results of the AnnAGNPS model can be found in the Results Section.

RESULTS

WATER QUALITY MONITORING

The data was evaluated based on the specific criteria that the DENR developed for listing water bodies in the 1998 and 2002 South Dakota 303(d) Waterbody List. Use support was based on the frequency of exceedences of water quality standards (if applicable) for the following chemical and field parameters. A stream segment or lake with only a slight exceedence (10% or more violations for each parameter) is considered to meet water quality criteria for that parameter. The EPA established the following general criteria in the 1992 305(b) Report Guidelines (SDDENR 2000) suitable for determining use support of monitored streams.

Fully supporting	≤ 10 % of samples violate standards
Not supporting	> 10 % of samples violate standards

This general criteria is based on having 20 or more samples for a monitoring location. However, for those monitoring sites with less than 20 samples, the following criteria will apply:

Fully supporting	≤ 25 % samples violate standards
Not supporting	> 25 % of samples violate standards

Use support assessment for fishable use (fish life propagation) primarily involved monitoring levels of the following major parameters: dissolved oxygen, unionized ammonia, water temperature, pH, and suspended solids. Use support for swimmable uses and limited contact recreation involved monitoring the levels fecal coliform bacteria (May 1 – September 30) and dissolved oxygen. If more than one beneficial use is assigned for the same parameter (i.e. fecal coliform bacteria) at a particular monitoring site, the more stringent criteria will apply. The use support for monitoring sites will be discussed further in the Assessment Section. The results for the following parameters are summarized below for all the tributary and river sites. See Appendix G for detailed information about means, minimums, maximums, medians, percent violations, and use support of each monitoring site and parameter.

Chemical Parameters

Fecal Coliform Bacteria

Tributary

Fecal coliform bacteria ranged from non-detect at both Wigdale Lake inlets (Sites T49 and T50), to a maximum of 9,000 cfu/100mL at School Lake inlet T51 (See Figure 11). There are no fecal coliform bacteria standards for these inlets.

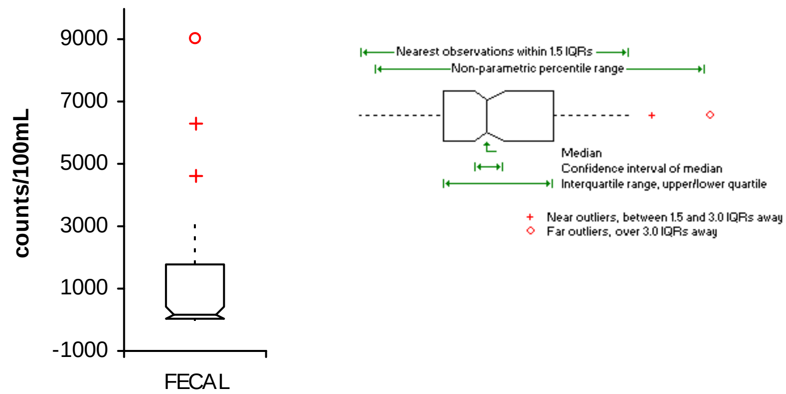


Figure 11. Box Plot of Fecal Coliform Bacteria for Tributary Sites

Inlake

Fecal coliform bacteria ranged from non-detect at all inlake sites (L3 through L9), to a maximum of 40 cfu/100ml at Site L8 (Round Lake I) for all inlake sites L3 through L9 (See Figure 12). A single grab sample daily maximum of 400 cfu/100mL was used to determine the percent violations and assess for the beneficial use support of (7) Immersion Recreation for inlake sites L3, L4, L6, L7, L8, and L9. Using this criterion, these inlake sites are fully supporting for this parameter. Based on the existing standards, inlake site L5 (Wigdale Lake) is not assigned a water quality standard for fecal coliform bacteria.

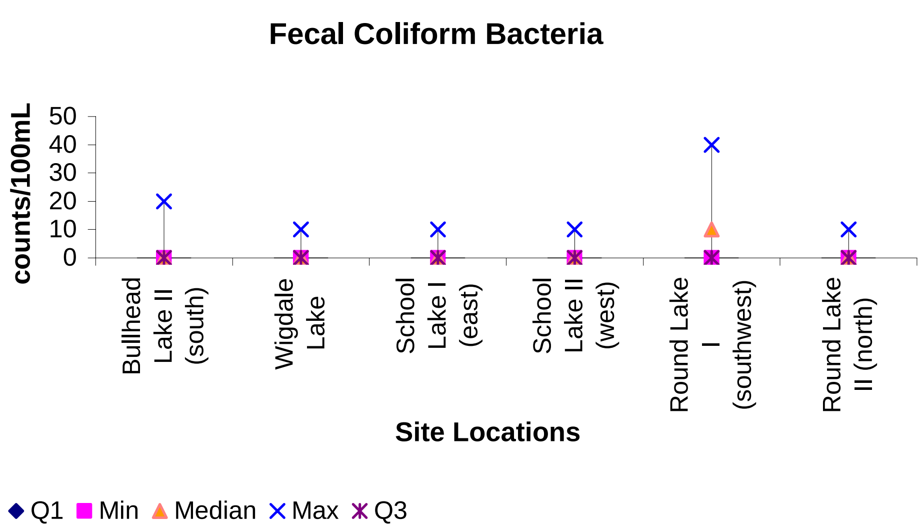


Figure 12. Box Plot of Fecal Coliform Bacteria for Inlake Sites

E. Coli

Tributary

E. coli ranged from a minimum of 2.0 mpn/100mL at site T51-School Lake inlet, to a maximum of >2420 mpn/100mL at all tributary sites T49, T50 and T51 (See Figure 13). There is no standard or assigned beneficial use for this parameter.

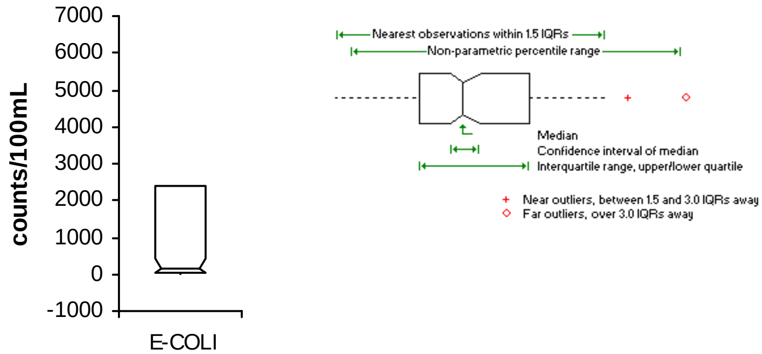


Figure 13. Box Plot of E. Coli for Tributary Sites

Inlake

E. coli ranged from a non-detect at inlake sites L3 and L4 (Bullhead Lake), L5 (Wigdale Lake), and L6 and L7 (School Lake), to a maximum of 20.5 mpn/100mL at site L8-Round Lake I, for all inlake sites L3 through L9 (See Figure 14). There is no standard or assigned beneficial use for this parameter.

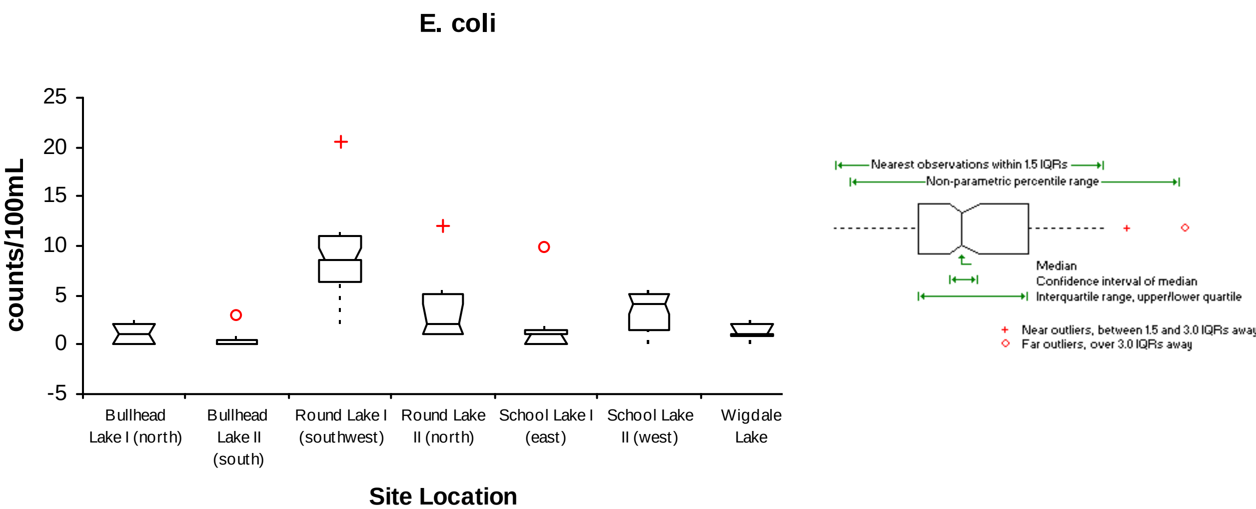


Figure 14. Box Plot of E. Coli for Inlake Sites

Total Solids

Tributary

Total solids at all tributary sites ranged from a minimum of 421 mg/L at Wigdale Lake Inlet T49, to a maximum of 1,251 mg/L at the same location (See Figure 15). There is no standard or assigned beneficial use for this parameter.

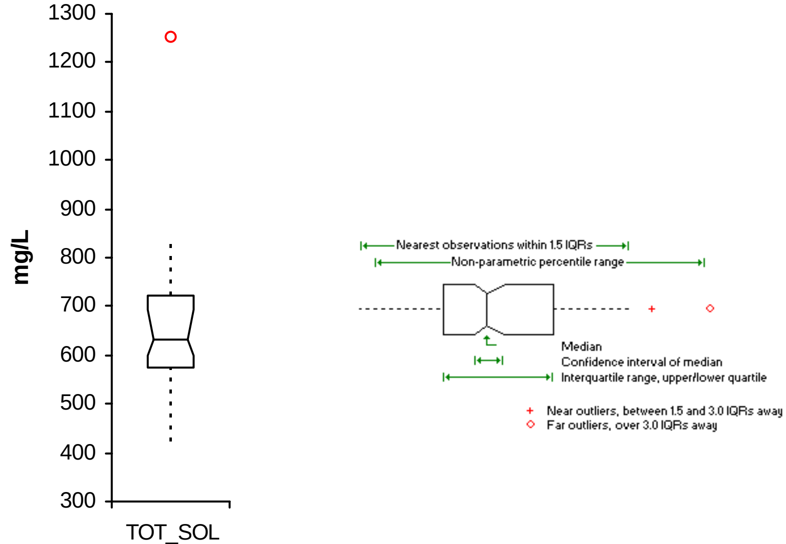


Figure 15. Box Plot of Total Solids for Tributary Sites

Inlake

Total solids ranged from a minimum of 326 mg/L at Site L5 (Wigdale Lake), to a maximum of 578 mg/L at Site L4 (Bullhead Lake II) for all inlake sites L3 through L9 (See Figure 16). There is no standard or assigned beneficial use for this parameter.

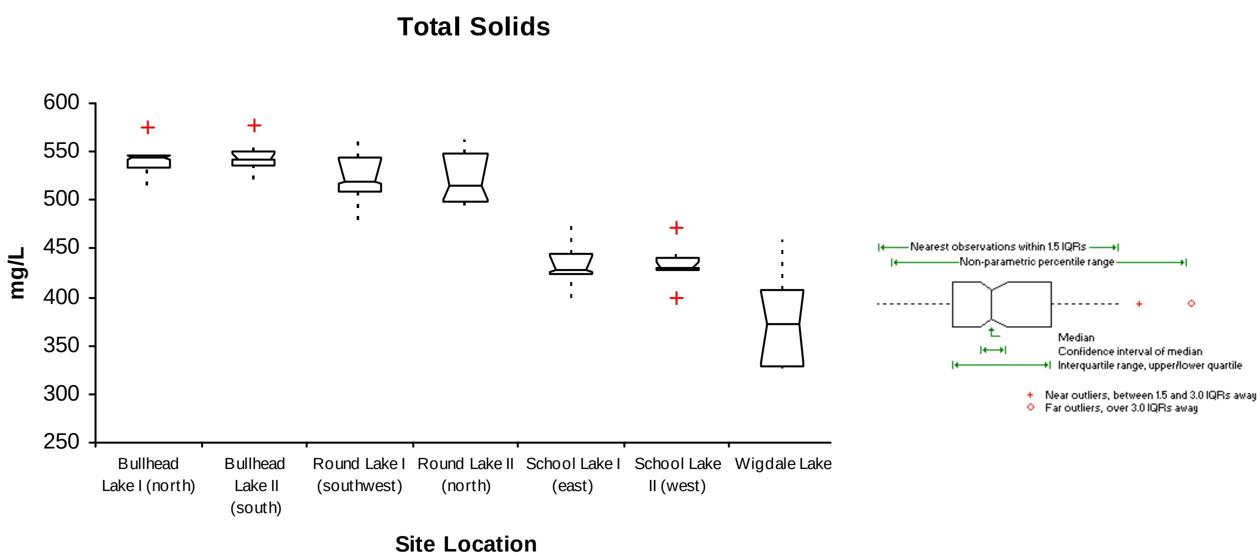


Figure 16. Box Plot of Total Solids for Inlake Sites

Total Suspended Solids

Tributary

Total suspended solids ranged from a minimum of 4 mg/L at Wigdale Lake Inlet T49, to a maximum of 55 mg/L at Wigdale Lake inlet T50 (See Figure 17). There are no total suspended solid standards for these inlets.

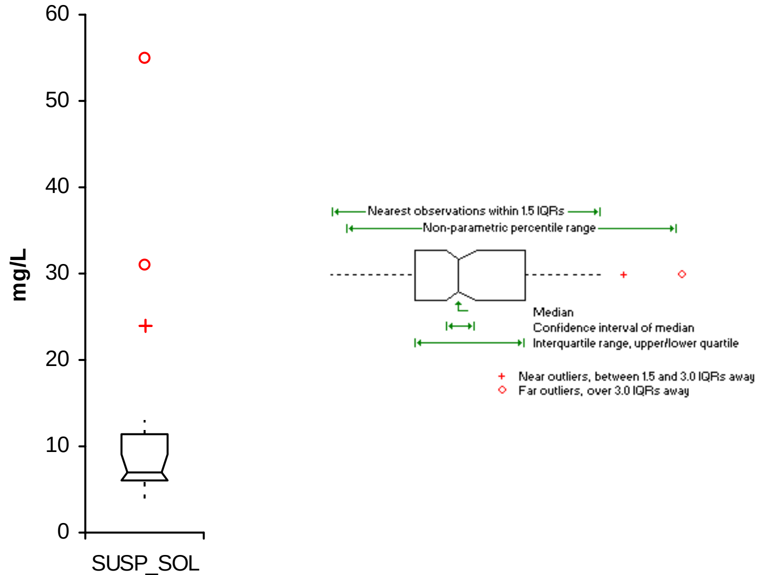


Figure 17. Box Plot of Total Suspended Solids for Tributary Sites

Inlake

Total suspended solids ranged from a minimum of 8 mg/L at L6 (School Lake I), to a maximum of 116 mg/L at L5 (Wigdale Lake) for all inlake sites L3 through L9 (See Figure 18). A single grab sample daily maximum of 158 mg/L was used to determine the percent violations and assess for the beneficial use support of (5) Warm Water Semi-permanent Fish Life Propagation for inlake sites L3 and L4 (Bullhead Lake). A single grab sample daily maximum of 263 mg/L was used to determine the percent violations and assess for the beneficial use support of (6) Warm Water Marginal Fish Life Propagation for inlake sites L6 and L7 (School Lake), and L8 and L9 (Round Lake). All inlake sites assigned this criteria are fully supporting of this parameter. Based on the existing standards, inlake site L5 (Wigdale Lake) is not assigned a water quality standard for total suspended solids.

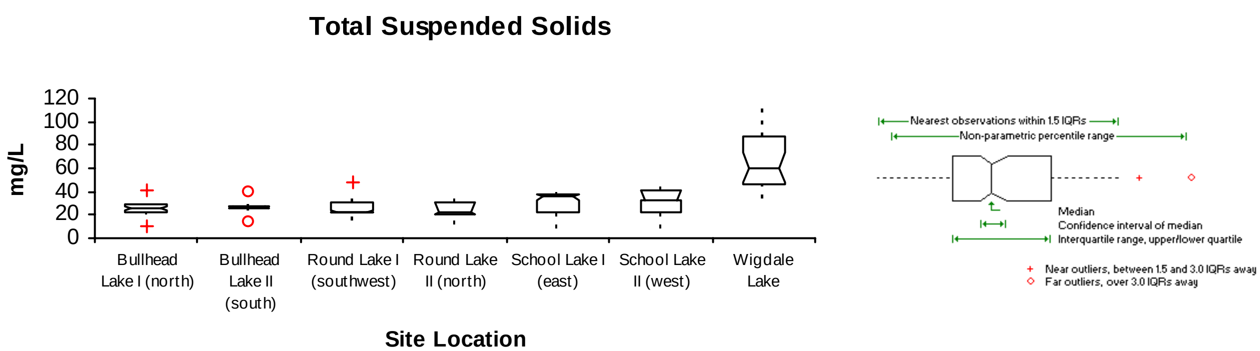


Figure 18. Box Plot of Total Suspended Solids for Inlake Sites

Total Dissolved Solids

Tributary

TDS at all tributaries ranged from a minimum of 414 mg/L at the Wigdale Lake inlet T49, to a maximum of 1,245 mg/L at the same location (See Figure 19). A single grab sample daily maximum of 4,375 mg/L was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife, Propagation, Recreation and Stock Watering for all tributary sites (T49, T50, and T51). Using this criterion, all these sites are fully supporting for this parameter.

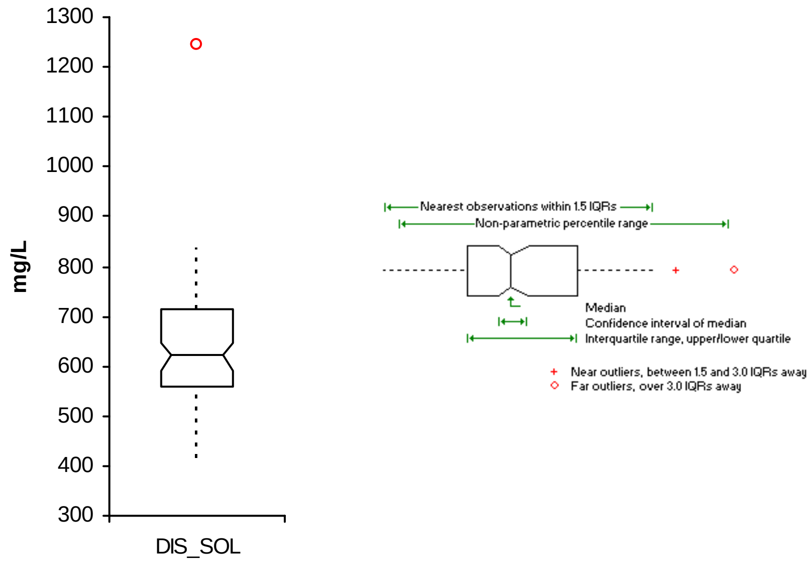


Figure 19. Box Plot of Total Dissolved Solids for Tributary Sites

Inlake

TDS for inlake sites ranged from a minimum of 267 mg/L at L5-Wigdale Lake, to a maximum of 541 mg/L at L9-Round Lake II (See Figure 20). A single grab sample daily maximum of 4,375 mg/L was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife, Propagation, Recreation and Stock Watering for all inlake sites L3 through L9. Using this criterion, all these sites are fully supporting for this parameter.

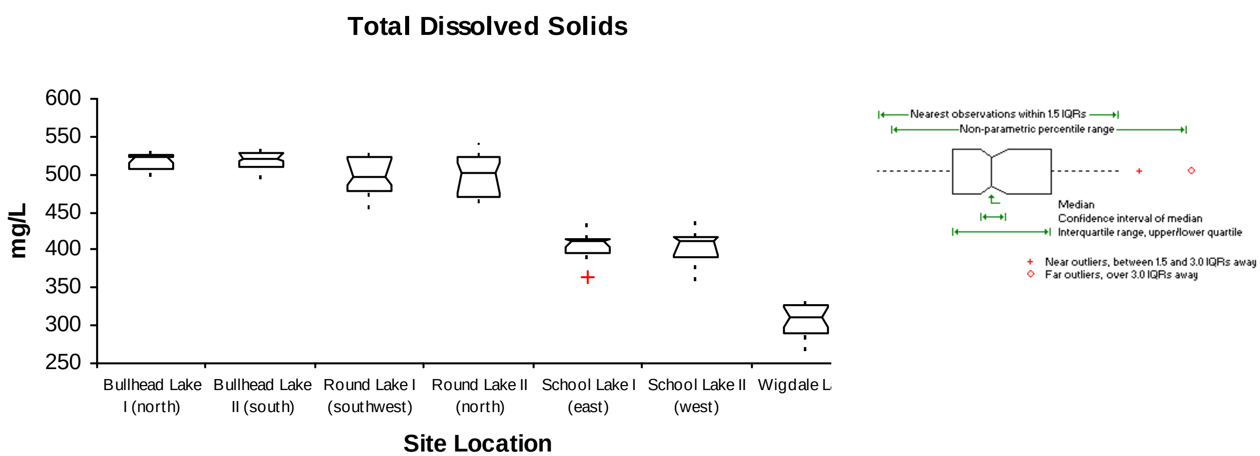


Figure 20. Box Plot of Total Dissolved Solids for Inlake Sites

Volatile Total Suspended Solids

Tributary

Volatile total suspended solids ranged from non-detect at site T51-School Lake inlet, to a maximum of 18.0 mg/L at site T50-Wigdale Lake inlet, for all tributary sites T49, T50, and T51 (See Figure 21). There is no standard or assigned beneficial use for this parameter.

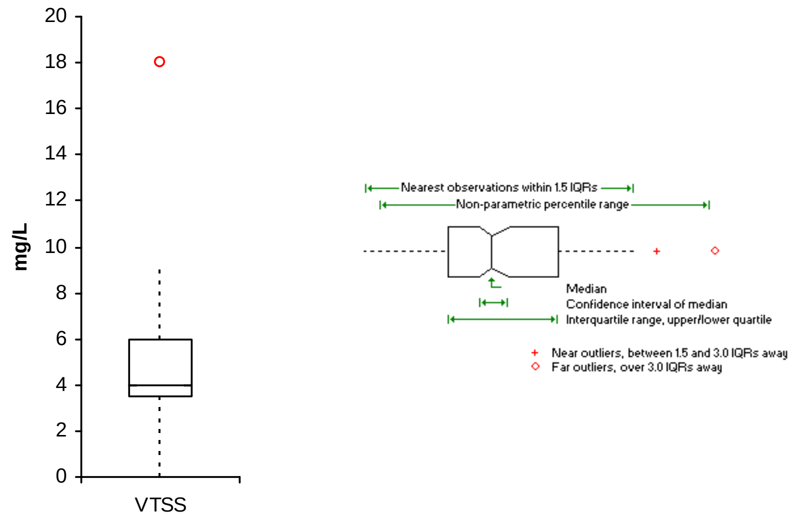


Figure 21. Box Plot of Volatile Total Suspended Solids for Tributary Sites

Inlake

Volatile total suspended solids ranged from a minimum of 3.0 mg/L at site L9-Round Lake II, to a maximum of 90 mg/L at site L5-Wigdale Lake, for all inlake sites L3 through L9 (See Figure 22). There is no standard or assigned beneficial use for this parameter.

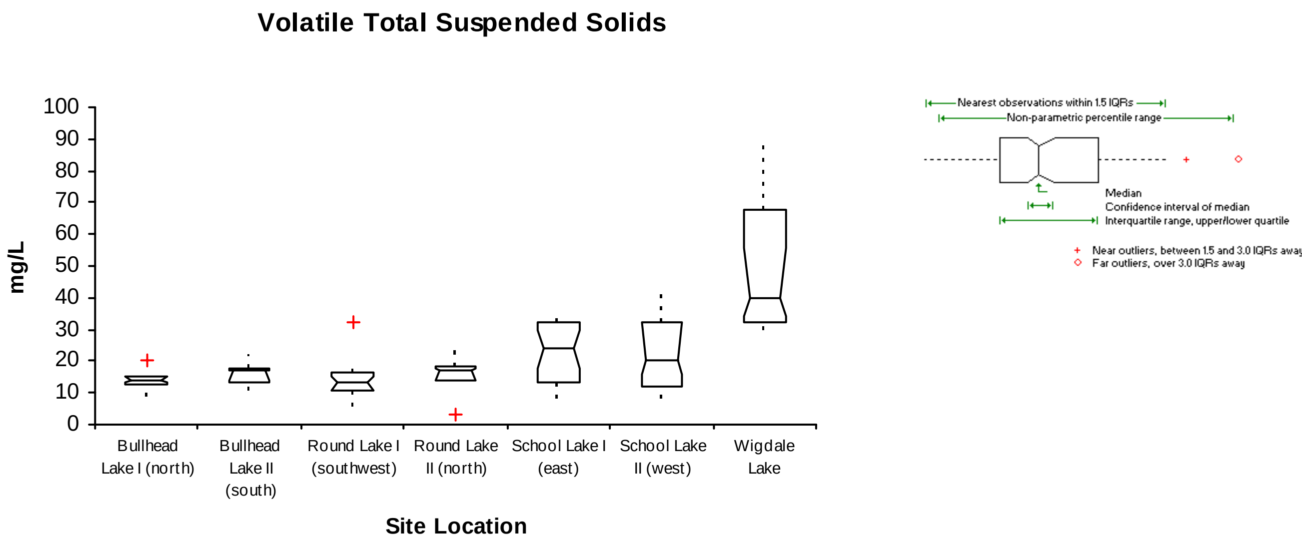


Figure 22. Box Plot of Volatile Total Suspended Solids for Inlake Sites

Alkalinity-M

Tributary

Alkalinity-M ranged from a minimum of 149 mg/L at site T49-Wigdale Lake inlet, to a maximum of 349 mg/L at the same location, for all tributary sites T49, T50, and T51 (See Figure 23). A single grab sample daily maximum of 1,313 mg/L was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife, Propagation, Recreation and Stock Watering for all tributary sites. Using this criterion, all sites are fully supporting for this parameter.

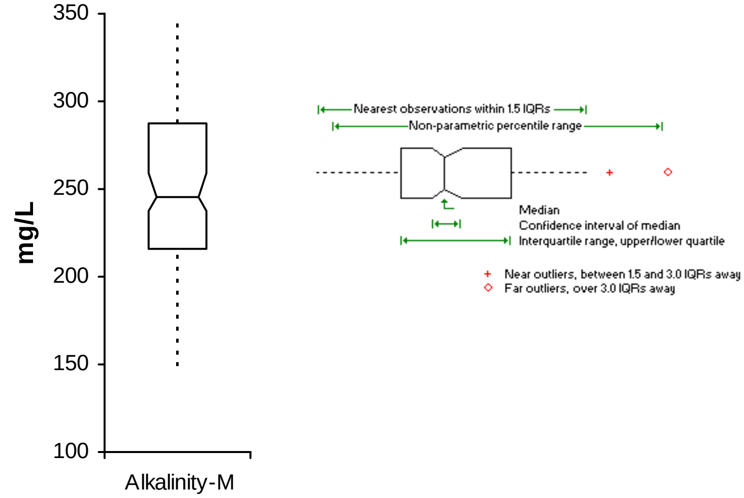


Figure 23. Box Plot of Alkalinity-M for Tributary Sites

Inlake

Alkalinity-M ranged from a minimum of 112 mg/L at site L7-School Lake II, to a maximum 306 mg/L at the same location, for all inlake sites L3 through L9 (See Figure 24). A single grab sample daily maximum of 1,313 mg/L was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife, Propagation, Recreation and Stock Watering for all inlake sites L3 through L9. Using this criterion, all these sites are fully supporting for this parameter.

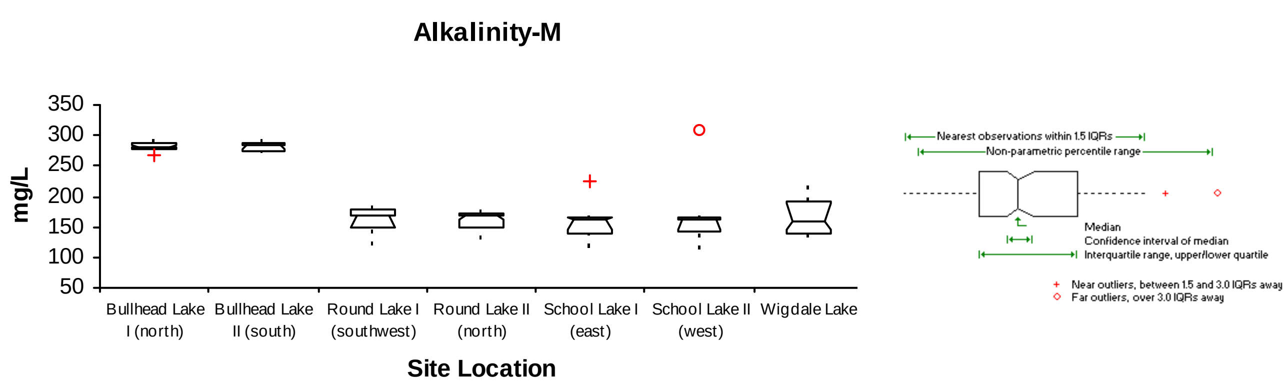


Figure 24. Box Plot of Alkalinity-M for Inlake Sites

Alkalinity-P

Tributary

Alkalinity-P ranged from a non-detect at all tributary sites (T49-T51), to a maximum of 3 mg/L at site T49-Wigdale Lake Inlet. The only tributary to register an alkalinity-P concentration was site T49. There is no standard or assigned beneficial use for this parameter.

Inlake

Alkalinity-P ranged from a non-detect at sites L5 (Wigdale Lake), L6 and L7 (School Lake) and sites L8 and L9 (Round Lake), to a maximum 46 mg/L at site L5-Wigdale Lake, for all inlake sites L3 through L9 (See Figure 25). There is no standard or assigned beneficial use for this parameter.

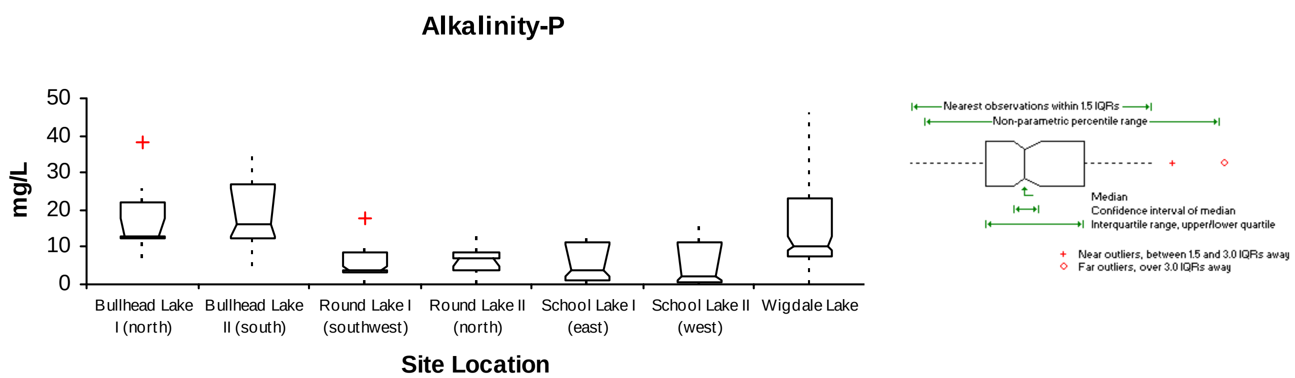


Figure 25. Box Plot of Alkalinity-P for Inlake Sites

Ammonia / Total Ammonia Nitrogen as N

Tributary

Ammonia ranged from a non-detect at all tributary sites (T49-T51), to a maximum of .78 mg/L at T49-Wigdale Lake Inlet (See Figure 26). Total ammonia nitrogen as N at all tributary sites were non-detect. There is no standard or assigned beneficial use for ammonia and total ammonia nitrogen as N.

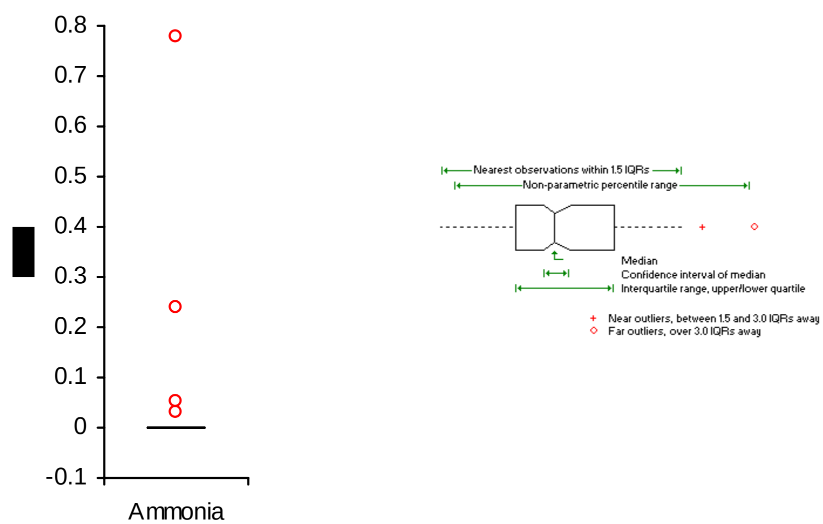


Figure 26. Box Plot of Ammonia for Tributary Sites

Inlake

Ammonia ranged from a non-detect at all inlake sites, to a maximum 0.05 mg/L at L3-Bullhead Lake I, for all inlake sites L3 through L9 (See Figure 27). There is no standard or assigned beneficial use for ammonia. Total ammonia nitrogen as N was calculated using a single grab sample of pH using this equation $(0.411 \div (1+10^{7.204-pH})) + (58.4 \div (1+10^{pH-7.204}))$. Total ammonia and total ammonia nitrogen as N was compared to determine percent violations and assess for beneficial use (5), Warmwater Semipermanent Fish Life Propagation for inlake sites L3 and L4, and beneficial use (6) Warmwater Marginal Fish Life Propagation for inlake sites L6, L7, L8, and L9. Using this criterion, these inlake sites are fully supporting for this parameter. Based on existing standards, inlake sites L5 (Wigdale Lake) is not assigned a water quality standard for total ammonia nitrogen as N.

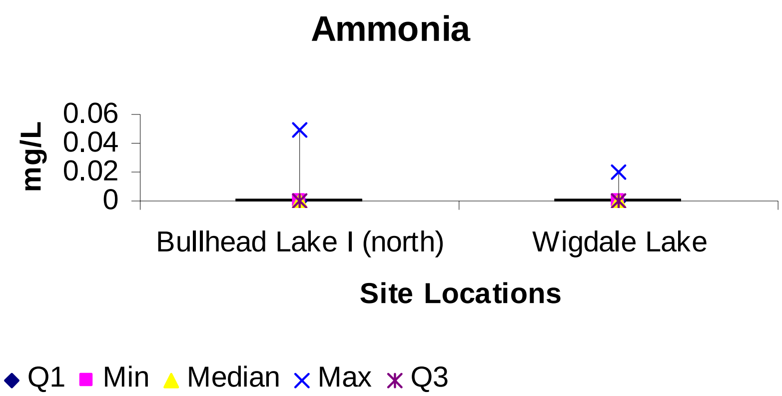


Figure 27. Box Plot of Ammonia for Inlake Sites

Unionized Ammonia

Tributary

Unionized ammonia concentration ranged from a non-detect at all tributary sites, to a maximum of 0.0133 mg/L at T49-Wigdale Lake inlet (See Figure 28). There are no unionized ammonia standards assigned to these inlets.

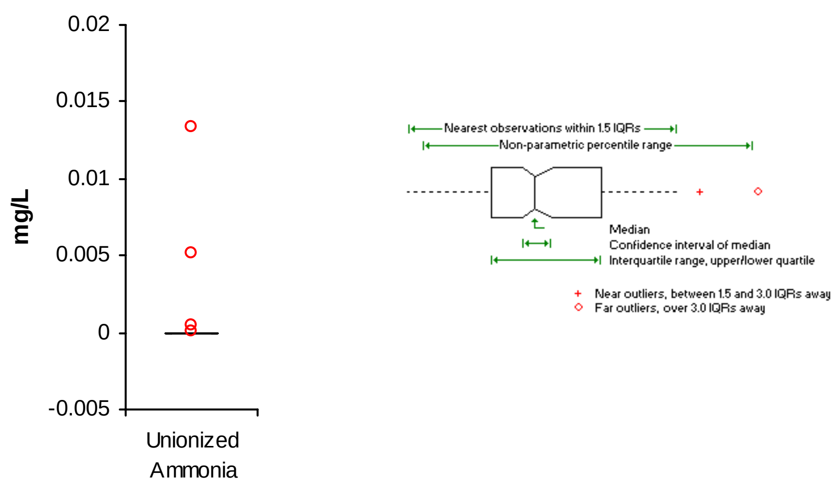


Figure 28. Box Plot of Unionized Ammonia for Tributary Sites

Inlake

Unionized ammonia concentration ranged from a non-detect at all inlake sites, to a maximum of 0.0107 mg/L at L5- Wigdale Lake, for all inlake sites L3 through L9 (See Figure 29). There are no unionized ammonia standards assigned to these inlets.

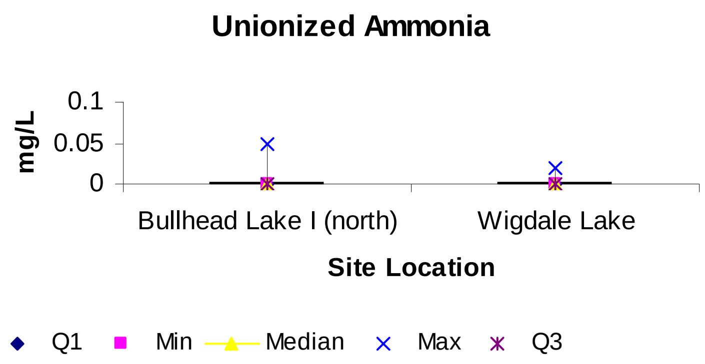


Figure 29. Box Plot of Unionized Ammonia for Inlake Sites

Nitrate-Nitrite

Tributary

Nitrate-nitrite ranged from a non-detect at all tributary sites, to a maximum of 3.5 mg/L at site T49- Wigdale Lake inlet (See Figure 30). A single grab sample daily maximum of 88 mg/L was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife Propagation, Recreation and Stock Watering for all tributary sites T49, T50 and T51. Using this criterion, all tributary sites are fully supporting of this parameter.

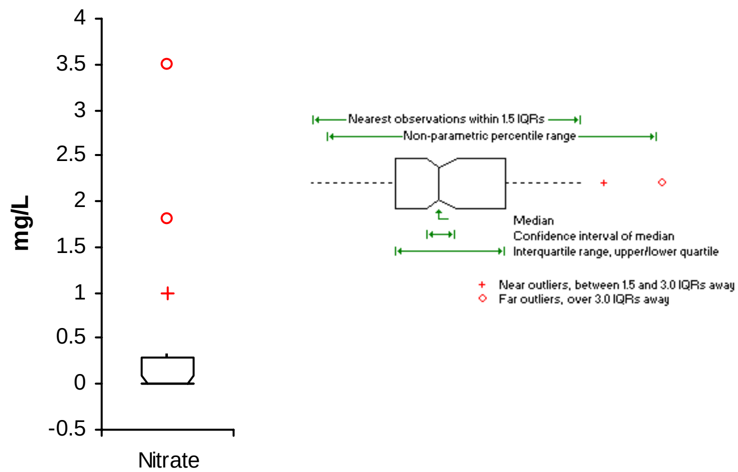


Figure 30. Box Plot of Nitrate-Nitrite for Tributary Sites

Inlake

Nitrate-nitrite concentration at all inlake sites were non-detects. A single grab sample daily maximum of 88 mg/L was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife Propagation, Recreation and Stock Watering for all inlake sites L3, L4, L5, L6, L7, L8, and L9. Using this criterion, all sites are fully supporting of this parameter.

Total Kjeldahl Nitrogen

Tributary

TKN ranged from a minimum of 0.56 mg/L at site T51-School Lake inlet, to a maximum of 3.25 mg/L at site T49-Wigdale Lake inlet, for all tributary sites T49, T50 and T51 (See Figure 31). There is no standard or assigned beneficial use for this parameter.

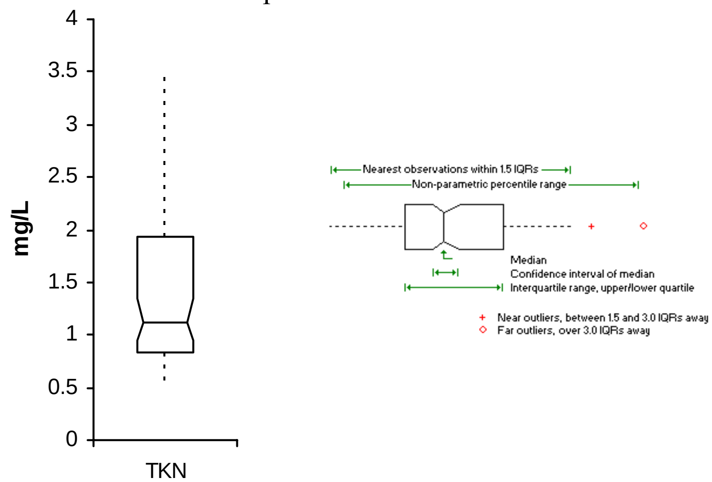


Figure 31. Box Plot of Total Kjeldahl Nitrogen for Tributary Sites

Inlake

TKN ranged from a minimum of one mg/L at inlake sites L6 and L7 (School Lake), to a maximum of 6.29 mg/L at site L5-Wigdale Lake, for all inlake sites L3 through L9 (See Figure 32). There is no standard or assigned beneficial use for this parameter.

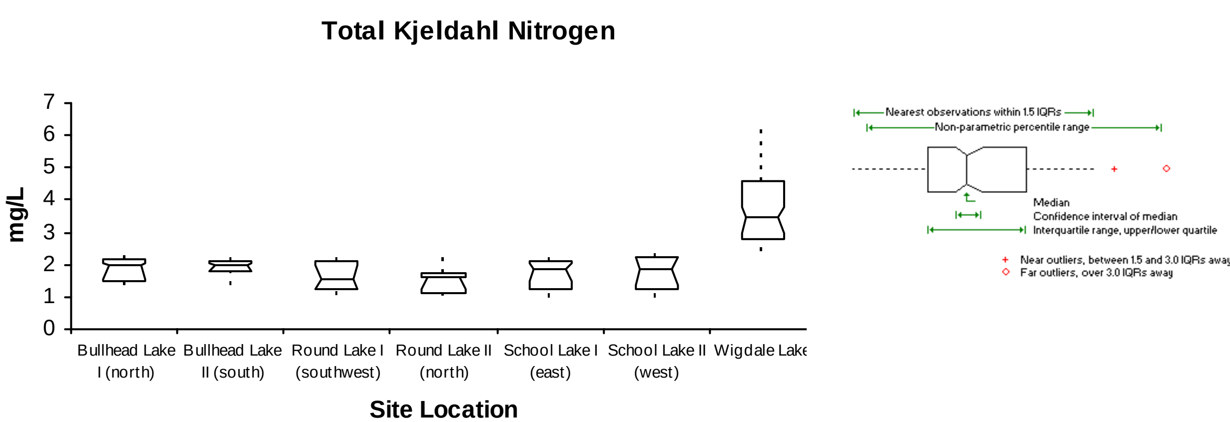


Figure 32. Box Plot of Total Kjeldahl Nitrogen for Inlake Sites

Total Phosphorus

Tributary

Total phosphorus ranged from a minimum of 0.029 mg/L at site T51-School Lake inlet, to a maximum of 0.936 mg/L at site T49-Wigdale Lake inlet, for all tributary sites T49, T50, T51 (See Figure 33). There is no standard or assigned beneficial use for this parameter.

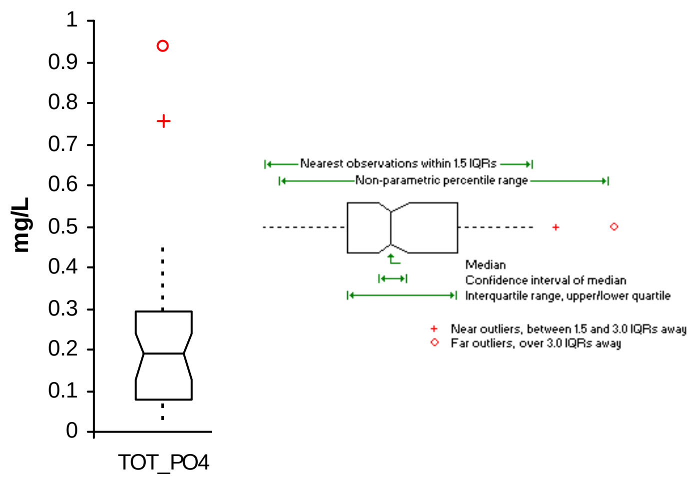


Figure 33. Box Plot of Total Phosphorus for Tributary Sites

Inlake

Total phosphorus ranged from a minimum of 0.054 mg/L at sites L6 and L7 (School Lake), to a maximum 0.453 mg/L at site L5-Wigdale Lake, for all inlake sites L3 through L9 (See Figure 34). There is no standard or assigned beneficial use for this parameter. However, phosphorous is an essential nutrient for the production of crops from commercial fertilizers and livestock waste. It is also the primary nutrient for algae growth in lakes and streams. Since a standard for total phosphorous has not been established, data was compared to the ecoregion mean for phosphorus in Minnesota (MPCA 1988). In the Northern Glaciated Plains, the total phosphorus range is 0.122 to 0.160 mg/L.

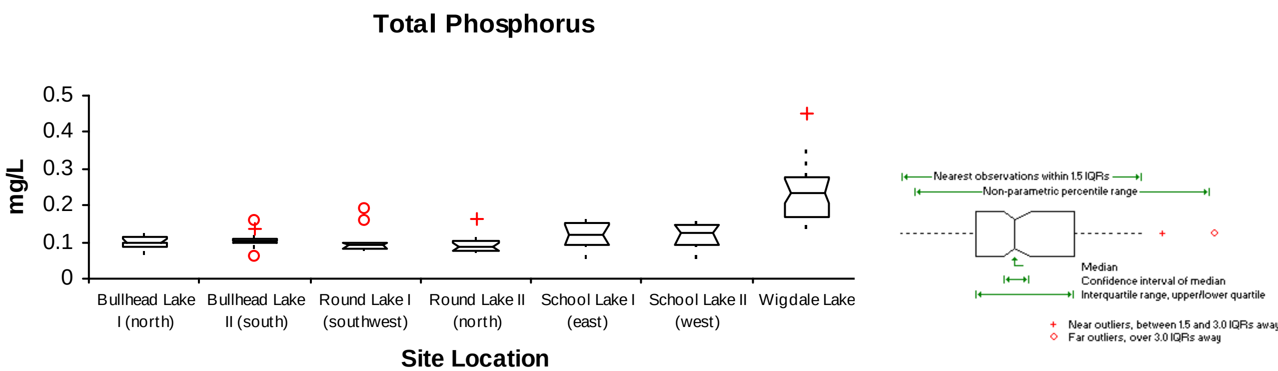


Figure 34. Box Plot of Total Phosphorus for Inlake Sites

Total Dissolved Phosphorus

Tributary

Total dissolved phosphorus ranged from a minimum of 0.032 mg/L at site T50-Wigdale Lake inlet, to a maximum of 0.74 mg/L at site T49-Wigldale Lake inlet, for all tributary sites T49, T50,and T51 (See Figure 35). There is no standard or assigned beneficial use for this parameter.

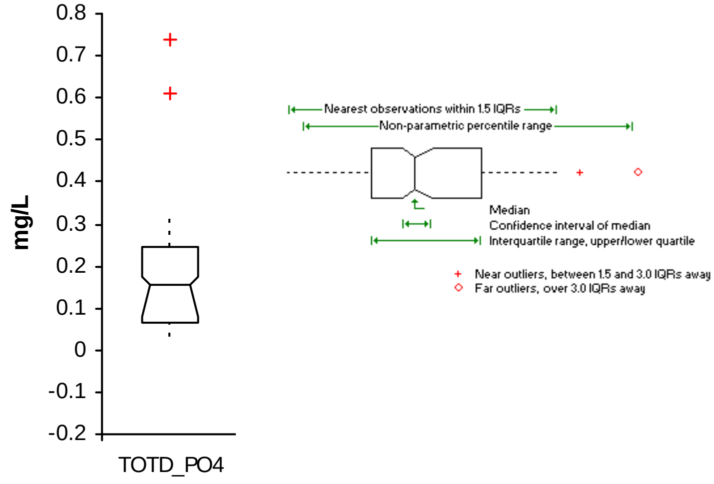


Figure 35. Box Plot of Total Dissolved Phosphorus for Tributary Sites

Inlake

Total dissolved phosphorus ranged from a minimum of 0.012 mg/L at sites L7 (School Lake II) and L9 (Round Lake II), to a maximum 0.094 mg/L at site L9 – Round Lake II, for all inlake sites L3 through L9 (See Figure 36). There is no standard or assigned beneficial use for this parameter.

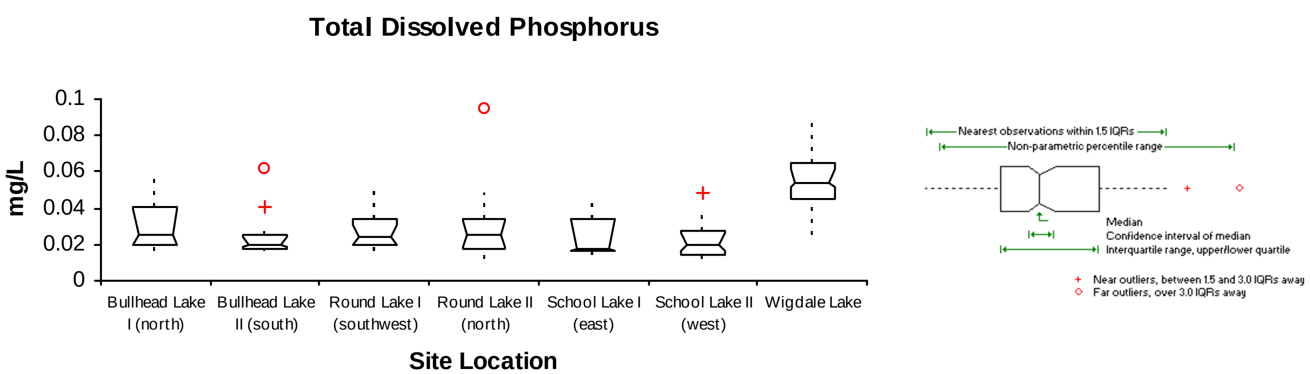


Figure 36. Box Plot of Total Dissolved Phosphorus for Inlake Sites

Field Parameters

Dissolved Oxygen

Tributary

Dissolved oxygen ranged from a minimum of 3.7 mg/L at T51-School Lake inlet, to a maximum of 20.0 mg/L at the same location, for all tributary sites T49, T50, and T51 (See Figure 37). There are no dissolved oxygen standards assigned to these inlets.

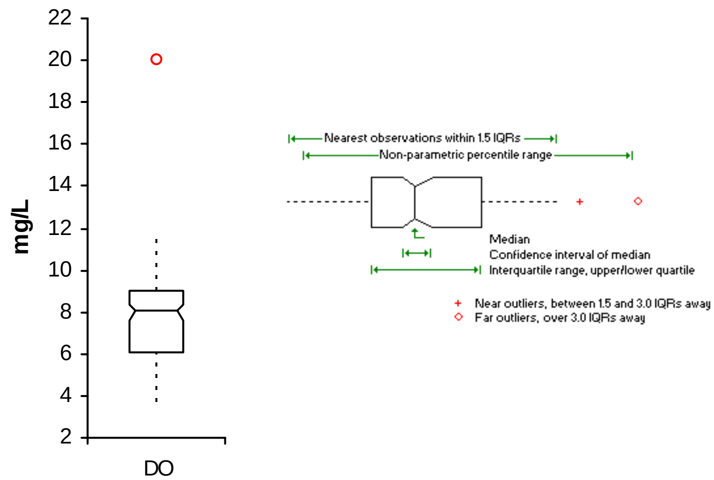


Figure 37. Box Plot of Dissolved Oxygen for Tributary Sites

Inlake

Dissolved oxygen ranged from a minimum of 4.48 mg/L at L8-Round Lake I, to a maximum of 13.6 mg/L at L3-Bullhead Lake I, for all inlake sites L3 through L9 (See Figure 38). A single grab sample daily maximum of ≥ 5 mg/L (most stringent) was used to determine the percent violations and assess for the beneficial use support of (5) Warmwater Semi-permanent Fish Life Propagation, (6) Warmwater Marginal Fish Life Propagation, (7) Immersion Recreation, and (8) at inlake sites L3 and L4 (Bullhead Lake), L6 and L7 (School Lake), and L8 and L9 (Round Lake). These sites are fully supporting of this parameter. Based on the existing standards, inlake site L5 (Wigdale Lake) is not assigned a water quality standard for dissolved oxygen.

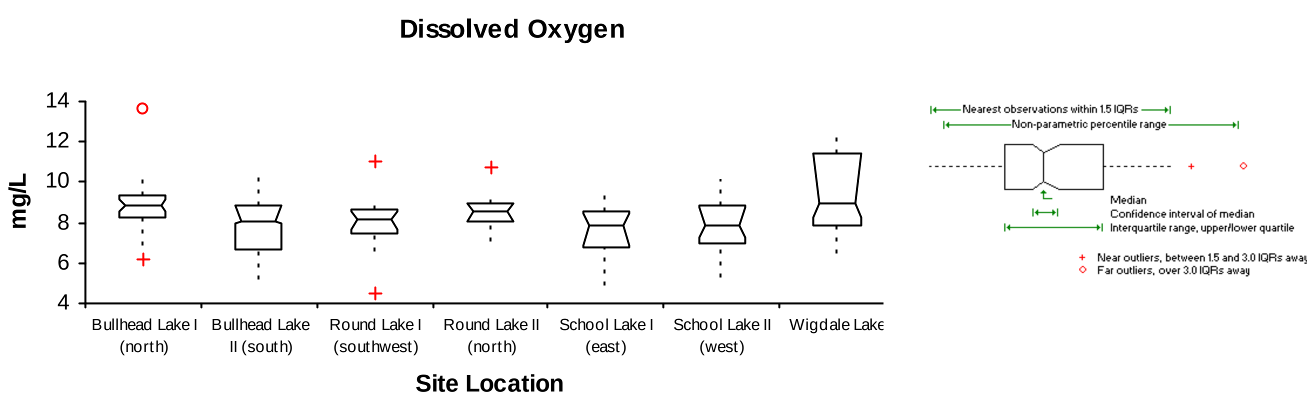


Figure 38. Box Plot of Dissolved Oxygen for Inlake Sites

pH

Tributary

pH ranged from a minimum of 7.12 at sites T50-Wigdale Lake inlet and T51-School Lake inlet, to a maximum of 8.62 at site T49-Wigdale Lake inlet, for all tributary sites T49, T50, and T51 (See Figure 39). A single grab sample daily maximum of ≥ 6.0-≤ 9.5 was used to determine the percent violations at and assess for the beneficial use support of (9) Fish and Wildlife Propagation, Recreation and Stock Watering for all tributary sites. Using this criterion, all tributary sites (T49, T50, and T51) are fully supporting of this parameter.

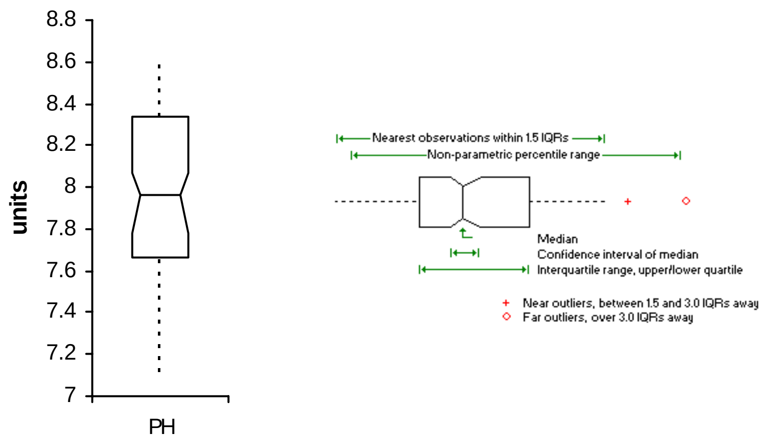


Figure 39. Box Plot of pH for Tributary Sites

Inlake

pH ranged from a minimum of 7.81 at site L8-Round Lake I, to a maximum of 10.2 at site L5-Wigdale Lake, for all inlake sites L3 through L9 (See Figure 40). A single grab sample daily maximum of the most restrictive standard of ≥ 6.5-≤ 9.0 was used to determine the percent violations at and assess for the beneficial use support of (5) Warmwater Semi-permanent Fish Life Propagation and (9) Fish and Wildlife Propagation, Recreation and Stock Watering for inlake sites L3 and L4 (Bullhead Lake). A single grab sample daily maximum of ≥ 6.0-≤ 9.5 was used to determine the percent violations at and assess for the beneficial use support of (9) Fish and Wildlife Propagation, Recreation and Stock Watering inlake site L5 (Wigdale Lake). A single grab sample daily maximum of the most restrictive standard of ≥ 6.0-≤ 9.0 was used to determine the percent violations at and assess for the beneficial use support of (6) Warmwater Marginal Fish Life Propagation and (9) Fish and Wildlife Propagation, Recreation and Stock Watering for inlake sites L6 and L7 (School Lake), and sites L8 and L9 (Round Lake). Using this criterion, Wigdale Lake is fully supporting of this parameter. Bullhead Lake, School Lake, and Round Lake are not supporting of this parameter.

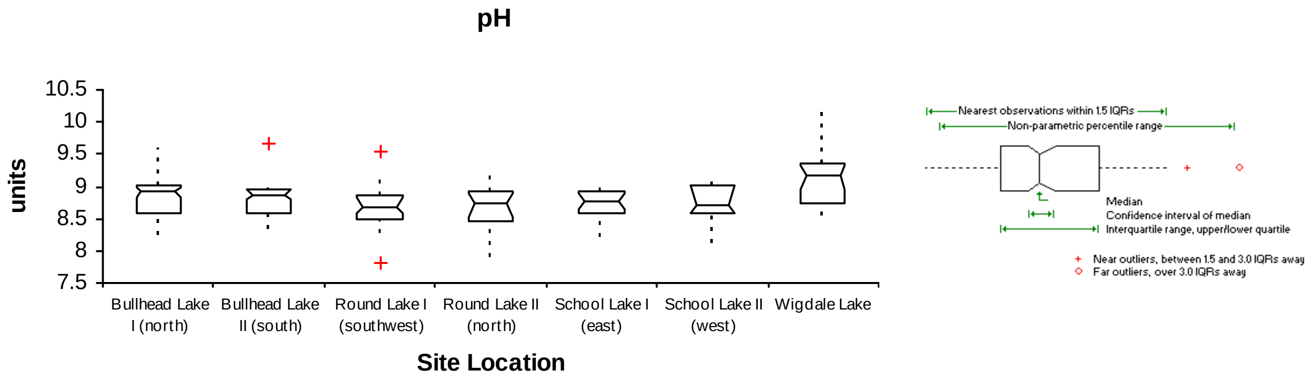


Figure 40. Box Plot of pH for Inlake Sites

Air Temperature

Tributary

Air temperature ranged from a minimum of 9.0° C at site T49-Wigdale Lake inlet and at site T51-School Lake inlet, to a maximum of 32.0° C at site T50-Wigdale Lake inlet, for all tributary sites T49, T50, and T51 (See Figure 41). There is no standard or assigned beneficial use for this parameter.

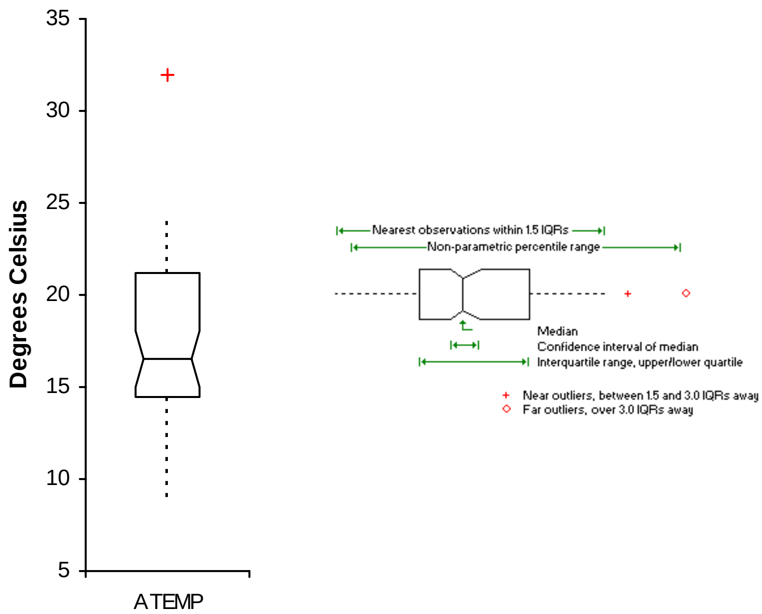


Figure 41. Box Plot of Air Temperature for Tributary Sites

Inlake

Air temperature ranged from a minimum of 8.5° C at site L7-School Lake II, to a maximum 28.0° C at all locations except L8-Round Lake I, for all inlake sites L3 through L9 (See Figure 42). There is no standard or assigned beneficial use for this parameter.

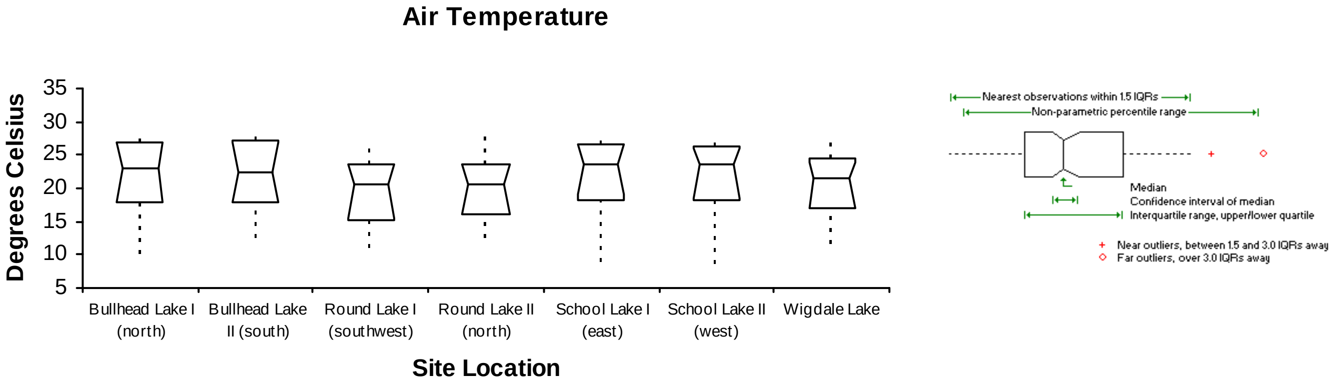


Figure 42. Box Plot of Air Temperature for Inlake Sites

Water Temperature

Tributary

Water temperature ranged from a minimum of 7.1° C at site T51-School Lake inlet, to a maximum of 25.9° C at site T50-Wigdale Lake inlet, for all tributary sites T49, T50, and T51 (See Figure 43). There are no water temperature standards assigned to these inlets.

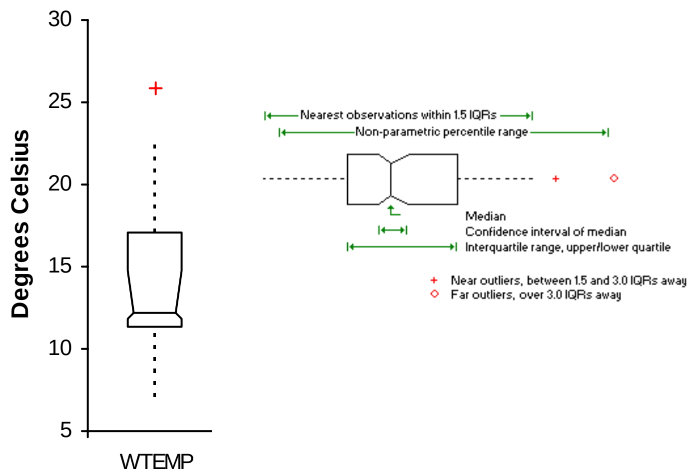


Figure 43. Box Plot of Water Temperature for Tributary Sites

Inlake

Water temperature ranged from a minimum of 8.4° C at site L5-Wigdale Lake, to a maximum of 25.2° C at site L3-Bullhead Lake I, for all inlake sites L3 through L9 (See Figure 44). A single grab sample daily maximum temperature of 32.2° C was used to determine the percent violations and assess for the beneficial use support of (5) Warmwater Semi-permanent Fish Life Propagation for inlake sites L3 and L4 (Bullhead Lake). A single grab sample daily maximum of 32.2° C was used to determine the percent violations and assess for the beneficial use support of (6) Warmwater Marginal Fish Life Propagation for inlake sites L6 and L7 (School Lake), and L8 and L9 (Round Lake). All inlake sites assigned this criterion are fully supporting of this parameter. Based on the existing standards, inlake site L5 (Wigdale Lake) is not assigned a water quality standard for water temperature.

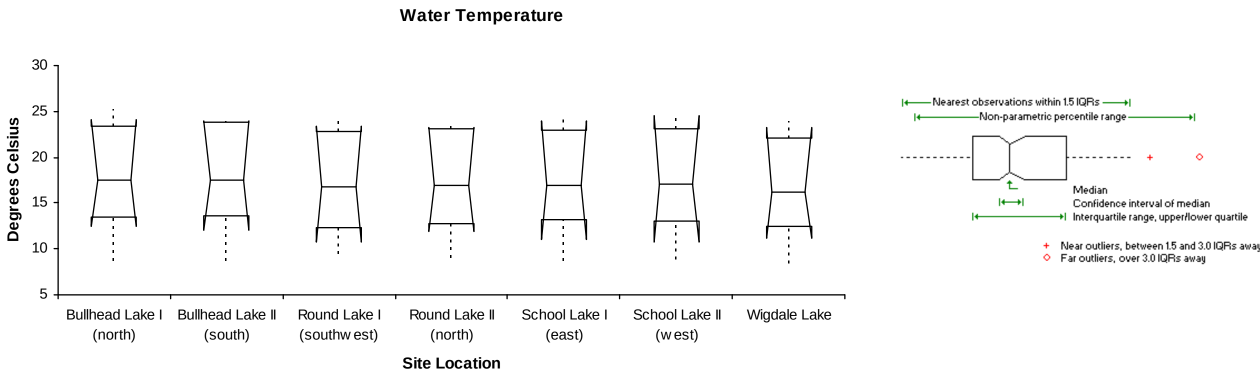


Figure 44. Box Plot of Water Temperature for Inlake Sites

Conductivity

Tributary

Conductivity ranged from a minimum of 483 µmhos/cm at site T50-Wigdale Lake inlet, to a maximum of 1,105 µmhos/cm at site T49-Wigdale Lake inlet, for all tributary sites T49, T50,and T51 (See Figure 45). There is no standard or assigned beneficial use for this parameter.

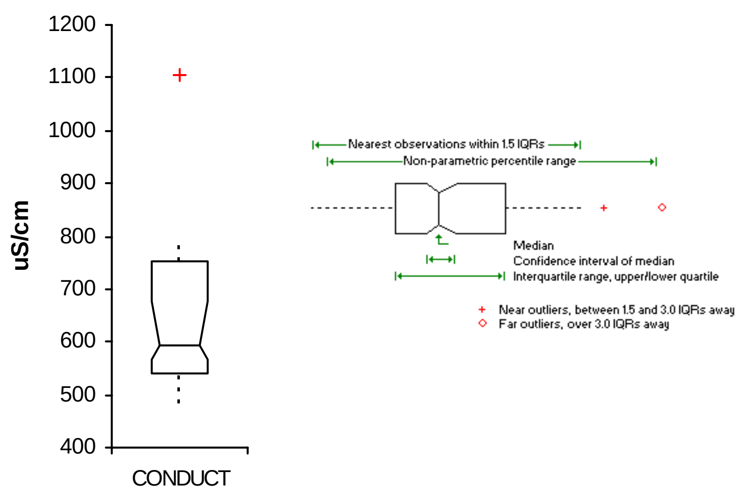


Figure 45. Box Plot of Conductivity for Tributary Sites

Inlake

Conductivity ranged from a minimum of 284 µmhos/cm at site L5-Wigdale Lake, to a maximum 738 µmhos/cm at site L4-Bullhead Lake II, for all inlake sites L3 through L9 (See Figure 46). There is no standard or assigned beneficial use for this parameter.

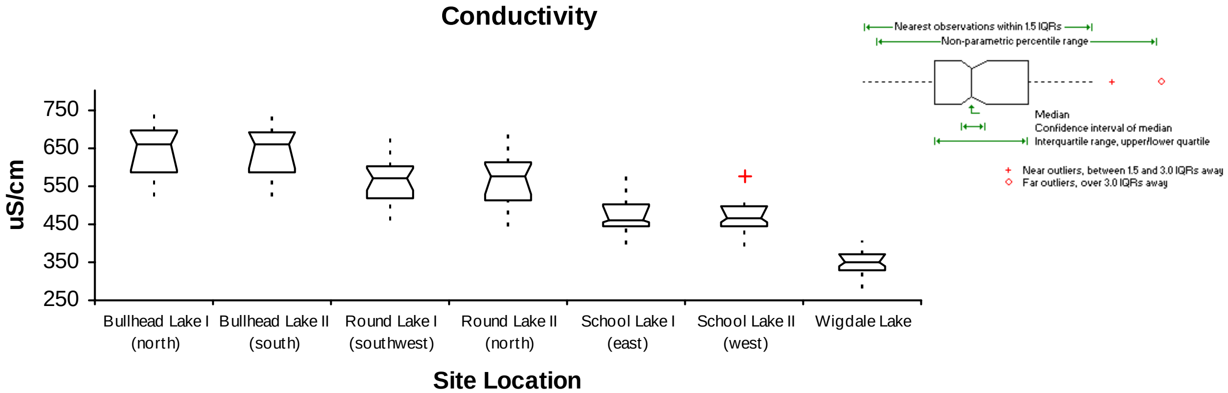


Figure 46. Box Plot of Conductivity for Inlake Sites

Specific Conductivity

Tributary

Specific conductivity ranged from a minimum of 554 µmhos/cm at site T49-Wigdale Lake inlet, to a maximum of 1,162 µmhos/cm at the same location, for all tributary sites T49, T50, and T51 (See Figure 47). A single grab sample daily maximum of the most restrictive standard of 4,375 µmhos/cm was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife Propagation, Recreation, and Stock Watering and (10) Irrigation for all of the tributary sites. Using this criterion, all tributary sites are fully supporting of this parameter.

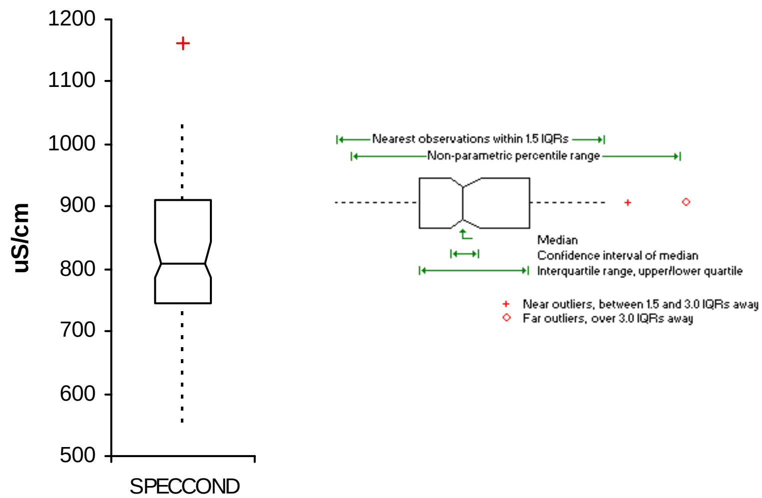


Figure 47. Box Plot of Specific Conductivity for Tributary Sites

Inlake

Specific conductivity ranged from a minimum of 351 µmhos/cm at site L5-Wigdale Lake, to a maximum of 778 µmhos/cm at site L3-Bullhead Lake I, for all inlake sites L3 through L9 (See Figure 48). A single grab sample daily maximum of 7,000 µmhos/cm was used to determine the percent violations and assess for the beneficial use support of (9) Fish and Wildlife Propagation, Recreation, and Stock Watering for all inlake sites. Using this criterion, all inlake sites are fully supporting of this parameter.

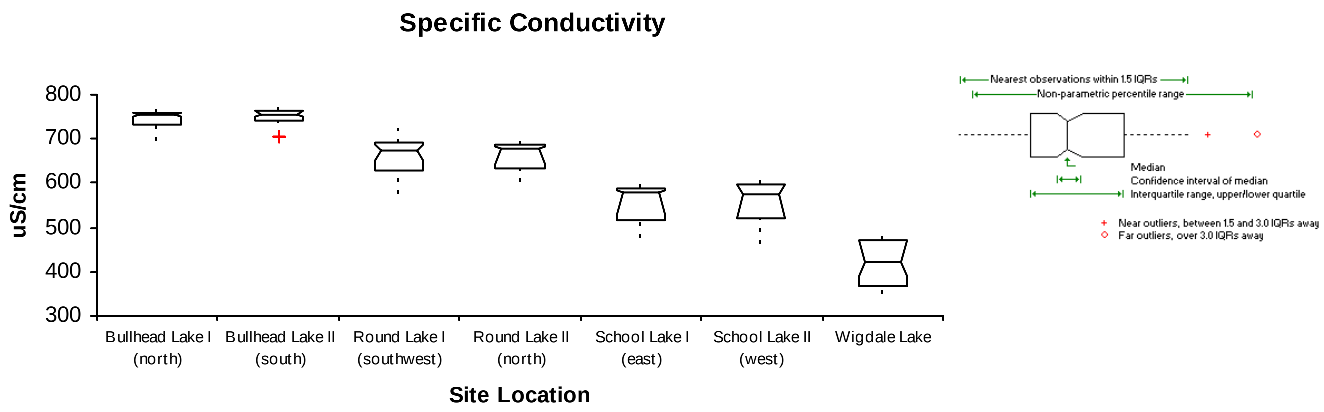


Figure 48. Box Plot of Specific Conductivity for Inlake Sites

Salinity

Tributary

Salinity ranged from a minimum of 0.3 ppt at sites T50-Wigdale Lake inlet and T51-School Lake inlet, to a maximum of 0.6 ppt at site T49-Wigdale Lake inlet, for all tributary sites T49, T50, and T51 (See Figure 49). There is no standard or assigned beneficial use for this parameter.

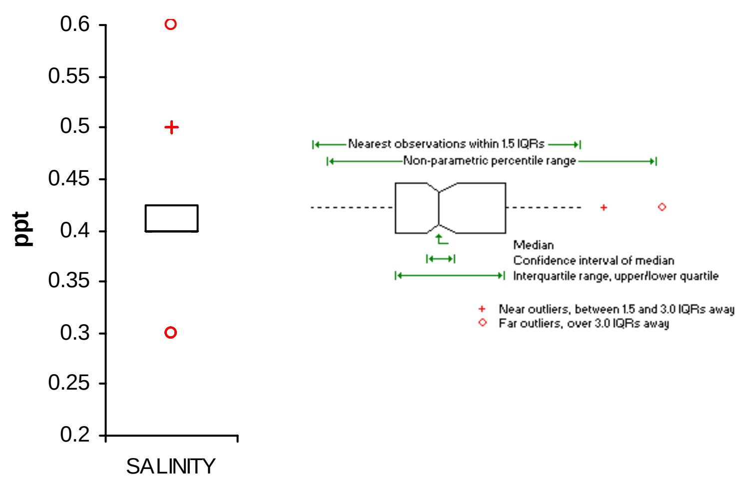


Figure 49. Box Plot of Salinity for Tributary Sites

Inlake

Salinity ranged from a minimum of 0.2 ppt at sites L5-Wigdale Lake, L6-School Lake I, and L7-School Lake II, to a maximum 0.4 ppt at sites L3-Bullhead Lake I, L4-Bullhead Lake II, and L8-Round Lake I, for all inlake sites L3 through L9 (See Figure 50). There is no standard or assigned beneficial use for this parameter.

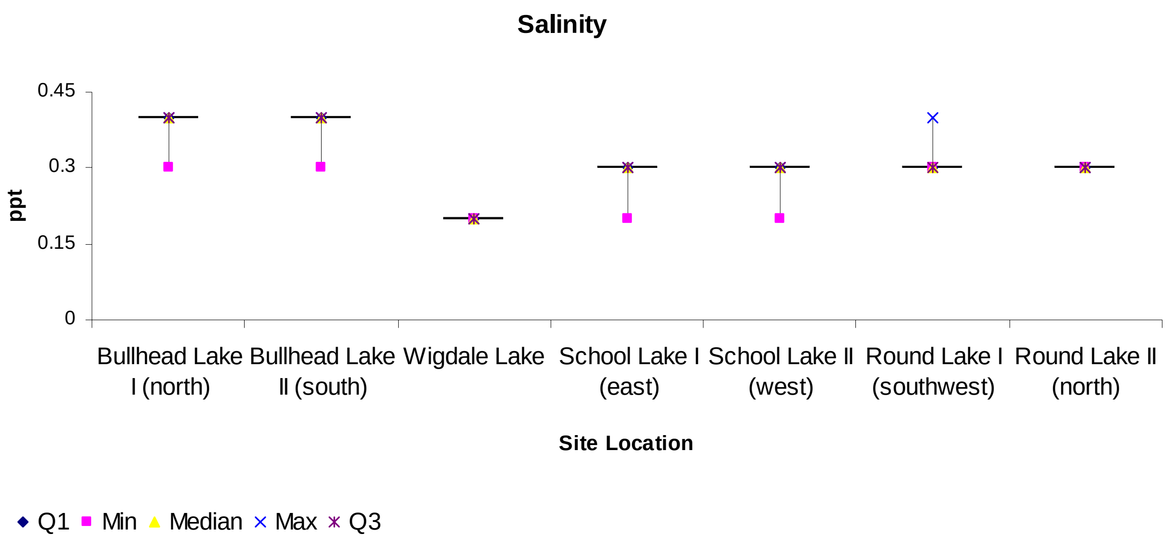


Figure 50. Box Plot of Salinity for Inlake Sites

Turbidity – NTU

Tributary

Turbidity ranged from non-detect at site T49-Wigdale Lake inlet, to a maximum of 25 NTU at site T50-Wigdale Lake inlet, for all tributary sites T49, T50, and T51 (See Figure 51). There is no standard or assigned beneficial use for this parameter.

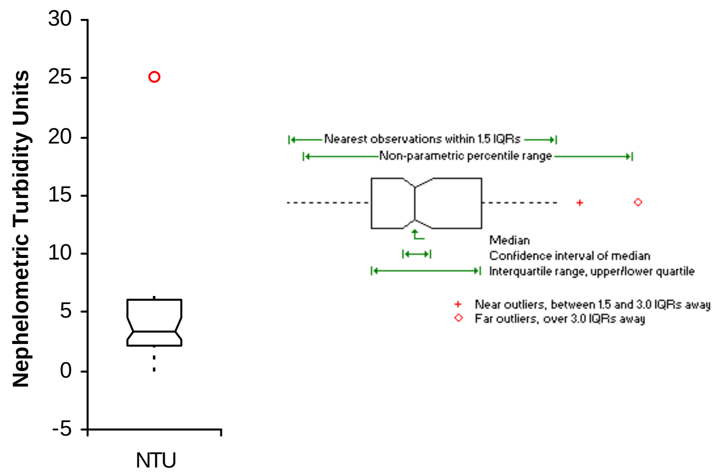


Figure 51. Box Plot of Turbidity (NTU) for Tributary Sites

Inlake

Turbidity ranged from a minimum of 4 NTU at site L7-School Lake II, to a maximum 60 NTU at site L5-Wigdale Lake, for all inlake sites L3 through L9 (See Figure 52). There is no standard or assigned beneficial use for this parameter.

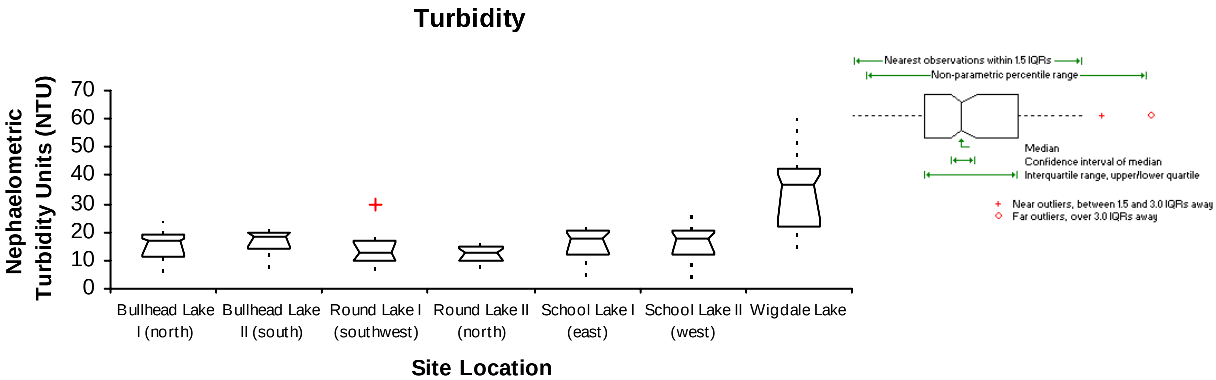


Figure 52. Box Plot of Turbidity (NTU) for Inlake Sites

HYDROLOGIC MONITORING

Project Hydrologic Loading Budget

Bathymetric maps of these four lakes have not been created. However, rough estimates of lake depths were derived from depth measurements taken at the time of sampling. In addition, six transects, in alignment with the aquatic plant transects on School Lake, were roughly mapped out and depths across each to the other side of the lake documented (See Appendix H for map).

Annual Hydrologic Loading Budget

Input and output sources for all lakes were estimated. Since the lakes were sampled during a dry period, the gauged and ungauged runoff did not contribute a large portion of the input sources. Output sources were estimated due to the lakes not having a flowing outlet.

Round Lake

Input sources for Round Lake included precipitation, ungauged runoff, and groundwater (See Figure 53). Precipitation loading contributed the largest portion with 2,119 acre-ft (51 percent). Ungauged runoff was estimated at 32 acre-ft (one percent) and groundwater with 1,974 acre-ft (48 percent).

Output sources for Round Lake included evaporation, advective flow, and change in storage. Evaporation loading contributed the largest portion with 2,356 acre-ft. Other sources included advective flow (74 acre-ft) and change in storage (1,694 acre-ft).

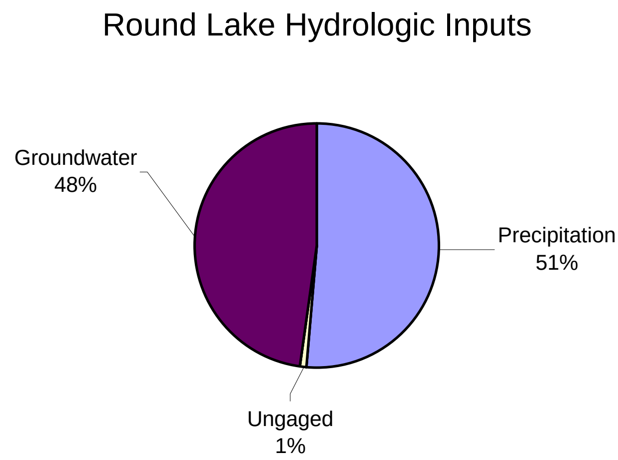


Figure 53. Input Sources for Hydrologic Budget in Round Lake

Bullhead Lake

Input sources for Bullhead Lake included precipitation, ungauged runoff, and groundwater (See Figure 54). Precipitation loading contributed the largest portion with 622 acre-ft (54 percent). Ungauged runoff was estimated to contribute 29 acre-ft (two percent) and groundwater with 511 acre-ft (44 percent).

Output sources for Bullhead Lake included evaporation, advective flow, and change in storage. Evaporation loading contributed the largest portion with 692 acre-ft. Other sources included advective flow (22 acre-ft) and change in storage (448 acre-ft).

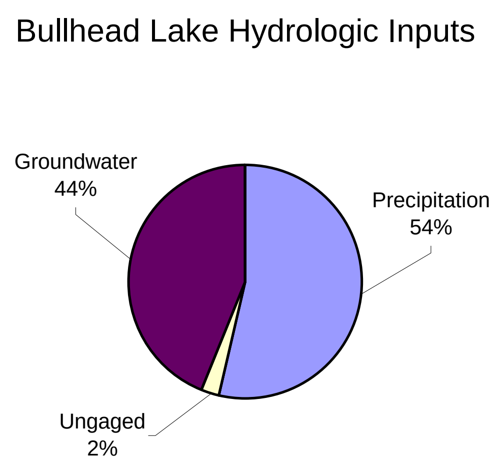


Figure 54. Input Sources for Hydrologic Budget in Bullhead Lake

School Lake

Input sources for School Lake included precipitation, ungauged runoff, and groundwater (See Figure 55). Precipitation loading contributed the largest portion with 591 acre-ft (53 percent). Ungauged runoff was estimated to contribute 33 acre-ft (three percent) and groundwater with 500 acre-ft (44 percent).

Output sources for School Lake included evaporation, advective flow, and change in storage. Evaporation loading contributed the largest portion with 657 acre-ft. Other sources included advective flow (21 acre-ft) and change in storage (446 acre-ft).

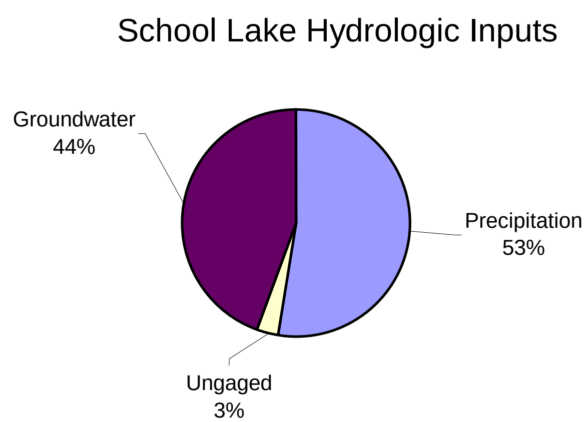


Figure 55. Input Sources for Hydrologic Budget in School Lake

Wigdale Lake

Input sources for Wigdale Lake included precipitation, monitored tributaries, and groundwater (See Figure 56). The monitored tributaries, Site T49 and Site T50, each contributed one percent. Groundwater loading contributed the largest portion with 1,592 acre-ft (54 percent). Precipitation contributed 1,303 acre-ft (44 percent).

Output sources for School Lake included evaporation, advective flow, and change in storage. Evaporation loading contributed the largest portion with 1,449 acre-ft. Other sources included advective flow (69 acre-ft) and change in storage (1,418 acre-ft).

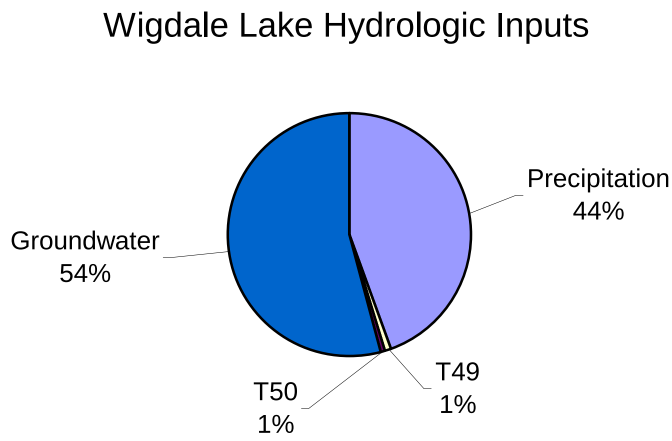


Figure 56. Input Sources for Hydrologic Budget in Wigdale Lake

Nutrient and Sediment Loadings

Suspended Solids Loading

The estimated percentage of total suspended solids loading into Wigdale Lake was derived from Sites T49 and T50. Measured loadings at both sites were similar with 56 percent of the load from T49 and 44 percent of the load from T50. It was assumed all the watershed runoff was included in the tributaries loading.

Because sampling occurred during a dry cycle (precipitation less than 13 inches for the sampling period), Round Lake, School Lake, and Bullhead Lake did not have any flowing tributaries. The suspended solid loading was estimated from the loading coefficients for the tributaries of Wigdale Lake. For Round Lake, estimated runoff load was 2,245 kg. The estimated runoff load for School Lake was 2,121 kg and for Bullhead Lake was 1,838 kg.

Nitrogen Loading

Because all lakes were sampled during a dry cycle (precipitation less than 13 inches for the sampling period) there were no out flows, so a nitrogen loading of inputs was estimated. The estimated percentage of total nitrogen loading into Wigdale Lake was derived from Site T49, Site T50, and groundwater. Site T49 contributed 31 percent of the nitrogen load and Site T50 contributed 7 percent. Groundwater contribution was estimated at 62 percent.

Round Lake, School Lake, and Bullhead Lake did not have any flowing tributaries during the sampling season. The total nitrogen ungaged runoff loading was estimated from the loading coefficients for the tributaries of Wigdale Lake. For Round Lake, nitrogen inputs included groundwater (76 percent) and ungauged runoff (24 percent). Total nitrogen loading for Bullhead Lake consisted of 53 percent ungauged runoff and 47 percent groundwater. For School Lake, ungauged runoff contributed 58 percent and 42 percent groundwater.

Phosphorus Loading

Because all lakes were sampled during a dry cycle (precipitation less than 13 inches for the sampling period), no outlets were sampled, so a phosphorus loading of inputs was estimated. The estimated percentage of total phosphorus loading into Wigdale Lake was derived from Site T49, Site T50, precipitation, internal loading, and groundwater. Measured loadings were 0.4 percent of the load from T50 and three percent of the load from T49. Estimated loadings included groundwater (2 percent), precipitation (3.6 percent), and internal loading (91 percent).

Round Lake, School Lake, and Bullhead Lake did not have any flowing tributaries during the sampling season. The phosphorus ungaged runoff loading was estimated from the loading coefficients for the tributaries of Wigdale Lake. For Round Lake, the loadings included ungaged runoff (three percent), groundwater (4 percent), precipitation (8 percent), and internal loading (84 percent). Total phosphorus loading for Bullhead Lake consisted of groundwater (one percent), ungaged runoff (four percent), precipitation (4 percent), and internal loading (91 percent). For School Lake, the loadings included groundwater (4 percent), precipitation (11 percent), ungaged runoff (15 percent), and internal loading (70 percent).

Total Dissolved Phosphorus

The estimated percentage of total dissolved phosphorus loading into Wigdale Lake was derived from Sites T49 and T50. Measured loadings at both sites were similar with 90 percent of the load from T49 and 10 percent of the load from T50. It was assumed all the watershed runoff was included in the tributaries loading.

Since sampling occurred during a dry cycle (precipitation less than 13 inches for the sampling period), Round Lake, School Lake, and Bullhead Lake did not have any flowing tributaries. The total dissolved phosphorus loading was estimated from the loading coefficients for the tributaries of Wigdale Lake. The loading coefficient was multiplied by each watershed area. For Round Lake, estimated runoff load was 24.7 kg. The estimated runoff load for School Lake was 25.7 kg and for Bullhead Lake was 22.3 kg.

INLAKE BIOLOGICAL MONITORING

Algae Sampling

Algae were sampled once in June and once in August at each lake by the East Dakota Water Development District. Additional samples were collected in June and July at School and Bullhead Lakes by the State Lake Assessment program. Table 16 represents the algal density by date and by lake. Table 17 represents the alga biovolume by date and by lake. A complete list of algal species identified in each lake can be found in Appendix I.

Table 16. Algal Density by Lake and Date Sampled

Algal Density (cells/mL) in 2003

Jun 17 & 18, 2003	School	Percent	Round	Percent	Bullhead	Percent	Wigdale	Percent
Flagellated Algae	12,382	0.55	3,260	0.08	13,363	1.44	3,240	0.08
Blue-Green Algae	2,210,737	97.85	3,843,189	99.80	872,445	94.23	4,091,585	98.34
Diatoms	4,937	0.22	300	0.01	10,605	1.15	25,790	0.62
Green Algae	22,672	1.00	4,140	0.11	23,303	2.52	35,250	0.85
Unidentified Algae	8,500	0.38			6,200	0.67	4,800	0.12
Yellow-Brown Algae	50	0.00						
Total Algal Density	**2,259,278**		**3,850,889**		**925,916**		**4,160,665**	

Jul 1, 2003	School	Percent	Round	Bullhead	Wigdale
Flagellated Algae	14,958	0.34			
Blue-Green Algae	4,328,289	98.00			
Diatoms	11,431	0.26			
Green Algae	46,846	1.06			
Unidentified Algae	15,200	0.34			
Yellow-Brown Algae					
Total Algal Density	**4,416,724**				

Jul 23, 2003	School	Percent	Round	Bullhead	Percent	Wigdale
Flagellated Algae	10,469	0.41		949	0.47	
Blue-Green Algae	2,451,133	96.62		162,874	81.06	
Diatoms	20,843	0.82		3,797	1.89	
Green Algae	41,707	1.64		27,519	13.70	
Unidentified Algae	12,800	0.50		5,800	2.89	
Yellow-Brown Algae						
Total Algal Density	**2,536,952**			**200,939**		

Aug 12 & 13, 2003	School	Percent	Round	Percent	Bullhead	Percent	Wigdale
Flagellated Algae	14,948	0.27	3,481	0.15	6,331	1.06	
Blue-Green Algae	5,479,224	98.60	2,277,648	99.43	572,850	95.85	
Diatoms	13,689	0.25	3,010	0.13	4,271	0.71	
Green Algae	35,953	0.65	4,862	0.21	13,676	2.29	
Unidentified Algae	13,300	0.24	1,650	0.07	530	0.09	
Yellow-Brown Algae							
Total Algal Density	**5,557,114**		**2,290,651**		**597,658**		

In School Lake, total phytoplankton density ranged from 2,259,278 cells/mL in June to 5,557,114 cells/mL in August. In Round Lake, total phytoplankton density ranged from 3,850,889 cells/mL in June to 2,290,651 cells/mL in August. In Bullhead Lake, total phytoplankton density ranged from 200,939 cells/mL in July to 597,658 cells/mL in August. The only viable sample from Wigdale Lake yielded 4,160,665 cells/mL in June. In all four lakes, blue-green algae showed the highest density with the *Aphanocapsa* species being the most dense. This species persisted with the highest density throughout the summer in all lakes, except for Bullhead Lake, where the *Phormidium* species was the most dominant in August. This species, however, was also present in the other three lakes.

Table 17. Algal Biovolume by Lake and Date Sampled

Algal Biovolume (µm³/mL) in 2003

Jun 17 & 18, 2003	School	Percent	Round	Percent	Bullhead	Percent	Wigdale	Percent
Flagellated Algae	1,113,277	4.57	211,460	1.24	1,156,264	4.97	1,135,800	1.94
Blue-Green Algae	20,608,882	84.67	16,183,286	95.05	17,468,060	75.14	47,981,491	81.91
Diatoms	739,990	3.04	103,100	0.61	1,612,750	6.94	5,233,150	8.93
Green Algae	1,622,526	6.67	527,840	3.10	2,823,717	12.15	4,081,360	6.97
Unidentified Algae	255,000	1.05			186,000	0.80	144,000	0.25
Yellow-Brown Algae		0.00						
Total Algal Density	**24,339,675**		**17,025,686**		**23,246,790**		**58,575,801**	

Jul 1, 2003	School	Percent	Round	Bullhead	Wigdale
Flagellated Algae	1,215,922	2.31			
Blue-Green Algae	44,360,546	84.37			
Diatoms	1,938,570	3.69			
Green Algae	4,608,382	8.76			
Unidentified Algae	456,000	0.87			
Yellow-Brown Algae	1500				
Total Algal Density	**52,580,920**				

Jul 23, 2003	School	Percent	Round	Bullhead	Percent	Wigdale
Flagellated Algae	1,270,396	2.70		295,136	1.14	
Blue-Green Algae	37,486,412	79.63		938,472	3.61	
Diatoms	4,274,670	9.08		20,142,465	77.58	
Green Algae	3,662,171	7.78		4,414,636	17.00	
Unidentified Algae	384,000	0.82		174,000	0.67	
Yellow-Brown Algae						
Total Algal Density	**47,077,649**			**25,964,709**		

Aug 12 & 13, 2003	School	Percent	Round	Percent	Bullhead	Percent	Wigdale
Flagellated Algae	2,040,869	4.25	257,630	1.35	774,538	3.83	
Blue-Green Algae	40,040,669	83.35	16,777,205	87.88	4,672,792	23.11	
Diatoms	2,292,590	4.77	1,551,750	8.13	12,657,280	62.59	
Green Algae	3,267,289	6.80	454,640	2.38	2,102,692	10.40	
Unidentified Algae	399,000	0.83	49,500	0.26	15,900	0.08	
Yellow-Brown Algae							
Total Algal Density	**48,040,417**		**19,090,725**		**20,223,202**		

In School Lake, total phytoplankton biovolume ranged from 24,339,675 µm³/mL in June to 52,580,920 µm³/mL in July. In Round Lake, total phytoplankton biovolume ranged from 17,025,686 µm³/mL in June to 19,090,725 µm³/mL in August. In Bullhead Lake, total phytoplankton biovolume ranged from 20,223,202 µm³/mL in August to 25,964,709 µm³/mL in July. The only viable sample from Wigdale Lake yielded 58,575,801 µm³/mL in June.

In June, blue-green algae dominated the biovolume in all four lakes. In School Lake, blue-green algae remained the most dominant throughout the summer. Blue-green algae biovolume in Round Lake dominated during both sampling days (once in June and once in August). Bullhead Lake was sampled in June, July, and August. Dominance of biovolume shifted to diatoms in July and August. The species of blue-green algae with the most biovolume (67 percent) in Bullhead Lake, during June, was the nuisance species *Anabaena subsylindrica*. In July, when the biovolume dominance shifted to diatoms, the

Nitzschia species dominated by 82 percent. However, in August the dominant diatom specie was *Stephanodiscus niagarae* (81 percent). In School Lake, the identified nuisance species of blue-green algae present during all four sampling days (once in June, two in July, and once in August), included *Microcystis*, *Oscillatoria*, and *Anabaena.*

All samples were incorporated into the following graphs (See Figures 57 through 62) . All lakes were sampled in June as shown by Figure 57. By far, blue-green algae dominated. Flagellated, blue-green, non-motile green, diatoms, and unidentified algae were compared among lakes. One other type of algae was found, yellow-brown, but only in School Lake. More detailed graphs of each lake can be found in the Analysis Section.

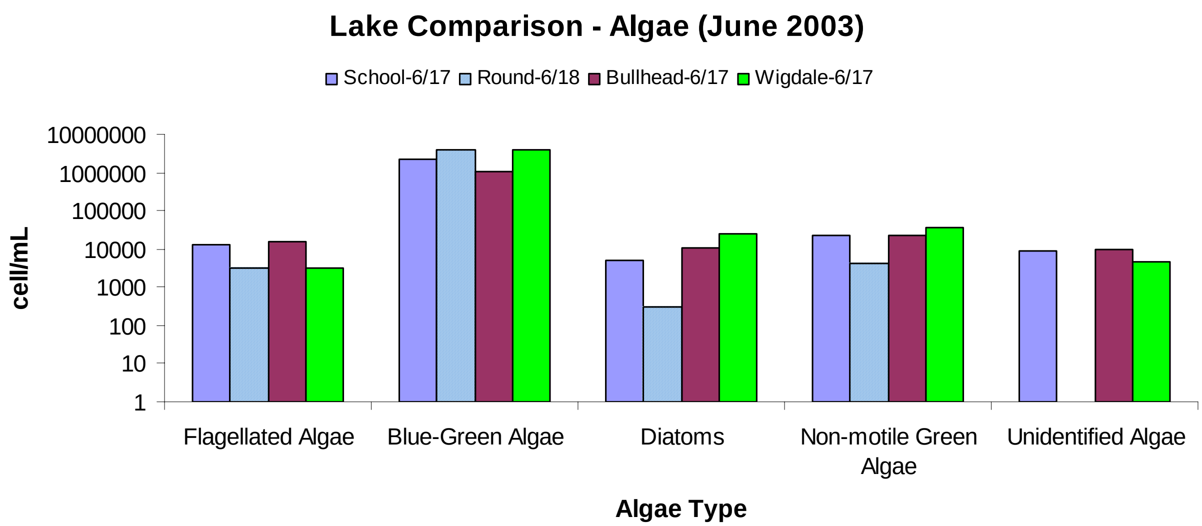


Figure 57. Total Algae Cells per Milliliter by Algae Type for School Lake, Bullhead Lake, Round Lake, and Wigdale Lake

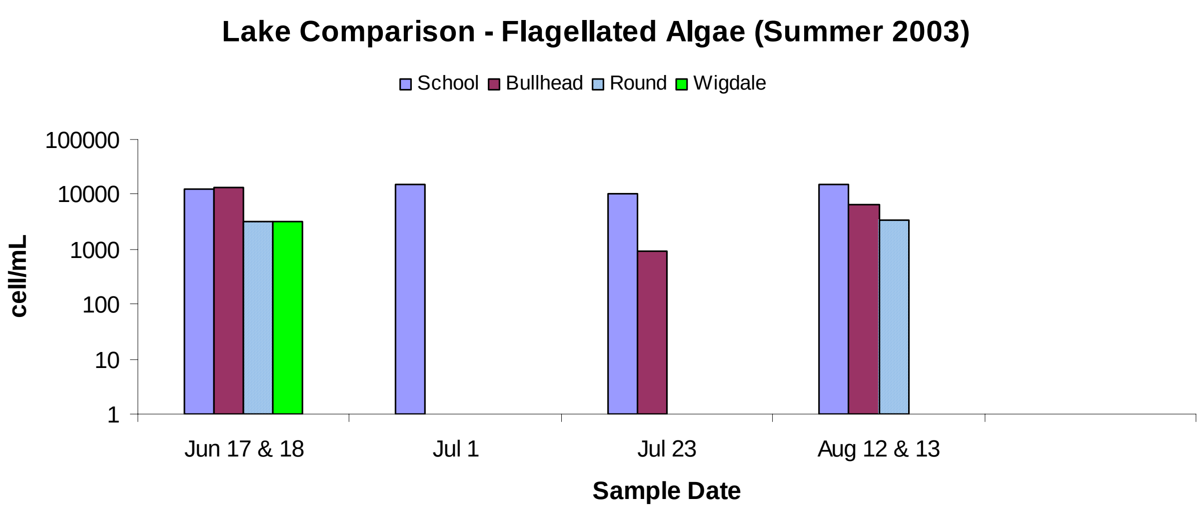


Figure 58. Total Flagellated Algae Cells per Milliliter by Sample Date for School Lake, Bullhead Lake, Round Lake, and Wigdale Lake

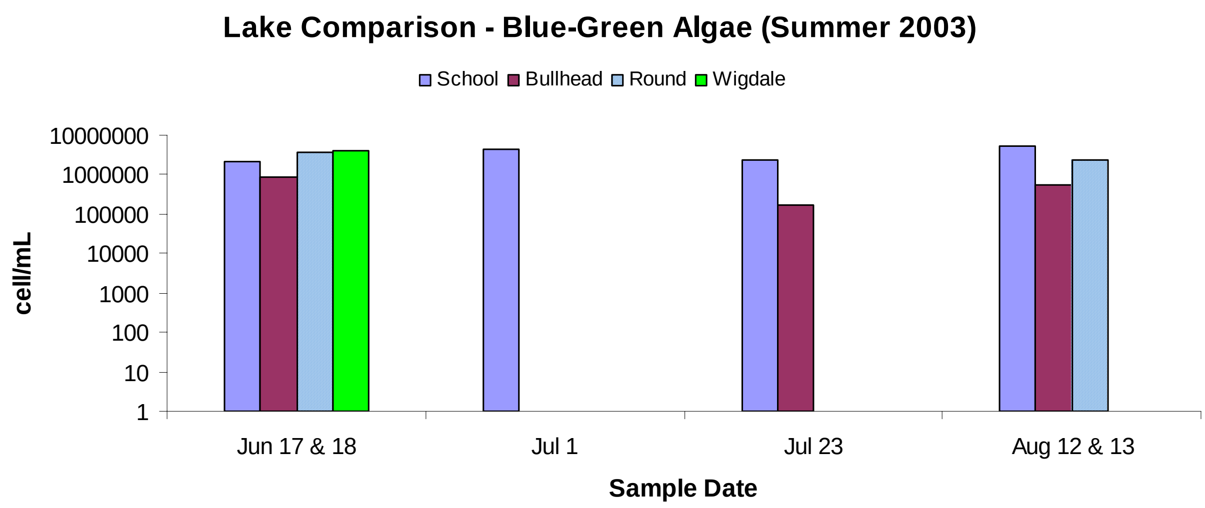


Figure 59. Total Blue-Green Algae Cells per Milliliter by Sample Date for School Lake, Bullhead Lake, Round Lake, and Wigdale Lake

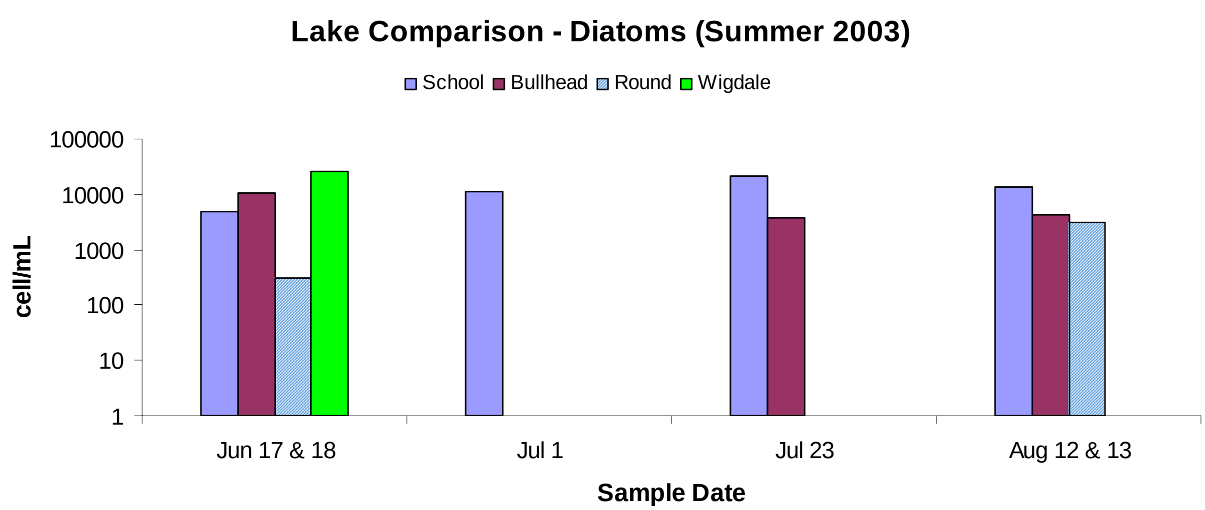


Figure 60. Total Diatoms Cells per Milliliter by Sample Date for School Lake, Bullhead Lake, Round Lake, and Wigdale Lake

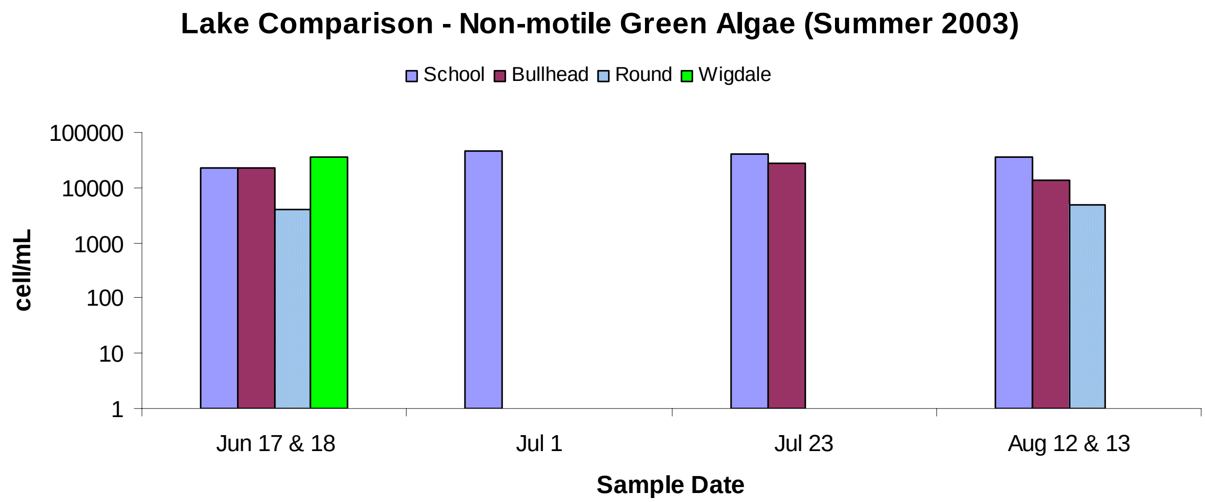


Figure 61. Total Non-Motile Green Algae Cells per Milliliters by Sampling Date for School Lake, Bullhead Lake, Round Lake, and Wigdale Lake

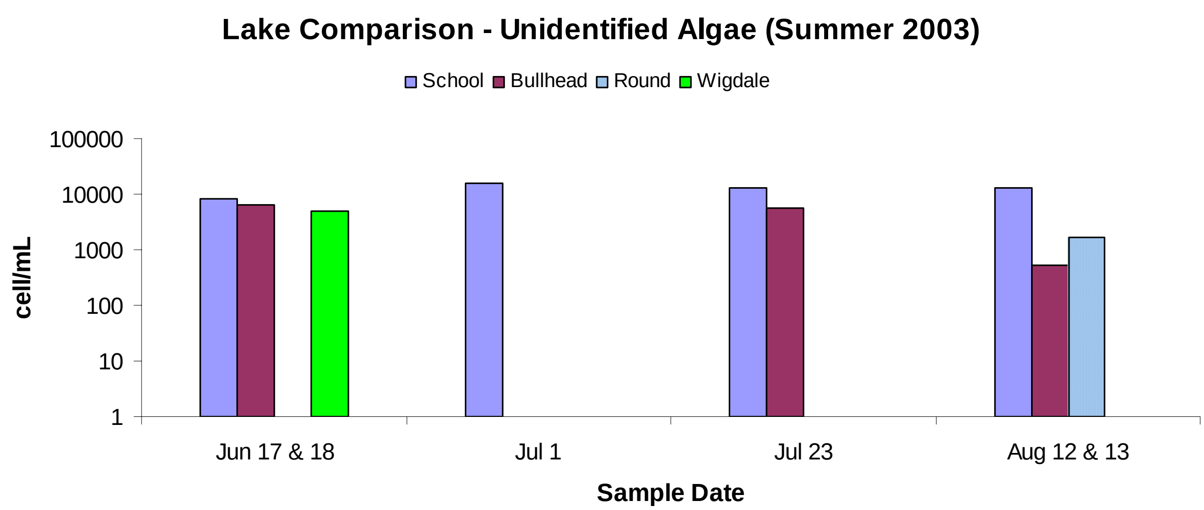


Figure 62. Total Unidentified Algae Cells per Milliliter by Sampling Date for School Lake, Bullhead Lake, Round Lake, and Wigdale Lake

Chlorophyll-*a* Sampling

Chlorophyll-*a* samples were collected at all in-lake sampling sites during the project (See Figure 63). Overall, the chlorophyll-a concentration for all lakes were relatively high. The maximum chlorophyll-a concentration (141.07 mg/m³) for School Lake was collected on July 30, 2003 at L7. The maximum chlorophyll-a concentration (73.6 mg/m³) for Bullhead Lake was collected on August 12, 2003 at L4. The maximum chlorophyll-a concentration (65.1 mg/m³) for Round Lake was collected on September 23, 2003 at L8. The maximum chlorophyll-a concentration (131.5 mg/m³) for Wigdale Lake was collected on September 25, 2003.

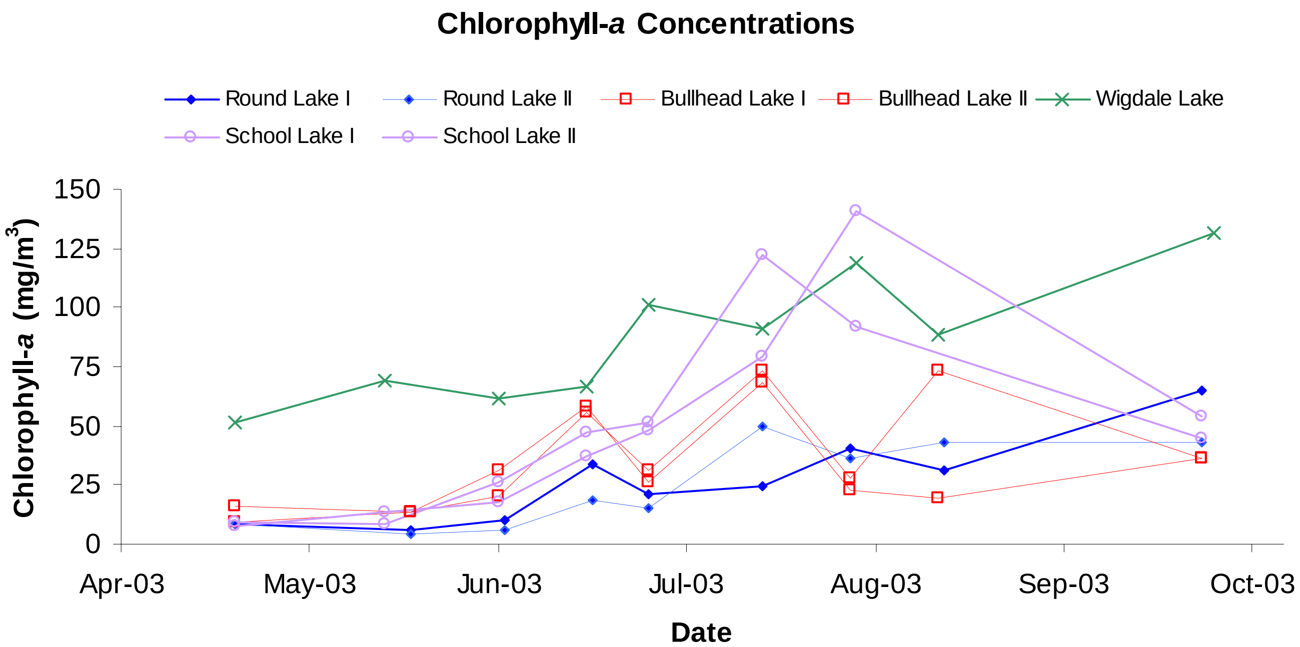


Figure 63. Monthly In-Lake Chlorophyll-a Concentrations by Date and Sampling Site for Round Lake, Bullhead Lake, School Lake, and Wigdale Lake

Aquatic Plant Sampling

A list of species found during the School Lake survey is shown in Table 18. The location of the aquatic plant species is shown in Figure 64. Additionally Chara spp., a type of algae, was also identified during the aquatic plant survey.

Table 18. Aquatic Plant Species Identified in School Lake

Common Name	Genus	Species	Habitat
Sago Pondweed	*Potamogeton*	*pectinatus*	Submergent
Claspingleaf Pondweed	*Potamogeton*	*richardsonii*	Submergent
Northern Milfoil	*Myriophyllum*	*exalbescens*	Submergent
Prairie Bulrush	*Scirpus*	*maritimus*	Emergent
Bulrushes	*Scirpus*	*spp.*	Emergent
Cattails	*Typha*	*spp.*	Emergent

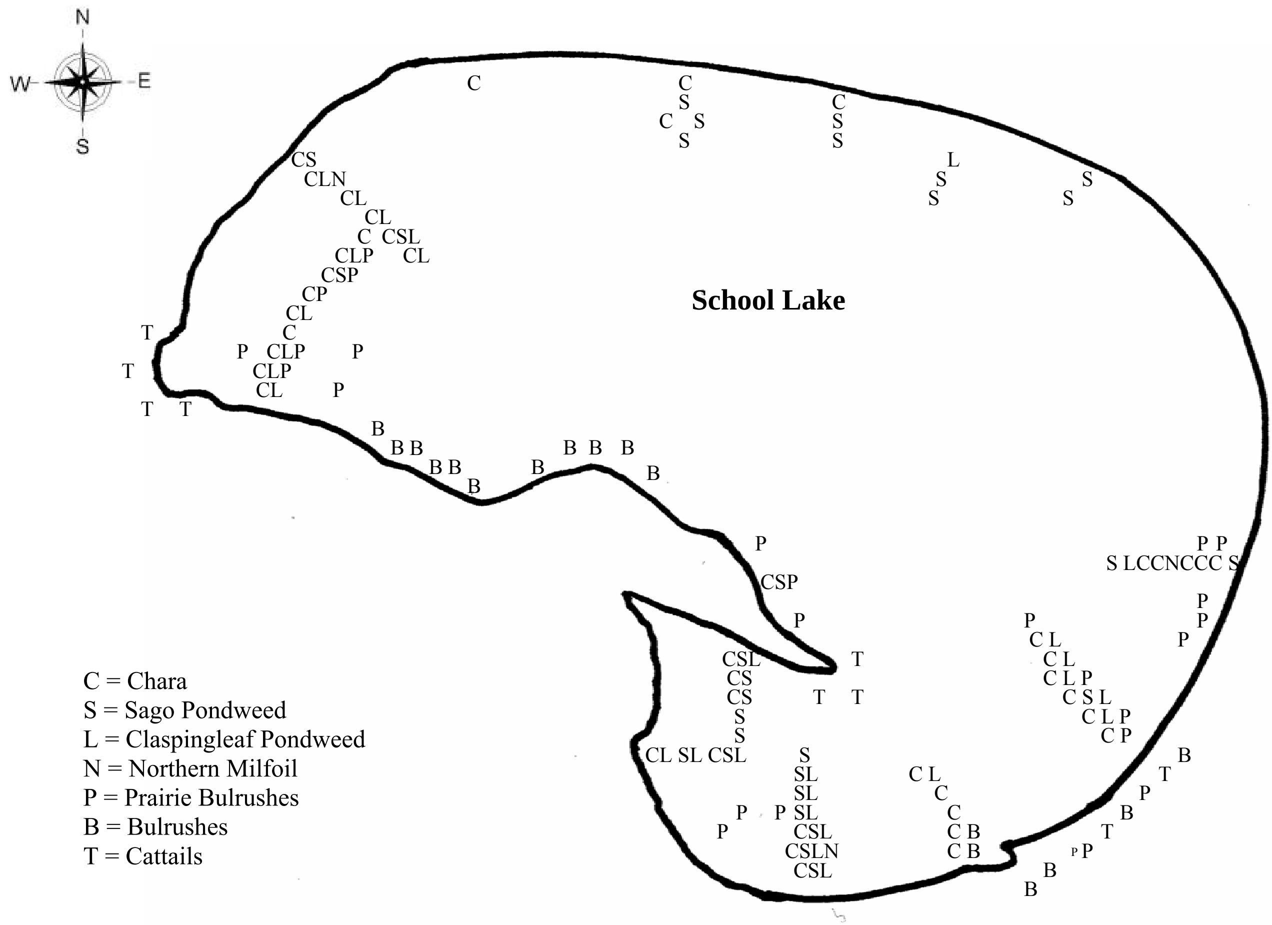


Figure 64. Location of Aquatic Plants in School Lake

TSI COMPUTATION

Carlson's (1977) Trophic State Index was calculated for Bullhead Lake, Round Lake, School Lake, and Wigdale Lake. The index was applied to inlake sampling data by date and site. The TSI values are shown in Figure 65, plotted by beneficial use categories.

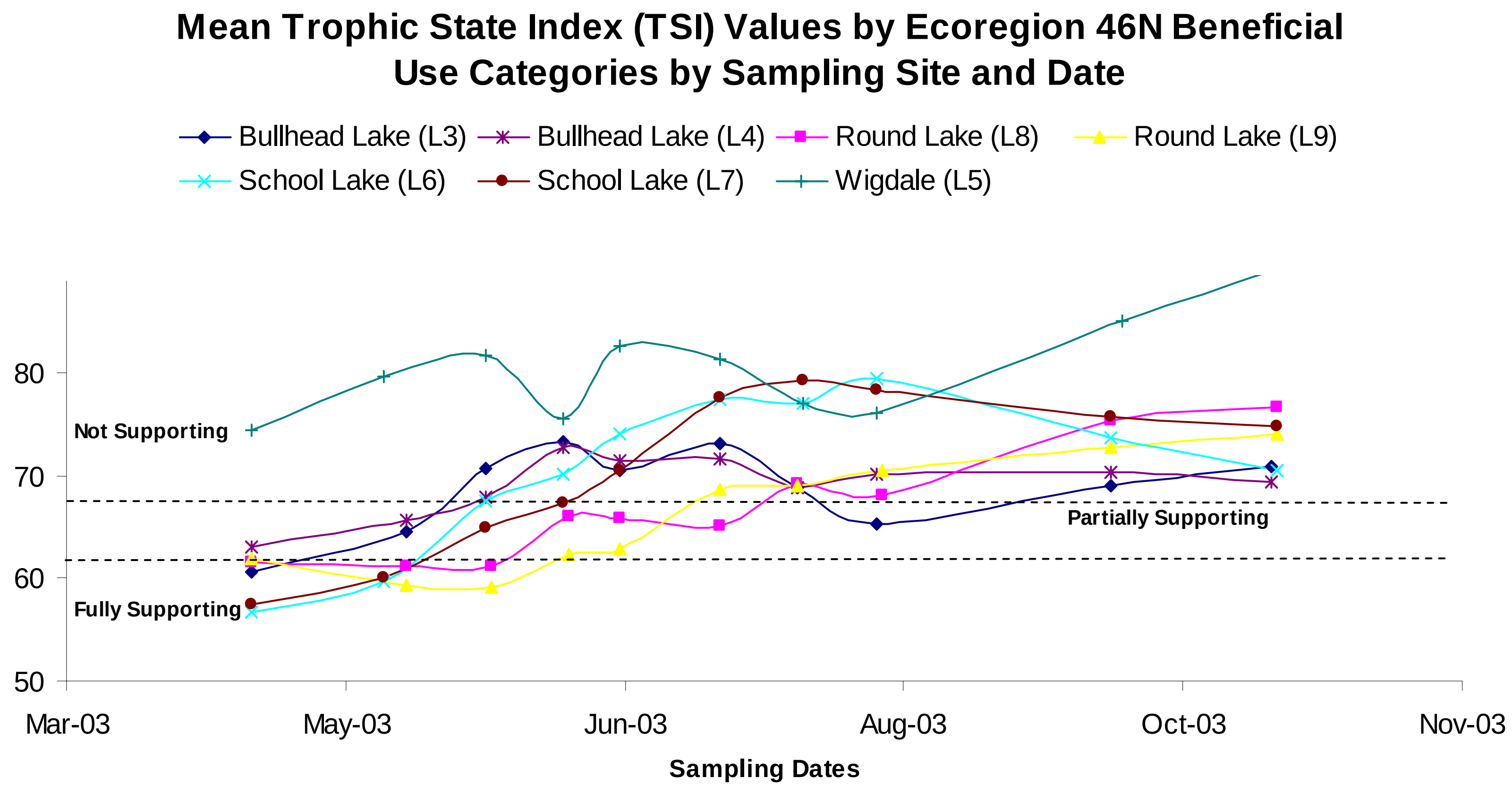


Figure 65. Mean Trophic State Index (TSI) Values by Ecoregion 46N Beneficial Use Categories in Bullhead Lake, Round Lake, School Lake, and Wigdale Lake by Sampling Site and Date

Round Lake mean TSI values ranged from 59.10 to 75.46 (mean = 66.73). School Lake mean TSI values ranged from 56.63 to 79.34 (mean=70.25). Wigdale Lake mean TSI values ranged from 74.43 to 85.14 (mean = 80.04). Bullhead Lake mean TSI values ranged from 60.69 to 73.29 (mean = 68.87).

ASSESSMENT OF SOURCES

Point Sources

Due to the City of Goodwin being a no discharge facility, point source contribution is of no consequence.

Non Point Sources

Urban Stormwater Runoff

The City of Goodwin is that only urban area in this watershed. The impact of this size of a town is negligible for stormwater runoff.

Agricultural Runoff

Agricultural runoff was taken into account when the ANNAGNPS Model calculated land use scenarios for nutrient and sediment reductions, and when AGNPS was used to perform ratings on the feedlots in the study area. See the AnnAGNPS Modeling section and the AGNPS Modeling Section on pages 66 through 70, for the results.

Background Wildlife Contribution

The total fecal bacteria contribution from deer within the project area was estimated at 1.62E+13 CFUs. The average contribution from deer is 4.05E+12 CFUs, watershed wide (See Table 19). This possible contribution surpasses the fecal coliform amounts found at each monitoring site. This number assumes a 100 percent contribution of fecal coliform bacteria from deer is delivered into the receiving waters. Therefore, due to its unrealistic 100 percent delivery only for deer, it will represent a maximum amount that can be contributed to the background.

Table 19. Wildlife Contribution of Fecal Coliform Bacteria

Watershed	Deer/Acre	Acres	Deer	Days	CFU's/deer/day	CFU's
Round Lake	0.00791	3,742	29.60	210	5.00E+08	3.11E+12
School Lake	0.00791	3,671	29.04	210	5.00E+08	3.05E+12
Bullhead Lake	0.00791	2,803	22.17	210	5.00E+08	2.33E+12
Wigdale Lake	0.00791	9,270	73.33	210	5.00E+08	7.70E+12

Failing Septic Systems Contribution

An informal survey of this watershed showed only a few residences in this rural area. All lakes are surrounded by scattered farm residences, while Bullhead Lake has a small number of summer lake home residences. According to USEPA (2002a) failure rates of onsite septic systems range from 10 to 20 percent, with a majority of these failures occurring with systems 30 or more years old. Until there is better factual data on the conditions of the rural septic systems in this study area, the 10 to 20 percent will be assumed however unlikely it seems. Since the number of units and percent is low, the overall contribution will be considered as negligible.

Modeling

FLUX Modeling

The FLUX Model (Army Corps of Engineers Loading Model) was used to estimate the nutrient loadings for each tributary monitoring site. These loads and their standard errors (CV) were calculated and are presented in Appendix E. Sample data (discharge and water quality) collected during this project were utilized in the calculation of the loads and concentrations.

BATHTUB Modeling

The BATHTUB model calculated the observed and predicted TSI values for Bullhead Lake, Round Lake, School Lake, and Wigdale Lake (Table 20). Observed TSI values are based on inlake data. Predicted TSI values are based upon inlake data and watershed nutrient loading calculating the interaction between the lake and watershed area. Wigdale Lake had the highest observed value with 79.9 and predicted value of 74.5. School Lake TSI observed value was 71.3 with a predicted TSI value of 70.4. Bullhead Lake TSI observed value was 69.3 and predicted TSI value of 68.7. Round Lake had the lowest observed value of 67 and the lowest predicted TSI value of 66.8.

Table 20. Observed and Predicted Mean Trophic State Index (TSI) Values Calculated Using the BATHTUB Model

	Observed TSI	Predicted TSI
Bullhead Lake	69.3	68.7
Round Lake	67	66.8
School Lake	71.3	70.4
Wigdale Lake	79.9	74.5

The BATHTUB model also calculated each lake’s responses to reductions in watershed loading. Watershed nutrient loading concentrations were reduced by 10 percent increments and modeled to create an in-lake reduction curve (Figure 66). In order to meet the beneficial uses of these lakes, School Lake and Bullhead Lake require reductions of nutrients higher than 80 percent. After 80 percent reductions, Wigdale Lake and Round Lake would be partially supporting. However, these reductions for all lakes were calculated using estimated ungaged runoff which does not include calculating reductions for internal loads. Therefore, Round Lake could possibly achieve full support by reducing internal phosphorus loads. School Lake and Bullhead Lake reductions could also be achieved by reducing internal loads in addition to ungaged runoff loading.

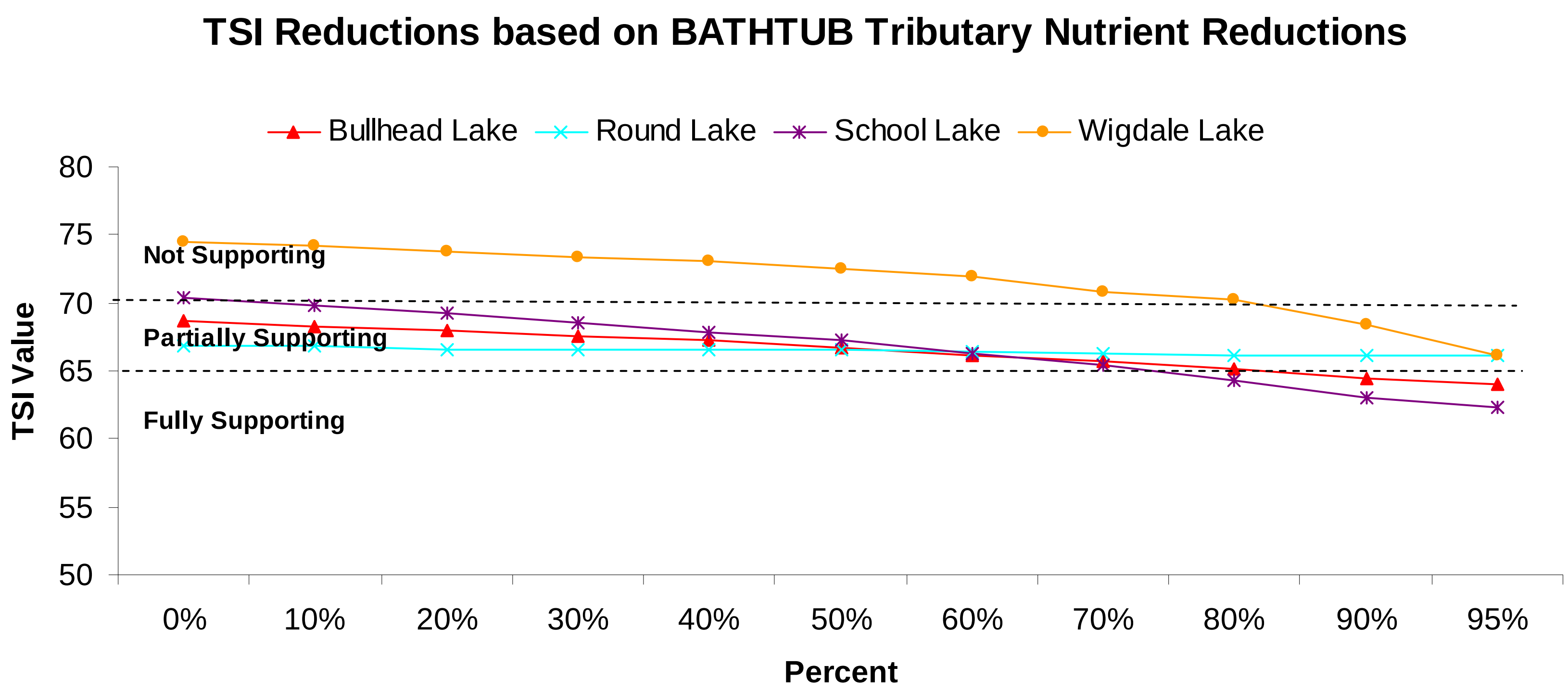


Figure 66. Predicted Mean Trophic State Index (TSI) Reductions Using the BATHTUB Reduction Model Ranked by Ecoregion 46R Beneficial Use Categories in Bullhead Lake, Round Lake, School Lake, and Wigdale Lake

AGNPS Feedlot Model

The Brookings County Conservation District evaluated nine feedlots within the School Lake watershed. Only one was identified as a CAFO. Four of the nine operations rated 50 or greater. Table 21 shows the AGNPS feedlot ratings for those feedlots by watershed. The AGNPS feedlot model ranks the feedlots on a scale from 0 to 100 with larger numbers indicating a greater release of pollutants. Model outputs are total phosphorus, total nitrogen, and chemical oxygen demand (See Table 21).

Table 21. AGNPS Feedlot Ratings for the School-Bullhead Lakes Watershed

AGNPS Feedlot Ratings		
Feedlot	**Watershed**	**Rating**
1267*	Wigdale Lake	0
1269	Wigdale Lake	67
1270	Wigdale Lake	0
1271	Wigdale Lake	16
1272	Wigdale Lake	58
1273	Wigdale Lake	53
1276	Wigdale Lake	0
1277	School Lake	28
1278	School Lake	61

* indicates a CAFO

Table 22. AGNPS Model Output for Phosphorus, Nitrogen, and Chemical Oxygen Demand

Watershed	Density	Mean PO4 (ppm)	Mean COD (ppm)	Mean PO4 (lbs)	Mean COD (lbs)	Sum Phos (ppm)	Sum COD (ppm)	Sum Phos (lbs)	Sum COD (lbs)
Wigdale	6	42	1896	140	7397	251	13275	839	44383
School	2	29	2511	57	5837	58	5021	113	11673

AnnAGNPS Model

The AnnAGNPS Model was used to compare sediment, nitrogen, and phosphorus loadings within the watershed (13,494 acre drainage area) during 1-year, 10-year, and 25-year rain events. Several scenarios were run through the model and included 1) present condition, 2) changing all cropland to all grass, 3) removing the feedlots, 4) removing any impoundments, and 5) changing all cropping practices to no-tillage. Tables 23, 24, and 25 show the results of these scenarios during 1-year, 10-year, and 25-year rain events, respectively. The percent differences and indicators of increasing or decreasing differences are at the bottom of each table using equation ((larger number – smaller number) ÷ larger number) × 100 to find percent difference or (smaller number ÷ larger number) then minus from one and multiply by 100. As indicated by all three tables, feedlots in the watershed are not having as great as an affect as probably the agricultural practices. During the 1-year event, removal of feedlots had a negligible impact. As precipitation amounts increased, feedlots only contributed one to three percent of the nitrogen loadings.

Table 23. AnnAGNPS Output for a 1-Year Simulated Period

School/Bullhead Lakes Watershed - 1 Year Simulation Period							
Scenerio	Sediment Load (tons/acre/year)	Nitrogen Load (mass) (lb/year)	Attached Nitrogen Load (lb/yr)	Dissolved Nitrogen Load (lb/yr)	Total Phosphorus Load (mass) (lb/yr)	Attached Phosphorus Load (lb/yr)	Dissolved Phosphorus Load (lb/yr)
Present Condition	0.0004	6730	2418	4312	1124	274	850
All Grass	0.0000	430	59	371	55	4	51
No Feedlots	0.0004	6706	2407	4299	1121	273	849
No Impoundments	0.0039	8398	3497	4901	1895	510	1385
No Tillage	0.0003	6142	1412	4730	995	145	850
	Percent Difference from Present Condition						
All Grass	100 ↓	94 ↓	98 ↓	91 ↓	95 ↓	99 ↓	94 ↓
No Feedlots	0	0 ↓	0 ↓	0 ↓	0 ↓	0 ↓	0 ↓
No Impoundments	90 ↑	20 ↑	31 ↑	12 ↑	41 ↑	46 ↑	39 ↑
No Tillage	25 ↓	9 ↓	42 ↓	9 ↑	11 ↓	47 ↓	0

Table 24. AnnAGNPS Output for a 10-Year Simulated Period

School/Bullhead Lakes Watershed - 10 Year Simulation Period							
Scenerio	Sediment Load (tons/acre/year)	Nitrogen Load (mass) (lb/year)	Attached Nitrogen Load (lb/yr)	Dissolved Nitrogen Load (lb/yr)	Total Phosphorus Load (mass) (lb/yr)	Attached Phosphorus Load (lb/yr)	Dissolved Phosphorus Load (lb/yr)
Present Condition	0.074	3474	1959	1515	3066	611	2455
All Grass	0.0001	1434	326	1108	1085	39	1046
No Feedlots	0.0000	3398	1903	1495	3060	609	2451
No Impoundments	0.0057	5955	3921	2035	4231	864	3366
No Tillage	0.0000	2919	1180	1739	2457	254	2203
	Percent Difference from Present Condition						
All Grass	100 ↓	59 ↓	83 ↓	27 ↓	65 ↓	94 ↓	57 ↓
No Feedlots	100 ↓	2 ↓	3 ↓	1 ↓	0 ↓	0 ↓	0 ↓
No Impoundments	92 ↓	42 ↑	50 ↑	26 ↑	28 ↑	29 ↑	27 ↑
No Tillage	100 ↓	16 ↓	40 ↓	13 ↑	20 ↓	58 ↓	10 ↓

Table 25. AnnAGNPS Output for a 25-Year Simulated Period

School/Bullhead Lakes Watershed - 25 Year Simulation Period							
Scenerio	Sediment Load (tons/acre/year)	Nitrogen Load (mass) (lb/year)	Attached Nitrogen Load (lb/yr)	Dissolved Nitrogen Load (lb/yr)	Total Phosphorus Load (mass) (lb/yr)	Attached Phosphorus Load (lb/yr)	Dissolved Phosphorus Load (lb/yr)
Present Condition	0.0001	2748	1508	1240	4054	556	3498
All Grass	0.0001	1104	245	859	1570	33	1537
No Feedlots	0.0000	2688	1466	1222	4050	555	3495
No Impoundments	0.0044	4655	3000	1655	5137	733	4404
No Tillage	0.0000	2394	909	1485	3568	233	3335
	Percent Difference from Present Condition						
All Grass	0	60 ↓	84 ↓	31 ↓	61 ↓	94 ↓	56 ↓
No Feedlots	100 ↓	2 ↓	3 ↓	1 ↓	0 ↓	0 ↓	0 ↓
No Impoundments	98 ↑	41 ↑	50 ↑	25 ↑	21 ↑	24 ↑	21 ↑
No Tillage	100 ↓	13 ↓	40 ↓	17 ↑	12 ↓	58 ↓	5 ↓

Approximately 4,685 acres were converted from cropland to grassland to run the 'all grass' scenario. Sediment loading only showed a marked decrease during the 1-year simulation period when cropland was converted to grassland. However, there were significant decreases in phosphorus loads during all three scenarios (See Table 26).

Table 26. Phosphorus Reduction Results after Converting Cropland to Grassland

Results of Conversion of Crops to Grassland			
Phosphorus	1-Year	10-Year	25-Year
lb/year reduction	1,069	1,981	2,484
lb/acre reduction	0.22	0.42	0.53

Approximately 1,833 acres of impoundments (10 acres or larger) were removed to run the 'no impoundments' scenario. The removal of the impoundments caused increases in nitrogen and phosphorus loadings in all three scenarios. This demonstrates the importance of impoundments in filtering out nutrients. This is especially true of wetland areas.

Approximately 48 percent of the total watershed area (22,152 acres) is in agricultural cropland. Converting all agricultural cropping practices to no-tillage (no-till planter and no-till drill) achieved sediment reductions (Tables 23, 24 and 25). The 1-year simulated period showed a 25 percent difference in sediment. Significant decreases in sediment load could be achieved over the long term (10 to 25 years) if no-tillage practices were implemented (See Table 25).

Those cells containing the evaluated feedlots (Table 27) were isolated. Total loadings of phosphorus, nitrogen, and sediment from only those cells were compared with one another. Cell numbers 13553, 13323, and 13663 contributed significantly more phosphorus, nitrogen, and sediment than other cells containing feedlots.

Table 27. Percentage of Phosphorus, Nitrogen, and Sediment Loading Based on Total Loads of Cells with Feedlots

Cells with Feedlots				Current Conditions 10-year Simulation					
Cell	Reach	Area	Rating	PO4 lb/yr	% of total	Nitrogen lb/yr	% of total	sediment tons/yr	% of total
13553	1355	193.0	68	199	48.2	833	57.0	77	65.7
13323	1332	34.3	35	118	28.6	485	33.1	37	31.6
13663	1366	232.4	61	46	11.1	89	6.1	2	1.8
13502	1350	102.3	56	25	6.0	34	2.3	1	0.8
13171	1317	113.0	0	22	5.4	20	1.4	0	0.2
13551	1355	79.2	68	3	0.6	1	0.1	0	0.0
			Totals	413		1462		117	

Cells with phosphorus and sediment loadings greater than one percent of the total watershed load during a 10-year rain event are show in Tables 28 and 29. The bolded cells in these tables contain feedlots. Results for all watershed cells (a total of 195), can be found in Appendix J (phosphorus and nitrogen) and Appendix K (sediment).

Table 28. Phosphorus Loadings > 1% of Total Watershed Load Based on a 10-Year Simulation at Current Conditions

Current Conditions 10-Year Simulation (sorted by P04 lb/yr)						
Cell	Reach	Area	PO4 lb/yr	% of total	Nitrogen lb/yr	% of total
13202	1320	265	532	8.7	1789	12.7
13552	1355	227	383	6.2	798	5.7
13241	1324	76	209	3.4	130	0.9
13553	1355	193	199	3.2	833	5.9
13523	1352	92	184	3.0	760	5.4
13402	1340	123	173	2.8	552	3.9
13503	1350	101	159	2.6	433	3.1
13342	1334	121	159	2.6	294	2.1
13661	1366	94	138	2.2	483	3.4
13543	1354	56	129	2.1	580	4.1
13401	1340	79	121	2.0	311	2.2
13323	1332	34	118	1.9	485	3.4
13571	1357	75	117	1.9	142	1.0
13542	1354	71	112	1.8	412	2.9
13351	1335	89	108	1.8	186	1.3
13533	1353	93	106	1.7	257	1.8
13471	1347	78	103	1.7	182	1.3
13371	1337	87	99	1.6	156	1.1
13211	1321	81	98	1.6	134	1.0
13291	1329	82	85	1.4	96	0.7
13403	1340	45	83	1.3	333	2.4
13511	1351	79	80	1.3	142	1.0
13063	1306	58	78	1.3	168	1.2
13481	1348	74	78	1.3	174	1.2
13561	1356	76	76	1.2	149	1.1
13141	1314	81	68	1.1	44	0.3
13122	1312	52	68	1.1	48	0.3
13493	1349	68	66	1.1	55	0.4
13051	1305	105	63	1.0	169	1.2

Table 29. Sediment Loadings > 1% of Total Watershed Load Based on a 10-Year Simulation at Current Conditions

Current conditions 10-Year Simulation (sorted by subtotals of sediment tons/year)									
Cell	**Reach**	**Area**	**Clay**	**Silt**	**Sand**	**Sm. Agg.**	**Lg. Agg.**	**Subtotals**	**% of Total**
13202	1320	265	38.69	51.76	33.85	0	0	124.30	12.49
13553	1355	193	22.72	44.35	9.78	0	0	76.85	7.72
13523	1352	92	20.69	39.54	7.41	0	0	67.65	6.80
13552	1355	227	18.57	28.74	7.62	0	0	54.94	5.52
13543	1354	56	16.19	30.80	5.78	0	0	52.78	5.30
13402	1340	123	14.26	26.50	4.74	0	0	45.50	4.57
13661	1366	94	12.95	24.62	4.13	0	0	41.70	4.19
13323	1332	34	11.80	23.76	1.37	0	0	36.93	3.71
13542	1354	71	11.33	21.01	3.42	0	0	35.76	3.59
13503	1350	101	10.09	19.13	3.34	0	0	32.56	3.27
13403	1340	45	8.67	17.41	1.08	0	0	27.16	2.73
13322	1332	117	7.28	13.99	2.99	0	0	24.26	2.44
13401	1340	79	7.05	13.04	2.21	0	0	22.30	2.24
13533	1353	93	6.27	11.77	1.86	0	0	19.90	2.00
13233	1323	24	5.54	9.06	2.28	0	0	16.88	1.70
13342	1334	121	5.27	7.01	3.65	0	0	15.93	1.60
13351	1335	89	4.09	6.46	1.80	0	0	12.36	1.24
13263	1326	15	4.03	6.44	1.78	0	0	12.25	1.23
13481	1348	74	3.79	7.03	1.25	0	0	12.07	1.21
13253	1325	16	3.94	6.33	1.54	0	0	11.80	1.19
13522	1352	52	3.36	6.49	1.37	0	0	11.23	1.13
13371	1337	87	3.54	5.53	1.34	0	0	10.40	1.05
13513	1351	24	3.14	6.03	1.03	0	0	10.20	1.02

ANALYSIS AND SUMMARY

SUMMARY OF POLLUTANT LOADINGS BY LAKE

Each of the four lakes (Figure 67) is summarized into landuse, water quality, hydrologic, sediment and nutrient budgets, phytoplankton, macrophytes, and source linkage. The main focus will be on the School Lake watershed which was listed as impaired and is centrally located within the chain of these lakes. The water quality assessment in this section (Summary of Pollutant Loadings) is based on the currently assigned beneficial uses and numeric criteria to meet those uses. Based on monitoring results, pH was the only water quality parameter found not meeting the water quality criteria throughout the watershed. In regards to the biological monitoring results all lakes contained several nuisance species of algae. In the Water Quality Goals, the Target Reductions and Priority Management Areas, and also Future Activity Recommendations Section water quality goals were established for all areas not meeting these standards. To meet the goals for water quality, TSI rating, and biological affects, lakes or inlets with less stringent standards and/or those with no standards at all may be identified as priority management areas to achieve the reductions needed to meet the goals of the School Lake Watershed.

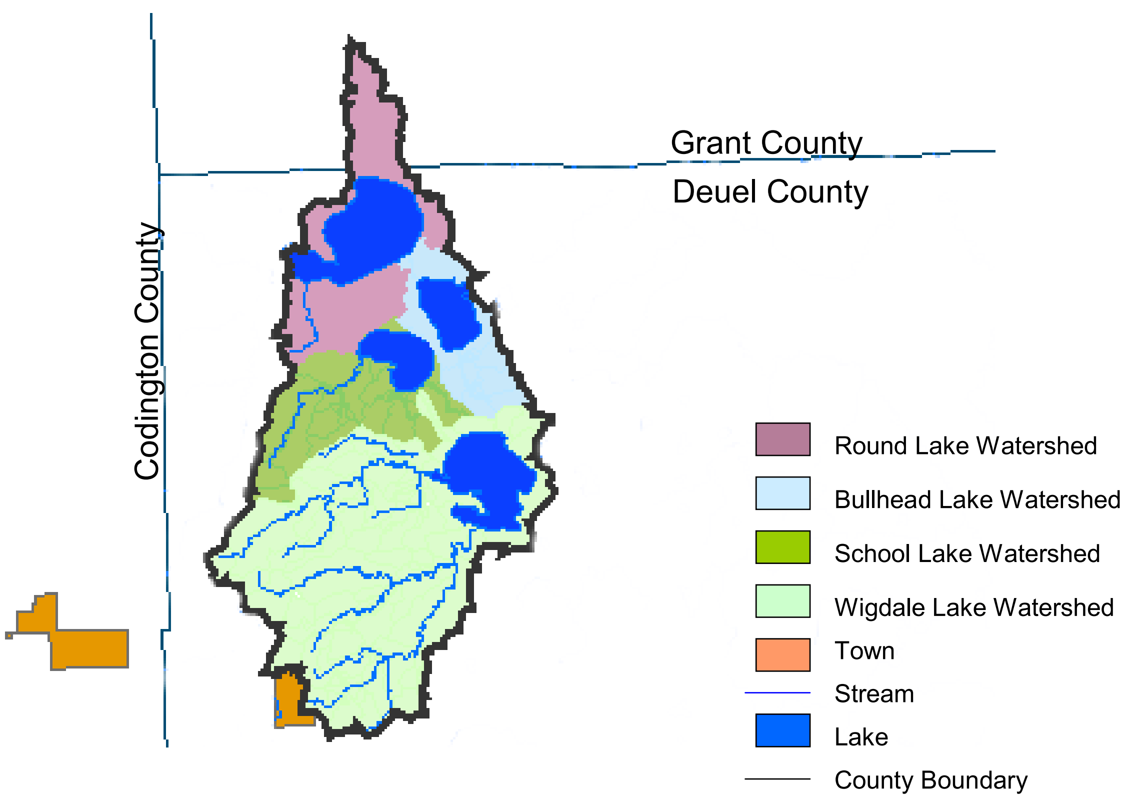


Figure 67. The Four Major Watersheds of the School Lake Watershed Study Area

Round Lake Watershed Area

This map (Figure 68) shows the location of the area designated as the Round Lake Watershed Area. This area encompasses approximately 4,903 acres, with the lake itself covering approximately 1,161 acres.

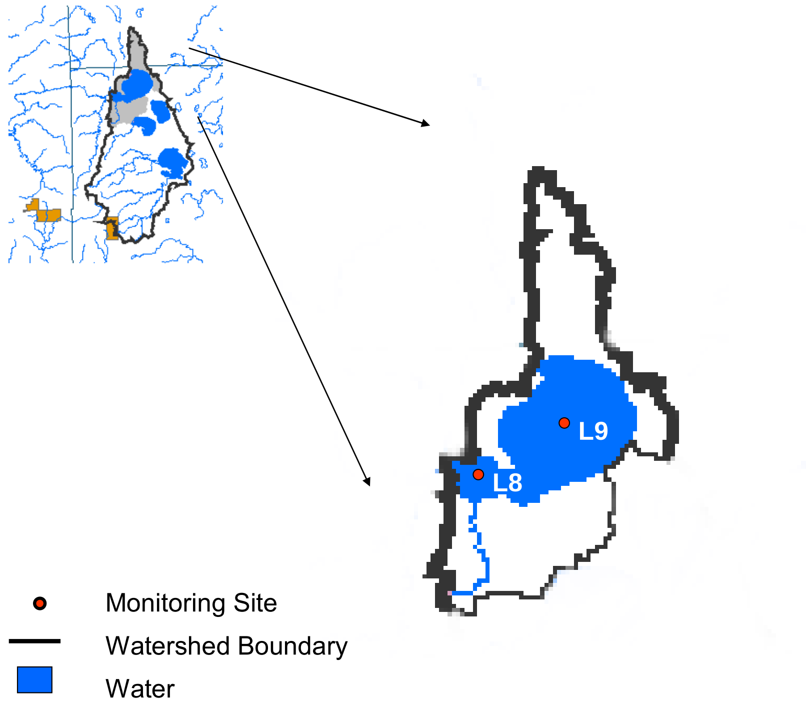


Figure 68. Round Lake Watershed Location Map

Land Use

The Round Lake watershed area is located within the Northern Glaciated Plains level III ecoregion and characterized by the level IV ecoregion of the Prairie Coteau. This is an area of rolling terrain and drift plains. Much of the rolling areas are in pastureland, while the flatter areas are tilled for agricultural crops. Approximately 32 percent of the area is cropland, such as corn and soybeans, and 38 percent is grassland and pastureland (Figure 69). There was one animal feeding operation assessed in the Round Lake watershed. This dairy cattle operation consisted of approximately 300 animals. The AGNPS surface rating for this particular feedlot was 59.

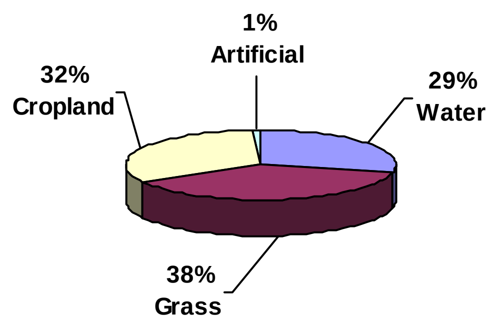


Figure 69. Round Lake Watershed Landuse

Water Quality Summary

Beneficial uses for the two inlake sites (L8 and L9) are 6, 7, 8, and 9.

(6) Warmwater Marginal Fish Life Propagation
(7) Immersion Recreation
(8) Limited Contact Recreation
(9) Fish and Wildlife Propagation, Recreation and Stock Watering

Based on the results from the water quality criteria established by DENR as described in Results section under Water Quality Monitoring, the two inlake sites are meeting the water quality criteria for beneficial use (7) Immersion Recreation, (8) Limited Contact Recreation, and (9) Fish and Wildlife Propagation, Recreation and Stock Watering. For beneficial use (6) Warm Water Marginal Fish Life Propagation, inlake sites are meeting the criteria as described in the 303(d) waterbody listing for water temperature, dissolved oxygen, total suspended solids, and unionized ammonia. Inlake site L9 is meeting the numeric standard for pH. However, inlake site L8 does not meet the water quality criteria for pH (See Figure 70). Table 30 is a summary of the water quality exceedences for the sampling period. See Appendix L for Round Lake Water Quality graphs.

Table 30. Round Lake Water Quality Exceedences

Date	Site	Parameter	Standard	Sampled Value
07/15/03	L8	pH	≥ 6.0 - ≤ 9.0	9.54
07/29/03	L8	pH	≥ 6.0 - ≤ 9.0	9.01
08/13/03	L8	pH	≥ 6.0 - ≤ 9.0	9.12
07/15/03	L9	pH	≥ 6.0 - ≤ 9.0	9.19
07/29/03	L8	DO	≥ 5.0	4.48

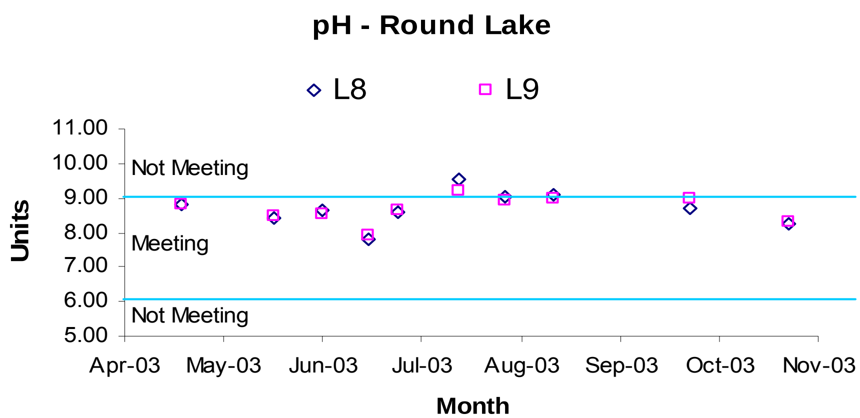


Figure 70. pH Grab Samples based on Numeric Standard ≥ 6.0 - ≤ 9.0 (Less Than 20 Samples) at Sites L8 and L9

Temperature and pH levels tend to increase as lakes become more productive. This higher productivity is likely caused by excessive nutrients. Thus, these higher pH levels may indicate elevated levels of nutrients in this lake, causing excessive algal and macrophyte growth. Figure 71 shows the pH levels in comparison to the water temperature in Round Lake.

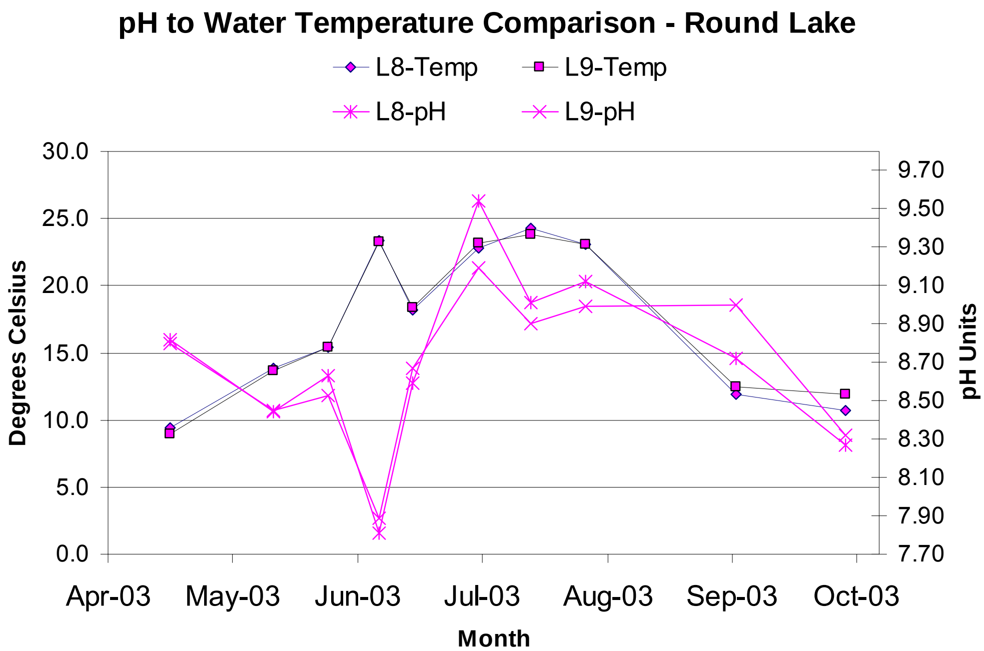


Figure 71. Round Lake pH to Water Temperature Comparison

Chlorophyll is the photosynthetic pigment in all green plants and can be a measure of the amount of algae present in a lake. Phosphorus is the primary nutrient algae use for growth. Plots of total phosphorus and chlorophyll-*a* were constructed (Figure 72) to show the relationship between the amount of phosphorus present versus the amount of algal growth. Phosphorus is usually the limiting nutrient in the growth of algae. Therefore, increases in phosphorus should yield increases in algae mass. Figure 72 indicates there is a correlation (R^2=0.6658 at Site L8 and R^2=0.4981 at Site L9) between chlorophyll-*a* and total phosphorus in Round Lake.

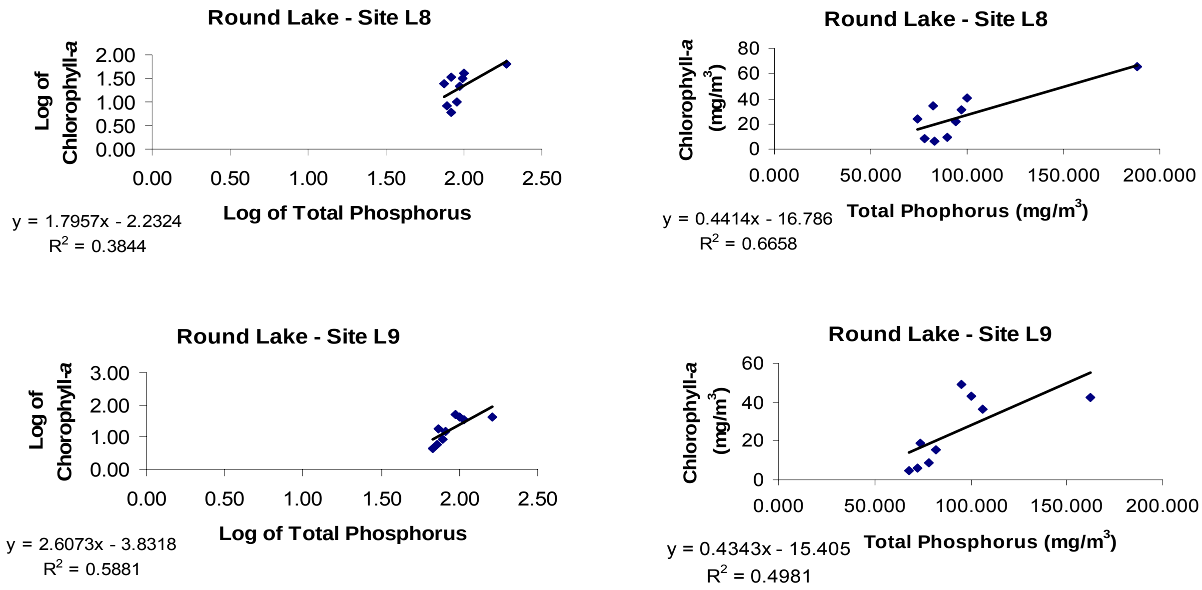


Figure 72. Phosphorus to Chlorophyll-*a* Relationship for Sites L8 and L9

The maximum inlake chlorophyll-*a* concentration of 65.09 mg/m^3 was collected at Site L8 on 23 September 23, 2003 (Figure 73). The average chlorophyll-*a* concentration was 25.83 mg/m^3 and the median concentration was 22.83 mg/m^3.

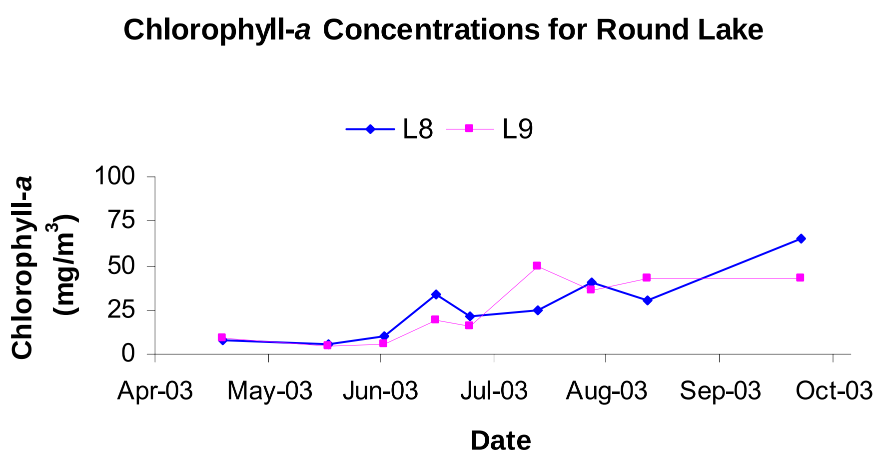


Figure 73. Graph of Chlorophyll-*a* Concentrations (mg/m^3) for Round Lake

Water clarity is measured using a Secchi disk. The deeper the Secchi disk can be seen, the clearer the water. Indicatively, water clarity decreases as the amount of chlorophyll-a increases, as shown by Figure 74.

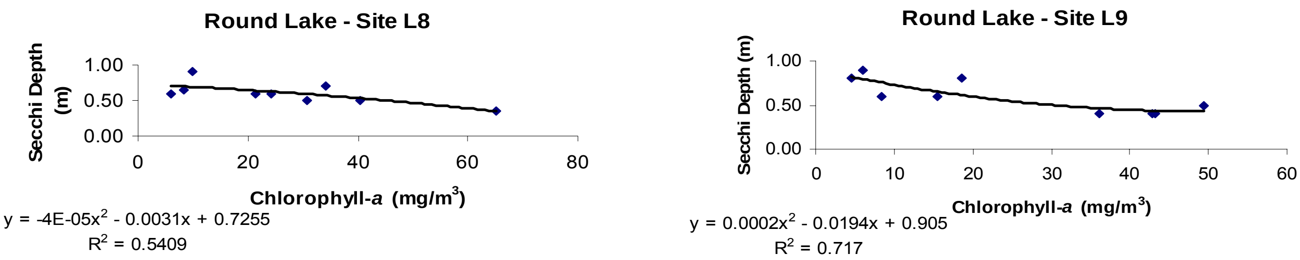


Figure 74. Chlorophyll-*a* to Secchi Depth Relationship for Sites L8 and L9

For an organism, such as algae, to survive in a given environment, it must have the necessary nutrients and environment to maintain life and successfully reproduce. If an essential life component approaches a critical minimum, this component will become the limiting factor (Odum 1959). Nutrients such as phosphorus and nitrogen are most often the limiting factors in highly eutrophic lakes. Typically, phosphorus is the limiting nutrient for algal growth. However, in many highly eutrophic lakes with an overabundance of phosphorus, nitrogen can become the limiting factor. Round Lake is a phosphorus-limited lake as shown by Figure 75.

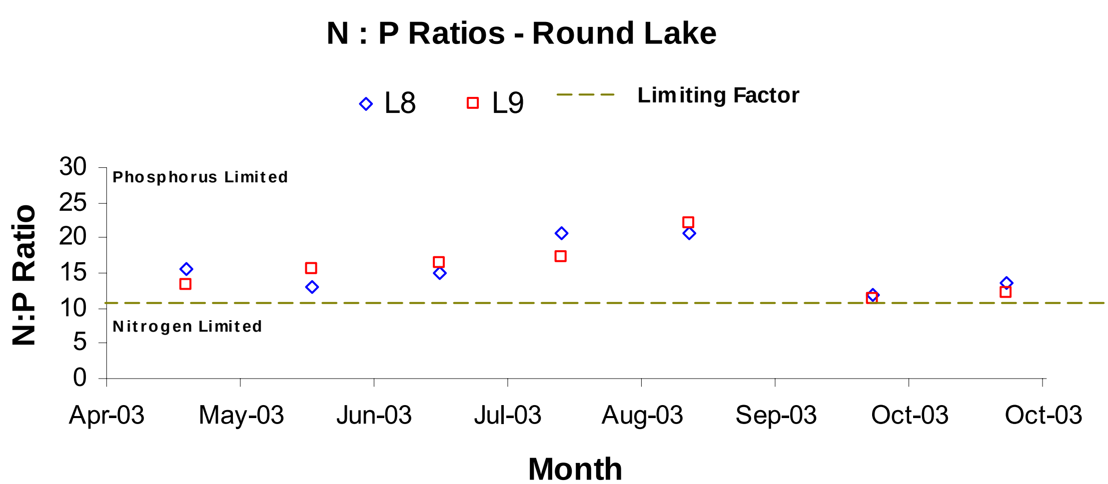


Figure 75. Total Nitrogen to Total Phosphorus Ratio for Round Lake

In 2003 lake levels in Round Lake dropped approximately 1.5 ft between the months of May and October. In 2004 the difference in lake levels between May and October was approximately 0.75 ft. As shown by Figure 76, lake levels rose in June and October of 2004 due to heavy rains.

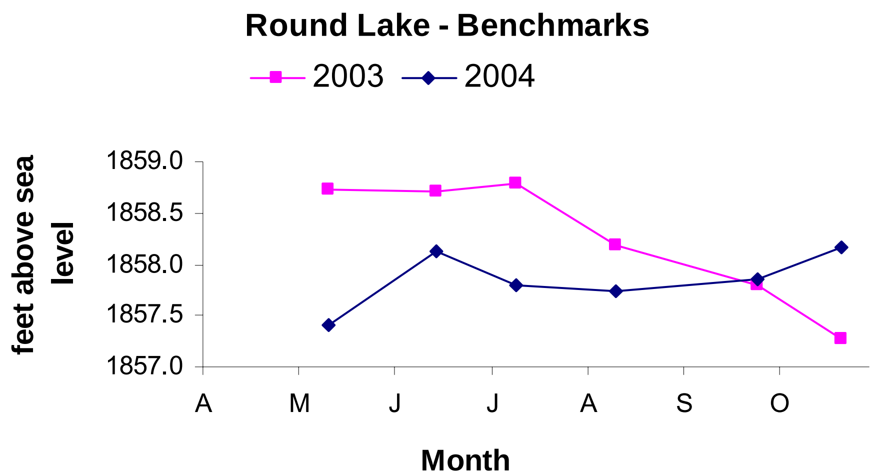


Figure 76. 2003 and 2004 Lake Level Readings for Round Lake

Hydrologic Budget

Hydrologic Budget

A hydrologic budget explains the amount of water entering and leaving a lake. In theory, all inputs of water must equal all outputs during the course of the hydrologic cycle (Table 31). The input sources during a dry season flowing into Round Lake included precipitation, groundwater, and ungaged runoff. During a wet season, the inputs would also include runoff from School and Bullhead Lakes. For the purpose of this study season, groundwater and ungaged runoff will be estimated to help balance the equation.

Table 31. Hydrologic Budget for Round Lake in 2003

Input Sources	Load (acre-ft)	Output Sources	Load (acre-ft)
Surface Area= 1161.4 acres			
Precipitation	2,119.5	Evaporation	2,356.6
Ungaged Runoff	31.8	Advective Flow	74.3
Groundwater	1,974.0	Change In Storage	1,694.4
Totals	4,125.31		4,125.31

In order to calculate the precipitation inputs, 2003 rainfall data were taken from the weather station located at Watertown AP. The amount of precipitation in inches was converted to feet and multiplied by the surface area of Round Lake (1.825 ft × 1,161.35 acres).

The ungaged portion of the project is comprised of the entire Round Lake watershed (3742 acres). Contribution from the watershed was estimated from the tributaries of Wigdale Lake. Loading coefficients were calculated for Site T49 and Site T50 by dividing the flow by the tributary drainage area. The average, of Site T49 and Site T50 loading coefficients, was then multiplied by the watershed area.

Round Lake had one flowing outlet that was not sampled during this assessment, since it was included in the North Central Big Sioux River Assessment Report. Therefore output sources only included evaporation, advective outflow, and change in storage. The nearest weather station that collected land evaporation data was two miles northeast of Brookings approximately 45 miles from our study area (SDSU 2003). In order to adjust the land data to surface water evaporation, monthly evaporation amounts were multiplied by the Class A monthly land pan coefficient (0.8) for the midwestern United States (Fetter 1988). The monthly evaporation amounts were added, converted to feet, and multiplied by the surface area of Round Lake.

Advective outflow (movement of water by gravity) for Round Lake was calculated using the BATHTUB model (Walker 1999). The storage of the lake decreased from its original measurement in April 2003 to the last measurement in October 2003. The difference between these measurements was 1.429 feet. This constitutes 1,694 acre-feet (1.429 ft × 1,161.35 acres) indicating a decrease in storage.

After all of the hydrologic outputs were subtracted from the inputs, 1,974 acre-ft were unaccounted for. The only source not yet included was groundwater, which can be difficult to estimate. Since, this lake was sampled during a dry cycle, and groundwater input was probably a large contributor.

Sediment and Nutrient Loadings

To calculate current and future water quality in Round Lake, loadings from the watershed were estimated from the tributaries of Wigdale Lake. Loadings from these tributaries were calculated by the FLUX model and are shown in Table 32.

Table 32. FLUX model data for Wigdale Lake Tributaries

	All Loads Reported in Kilograms		
	T49	T50	Total Load
Total Phosphorus	42.4	5.1	47.5
Total Dissolved Phosphorus	33.9	3.8	37.7
Total Suspended Solids	1,048.2	1,316.7	2,364.9
Total Solids	71,281.7	33,508.6	104,790.3
Total Dissolved Solids	69,687.2	32,191.9	101,879.1
TKN	206.9	44.4	251.3
VTSS	557.9	324.5	882.4

An important comparison of conditions in Round Lake watershed can be made through the use of the loading coefficients from the tributaries of Wigdale Lake (Table 33). Loading coefficients are calculated by using the total loading discharged from the site and then dividing by the surface drainage area. For example, the loading phosphorus coefficient for Site T49 is the total loading (42.4 kg) divided by the number of acres (3,172.8). The loading coefficients for Site T49 and Site T50 were averaged to estimate a nutrient loading coefficient for the runoff delivered to Round Lake.

Table 33. Loading Coefficients for Wigdale Lake (kg/acre)

	Watershed acres	TPO4 kg/acres	TDPO4 kg/acres	TSS kg/acres	TSOL kg/acres	TDSOL kg/acres	TKN kg/acres	VTSS kg/acres
T49	3,172.83	0.013	0.011	0.33	22.47	21.96	0.065	0.18
T50	1,729.74	0.0029	0.0022	0.76	19.37	18.61	0.026	0.19
	Average	0.00795	0.0066	0.545	20.92	20.285	0.0455	0.185

Suspended Solids Loadings

The estimated total suspended solids loading from Round Lake watershed runoff was derived from the loading coefficients in Table 33. The TSS loading was calculated by multiplying the loading coefficient (0.6 kg/acres) by the watershed area of Round Lake (3,742 acres). The estimated runoff load for Round Lake watershed is 2,245.2 kg. This estimated total yearly load of sediment (2,245.2 kg) was retained within the lake, since during a dry cycle Round Lake has no tributary outlets.

Nitrogen Loadings

Round Lake's tributary outlet was not sampled during 2003 due to the lack of flow. Input loading was estimated from the tributaries load coefficients of Wigdale Lake for the ungaged runoff. Total nitrogen concentrations are derived from adding TKN concentrations to nitrate-nitrite concentrations. Nitrogen inputs to Round Lake during the 2003 sampling season were insignificant at 689.7 kg. The total yearly load of nitrogen (689 kg) is retained within the lake, since no nitrogen is lost to tributary outlets. Inputs to Round Lake included ungaged runoff and groundwater (Figure 77). Atmospheric nitrogen was not included in the input estimates. As atmospheric nitrogen enters the lake, it is utilized by different species of algae, therefore, it is impossible to calculate. Of the 689.7 kg, ungaged runoff contributed 24 percent. The following calculations were used to find ungaged runoff for Round Lake watershed:

Watershed area converted to acres:

$$15.14 \text{ km}^2 \div .004047 = 3742 \text{ acres}$$

Watershed acres multiplied by the loading coefficient:

$$3742 \text{ acres} \times .045 \text{ kg/acres} = 168.4 \text{ kg}$$

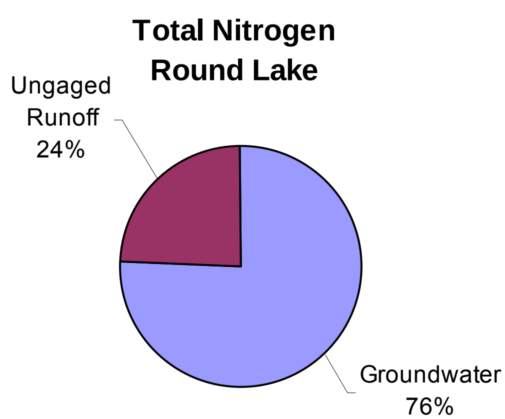


Figure 77. Round Lake Watershed Total Nitrogen Loads

Nitrogen is water soluble which makes it very difficult to estimate groundwater contributions. For the purpose of this study, a total nitrogen concentration of 0.214 mg/L was used for groundwater input. The concentration was averaged from SDGS monitored wells. Because this watershed was sampled during a dry cycle, groundwater is responsible for 76 percent of the input phosphorus loading. The following calculations were used to find the groundwater load:

Hydrologic load converted to m^3:

$$1{,}974 \text{ acre-ft} \times 1{,}234 = 2{,}435{,}965.4 \text{ m}^3$$

Converted m^3 to liters:

$$2{,}435{,}965.4 \text{ m}^3 \times 1{,}000 = 2{,}435{,}965{,}360 \text{ L}$$

Groundwater phosphorus average concentration multiplied by hydrologic load (L):

$$0.214 \text{ mg/L} \times 2{,}435{,}965{,}360 \text{ L} = 521{,}296{,}587 \text{ mg}$$

Total groundwater nitrogen load converted to kg:

$$521{,}296{,}587 \text{ mg} \div 1{,}000{,}000 = 521.3 \text{ kg}$$

Phosphorus Loadings

Since Round Lake's tributary outlet was not sampled during 2003 sampling season. School Lake and Bullhead Lake were possible inputs to Round Lake but were not included since sampling occurred during a dry season. Phosphorus inputs to Round Lake averaged 937 kg from April to October. Inputs included ungaged runoff, internal loading, groundwater, and precipitation (Figure 78). The yearly load of phosphorus (937 kg) is retained within the lake, since no phosphorus is lost to tributary outlets. Of the 937 kg, ungaged runoff contributed three percent. Input loading was estimated from the tributaries load coefficients of Wigdale Lake for the ungaged runoff. The following calculations were used to find ungaged runoff for Round Lake watershed:

Watershed area converted to acres:

$$15.14 \text{ km}^2 \div 0.004047 = 3{,}742 \text{ acres}$$

Watershed acres multiplied by the loading coefficient:

$$3{,}742 \text{ acres} \times 0.008 \text{ kg/acres} = 29.94 \text{ kg}$$

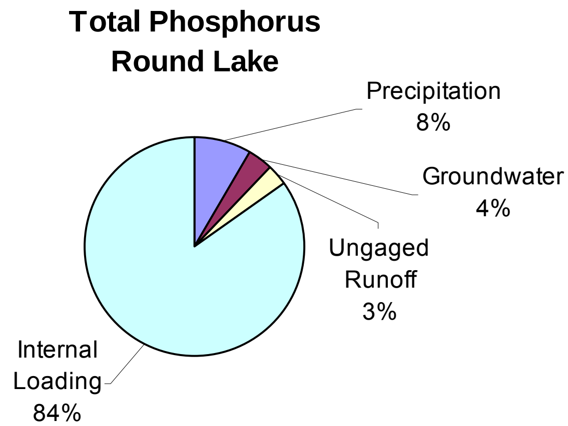


Figure 78. Round Lake Watershed Phosphorus Loads

Groundwater was responsible for four percent of the total phosphorus delivered to the lake. Groundwater contribution was a larger portion due to the sampling season occurring during a dry cycle. Groundwater contribution was estimated by multiplying the mean total phosphorus concentration (0.014 mg/L) from groundwater samples collected from the SDGS and amount of groundwater discharged into the lake (1,974 acre-feet). The following calculations were used to find the groundwater load:

Hydrologic load converted to m^3:

$$1{,}974 \text{ acre-ft} \times 1{,}234 = 2{,}435{,}965 \text{ m}^3$$

Converted m^3 to liters:

$$2{,}435{,}965 \text{ m}^3 \times 1{,}000 = 2{,}435{,}965{,}360 \text{ L}$$

Groundwater phosphorus average concentration multiplied by hydrologic load (L):

$$0.014 \text{ mg/L} \times 2{,}435{,}965{,}360 \text{ L} = 34{,}103{,}515 \text{ mg}$$

Total groundwater phosphorus load converted to kg:

$$34{,}103{,}515 \text{ mg} \div 1{,}000{,}000 = 34.1 \text{ kg}$$

The precipitation load (2,119.5 acres-feet) was multiplied by 0.03 mg/L, average phosphorus content often found in nonpopulated regions, to determine the precipitation phosphorus load (Wetzel 1975). Total estimated precipitation concentration was responsible for eight percent of the total phosphorus load. Contributions of phosphorus from tributaries and groundwater were insignificant. The lack of phosphorus load from ungaged runoff was mainly due to it being a dry period and groundwater in this area carries little phosphorus. The following calculations were used to find the precipitation load:

Hydrologic load converted to m^3:

2,119.5 acre-ft × 1,234 = 2,615,413.6 m³

Converted m³ to liters:

2,615,413.6 m³ × 1,000 = 2,615,413,640 L

Precipitation phosphorus average concentration multiplied by hydrologic load (L):

0.03 mg/L × 2,615,413,640 L = 78,462,409 mg

Total precipitation phosphorus load converted to kg:

78,462,409 mg ÷ 1,000,000 = 78.5 kg

The internal loading of phosphorus from the sediment was estimated by calculating the total phosphorus load in the lake and subtracting the other inputs. Internal loading contributed an estimated 84% to the total phosphorus load in Round Lake. Internal loading of phosphorus refers to the release of phosphorus from lake sediments. In shallow lakes, resuspension of bottom sediment can occur from wind action. Figure 79 shows a strong correlation between the grab samples of Total Phosphorus and TSS.

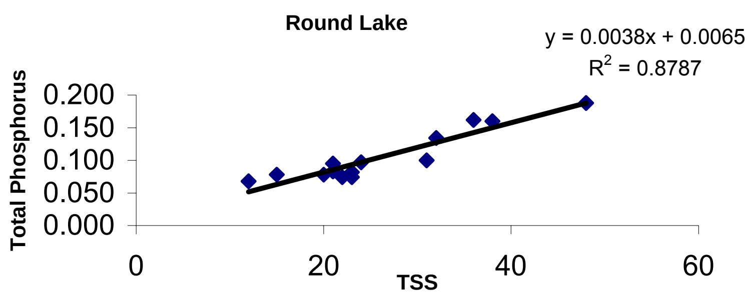


Figure 79. TSS to Total Phosphorus Relationship in Round Lake

In order to estimate the amount internal phosphorus, total phosphorus was calculated. The following calculations were used to find the total phosphorus amount in Round Lake from April to May:

Volume of the lake:

1,161 acres × 6 ft = 6, 966 acre-ft

Hydrologic load converted to m³:

6,966 acre-ft × 1,234 = 8,596,044 m³

Converted m³ to liters:

8,596,044 m³ × 1,000 = 8,596,044,000 L

Average phosphorus concentration multiplied by hydrologic load (L):

.077 mg/L × 8,596,044,000 L = 661,895,388 mg

Total internal phosphorus load converted to kg:

661,895,388 mg ÷ 1,000,000 = 661.9 kg

The total phosphorus concentration amount was calculated for three separate seasons: April to May, June to August, and September to October. The internal phosphorus loading was calculated by subtracting the other inputs from the total phosphorus load. The total phosphorus load also includes the increase of concentration from evaporation. Although internal loading is the vast majority of loading, shrinking lake volume is also playing a role in increasing the phosphorus concentration in the lake. The three internal loads were then averaged. The highest internal load calculated was from September to October with a load of 1241.5 kg (90%).

Total Dissolved Phosphorus

The estimated total dissolved phosphorus loading from Round Lake watershed runoff was derived from the loading coefficients in Table 33. The TDP loading was calculated by multiplying the loading coefficient (0.0066 kg/acres) by the watershed area of Round Lake (3,742 acres). The estimated runoff load for Round Lake watershed is 24.7 kg.

Phytoplankton (Algae) Data Summary

Planktonic algae were collected once in June and once in August and consisted of 44 species which represented 38 genera. They were divided into four separate algal divisions – flagellated algae, blue-green algae, diatoms, and non-motile green algae. The most diverse group was the non-motile green algae with 16 species. However, the blue-green algae exhibited the most abundance (Figure 80), with the *Aphanocapsahe* species being the most dense. Most noxious/nuisance conditions in lakes are produced by just three algae *Anabaena flos-aquae*, *Aphanizomenon flos-aquae*, and *Microcystis aeruginosa.* An oversupply of nutrients, especially phosphorus, will result in the excessive growth of these species. In June, four noxious species were identified, *Anabaena circinalis*, *Anabaena flos-aquae*, *Anabaena subcylindrica*, and *Aphanizomenon flos-aquae*. In August these same noxious species were found along with *Microcystis aeruginosa* (See Appendix I).

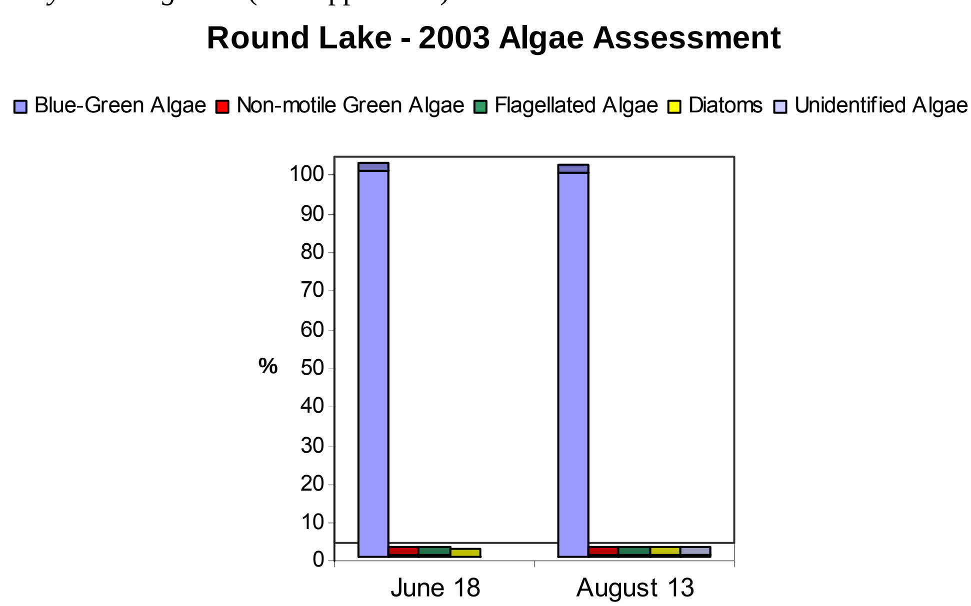


Figure 80. Percentage by Division of Major Algae Groups Collected in Round Lake

Source Linkage and Conclusion

Trophic State Index

The trophic state of a lake is a numerical value that ranks its relative productivity. Developed by Carlson (1977), the Trophic State Index (TSI), allows a lake's productivity to be easily quantified and compared to other lakes. Low TSI values correlate with small nutrient concentrations, while higher TSI values correlate higher levels of nutrient concentrations. TSI values range from 0 (oligotrophic) to 100 (hypereutrophic). Table 34 describes the TSI trophic levels and numeric ranges applicable to Round Lake. In this index, each increase of 10 units represents a doubling of algal biomass.

Table 34. Carlson Trophic Levels and Numeric Ranges by Category

Trophic Level	Numeric Range
Oligotrophic	0-35
Mesotrophic	36-50
Eutrophic	51-65
Hypereutrophic	66-100

Average values for the trophic levels in Round Lake are shown in Table 35. The mean and median of total phosphorus and Secchi depth are categorized as hypereutrophic, while chlorophyll a mean is categorized as eutrophic (Figure 81). Overall, Round Lake is considered to be hypereutrophic in condition (TSI=65.4). The transparency TSI value is more comparable to total phosphorus TSI value, instead of the chlorophyll a TSI value. This relationship of parameters may indicate a non-algal material, containing phosphorus, decreasing the transparency. This non-algal material may be eroded soils or clay (Carlson 1981).

Table 35. Observed Tropic State Index Values Collected in Round Lake

Parameter	Total Phosphorus	Secchi Depth	Chlorophyll-*a*	Parameters Combined
Mean TSI	70.08	68.29	59.66	65.42
Median TSI	69.38	67.37	61.24	67.37
Standard Deviation	4.19	4.29	8.22	7.25

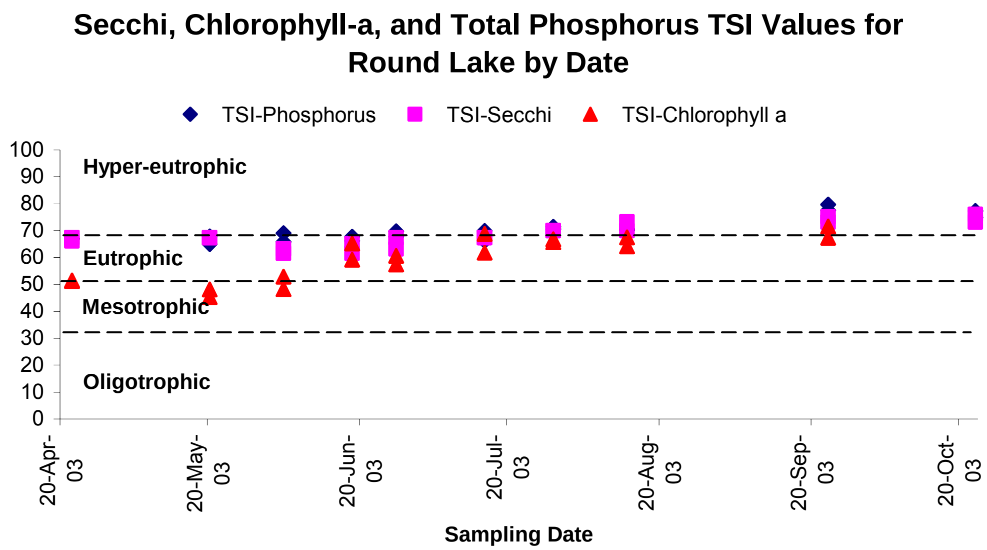


Figure 81. Secchi, Chlorophyll-a, and Total Phosphorus TSI Values Plotted by Carlson Trophic Levels in Round Lake

In South Dakota, TSI values are now evaluated upon ecoregion-specific beneficial use categories. Round Lake is located in Ecoregion 46N and is categorized as partially supporting based on SD DENR standards (SDDENR 2000a). There are three beneficial use categories: non-supporting, partially supporting, and fully supporting. Numeric ranges for beneficial use categories are shown in Table 36.

Table 36. Ecoregion 46N Beneficial Use Category and Carlson TSI Numeric Ranges by Category

Ecoregion (46N) Beneficial Use Category	TSI Numeric Range
Fully supporting	≤ 65
Partially supporting	≥ 65.01 - ≤ 70
Non-supporting	≥ 70.01

Trophic State Index values are plotted using beneficial use categories in Figure 82. TSI values in the spring and early summer are within the partially supporting range. After August, the values increase and no longer meet the beneficial uses. The continual increase in phosphorus TSI from August to October may have been the result of increased concentration from evaporation or internal phosphorus load. Due to the landuse and the inlets of the watershed, Round Lake has little nutrient input from the watershed. As mentioned earlier, the TSI values for phosphorus and Secchi are comparable throughout the sampling season.

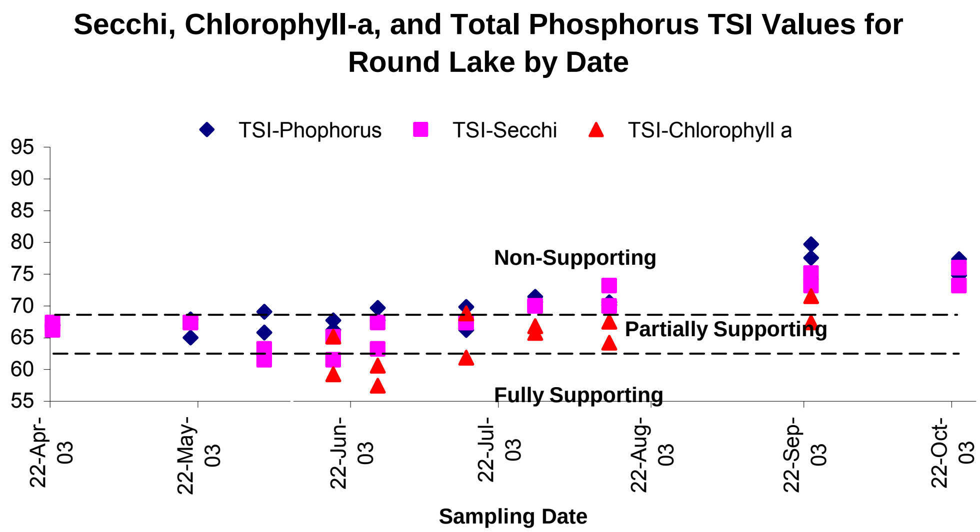


Figure 82. Secchi, Chlorophyll-a, and Total Phosphorus TSI Values Plotted by Ecoregion 46N Beneficial Use Categories for Round Lake

Reduction Prediction based on BATHTUB Model

Inlake responses to reductions for watershed nutrient loading were calculated using the BATHTUB model. Each lake variable was modeled and shown in Table 37 and Figure 83. A description of each BATHTUB variable from Table 37 is shown in Appendix M. The amount of phosphorus that entered Round Lake was a relatively small amount. Therefore, reduction of watershed phosphorus contribution did not improve the TSI values. The phosphorus loading can be attributed to sediment internal loading from previous watershed runoff.

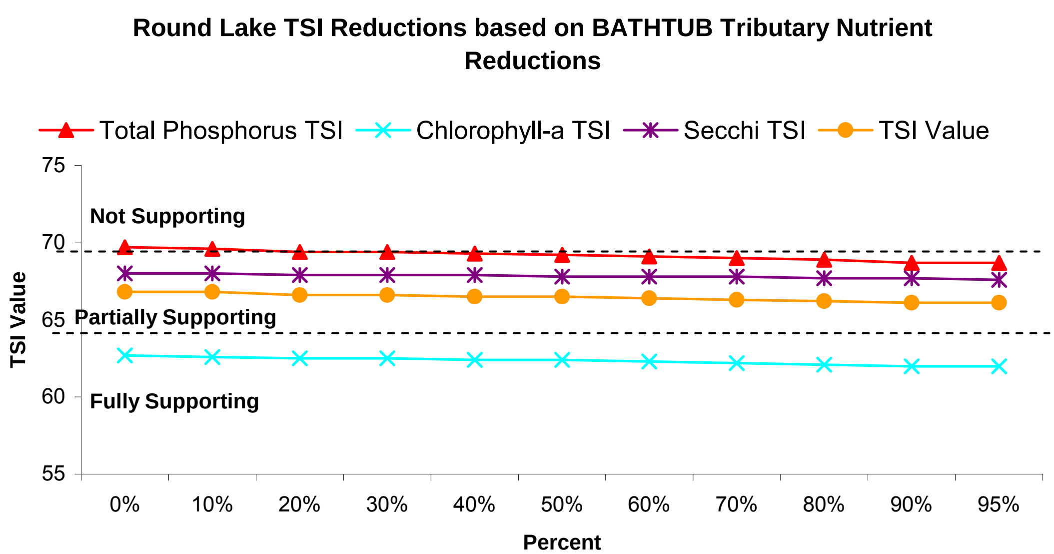


Figure 83. Predicted Trophic State Index Reductions Using the BATHTUB Reduction Model Ranked by Ecoregion 46N Beneficial Use Categories in Round Lake

Table 37. Round Lake Observed and Predicted Watershed Reductions in Nitrogen and Phosphorus Concentrations and Predicted In-Lake Mean TSI Values Using the BATHTUB Model

Variable	Observed Values caluculated using BATHTUB OBSERVED	Condition of the Lake based on current loadings Predicted	Equal Reductions assumed in all subwatersheds, percentages are for total lake load 10% Predicted	20% Predicted	30% Predicted	40% Predicted	50% Predicted	60% Predicted	70% Predicted	80% Predicted	90% Predicted	95% Predicted
Total P	101	94	93.4	92.3	92.3	91.6	91	90.3	89.6	88.9	88.1	87.6
Total N	1579	2378.2	2374.5	2366.9	2366.9	2363	2359	2355	2350.9	2346.8	2342.5	2340.4
CHL-A	25.9	26.3	26.2	25.8	25.8	25.7	25.5	25.3	25.1	24.9	24.7	24.5
SECCHI	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
ORGANIC N	1579	838.5	835	827.6	827.6	823.7	819.6	815.4	810.8	806	801	798.2
ANTILOG PC-1	1394.7	1180.1	1169.9	1148.5	1148.5	1137.3	1125.5	1113.3	1100.2	1086.6	1072.6	1064.8
ANTILOG PC-2	8.8	7.8	7.8	7.8	7.8	7.8	7.8	7.7	7.7	7.7	7.7	7.6
(N-150)/P	14.1	23.7	23.8	24	24	24.1	24.3	24.4	24.6	24.7	24.9	25
INORGANIC N/P	0	60.4	61	62.4	62.4	63.2	64.1	65	66	67.1	68.3	69
FREQ (CHL-a>10)%	89	89.4	89.3	88.9	88.9	88.7	88.5	88.2	88	87.7	87.4	87.2
FREQ (CHL-a>20)%	54.3	55.3	54.9	54.1	54.1	53.7	53.2	52.7	52.2	51.7	51.1	50.8
FREQ (CHL-a>30)%	29.3	30.1	29.8	29.1	29.1	28.7	28.3	27.9	27.5	27	26.6	26.3
FREQ (CHL-a>40)%	15.6	16.2	16	15.5	15.5	15.2	15	14.7	14.4	14.1	13.8	13.6
FREQ (CHL-a>50)%	8.5	8.9	8.8	8.4	8.4	8.3	8.1	7.9	7.7	7.6	7.4	7.2
FREQ (CHL-a>60)%	4.8	5.1	5	4.8	4.8	4.6	4.5	4.4	4.3	4.2	4.1	4
TSI-P	70.7	69.7	69.6	69.4	69.4	69.3	69.2	69.1	69	68.9	68.7	68.7
TSI-CHLA	62.5	62.7	62.6	62.5	62.5	62.4	62.4	62.3	62.2	62.1	62	62
TSI-SEC	67.9	68	68	67.9	67.9	67.9	67.8	67.8	67.8	67.7	67.7	67.6
Mean TSI	67.1	66.8	66.8	66.6	66.6	66.5	66.5	66.4	66.3	66.2	66.1	66.1

Note: Description of each variable in Appendix M

Point Sources

There are no identified point sources of pollution in the Round Lake watershed.

Non-Point Sources (NPS)

Nonpoint sources of concern are those that contribute TSS and nutrients. Since nonpoint sources can be difficult to pinpoint, the following are the possible sources of sediment and nutrients in this watershed. Sediment sources of pollution include agricultural runoff, and eroding stream bed and banks. Sources of phosphorus include human and animal waste, soil erosion, fertilizer runoff, and detergents. Sources of nitrogen are fertilizers, animal wastes and septic systems.

Bullhead Lake Watershed

This map (Figure 84) shows the area and location designated as the Bullhead Lake watershed. This area encompasses approximately 3,374 acres, with the lake itself covering approximately 571 acres.

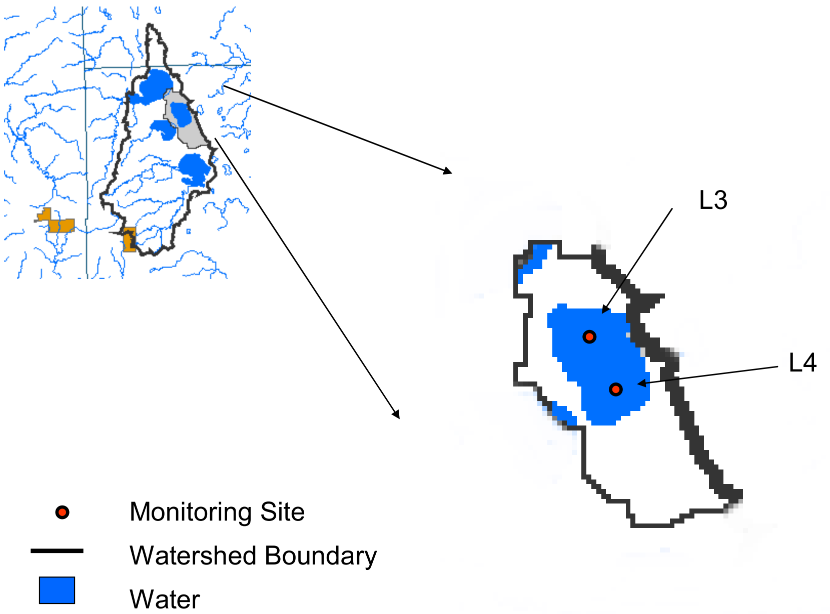


Figure 84. Bullhead Lake Watershed Location Map

Land Use Summary

The Bullhead Lake watershed area is located within the Northern Glaciated Plains level III ecoregion and characterized by the level IV ecoregion of the Prairie Coteau. This is an area of rolling terrain and drift plains. Much of the rolling areas are in pastureland, while the flatter areas are tilled for agricultural crops. Approximately 22 percent of the area is cropland, such as corn and soybeans, and 25 percent is grassland and pastureland (Figure 85). There were no animal feeding operations assessed in the Bullhead Lake watershed.

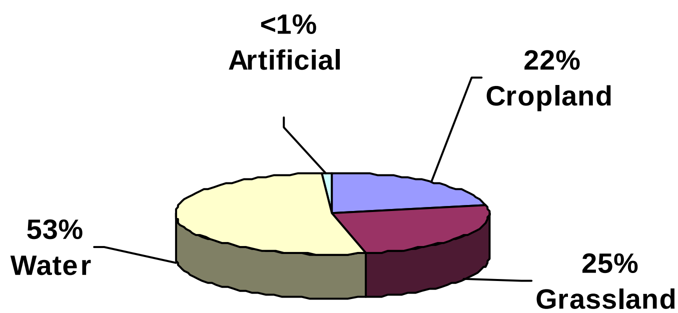


Figure 85. Bullhead Lake Watershed Landuse

Water Quality Summary

Beneficial uses for the two inlake sites (L3 and L4) are 5, 7, 8, and 9.

(5) Warmwater Semi-permanent Fish Life Propagation
(7) Immersion Recreation
(8) Limited Contact Recreation
(9) Fish and Wildlife Propagation, Recreation and Stock Watering

Based on the results from the water quality criteria established by DENR as described in Results section under Water Quality Monitoring, the two inlake sites are meeting the water quality criteria for beneficial use (7) Immersion Recreation, (8) Limited Contact Recreation, and (9) Fish and Wildlife Propagation, Recreation and Stock Watering. For beneficial use (5) Warm Water Semi-permanent Fish Life Propagation, inlake sites are meeting the criteria as described in the 303(d) waterbody listing for water temperature, dissolved oxygen, total suspended solids, and unionized ammonia. Inlake site L4 is meeting the numeric standard for pH. However, inlake site L3 does not meet the water quality criteria for pH (See Figure 86). Table 38 is a summary of the water quality exceedences for the sampling period. See Appendix N for Bullhead Lake Water Quality graphs.

Table 38. Water Quality Exceedences of Bullhead Lake

Date	Site	Parameter	Standard	Sampled Value
04/22/03	L3	pH	≥ 6.5 - ≤ 9.0	9.02
07/15/03	L3	pH	≥ 6.5 - ≤ 9.0	9.61
07/29/03	L3	pH	≥ 6.5 - ≤ 9.0	9.07
07/15/03	L4	pH	≥ 6.5 - ≤ 9.0	9.66

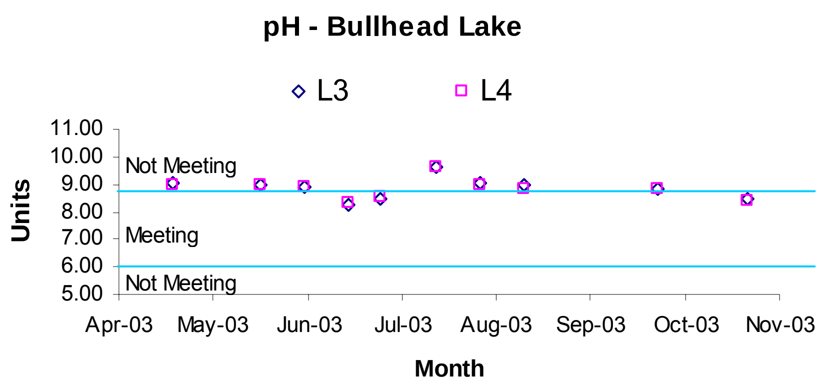


Figure 86. pH Grab Samples based on Numeric Standard ≥ 6.5 - ≤ 9.0 (Less Than 20 Samples) at Sites L3 and L4

Water temperatures and pH levels tend to increase as lakes become more productive. This higher productivity is likely caused by excessive nutrients. Thus, these higher pH levels may indicate elevated levels of nutrients in this lake, causing excessive algal and macrophyte growth. Figure 87 shows the pH levels in comparison to the water temperature in Bullhead Lake.

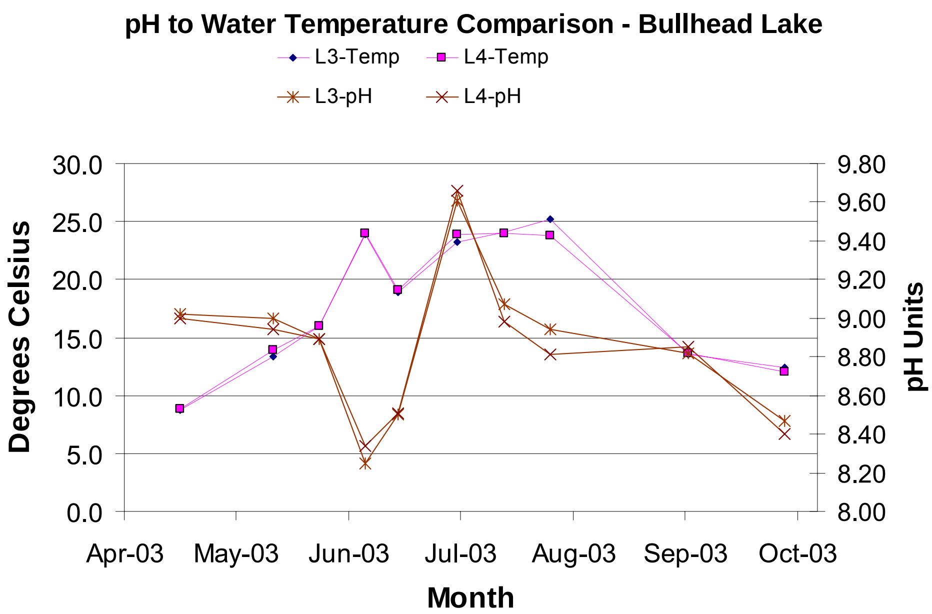


Figure 87. Bullhead Lake pH to Water Temperature Comparison

Chlorophyll is the photosynthetic pigment in all green plants and can be a measure of the amount of algae present in a lake. Phosphorus is the primary nutrient algae use for growth. Plots of total phosphorus and chlorophyll-*a* were constructed (Figure 88) to show the relationship between the amount of phosphorus present versus the amount of algal growth. Phosphorus may be the limiting nutrient in the growth of algae. Therefore, increases in phosphorus should yield increases in algae mass. Figure 88 indicates there is a correlation (R^2=0.34) between chlorophyll-*a* and total phosphorus at Site L3. However, Site L4 does not show a correlation between the two (R^2=0.0647).

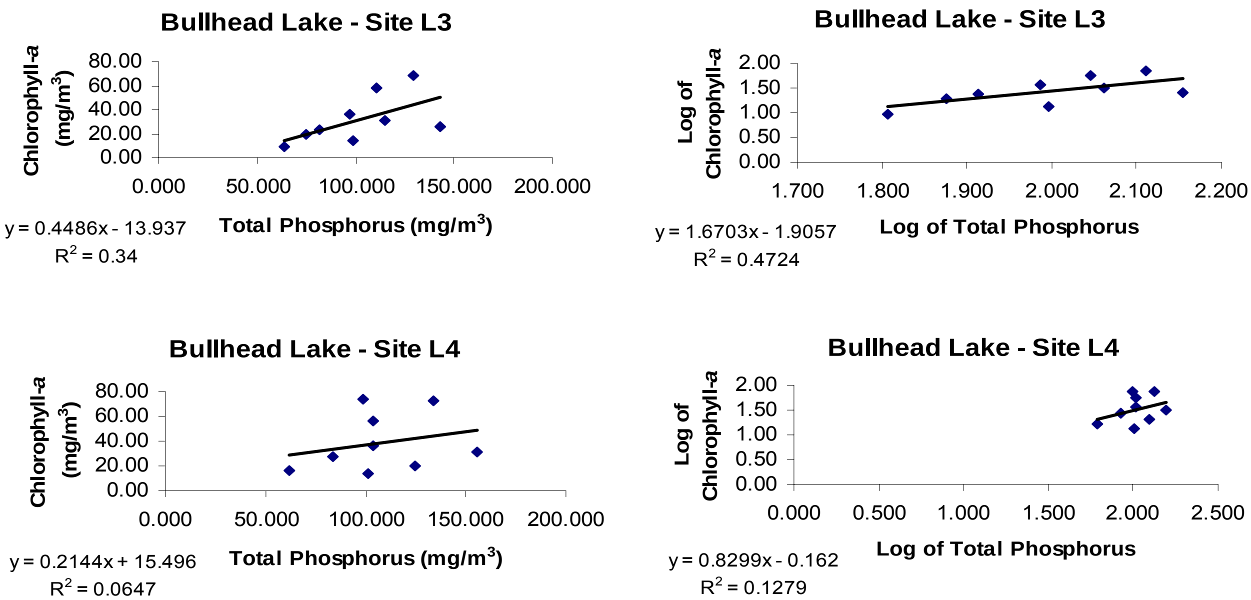


Figure 88. Phosphorus to Chlorophyll-*a* Relationship for Sites L3 and L4

The maximum inlake chlorophyll-*a* concentration of 73.55 mg/m^3 was collected at Site L4 on August 12, 2003 (Figure 89). The average chlorophyll-*a* concentration was 35.13 mg/m^3 and the median concentration was 29.32 mg/m^3.

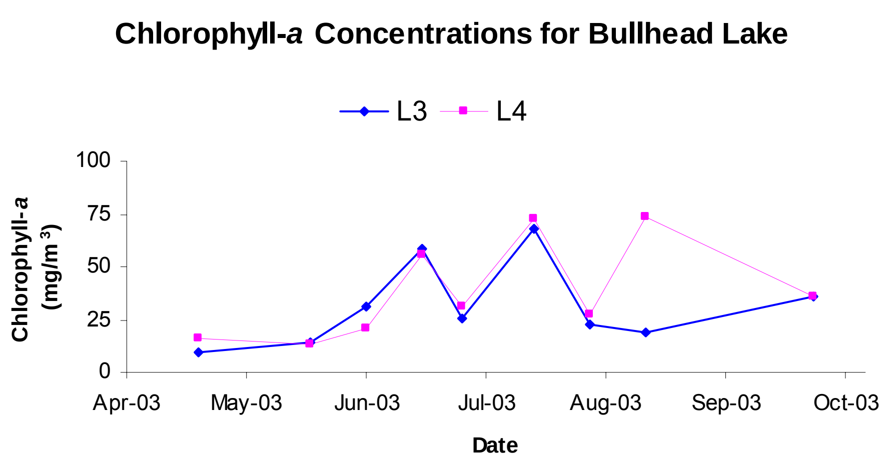


Figure 89. Graph of Chlorophyll-*a* Concentrations (mg/m^3) for Bullhead Lake

Water clarity is measured using a Secchi disk. The deeper the Secchi disk can be seen, the clearer the water. Indicatively, water clarity decreases as the amount of chlorophyll-*a* increases, as shown by Figure 90.

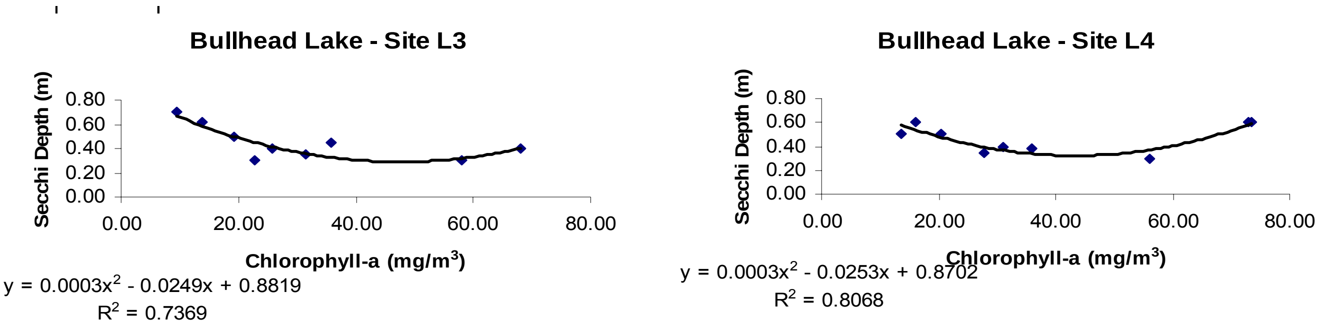


Figure 90. Chlorophyll-*a* to Secchi Depth Relationship for Sites L3 and L4

For an organism, such as algae, to survive in a given environment, it must have the necessary nutrients and environment to maintain life and successfully reproduce. If an essential life component approaches a critical minimum, this component will become the limiting factor (Odum 1959). Nutrients such as phosphorus and nitrogen are most often the limiting factors in highly eutrophic lakes. Typically, phosphorus is the limiting nutrient for algal growth. However, nitrogen can become the limiting factor in many highly eutrophic lakes with an overabundance of phosphorus. Bullhead Lake is a phosphorus-limited lake as shown by Figure 91.

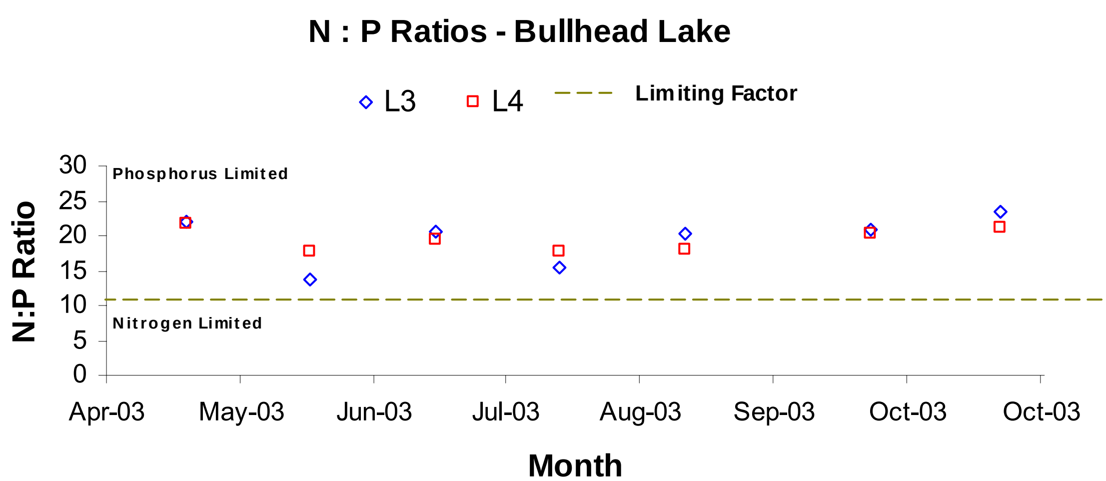


Figure 91. Total Nitrogen to Total Phosphorus Ratio for Bullhead Lake

In 2003 lake levels in Bullhead Lake dropped approximately 1.7 ft between the months of April and September. In 2004 the difference in lake levels between May and October was approximately 0.56 ft. As shown by Figure 92, lake levels rose in August to October of 2004 due to heavy rains.

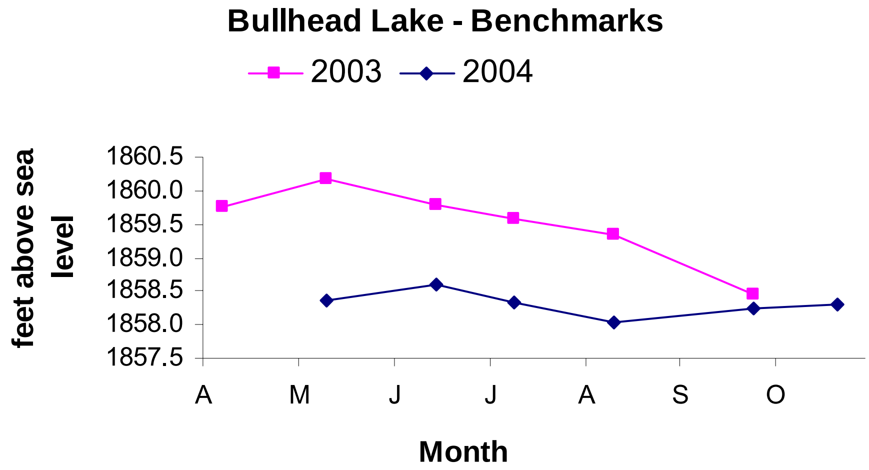


Figure 92. 2003 and 2004 Lake Level Readings for Bullhead Lake

Hydrologic Budget

Hydrologic Budget

A hydrologic budget explains the amount of water entering and leaving a lake. In theory, all inputs of water must equal all outputs during the course of the hydrologic cycle (Table 39). The input sources to Bullhead Lake included precipitation, groundwater, and ungaged runoff. Some inputs, groundwater and ungaged runoff, will be estimated to help balance the equation since monitoring all possible inputs in a lake is very difficult.

Table 39. Hydrologic Budget for Bullhead Lake in 2003

Input Sources	Load (acre-ft)	Output Sources	Load (acre-ft)
Surface Area= 340.9 acres			
Precipitation	622.1	Evaporation	692
Ungaged Runoff	28.7	Advective Flow	21.9
Groundwater	510.8	Change In Storage	447.6
Totals	1,161.6		1,161.6

In order to calculate the precipitation inputs, 2003 rainfall data were taken from the weather station located at Watertown AP. The amount of precipitation in inches was converted to feet and multiplied by the surface area of Bullhead Lake (1.825 ft × 340.9 acres).

The ungaged portion of the project is comprised of the entire Bullhead Lake watershed (3373 acres). Contribution from the watershed was estimated from the tributaries of Wigdale Lake. Loading coefficients were calculated for Site T49 and Site T50 by dividing the flow by the tributary drainage area. The average, of Site T49 and Site T50 loading coefficients, was then multiplied by the watershed area.

Bullhead Lake had no flowing outlets during this sampling season, therefore output sources only included evaporation, advective outflow, and change in storage. The nearest weather station that collected land evaporation data was two miles northeast of Brookings, approximately 45 miles from our study area (SDSU 2003). In order to adjust the land data to surface water evaporation, monthly evaporation amounts were multiplied by the Class A monthly land pan coefficient (0.8) for the midwestern United States (Fetter 1988). The monthly evaporation amounts were added, converted to feet, and multiplied by the surface area of Bullhead Lake.

Advective outflow (movement of water by gravity) for Bullhead Lake was calculated using the BATHTUB model (Walker 1999). The level of the lake decreased from its original measurement in April 2003 to the last measurement in October 2003. The difference between these measurements was 1.3 feet. This constitutes 447.6 acre-feet (1.313 ft × 340.9 acres) indicating a decrease in storage.

After all of the hydrologic outputs were subtracted from the inputs, 510.8 acre-ft were unaccounted for. The only source not yet included was groundwater, which can be difficult to estimate. Since, this lake was sampled during a dry cycle, and groundwater input was probably a large contributor.

Sediment and Nutrient Loadings

To calculate current and future water quality in Bullhead Lake, loadings from the watershed were estimated from the tributaries of Wigdale Lake. Loadings from these tributaries were calculated by the FLUX model and are shown in Table 40.

Table 40. FLUX model data for Wigdale Lake Tributaries

	All Loads Reported in Kilograms		
	T49	T50	Total Load
Total Phosphorus	42.4	5.1	47.5
Total Dissolved Phosphorus	33.9	3.8	37.7
Total Suspended Solids	1,048.2	1,316.7	2,364.9
Total Solids	71,281.7	33,508.6	104,790.3
Total Dissolved Solids	69,687.2	32,191.9	101,879.1
TKN	206.9	44.4	251.3
VTSS	557.9	324.5	882.4

An important comparison of conditions in Bullhead Lake watershed can be made through the use of the loading coefficients from the tributaries of Wigdale Lake (Table 41). Loading coefficients are calculated by using the total loading discharged from the site and then dividing by the surface drainage area. For example, the loading phosphorus coefficient for Site T49 is the total loading (42.4 kg) divided by the number of acres (3,172.8). The loading coefficients for Site T49 and Site T50 were averaged to estimate a nutrient loading coefficient for the runoff delivered to Bullhead Lake.

Table 41. Loading Coefficients for Wigdale Lake (kg/acre)

	Watershed acres	TPO4 kg/acres	TDPO4 kg/acres	TSS kg/acres	TSOL kg/acres	TDSOL kg/acres	TKN kg/acres	VTSS kg/acres
T49	3,172.83	0.013	0.011	0.33	22.47	21.96	0.065	0.18
T50	1,729.74	0.0029	0.0022	0.76	19.37	18.61	0.026	0.19
	Average	0.00795	0.0066	0.545	20.92	20.285	0.0455	0.185

Suspended Solids Loadings

The estimated total suspended solids loading from Bullhead Lake watershed runoff was derived from the loading coefficients in Table 41. The TSS loading was calculated by multiplying the loading coefficient (0.6 kg/acres) by the watershed area of Bullhead Lake (3,372.9 acres). The estimated runoff load for Bullhead Lake watershed is 1,838 kg. This estimated total yearly load of sediment (1,838 kg) was retained within the lake, since during a dry cycle Bullhead Lake has no tributary outlets.

Nitrogen Loadings

Bullhead Lake did not have a flowing outlet during the 2003 sampling season. Input loading was estimated from the tributaries load coefficients of Wigdale Lake for the ungaged runoff. Total nitrogen concentrations are derived from adding TKN concentrations to nitrate-nitrite concentrations. Nitrogen inputs to Bullhead Lake during the 2003 sampling season were insignificant at 290 kg. The total yearly load of nitrogen (290 kg) is retained within the lake, since no nitrogen is lost to tributary outlets. Inputs to Bullhead Lake included ungaged runoff and groundwater (Figure 93). Atmospheric nitrogen was not included in the input estimates. As atmospheric nitrogen enters the lake, it is utilized by different species of algae, therefore, it is impossible to calculate. Of the 290 kg, ungaged runoff contributed 53 percent. The following calculations were used to find ungaged runoff for Bullhead Lake watershed:

Watershed area converted to acres:

$$13.7 \text{ km}^2 \div .004047 = 3372.9 \text{ acres}$$

Watershed acres multiplied by the loading coefficient:

$$3372.9 \text{ acres} \times .05 \text{ kg/acres} = 155.2 \text{ kg}$$

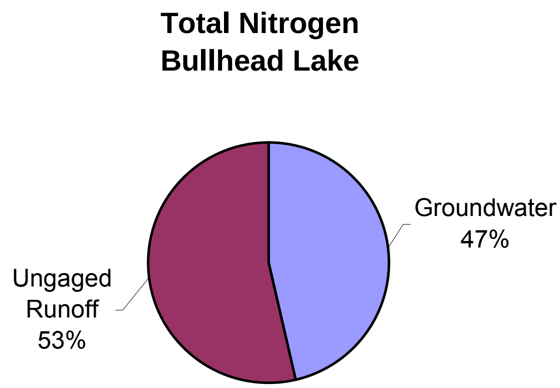


Figure 93. Bullhead Lake Watershed Total Nitrogen Loads

Nitrogen is water soluble which makes it very difficult to estimate groundwater contributions. For the purpose of this study, a total nitrogen concentration of 0.214 mg/L was used for groundwater input. The concentration was averaged from SDGS monitored wells. Because this watershed was sampled during a dry cycle, groundwater is responsible for 47 percent of the input phosphorus loading. The following calculations were used to find the groundwater load:

Hydrologic load converted to m^3:

$$510.8 \text{ acre-feet} \times 1{,}234 = 630{,}278 \text{ m}^3$$

Converted m^3 to liters:

$$630{,}278 \text{ m}^3 \times 1{,}000 = 630{,}277{,}840 \text{ L}$$

Groundwater phosphorus average concentration multiplied by hydrologic load (L):

$$0.214 \text{ mg/L} \times 630{,}277{,}840 \text{ L} = 134{,}879{,}457 \text{ mg}$$

Total groundwater nitrogen load converted to kg:

$$134{,}879{,}457 \text{ mg} \div 1{,}000{,}000 = 134.9 \text{ kg}$$

Phosphorus Loadings

Since Bullhead Lake did not have a flowing tributary outlet during the 2003 sampling season. Phosphorus inputs to Bullhead Lake averaged 637 kg from April to October. The total yearly load of phosphorus (637 kg) is retained within the lake, since no phosphorus is lost to tributary outlets. Inputs to Bullhead Lake included ungaged runoff, internal loading, groundwater, and precipitation (Figure 94). Of the 637 kg, ungaged runoff contributed four percent. Input loading was estimated from the tributaries load coefficients of Wigdale Lake for the ungaged runoff. The following calculations were used to find ungaged runoff for Bullhead Lake watershed:

Watershed area converted to acres:

$$13.7 \text{ km}^2 \div 0.004047 = 3{,}372.9 \text{ acres}$$

Watershed acres multiplied by the loading coefficient:

$$3{,}372.9 \text{ acres} \times 0.008 \text{ kg/acres} = 26.98 \text{ kg}$$

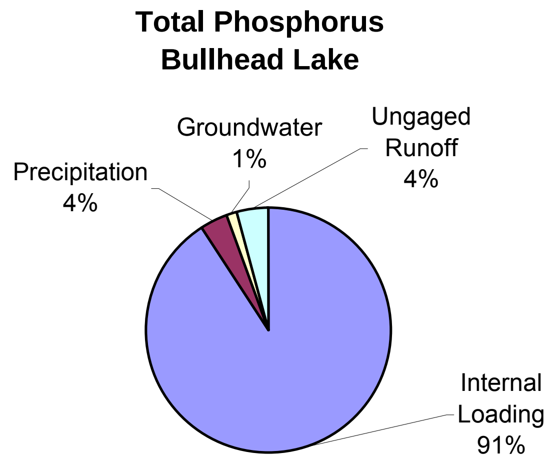


Figure 94. Bullhead Lake Watershed Phosphorus Loads

Groundwater was responsible for one percent of the total phosphorus delivered to the lake. Groundwater contribution was estimated by multiplying the mean total phosphorus concentration (0.014 mg/L) from groundwater samples collected from the SDGS and amount of groundwater discharged into the lake (510.8 acre-feet). The following calculations were used to find the groundwater load:

Hydrologic load converted to m^3:

$$510.8 \text{ acre-ft} \times 1{,}234 = 630{,}278 \text{ m}^3$$

Converted m^3 to liters:

$$630{,}278 \text{ m}^3 \times 1{,}000 = 630{,}277{,}840 \text{ L}$$

Groundwater phosphorus average concentration multiplied by hydrologic load (L):

$$0.014 \text{ mg/L} \times 630{,}277{,}840 \text{ L} = 8{,}823{,}889 \text{ mg}$$

Total groundwater phosphorus load converted to kg:

$$8{,}823{,}889 \text{ mg} \div 1{,}000{,}000 = 8.8 \text{ kg}$$

The precipitation load (622.1 acres-feet) was multiplied by 0.03 mg/L, an average phosphorus content often found in nonpopulated regions, to determine the precipitation phosphorus load (Wetzel 1975). Total estimated precipitation concentration was responsible for four percent of the total phosphorus load. The following calculations were used to find the precipitation load:

Hydrologic load converted to m^3:

$$622.1 \text{ acre-feet} \times 1{,}234 = 767{,}721 \text{ m}^3$$

Converted m³ to liters:

$$767{,}721\ m^3 \times 1{,}000 = 767{,}720{,}760\ L$$

Precipitation phosphorus average concentration multiplied by hydrologic load (L):

$$0.03\ mg/L \times 767{,}720{,}760\ L = 23{,}031{,}623\ mg$$

Total precipitation phosphorus load converted to kg:

$$23{,}031{,}623\ mg \div 1{,}000{,}000 = 23.03\ kg$$

The internal loading of phosphorus from the sediment was estimated by calculating the total phosphorus load in the lake and subtracting the other inputs. Internal loading contributed an estimated 91% to the total phosphorus load in Bullhead Lake. Internal loading of phosphorus refers to the release of phosphorus from lake sediments. In shallow lakes, resuspension of bottom sediment can occur from wind action. Figure 95 shows a strong correlation between the grab samples of total phosphorus and TSS.

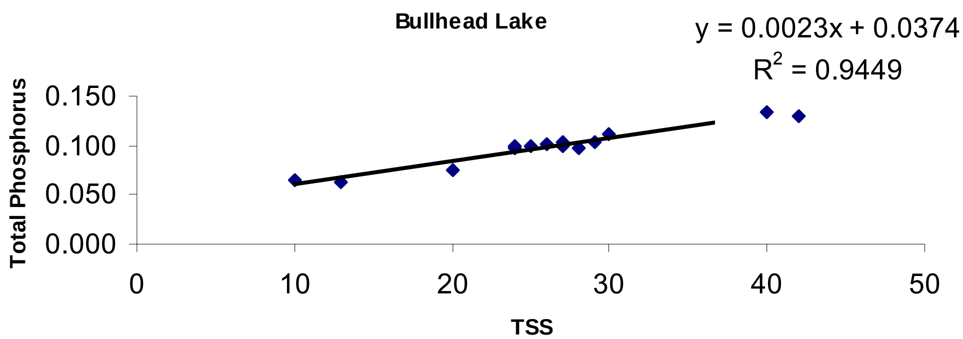


Figure 95. TSS to Total Phosphorus Relationship in Bullhead Lake

In order to estimate the amount of internal phosphorus, total phosphorus was calculated. The following calculations were used to find the total phosphorus amount in Bullhead Lake from April to May:

Volume of the lake:

$$571\ acres \times 9.29\ ft = 5301.9\ acres\text{-}ft$$

Hydrologic load converted to m³:

$$5{,}301.9\ acres\text{-}ft \times 1{,}234 = 6{,}542{,}544.6\ m^3$$

Converted m³ to liters:

$$6{,}542{,}544.6\ m^3 \times 1{,}000 = 6{,}542{,}544{,}600\ L$$

Average phosphorus concentration multiplied by hydrologic load (L):

$$.08\ mg/L \times 6{,}542{,}544{,}600\ L = 523{,}403{,}568\ L$$

Total internal phosphorus load converted to kg:

523,403,568 mg ÷ 1,000,000 = 523.4 kg

The total phosphorus concentration amount was calculated for three separate seasons: April to May, June to August, and September to October. The internal phosphorus loading was calculated by subtracting the other inputs from the total phosphorus load. The total phosphorus load also includes the increase of concentration from evaporation. Although internal loading is the vast majority of loading, shrinking lake volume is also playing a role in increasing the phosphorus concentration in the lake. The three internal loads were then averaged. The highest internal load calculated was from June to August with a load of 680.5 kg (92%).

Total Dissolved Phosphorus

The estimated total dissolved phosphorus loading from Bullhead Lake watershed runoff was derived from the loading coefficients in Table 41. The TDP loading was calculated by multiplying the loading coefficient (0.0066 kg/acres) by the watershed area of Bullhead Lake (3,372.9 acres). The estimated runoff load for School Lake watershed is 22.3 kg.

Phytoplankton (Algae) Data Summary

Planktonic algae were collected once in June and once in August by EDWDD and once in June and one in July by the DENR, and consisted of 100 species which represented 62 genera. They were divided into four separate algal divisions – flagellated algae, blue-green algae, diatoms, and non-motile green algae. The most diverse group was the non-motile green algae with 50 species. However, the blue-green algae exhibited the most abundance (Figure 96), with the *Aphanocapsa* species being the most dense. Most noxious/nuisance conditions in lakes are produced by just three algae *Anabaena flos-aquae*, *Aphanizomenon flos-aquae*, and *Microcystis aeruginosa.* An oversupply of nutrients, especially phosphorus, will result in the excessive growth of these species. In June, four noxious species were identified, *Anabaena circinalis*, *Oscillatoria agardhii*, *Anabaena subcylindrica*, and *Microcystis aeruginosa*. In the DENR July sample these species were also found except for the *Anabaena circinalis* species and in the August sampling the only two noxious species found were *Anabaena subcylindrica*, and *Microcystis aeruginosa* (See Appendix I).

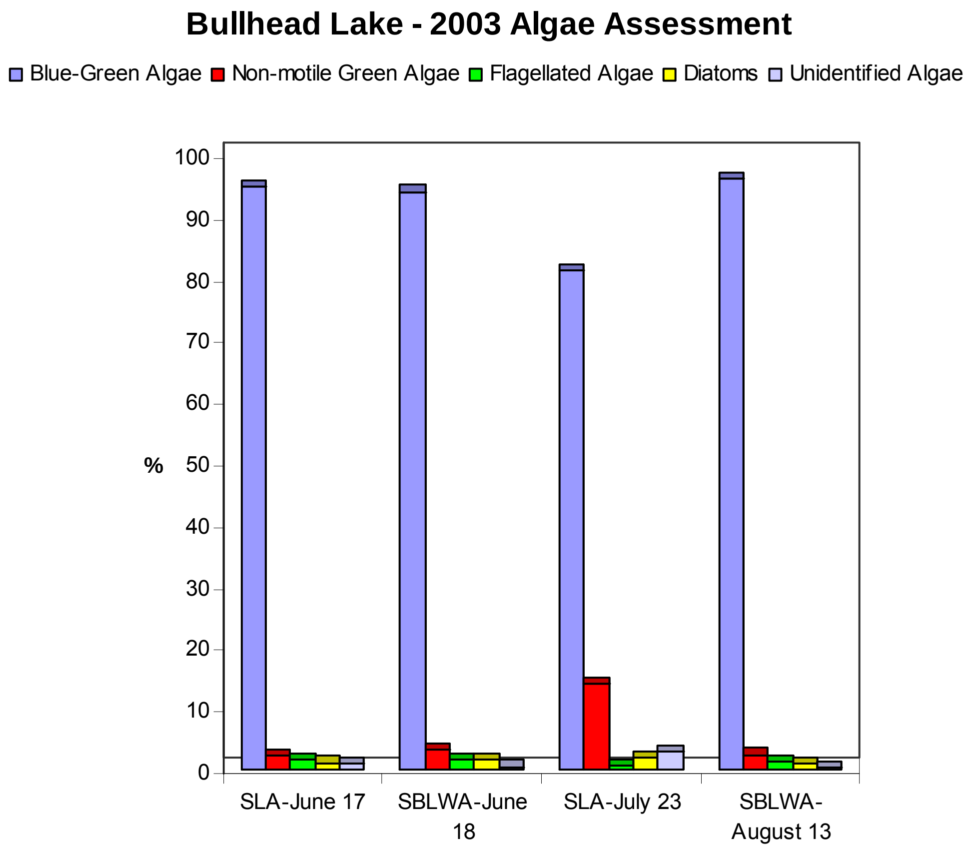


Figure 96. Percentage by Division of Major Algae Groups Collected in Bullhead Lake

Source Linkage and Conclusion

Trophic State Index

The trophic state of a lake is a numerical value that ranks its relative productivity. Developed by Carlson (1977), the Trophic State Index (TSI), allows a lake's productivity to be easily quantified and compared to other lakes. Low TSI values correlate with small nutrient concentrations, while higher TSI values correlate with higher levels of nutrient concentrations. TSI values range from 0 (oligotrophic) to 100 (hypereutrophic). Table 42 describes the TSI trophic levels and numeric ranges applicable to Bullhead Lake. In this index, each increase of 10 units represents a doubling of algal biomass.

Table 42. Carlson Trophic Levels and Numeric Ranges by Category

Trophic Level	Numeric Range
Oligotrophic	0-35
Mesotrophic	36-50
Eutrophic	51-65
Hypereutrophic	66-100

Average values for the trophic levels in Bullhead Lake are shown in Table 43. The mean and median of total phosphorus and Secchi depth are categorized as hypereutrophic, while chlorophyll a mean is categorized as eutrophic (Figure 97). Overall, Bullhead Lake is considered to be hypereutrophic in condition (TSI=68.9).

Table 43. Observed Trophic State Index Values Collected in Bullhead Lake

Parameter	Total Phosphorus	Secchi Depth	Chlorophyll-*a*	Parameters Combined
Mean TSI	70.75	71.59	63.76	68.87
Median TSI	70.59	71.52	63.69	70.15
Standard Deviation	0.05	0.05	0.10	0.08

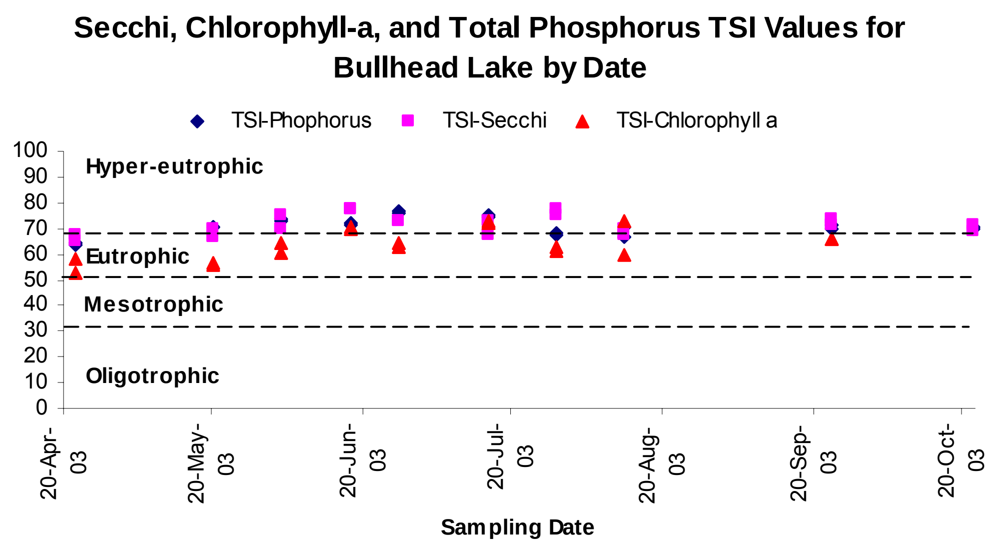


Figure 97. Secchi, Chlorophyll-a, and Total Phosphorus TSI plotted by Carlson Trophic Level in Bullhead Lake

In South Dakota, TSI values are now evaluated upon ecoregion-specific beneficial use categories. Bullhead Lake is located in Ecoregion 46N and is categorized as partially supporting based on SD DENR standards (SDDENR 2000a). There are three beneficial use categories: non-supporting, partially supporting, and fully supporting. Numeric ranges for beneficial use categories are shown in Table 44.

Table 44. Ecoregion 46N Beneficial Use Category and Carlson TSI Numeric Ranges by Category

Ecoregion (46N) Beneficial Use Category	TSI Numeric Range
Fully supporting	≤ 65
Partially supporting	≥ 65.01 - ≤ 70
Non-supporting	≥ 70.01

Trophic State Index values are plotted using beneficial use categories in Figure 98. TSI values varied throughout the sampling season. TSI values for total phosphorus and Secchi depth were non supporting from June through August. Chlorophyll a TSI values were supporting except for the July 15th sample.

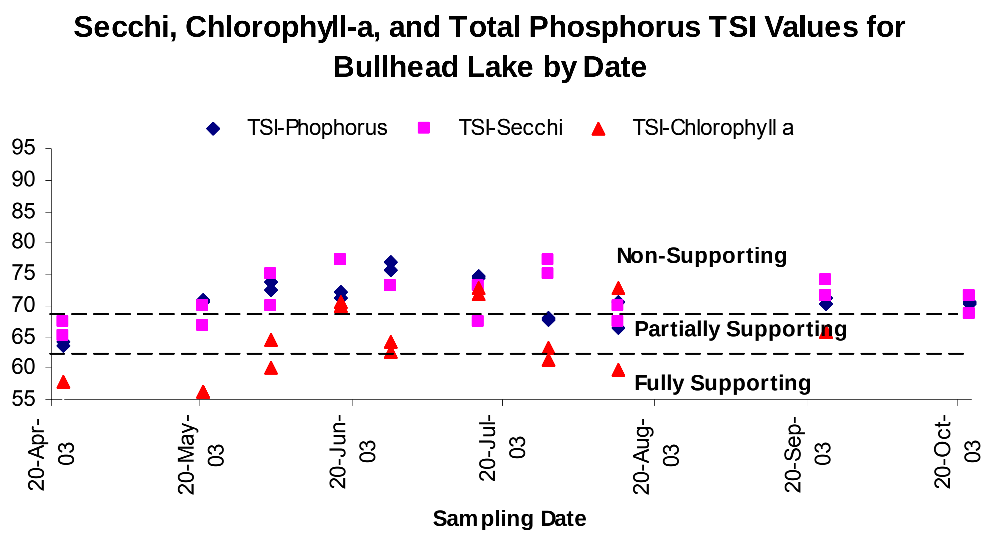


Figure 98. Secchi, Chlorophyll-a, and Total Phosphorus TSI Values Plotted by Ecoregion 46N Benefical Uses Categories in Bullhead Lake

Reduction Prediction based on BATHTUB Model

Inlake responses to watershed nutrient loading reductions were calculated using the BATHTUB model. Each lake variable was modeled and shown in Table 45 and Figure 99. See Appendix M for a description of each BATHTUB variable from Table 45. The amount of phosphorus that entered Bullhead Lake was relatively small. Therefore, reduction of watershed phosphorus contribution did not improve the TSI values. The phosphorus loading can be attributed to inlake loading from sediment within the lake from previous watershed runoff.

Table 45. Bullhead Lake Observed and Predicted Watershed Reductions in Nitrogen and Phosphorus Concentrations and Predicted In-Lake Mean TSI Values Using the BATHTUB Model

Bullhead Lake			Equal Reductions assumed in all subwatersheds, percentages are for total lake load									
Variable	Observed Values caluculated using BATHTUB OBSERVED	Condition of the Lake based on current loadings Predicted	10% Predicted	20% Predicted	30% Predicted	40% Predicted	50% Predicted	60% Predicted	70% Predicted	80% Predicted	90% Predicted	95% Predicted
Total P	104	82.6	79.8	77.1	74.2	71.2	68.1	64.9	61.5	58	54.4	52.4
Total N	1884	1593.9	1572.5	1550.9	1528.9	1506.8	1484.3	1461.6	1438.6	1415.2	1391.5	1379.6
CHL-A	35.9	39.1	37.8	36.4	35	33.6	32.1	30.5	28.9	27.2	25.3	24.4
SECCHI	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
ORGANIC N	1884	1143.7	1113.5	1082.4	1050.4	1017.3	983	947.4	910.2	871.2	830	808.5
ANTILOG PC-1	2084.9	1639.4	1556.5	1473.2	1389.3	1304.8	1219.5	1133.3	1046	957.4	867.4	821.8
ANTILOG PC-2	9.6	9.6	9.4	9.3	9.2	9	8.9	8.7	8.5	8.3	8.1	8
(N-150)/P	16.7	17.5	17.5	18.2	18.6	19.1	19.6	20.2	20.9	21.8	22.8	23.4
INORGANIC N/P	0	450.2	459	468.4	478.5	489.5	501.3	514.2	528.4	544	561.5	571.1
FREQ (CHL-a>10)%	96	97.1	96.7	96.2	95.6	95	94.2	93.2	91.9	90.3	88.3	87.1
FREQ (CHL-a>20)%	73.7	78	76.3	74.4	72.4	70	67.4	64.5	61.1	57.3	52.9	50.5
FREQ (CHL-a>30)%	49.2	54.7	52.5	50.1	47.6	44.9	42	38.8	35.5	31.9	28	26
FREQ (CHL-a>40)%	31.4	36.4	34.4	32.2	30	27.7	25.2	22.7	20.2	17.5	14.8	13.4
FREQ (CHL-a>50)%	20	24	22.3	20.6	18.8	17	15.2	13.4	11.6	9.8	8	7.1
FREQ (CHL-a>60)%	12.8	15.9	14.5	13.2	11.9	10.6	9.3	8.1	6.8	5.6	4.5	3.9
TSI-P	71.1	67.8	67.3	66.8	66.2	65.7	65	64.3	63.6	62.7	61.8	61.2
TSI-CHLA	65.7	66.6	66.2	65.9	65.5	65.1	64.6	64.1	63.6	63	62.3	61.9
TSI-SEC	71.1	71.6	71.4	71.2	70.9	70.7	70.4	70.2	69.9	69.6	69.2	69
Mean TSI	69.3	68.7	68.3	68	67.5	67.2	66.7	66.2	65.7	65.1	64.4	64

Note: Description of each variable in Appendix M

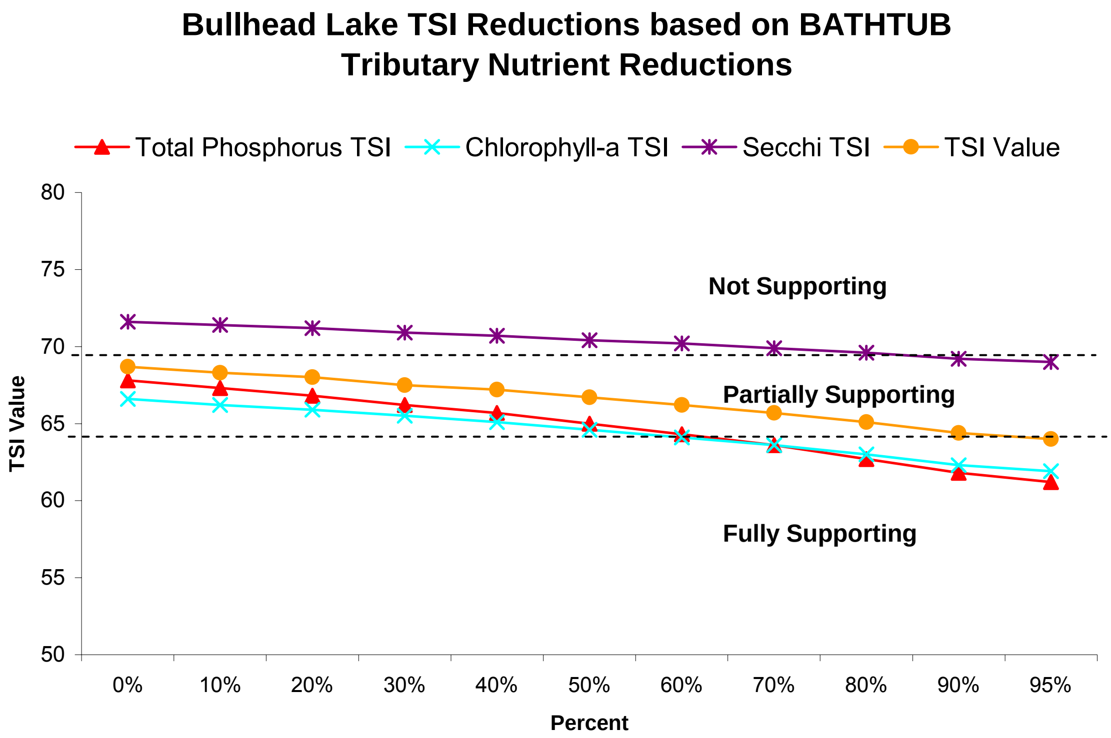


Figure 99. Predicted Trophic State Index Reductions Using the BATHTUB Reduction Model Ranked by Ecoregion 46N Beneficial Use Categories in Bullhead Lake

Point Sources

There are no point sources of pollution in the Bullhead Lake watershed.

Non-Point Sources (NPS)

Nonpoint sources of concern are those that contribute TSS and nutrients. Since nonpoint sources can be difficult to pinpoint, the following are the possible sources of sediment and nutrients in this watershed. Sediment sources of pollution include agricultural runoff, and eroding stream bed and banks. Sources of phosphorus include human and animal waste, soil erosion, fertilizer runoff, and detergents. Sources of nitrogen are fertilizers, animal wastes and septic systems.

School Lake Watershed

This map (Figure 100) shows the area and location designated as the School Lake watershed. This area encompasses approximately 3,892 acres, with the lake itself covering approximately 221 acres.

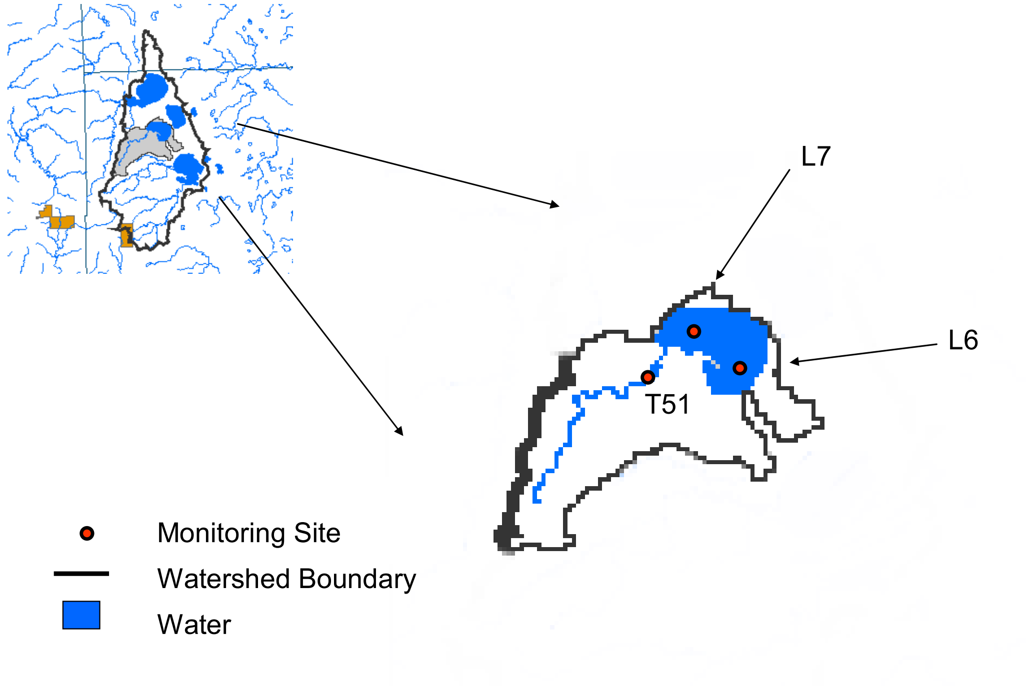


Figure 100. School Lake Watershed Location Map

Land Use Summary

The School Lake watershed area is located within the Northern Glaciated Plains level III ecoregion and characterized by the level IV ecoregion of the Prairie Coteau. This is an area of rolling terrain and drift plains. Much of the rolling areas are in pastureland, while the flatter areas are tilled for agricultural crops. Approximately 46 percent of the area is cropland, such as corn and soybeans, and 44 percent is grassland and pastureland (Figure 101). There were two animal feeding operation assessed in the School Lake watershed. Total animal number for these beef cattle operations is approximately 125 animals. The AGNPS surface ratings for these two operations were 28 and 61.

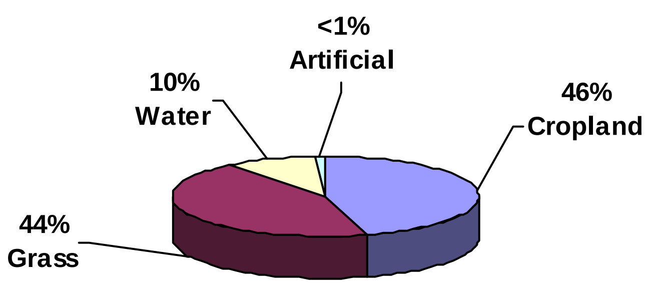


Figure 101. School Lake Watershed Landuse

Water Quality Summary

Comparisons between the lake samples and tributary samples were made. Table 46 shows fecal samples in the tributaries were much higher than in the lake. The higher TSS in the lake may indicate resuspension of solids from the bottom, which in turn releases more phosphorus stimulating more organic growth.

Table 46. Comparison of Lake and Tributary Water Quality in School Lake

	School Lake Tributaries				School Lake	
	Spring April-May 2003		Summer June-August 2003		Spring April-May 2003	Summer June-August 2003
Parameter	mg/L	%	mg/L	%	mg/L	mg/L
Alk-M	270	56	215	44	214.8	145.2
TSS	7	58	5	42	10.75	37.6
TotSol	657	58	475	42	426	437.9
TDS	650	58	470	42	415.3	400.3
Nitrates	0.1	50	0.1	50	<0.1	<0.1
Ammonia	0.02	50	0.02	50	<0.02	<0.02
TKN	0.7	34	1.34	66	1.03	2.02
TPO4	0.04	15	0.22	85	0.06	0.13
TDPO4	0.04	20	0.16	80	0.036	0.02
	counts/100mL		counts/100mL		counts/100mL	counts/100mL
Fecal Coliform	<10	<1	9000	99	<10	3
E. Coli	2	<1	>2420	99	<1	3.76

Beneficial uses for the two inlake sites (L6 and L7) are 6, 7, 8, and 9.

(6) Warmwater Marginal Fish Life Propagation
(7) Immersion Recreation
(8) Limited Contact Recreation
(9) Fish and Wildlife Propagation, Recreation and Stock Watering

Based on the results from the water quality criteria established by DENR as described in Results section under Water Quality Monitoring, the two inlake sites are meeting the water quality criteria for beneficial use (7) Immersion Recreation, (8) Limited Contact Recreation, and (9) Fish and Wildlife Propagation, Recreation and Stock Watering. For beneficial use (6) Warm Water Marginal Fish Life Propagation, inlake sites are meeting the criteria as described in the 303(d) waterbody listing for water temperature, dissolved oxygen, total suspended solids, and unionized ammonia. Both inlake site L6 and L7 not meeting the water quality criteria for pH (See Figure 102). Table 47 is a summary of the water quality exceedences for the sampling period. See Appendix O for School Lake Water Quality graphs.

Table 47. **Water Quality Exceedences of School Lake**

Date	Site	Parameter	Standard	Sampled Value
07/15/03	L6	pH	≥ 6.0 - ≤ 9.0	9.10
07/30/03	L6	pH	≥ 6.0 - ≤ 9.0	9.10
09/23/03	L6	pH	≥ 6.0 - ≤ 9.0	9.04
07/15/03	L7	pH	≥ 6.0 - ≤ 9.0	9.06
07/30/03	L7	pH	≥ 6.0 - ≤ 9.0	9.01
08/12/03	L7	pH	≥ 6.0 - ≤ 9.0	9.10
09/23/03	L7	pH	≥ 6.0 - ≤ 9.0	9.06
07/15/03	L6	DO	≥ 5.0	4.85

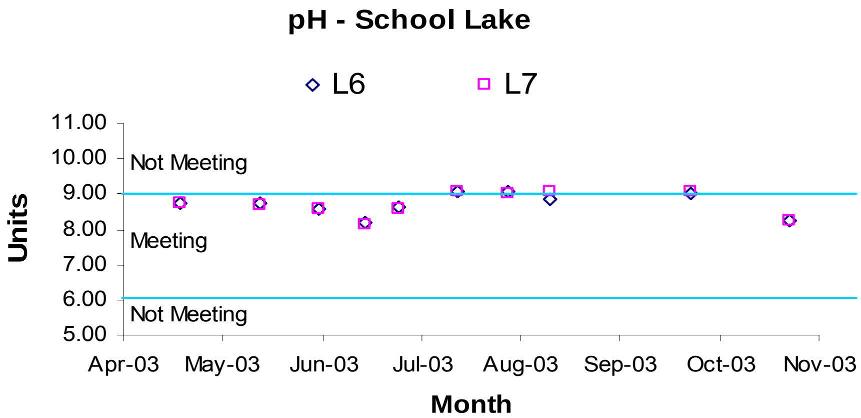


Figure 102. pH Grab Samples based on Numeric Standard ≥ 6.0 - ≤ 9.0 (Less Than 20 Samples) at sites L6 and L7

Water temperatures and pH levels tend to increase in highly productive lakes. This higher productivity is likely caused by excessive nutrients. Thus, these higher pH levels may indicate elevated levels of nutrients in this lake, causing excessive algal and macrophyte growth. Figure 103 shows the pH levels in comparison to the water temperature in School Lake.

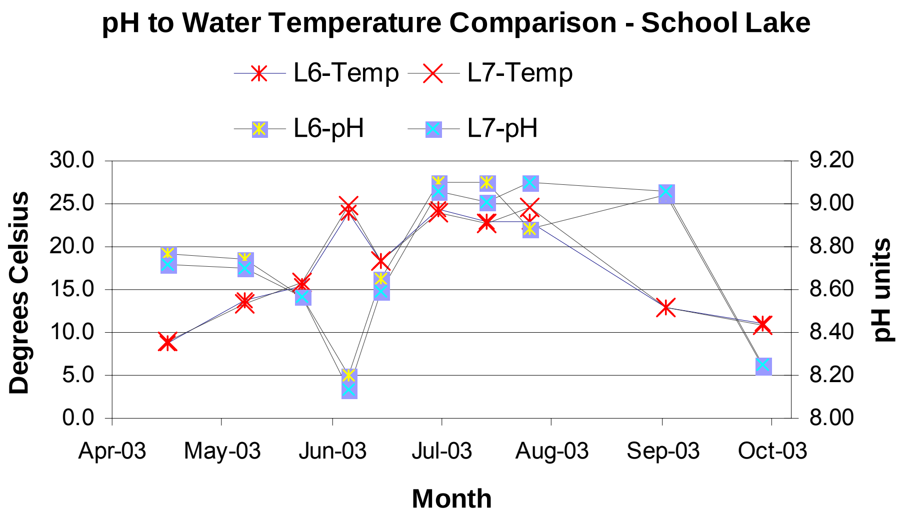


Figure 103. School Lake pH to Water Temperature Comparison

Chlorophyll is the photosynthetic pigment in all green plants and can be a measure of the amount of algae present in a lake. Phosphorus is the primary nutrient algae use for growth. Plots of total phosphorus and chlorophyll-*a* were constructed (Figure 104) to show the relationship between the amount of phosphorus present versus the amount of algal growth. Phosphorus is usually the limiting nutrient in the growth of algae. Therefore, increases in phosphorus should yield increases in algae mass. Figure 104 indicates there is a strong correlation (R^2=0.7074 at Site L6 and R^2=0.7363 at Site L7) between chlorophyll-*a* and total phosphorus in School Lake.

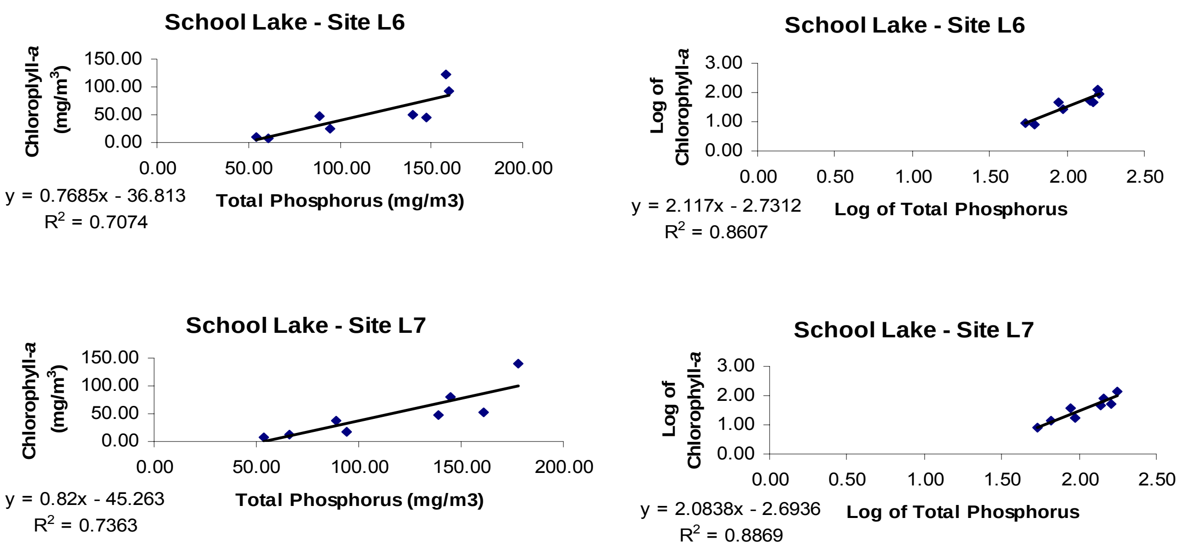


Figure 104. Phosphorus to Chlorophyll-*a* Relationship for Sites L6 and L7

The maximum inlake chlorophyll-*a* concentration of 141.07 mg/m^3 was collected at Site L7 on July 30, 2003 (Figure 105). The average chlorophyll-*a* concentration was 49.84 mg/m^3 and the median concentration was 46.0 mg/m^3.

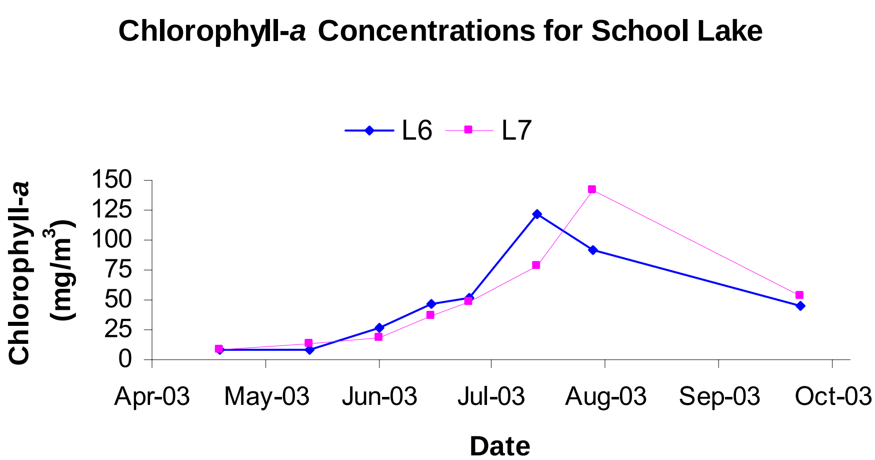


Figure 105. Graph of Chlorophyll-*a* Concentrations (mg/m^3) for School Lake

Water clarity is measured using a Secchi disk. The deeper the Secchi disk can be seen, the clearer the water. Indicatively, water clarity decreases as the amount of chlorophyll-*a* increases, as shown by Figure 106.

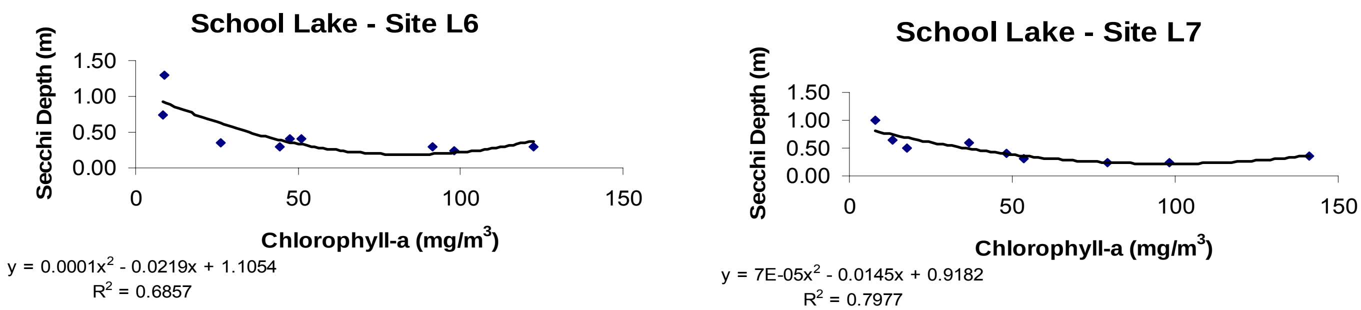


Figure 106. Chlorophyll-a to Secchi Depth Relationship for Sites L6 and L7

For an organism, such as algae, to survive in a given environment, it must have the necessary nutrients and environment to maintain life and successfully reproduce. If an essential life component approaches a critical minimum, this component will become the limiting factor (Odum 1959). Nutrients such as phosphorus and nitrogen are most often the limiting factors in highly eutrophic lakes. Typically, phosphorus is the limiting nutrient for algal growth. However, in many highly eutrophic lakes with an overabundance of phosphorus, nitrogen can become the limiting factor. School Lake is a phosphorus-limited lake as shown by Figure 107.

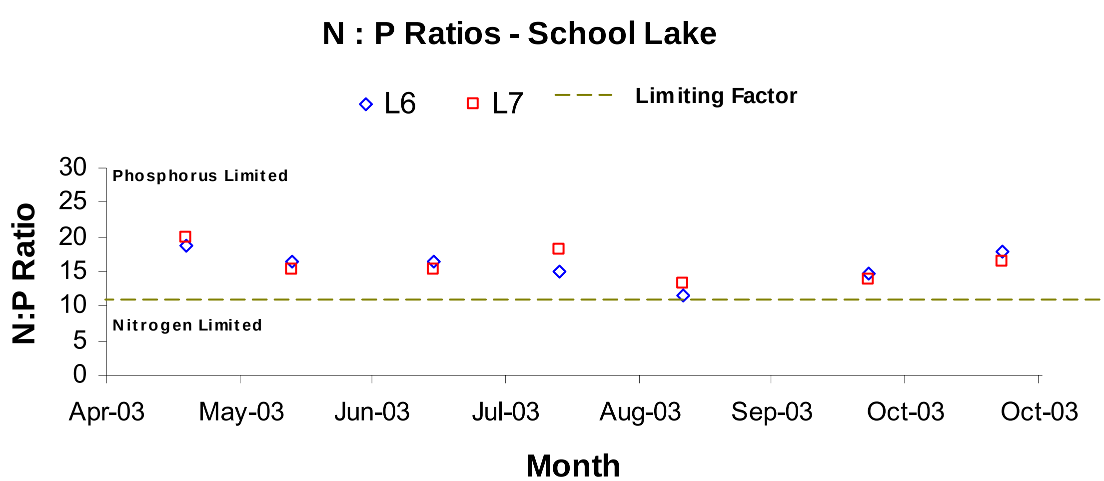


Figure 107. Total Nitrogen to Total Phosphorus Ratio for School Lake

In 2003 lake levels in School Lake dropped approximately 1.5 ft between the months of April and October. In 2004 the difference in lake levels between May and October was approximately 0.86 ft. As shown by Figure 108, lake levels rose in June and July of 2004 due to heavy rains.

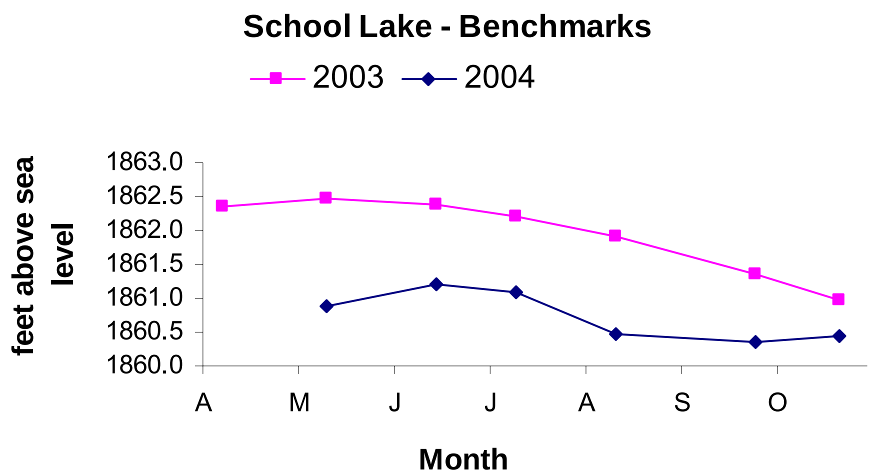


Figure 108. 2003 and 2004 Lake Level Readings for School Lake

The inlet site T51 is assigned beneficial uses (9) Fish and Wildlife Propagation, Recreation and Stock Watering, and (10) Irrigation. Based on the water quality results this site is meeting the water quality criteria for its beneficial uses. There were no violations of water quality during the study period. See Appendix G for the water quality results.

Hydrologic Budget

Hydrologic Budget

A hydrologic budget explains the amount of water entering and leaving a lake. In theory, all inputs of water must equal all outputs during the course of the hydrologic cycle (Table 48). The input sources to School Lake included precipitation, groundwater, and ungaged runoff. Some inputs, groundwater and ungaged runoff, will be estimated to help balance the equation, since monitoring all possible inputs in a lake is very difficult.

Table 48. Hydrologic Budget for School Lake in 2003

Input Sources	Load (acre-ft)	Output Sources	Load (acre-ft)
Surface Area= 323.71 acres			
Precipitation	590.8	Evaporation	657.1
Ungaged Runoff	33.1	Advective Flow	20.7
Groundwater	500.1	Change In Storage	446.1
Totals	1123.9		1123.9

In order to calculate the precipitation inputs, 2003 rainfall data were taken from the weather station located at Watertown AP. The amount of precipitation in inches was converted to feet and multiplied by the surface area of School Lake (1.8 ft × 323.7 acres).

The ungaged portion of the project is comprised of the entire School Lake watershed (3,891.8 acres). One tributary (T51) was monitored within this watershed but not included in the hydrologic budget. Site T51 showed zero flow due to the sampling season occurring during a dry cycle. Contribution from the watershed was estimated from the tributaries of Wigdale Lake. Loading coefficients were calculated for Site T49 and Site T50 by dividing the flow by the tributary drainage area. The average, of Site T49 and Site T50 loading coefficients, was then multiplied by the watershed area.

School Lake had no flowing outlets during this sampling season, therefore output sources only included evaporation, advective outflow, and change in storage. The nearest weather station that collected land evaporation data was two miles northeast of Brookings approximately 45 miles from the study area (SDSU 2003). In order to adjust the land data to surface water evaporation, monthly evaporation amounts were multiplied by the Class A monthly land pan coefficient (0.75) for the midwestern United States (Fetter 1988). The monthly evaporation amounts were added, converted to feet, and multiplied by the surface area of School Lake.

Advective outflow (movement of water by gravity) for School Lake was calculated using the BATHTUB model (Walker 1999). The level of the lake decreased from its original measurement in April 2003 to the last measurement in October 2003. The difference between these measurements was 1.4 feet. This constitutes 446.1 acre-feet (1.4 ft × 323.71 acres) indicating a decrease in storage.

After all of the hydrologic outputs were subtracted from the inputs, 500 acre-ft were unaccounted for. The only source not yet included was groundwater, which can be difficult to estimate. Since, this lake was sampled during a dry cycle, and groundwater input was probably a large contributor.

Sediment and Nutrient Loadings

To calculate current and future water quality in School Lake, loadings from the watershed were estimated from the tributaries of Wigdale Lake. Loadings from these tributaries were calculated by the FLUX model and are shown in Table 49.

Table 49. FLUX Model Data for Wigdale Lake Tributaries

	All Loads Reported in Kilograms		
	T49	T50	Total Load
Total Phosphorus	42.4	5.1	47.5
Total Dissolved Phosphorus	33.9	3.8	37.7
Total Suspended Solids	1,048.2	1,316.7	2,364.9
Total Solids	71,281.7	33,508.6	104,790.3
Total Dissolved Solids	69,687.2	32,191.9	101,879.1
TKN	206.9	44.4	251.3
VTSS	557.9	324.5	882.4

An important comparison of conditions in School Lake watershed can be made through the use of the loading coefficients from the tributaries of Wigdale Lake (Table 50). Loading coefficients are calculated by using the total loading discharged from the site and then dividing by the surface drainage area. For example, the loading phosphorus coefficient for Site T49 is the total loading (42.4 kg) divided by the number of acres (3,172.8). The loading coefficients for Site T49 and Site T50 were averaged to estimate a nutrient loading coefficient for the runoff delivered to School Lake.

Table 50. Loading Coefficients for Wigdale Lake (kg/acre)

	Watershed acres	TPO4 kg/acres	TDPO4 kg/acres	TSS kg/acres	TSOL kg/acres	TDSOL kg/acres	TKN kg/acres	VTSS kg/acres
T49	3,172.83	0.013	0.011	0.33	22.47	21.96	0.065	0.18
T50	1,729.74	0.0029	0.0022	0.76	19.37	18.61	0.026	0.19
	Average	0.00795	0.0066	0.545	20.92	20.285	0.0455	0.185

Suspended Solids Loadings

The estimated total suspended solids loading from School Lake watershed runoff was derived from the loading coefficients in Table 50. The TSS loading was calculated by multiplying the loading coefficient (0.545 kg/acres) by the watershed area of School Lake (3891.8 acres). The estimated runoff load for School Lake watershed is 2121 kg. This estimated total yearly load of sediment (2121 kg) was retained within the lake, since during a dry cycle School Lake has no tributary outlets.

Nitrogen Loadings

School Lake did not have a flowing outlet during the 2003 sampling season therefore. Input loading was estimated from the tributaries load coefficients of Wigdale Lake for the ungaged runoff, and groundwater was estimated. Total nitrogen concentrations are derived from adding TKN concentrations to nitrate-nitrite concentrations. Nitrogen inputs to School Lake during the 2003 sampling season were insignificant at 311 kg. The total yearly loads of nitrogen (311 kg) is retained within the lake, since not nitrogen is lost to tributary outlets. Inputs to School Lake included ungaged runoff and groundwater (Figure 109). Atmospheric nitrogen was not included in the input estimates. As atmospheric nitrogen enters the lake, it is utilized by different species of algae, therefore, it is impossible to calculate. Of the 311 kg, ungaged runoff contributed 58 percent. The following calculations were used to find ungaged runoff for School Lake watershed:

Watershed area converted to acres:

$$15.8 \text{ km}^2 \div .004047 = 3891.8 \text{ acres}$$

Watershed acres multiplied by the loading coefficient

$$3891.8 \text{ acres} \times .046 \text{ kg/acres} = 179 \text{ kg}$$

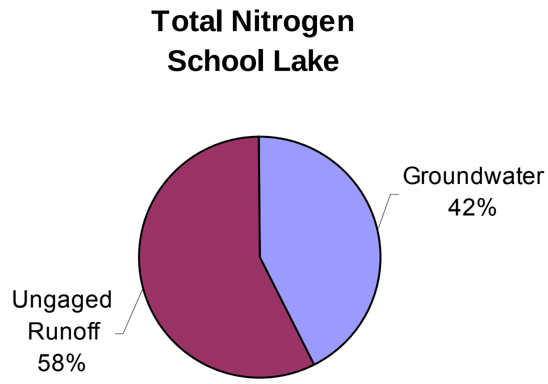


Figure 109. School Lake Watershed Total Nitrogen Loads

Nitrogen is water soluble which makes it very difficult to estimate groundwater contributions. For the purpose of this study, a total nitrogen concentration of 0.214 mg/L was used for groundwater input. The concentration was averaged from SDGS monitored wells. Groundwater is responsible for 42 percent of the input phosphorus loading since the tributaries were sampled during a dry cycle. The following calculations were used to find the groundwater load:

Hydrologic load converted to m^3:

$$500 \text{ acre-feet} \times 1{,}234 = 617{,}074 \text{ m}^3$$

Converted m^3 to liters:

$$617{,}074 \text{ m}^3 \times 1{,}000 = 617{,}074{,}000 \text{ L}$$

Groundwater phosphorus average concentration multiplied by hydrologic load (L):

$$0.214 \text{ mg/L} \times 617{,}074{,}000 \text{ L} = 132{,}053{,}836 \text{ mg}$$

Total groundwater nitrogen load converted to kg:

$$132{,}053{,}836 \text{ mg} \div 1{,}000{,}000 = 132 \text{ kg}$$

Phosphorus Loadings

Since School Lake did not have a flowing tributary outlet during the 2003 sampling season. Inputs to School Lake averaged 207.7 kg of phosphorus from April to October. The total yearly load of phosphorus (207.7 kg) is retained within the lake, since no phosphorus is lost to tributary outlets. Inputs included ungaged runoff, internal loading, groundwater, and precipitation (Figure 110). Of the 207.7 kg, ungaged runoff contributed 15 percent. The following calculations were used to find ungaged runoff for School Lake watershed:

Watershed area converted to acres:

$$15.8 \text{ km}^2 \div 0.004047 = 3891.8 \text{ acres}$$

Watershed acres multiplied by the loading coefficient:

$$3891.8 \text{ acres} \times 0.008 \text{ kg/acres} = 31.1 \text{ kg}$$

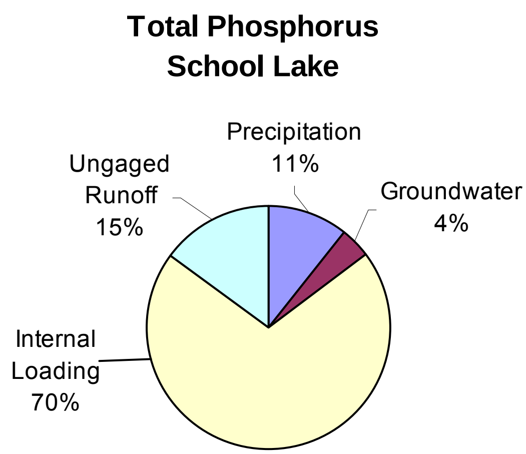


Figure 110. School Lake Watershed Phosphorus Loads

Groundwater was responsible for four percent of the total phosphorus delivered to the lake. Groundwater contribution was estimated by multiplying the mean total phosphorus concentration (0.014 mg/L) from groundwater samples collected from the SDGS and amount of groundwater discharged into the lake (500 acre-ft). The following calculations were used to find the groundwater load:

Hydrologic load converted to m^3:

$$500 \text{ acre-ft} \times 1{,}234 = 617{,}074 \text{ m}^3$$

Converted m^3 to liters:

$$617{,}074 \text{ m}^3 \times 1{,}000 = 617{,}074{,}000 \text{ L}$$

Groundwater phosphorus average concentration multiplied by hydrologic load (L):

$$0.014 \text{ mg/L} \times 617{,}074{,}000 \text{ L} = 8{,}639{,}036 \text{ mg}$$

Total groundwater phosphorus load converted to kg:

$$8{,}639{,}036 \text{ mg} \div 1{,}000{,}000 = 8.6 \text{ kg}$$

The precipitation load (590.8 acre-feet) was multiplied by 0.03 mg/L, average phosphorus content often found in nonpopulated regions, to determine the precipitation phosphorus load (Wetzel 1975). Total estimated precipitation concentration was responsible for 11 percent of the total phosphorus load. The following calculations were used to find the precipitation load:

Hydrologic load converted to m^3:

$$590.8 \text{ acre-ft} \times 1{,}234 = 729{,}047.2 \text{ m}^3$$

Converted m^3 to liters:

$$729{,}047.2 \text{ m}^3 \times 1{,}000 = 729{,}047{,}200 \text{ L}$$

Precipitation phosphorus average concentration multiplied by hydrologic load (L):

0.03 mg/L × 729,047,200 L = 21,871,416 mg

Total precipitation phosphorus load converted to kg:

21,871,416 mg ÷ 1,000,000 = 21.9 kg

The internal loading of phosphorus from the sediment was estimated by calculating the total phosphorus load in the lake and subtracting the other inputs. Internal loading contributed an estimated 70 percent to the total phosphorus load in School Lake. Internal loading of phosphorus refers to the release of phosphorus from lake sediments. In shallow lakes, resuspension of bottom sediment can occur from wind action. Figure 111 shows a strong correlation between the grab samples of total phosphorus and TSS.

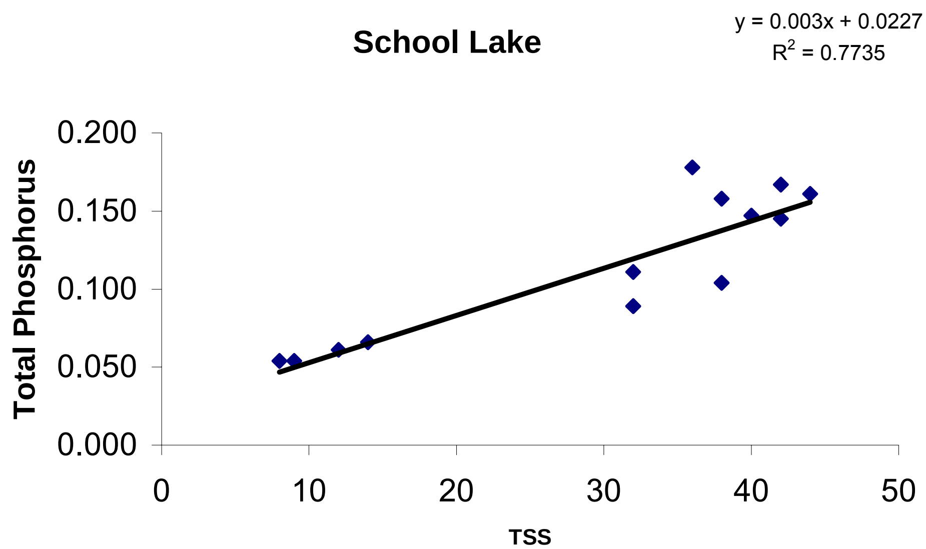


Figure 111. TSS to Total Phosphorus Relationship in School Lake

In order to estimate the amount of internal phosphorus, total phosphorus was calculated. The following calculations were used to find the total phosphorus amount in School Lake from April to May:

Volume of the lake:

221 acres × 6.6 ft = 1,471.96 acres-ft

Hydrologic load converted to m^3:

1,471.96 acres-ft × 1,234 = 1,816,398.6 m^3

Converted to m^3 to liters:

1,816,398.6 m^3 × 1,000 = 1,816,398,600 L

Average phosphorus concentration multiplied by hydrologic load (L):

1,816,398,600 L × 0.06 mg/L = 108,983,916 mg

Total internal phosphorus load converted to kg:

108,938,916 mg ÷ 1,000,000 = 108.9 kg

The total phosphorus concentration amount was calculated for three separate seasons: April to May, June to August, and September to October. The internal phosphorus loading was calculated by subtracting the other inputs from the total phosphorus load. The total phosphorus load also includes the increase of concentration from evaporation. Although internal loading is the vast majority of loading, shrinking lake volume is also playing a role in increasing the phosphorus concentration in the lake. The three internal loads were then averaged. The highest internal load calculated was from September to October with a load of 205.63 kg (87%).

Total Dissolved Phosphorus

The estimated total dissolved phosphorus loading from School Lake watershed runoff was derived from the loading coefficients in Table 50. The TDP loading was calculated multiplying the loading coefficient (0.0066 kg/acres) by the watershed area of School Lake (3891.8 acres). The estimated runoff load for School Lake watershed is 25.7 kg.

Phytoplankton (Algae) Data Summary

Planktonic algae were collected once in June and once in August and consisted of 111 species which represented 75 genera. They were divided into five separate algal divisions – flagellated algae, blue-green algae, diatoms, yellow-brown algae, and non-motile green algae. The most diverse group was the non-motile green algae with 45 species. However, the blue-green algae exhibited the most abundance (Figure 112), with the *aphanocapsa* species being the most dense. Most noxious/nuisance conditions in lakes are produced by just three algae *Anabaena flos-aquae*, *Aphanizomenon flos-aquae*, and *Microcystis aeruginosa.* An oversupply of nutrients, especially phosphorus, will result in the excessive growth of these species. Four noxious species were identified, *Anabaena circinalis*, *Oscillatoria agardhii*, *Anabaena subcylindrica*, and *Microcystis aeruginosa*, which persisted throughout the months of June, July, and August (See Appendix I).

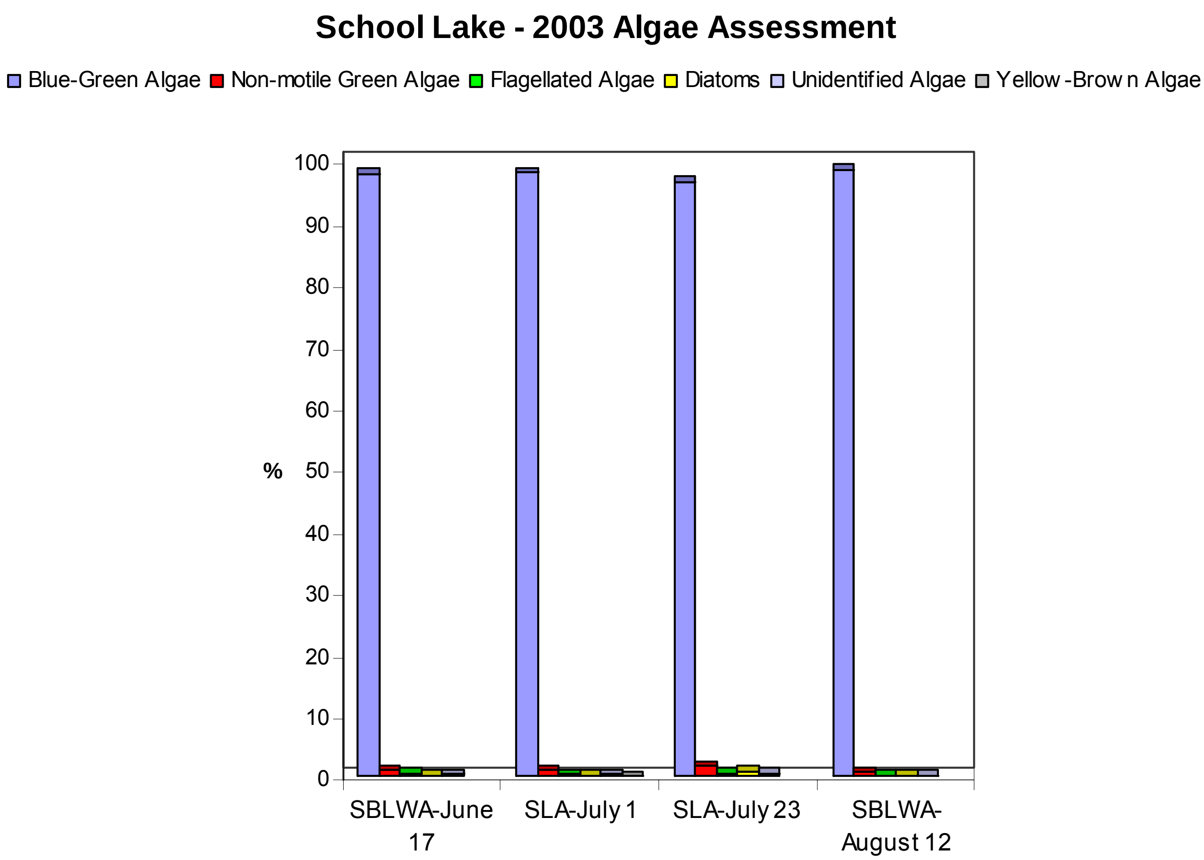


Figure 112. Percentage by Division of Major Algae Groups Collected in School Lake

Aquatic Macrophyte (Plants) Survey

Aquatic plants were surveyed in School Lake between 22 July and 5 August 2003, along 19 transects at 110 sampling locations. Table 51 lists species identified during the survey. *Scirpus maritimus* was the most abundant of the emergent species. Emergents were found at seven of the 19 transects. Aquatic plants were absent at transects 1, 6, 7, 15, and 16. See Figure 9 in Methods Section of report for transects and see Figure 64 in the Results Section for exact location of these species. Figure 113 shows the frequency of occurrence of each species using data from the 19 transects. Additionally, *Chara* spp., a type of algae, was also identified during the aquatic plant survey.

Table 51. School Lake Aquatic Macrophytes

Common Name	Genus	Species	Habitat
Sago Pondweed	*Potamogeton*	*pectinatus*	Submergent
Claspingleaf Pondweed	*Potamogeton*	*richardsonii*	Submergent
Northern Milfoil	*Myriophyllum*	*exalbescens*	Submergent
Prairie Bulrush	*Scirpus*	*maritimus*	Emergent
Bulrushes	*Scirpus*	*spp.*	Emergent
Cattails	*Typha*	*spp.*	Emergent

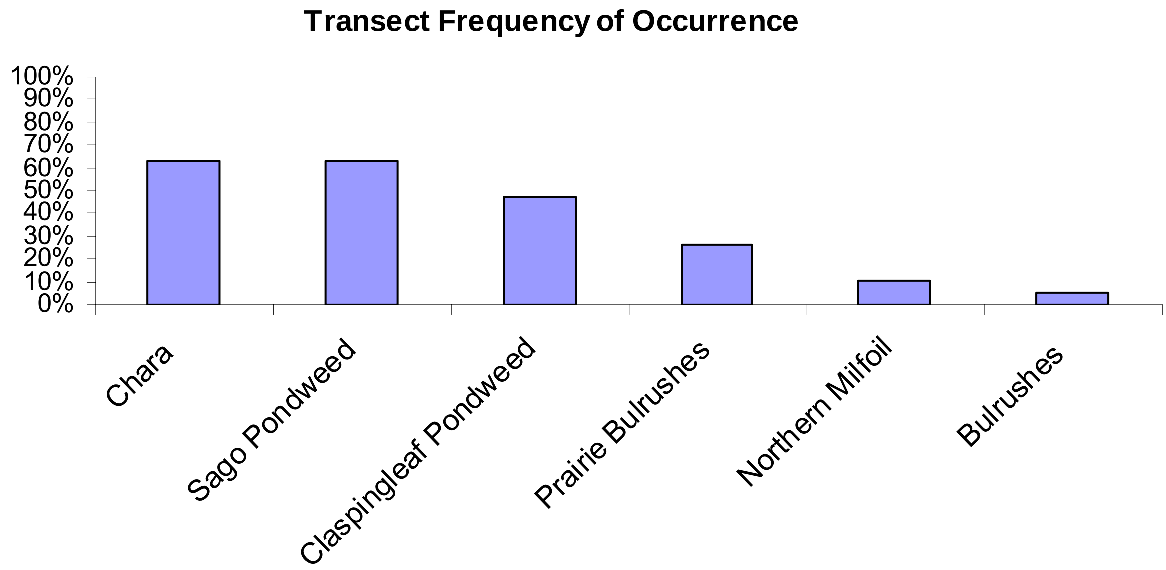


Figure 113. Type and Frequency of Aquatic Macrophytes at 19 Transects

Source Linkage and Conclusion

Trophic State Index

The trophic state of a lake is a numerical value that ranks its relative productivity. Developed by Carlson (1977), the Trophic State Index (TSI), allows a lake's productivity to be easily quantified and compared to other lakes. Low TSI values correlate with small nutrient concentrations, while higher TSI values correlate with higher levels of nutrient concentrations. TSI values range from 0 (oligotrophic) to 100 (hypereutrophic). Table 52 describes the TSI trophic levels and numeric ranges applicable to School Lake. In this index, each increase of 10 units represents a doubling of algal biomass.

Table 52. Carlson Trophic Levels and Numeric Ranges by Category

Trophic Level	Numeric Range
Oligotrophic	0-35
Mesotrophic	36-50
Eutrophic	51-65
Hypereutrophic	66-100

Average values for the trophic levels in School Lake are shown in Table 53. The mean and median of total phosphorus and Secchi depth are categorized as hypereutrophic, while chlorophyll-*a* mean is categorized as eutrophic (Figure 114). Overall, School Lake is considered to be hypereutrophic in condition (TSI=70.3).

Table 53. Observed Trophic State Index Values Collected in School Lake

Parameter	Total Phosphorus	Secchi Depth	Chlorophyll-*a*	Parameters Combined
Mean TSI	72.14	72.26	65.37	70.25
Median TSI	73.72	75.29	68.12	70.00
Standard Deviation	5.81	7.97	9.27	8.17

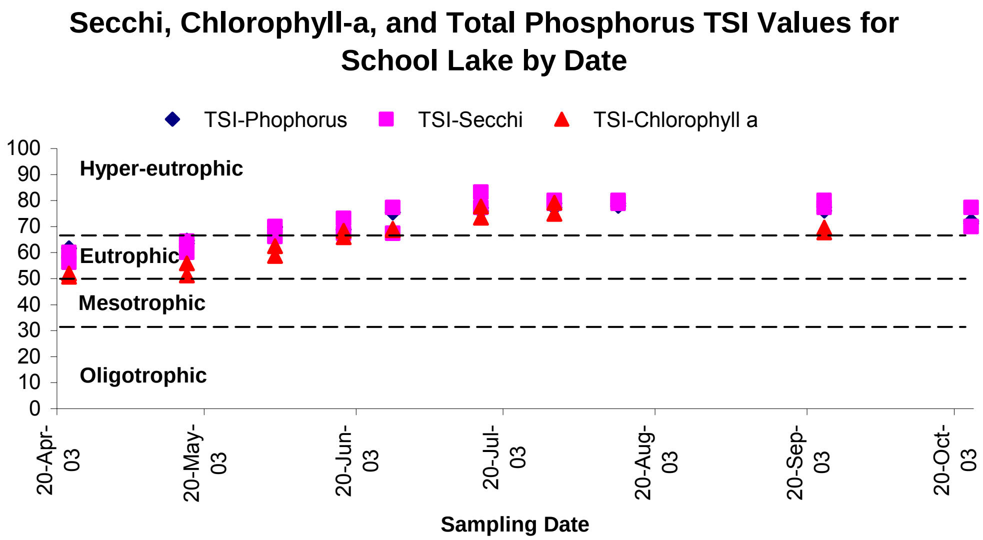


Figure 114. Secchi, Chlorophyll-*a*, and Total Phosphorus TSI Values Plotted by Carlson Trophic Levels in School Lake

In South Dakota, TSI values are now evaluated upon ecoregion-specific beneficial use categories. School Lake is located in Ecoregion 46N and is categorized as not supporting based on SD DENR standards (SDDENR 2000a). There are three beneficial use categories: non-supporting, partially supporting, and fully supporting. Numeric ranges for beneficial use categories are shown in Table 54.

Table 54. Ecoregion 46N Beneficial Use Category and Carlson TSI Numeric Ranges by Category

Ecoregion (46N) Beneficial Use Category	TSI Numeric Range
Fully supporting	≤ 65
Partially supporting	≥ 65.01 - ≤ 70
Non-supporting	≥ 70.01

Trophic State Index values are plotted using beneficial uses categories in Figure 115. TSI values steadily increase from May through July. All parameters are not supporting the beneficial uses during July and August.

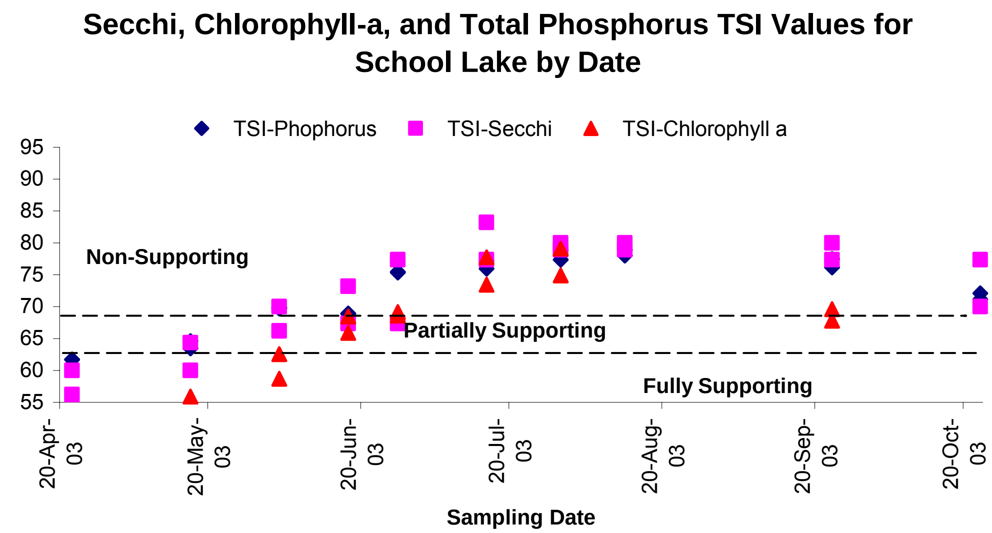


Figure 115. Secchi, Chlorophyll-*a*, and Total Phosphorus TSI Values Plotted by Ecoregion 46N Beneficial Uses Categories in School Lake

Reduction Prediction based on BATHTUB Model

Inlake responses to watershed nutrient loading reductions were calculated using the BATHTUB model. Each lake variable was modeled and shown in Table 55 and Figure 116. See Appendix M for a description of each BATHTUB variable from Table 55. The reduction of watershed phosphorus contribution would improve the lake from non supporting TSI value (70.4) to supporting with at TSI value of 62.3. The phosphorus loading can be attributed to watershed runoff and sediment internal loading from previous watershed runoff.

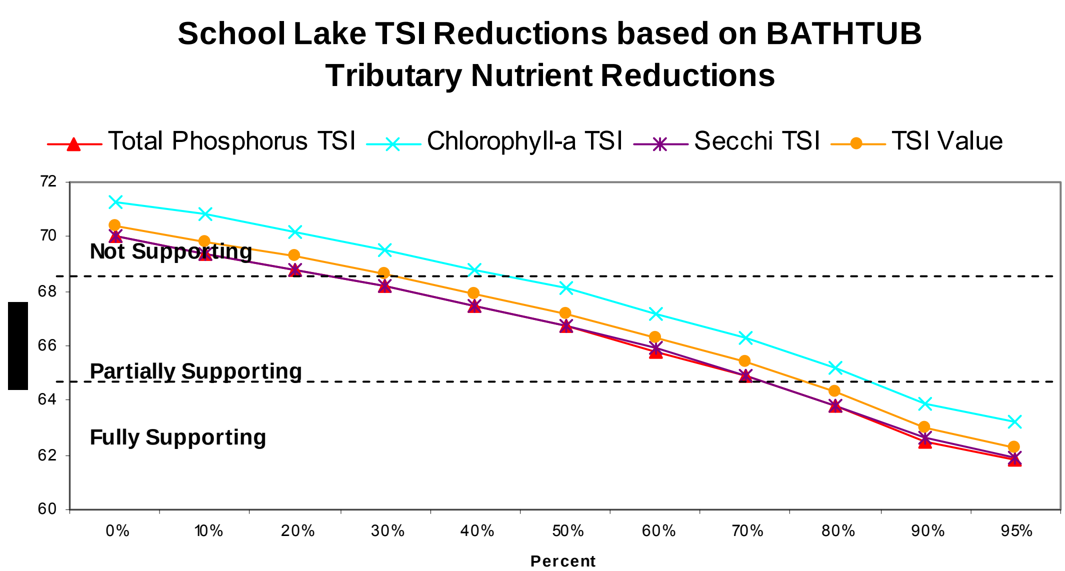


Figure 116. Predicted Trophic State Index Reductions Using the BATHTUB Reduction Model Ranked by Ecoregion 46N Beneficial Use Categories in School Lake

Table 55. School Lake Observed and Predicted Watershed Reductions in Nitrogen and Phosphorus Concentrations and Predicted In-Lake Mean TSI Values Using the BATHTUB Model

Variable	Observed Values caluculated using BATHTUB OBSERVED	Condition of the Lake based on current loadings Predicted	Equal Reductions assumed in all subwatersheds, percentages are for total lake load									
			10% Predicted	20% Predicted	30% Predicted	40% Predicted	50% Predicted	60% Predicted	70% Predicted	80% Predicted	90% Predicted	95% Predicted
Total P	120	96	92.4	88.6	84.7	80.7	76.5	72.1	67.4	62.5	57.4	54.6
Total N	1739	1743.7	1713.6	1683	1652	1620.6	1558.6	1556.1	1523.1	1489.5	1455.2	1437.9
CHL-A	54.7	63.5	60	56.5	52.9	49.2	45.5	41.8	37.9	34	29.9	27.9
SECCHI	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.9
ORGANIC N	1739	1661.8	1582.5	1502	1420.3	1337.2	1252.7	1166.5	1078.6	988.7	896.6	849.6
ANTILOG PC-1	2619.9	2512.1	2305.7	2103.1	1904.2	1709.5	1519.2	1333.6	1153.2	978.4	810	728.4
ANTILOG PC-2	12.6	14.9	14.7	14.5	14.2	14	13.7	13.4	13.1	12.8	12.4	12.2
(N-150)/P	13.2	16.6	16.9	17.3	17.7	18.2	18.8	19.5	20.4	21.4	22.8	23.6
INORGANIC N/P	0	81.9	131.1	181	231.7	283.3	335.9	389.6	444.5	500.8	558.7	588.3
FREQ (CHL-a>10)%	99.2	99.6	99.5	99.3	99.1	98.8	98.4	97.7	96.7	95.2	92.8	91
FREQ (CHL-a>20)%	90.5	94	92.8	91.4	89.6	87.4	84.6	81	76.5	70.7	63.3	58.9
FREQ (CHL-a>30)%	74.5	81.6	79.1	76.1	72.7	68.8	64.2	58.8	52.7	45.6	37.7	33.4
FREQ (CHL-a>40)%	57.7	66.8	63.5	59.7	55.6	51	46	40.5	34.6	28.3	21.8	18.6
FREQ (CHL-a>50)%	43.4	53	49.4	45.5	41.3	36.9	32.2	27.4	22.5	17.5	12.7	10.5
FREQ (CHL-a>60)%	32.3	41.3	37.8	34.2	30.4	26.5	22.5	18.5	14.7	11	7.6	6.1
TSI-P	73.2	70	69.4	68.8	68.2	67.5	66.7	65.8	64.9	63.8	62.5	61.8
TSI-CHLA	69.9	71.3	70.8	70.2	69.5	68.8	68.1	67.2	66.3	65.2	63.9	63.2
TSI-SEC	70.9	70	69.4	68.8	68.2	67.5	66.7	65.9	64.9	63.8	62.6	61.9
Mean TSI	71.3	70.4	69.8	69.3	68.6	67.9	67.2	66.3	65.4	64.3	63	62.3

Note: Description of each variable in Appendix M

Point Sources

There are no point sources of pollution in the School Lake watershed.

Non-Point Sources (NPS)

Nonpoint sources of concern are those that contribute TSS and nutrients. Since nonpoint sources can be difficult to pinpoint, the following are the possible sources of sediment and nutrients in this watershed. Sediment sources of pollution include agricultural runoff, and eroding stream bed and banks. Sources of phosphorus include human and animal waste, soil erosion, fertilizer runoff, and detergents. Sources of nitrogen are fertilizers, animal wastes and septic systems.

Wigdale Lake Watershed

This map (Figure 117) shows the area and location designated as the Wigdale Lake Watershed. This area encompasses approximately 9,983 acres, with the lake itself covering approximately 713 acres.

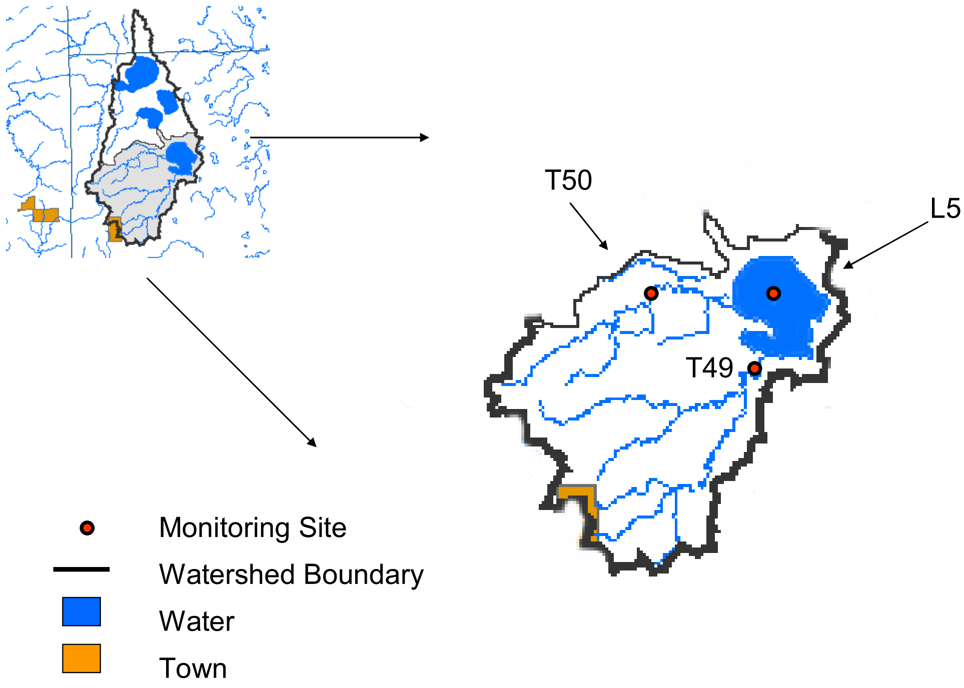


Figure 117. Wigdale Lake Watershed Location Map

Land Use Summary

The Wigdale Lake watershed area is located within the Northern Glaciated Plains level III ecoregion and characterized by the level IV ecoregion of the Prairie Coteau. This is an area of rolling terrain and drift plains. Much of the rolling areas are in pastureland, while the flatter areas are tilled for agricultural crops. Approximately 64 percent of the area is cropland, such as corn and soybeans, and 27 percent is grassland and pastureland (Figure 118). There were seven animal feeding operation assessed in the Wigdale Lake watershed. Table 56 shows the feedlot ratings for each operation. These beef cattle operations consisted of approximately 395 total animals.

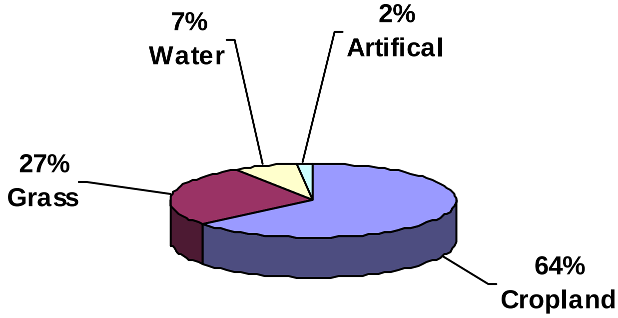


Figure 118. Wigdale Lake Watershed Landuse

Table 56. Feedlot Ratings in the Wigdale Lake Watershed

LMU	Feedlot Rating
Wg	67
Wg	58
Wg	53
Wg	16
Wg	0
Wg	0
Wg	-----

------ no livestock

Water Quality Summary

Comparisons between the lake samples and tributary samples were made. Table 57 shows fecal samples in the tributaries were much higher than in the lake. The higher TSS in the lake may indicate resuspension of solids from the bottom, which in turn releases more phosphorus stimulating more organic growth.

Table 57. Comparison of Lake and Tributary Water Quality for Wigdale Lake

	Wigdale Lake Tributaries				Wigdale Lake	
	Spring April-May 2003		Summer June-August 2003		Spring April-May 2003	Summer June-August 2003
Parameter	mg/L	%	mg/L	%	mg/L	mg/L
Alk-M	305	65	166	35	205.5	151.4
TSS	17	71	7	29	61	71.2
TotSol	639	50	634	50	389	371.2
TDS	622	50	627	50	328	300
Nitrates	<0.1	29	0.25	71	<0.1	<0.1
Ammonia	0.08	17	0.4	83	<0.02	0.004
TKN	1.1	30	2.6	70	2.5	4.38
TPO4	0.15	19	0.63	81	0.227	0.257
TDPO4	0.12	19	0.51	81	0.057	0.005
	counts/100mL		counts/100mL		counts/100mL	counts/100mL
Fecal Coliform	15	<1	3300	99	<10	2
E. Coli	3	<1	2420	99	1.45	1.42

Beneficial use for the inlake site L5 is (9) Fish and Wildlife Propagation, Recreation and Stock Watering. Based on the results from the water quality criteria established by DENR as described in Results section under Water Quality Monitoring, the inlake site is meeting the water quality criteria for its beneficial use. There were two violations of pH, at 9.66 and 10.2 (Figure 119). See Appendix P for Wigdale Lake Water Quality graphs.

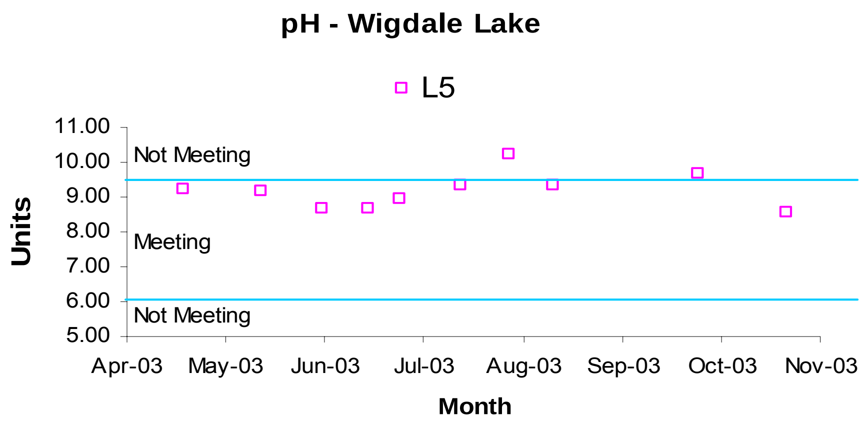


Figure 119. pH Grab Samples Based on Numeric Standard ≥ 6.0 - ≤ 9.5 (Less Than 20 Samples) at Site L5

Water temperature and pH levels tend to increase as lakes become more productive. This higher productivity is likely caused by excessive nutrients. Thus, these higher pH levels may indicate elevated levels of nutrients in this lake, causing excessive algal and macrophyte growth. Figure 120 shows the pH levels in comparison to the water temperature in Wigdale Lake.

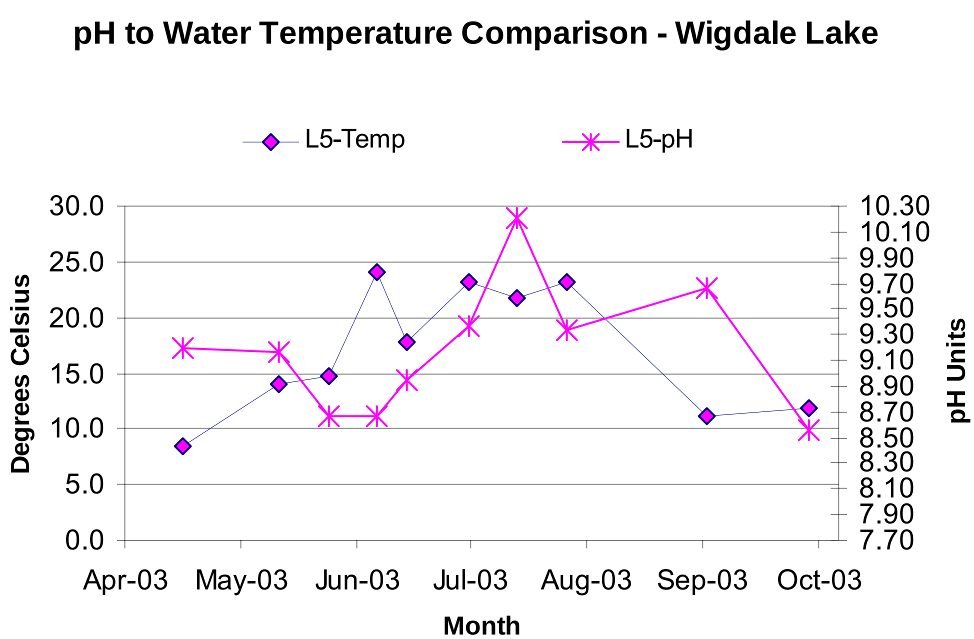


Figure 120. Wigdale Lake pH to Water Temperature Comparison

Chlorophyll is the photosynthetic pigment in all green plants and can be a measure of the amount of algae present in a lake. Phosphorus is the primary nutrient algae use for growth. Plots of total phosphorus and chlorophyll-*a* were constructed (Figure 121) to show the relationship between the amount of phosphorus present versus the amount of algal growth. Phosphorus is usually the limiting nutrient in the growth of algae. Therefore, increases in phosphorus should yield increases in algae mass. Figure 121 indicates there is not a correlation (R^2=0.0001 at Site L5) between chlorophyll-*a* and total phosphorus in Wigdale Lake.

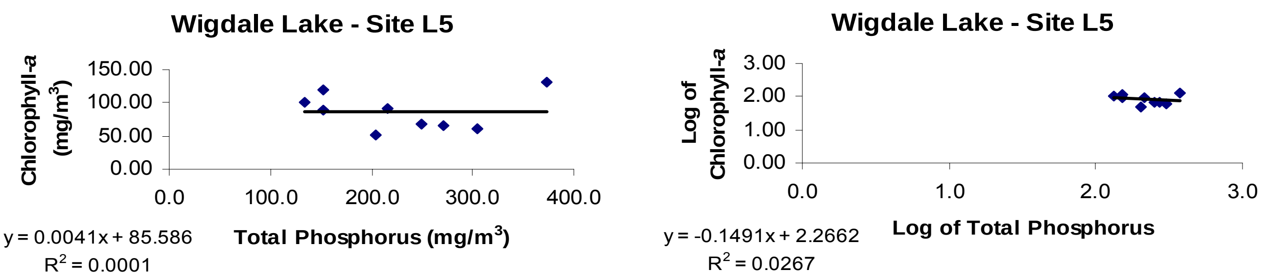


Figure 121. Phosphorus to Chlorophyll-*a* Relationship for Site L5

The maximum inlake chlorophyll-*a* concentration of 131.48 mg/m^3 was collected at Site L5 on 23 Sep 03 (Figure 122). The average chlorophyll-*a* concentration was 86.52 mg/m^3 and the median concentration was 88.49 mg/m^3.

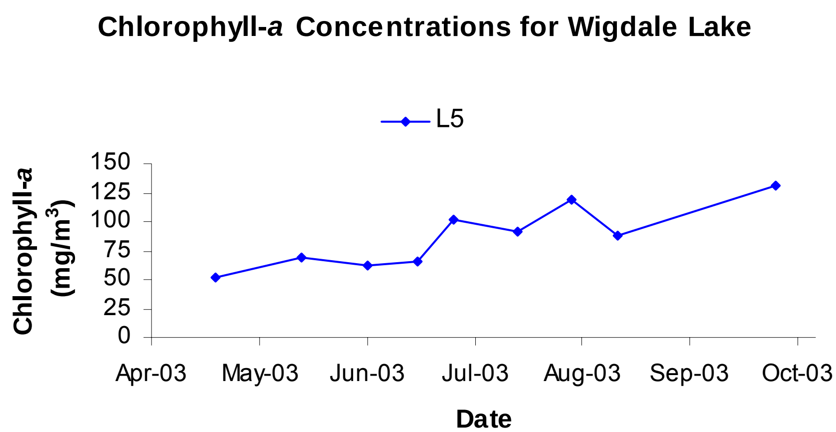


Figure 122. Graph of Chlorophyll-*a* Concentration (mg/m^3) for Wigdale Lake

Water clarity is measured using a Secchi disk. The deeper the Secchi disk can be seen, the clearer the water. Indicatively, water clarity decreases as the amount of chlorophyll-*a* increases, as shown by Figure 123.

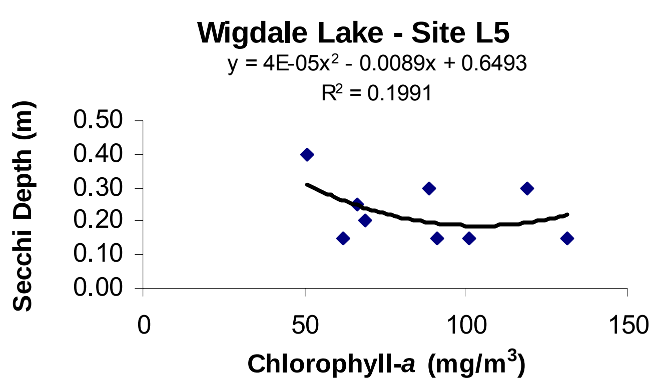


Figure 123. Chlorophyll-*a* to Secchi Depth Relationship for Site L5

For an organism, such as algae, to survive in a given environment, it must have the necessary nutrients and environment to maintain life and successfully reproduce. If an essential life component approaches a critical minimum, this component will become the limiting factor (Odum 1959). Nutrients such as phosphorus and nitrogen are most often the limiting factors in highly eutrophic lakes. Typically, phosphorus is the limiting nutrient for algal growth. However, in many highly eutrophic lakes with an overabundance of phosphorus, nitrogen can become the limiting factor. Wigdale Lake is a phosphorus-limited lake as shown by Figure 124.

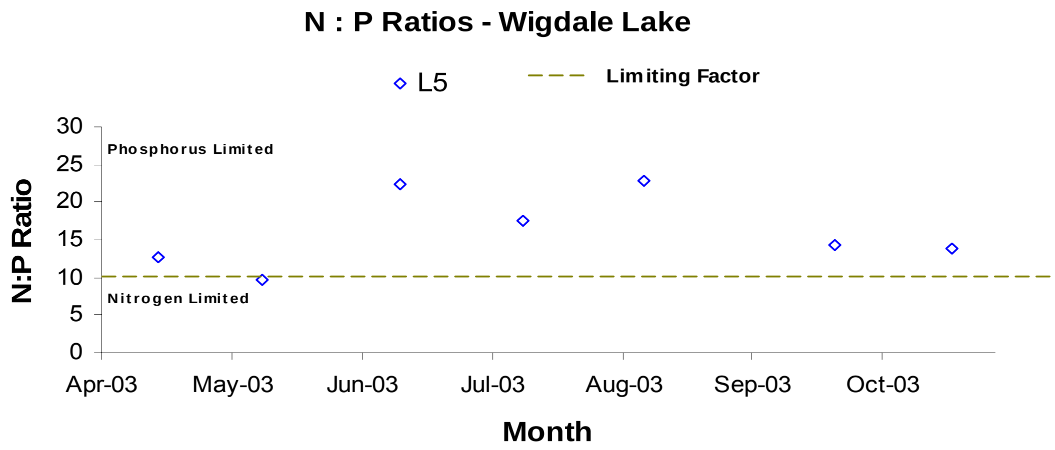


Figure 124. Total Nitrogen to Total Phosphorus Ratio for Wigdale Lake

In 2003 lake levels in Wigdale Lake dropped approximately 1.99 ft between the months of April and October. In 2004 the difference in lake levels between May and August was approximately 1.15 ft. As shown by Figure 125, lake levels rose in June of 2004 due to heavy rains.

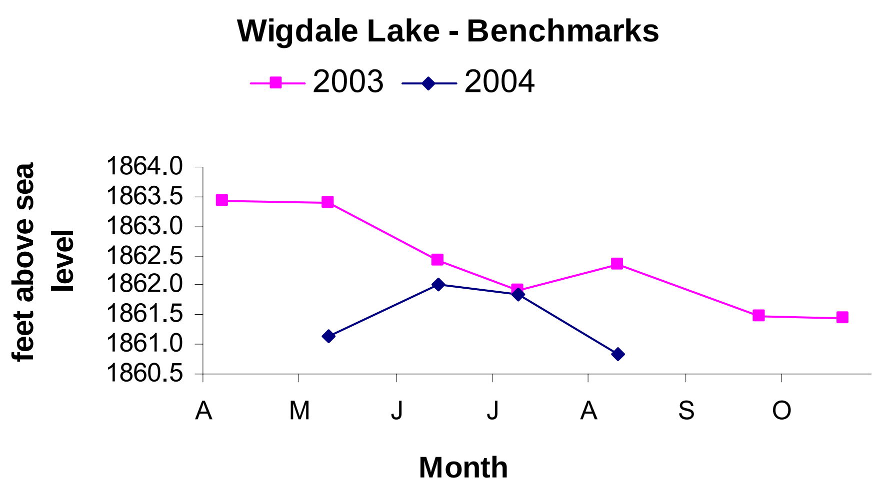


Figure 125. 2003 and 2004 Lake Level Readings for Wigdale Lake

The two inlet sites (T49 and T50) are assigned beneficial uses (9) Fish and Wildlife Propagation, Recreation and Stock Watering, and (10) Irrigation. Based on the water quality results these two sites are meeting the water quality criteria for their beneficial uses. There were no violations of water quality during the study period. See Appendix A for the water quality results.

Hydrologic Budget

Hydrologic Budget

A hydrologic budget explains the amount of water entering and leaving a lake. In theory, all inputs of water must equal all outputs during the course of the hydrologic cycle (Table 58). Some inputs will be estimated to help balance the equation, since monitoring all possible inputs in a lake is very difficult.

Table 58. Hydrologic Budget for Wigdale Lake in 2003

Input Sources	Load (acre-ft)	Output Sources	Load (acre-ft)
Surface Area= 714.13			
Precipitation	1,303.29	Evaporation	1,449
T49	24.31	Advective Flow	68.91
T50	16.21	Change In Storage	1,418.20
Groundwater	1,592.30		
Totals	2,936.11		2,936.11

The measured input sources to Wigdale Lake included precipitation and tributary run-off. In order to calculate the precipitation inputs, 2003 rainfall data were taken from the weather station located at Watertown AP. The amount of precipitation in inches was converted to feet and multiplied by the surface area of Wigdale Lake (1.825 ft × 714.13 acres). Tributary run-off was based on the 2003 sampling period (April to October). The FLUX model calculated the volume of water each tributary contributed to the lake. The volume of water (hm^3) was converted to acre-ft.

Wigdale Lake has no outlets, therefore output sources only included evaporation, advective outflow, and change in storage. The nearest weather station that collected land evaporation data was two miles northeast of Brookings, approximately 45 miles from the study area (SDSU 2003). In order to adjust the land data to surface water evaporation, monthly evaporation amounts were multiplied by the Class A monthly land pan coefficient (0.75) for the midwestern United States (Fetter 1988). The monthly evaporation amounts were added, converted to feet, and multiplied by the surface area of Wigdale Lake.

Advective outflow (movement of water by gravity) for Wigdale Lake was calculated using the BATHTUB model (Walker 1999). The level of the lake decreased from its original measurement in April 2003 to the last measurement in October 2003. The difference between these measurements was 1.986 feet. This constitutes 1418.2 acre-feet (1.986 ft × 714.1 acres) indicating a decrease in storage.

After comparing the totals of inputs and outputs, the input total was 1,592.30 acre-ft less. Reasonable assumption indicates the difference could be attributed to input from groundwater, which can be difficult to estimate. Since, this lake was sampled during a dry cycle, and groundwater input was probably a large contributor.

Sediment and Nutrient Loadings

To calculate current and future water quality in Wigdale Lake, loadings from the inlets were calculated using the FLUX model (Table 59). Since these tributaries are intermittent in nature they are mainly influenced by heavy rains and runoff events occurring in the spring of the year.

Table 59. FLUX Model Data for Wigdale Lake Tributaries

	All Loads Reported in Kilograms		
	T49	T50	Total Load
Total Phosphorus	42.4	5.1	47.5
Total Dissolved Phosphorus	33.9	3.8	37.7
Total Suspended Solids	1,048.2	1,316.7	2,364.9
Total Solids	71,281.7	33,508.6	104,790.3
Total Dissolved Solids	69,687.2	32,191.9	101,879.1
TKN	206.9	44.4	251.3
VTSS	557.9	324.5	882.4

An important comparison of watershed conditions can be made through the use of loading coefficients (Table 60). Loading coefficients are calculated by using the total loading discharged from the site and then dividing by the surface drainage area. For example, the loading phosphorus coefficient for T49 is the total loading (42.4 kg) divided by the number of acres (3,172.83).

Table 60. Loading Coefficients for Wigdale Lake (kg/acre)

	Watershed acres	TPO4 kg/acres	TDPO4 kg/acres	TSS kg/acres	TSOL kg/acres	TDSOL kg/acres	TKN kg/acres	VTSS kg/acres
T49	3,172.83	0.013	0.011	0.33	22.47	21.96	0.065	0.18
T50	1,729.74	0.0029	0.0022	0.76	19.37	18.61	0.026	0.19

Suspended Solids Loadings

Figure 126 shows the estimated percentage of total suspended solids loading from Wigdale Lake tributaries derived from water quality sampling. Measured loadings at both sites were similar with 56 percent of the load from T49 and 44 percent of the load from T50. The total yearly load of sediment (2,364.9 kg) is retained within the lake, since no sediment is lost to tributary outlets.

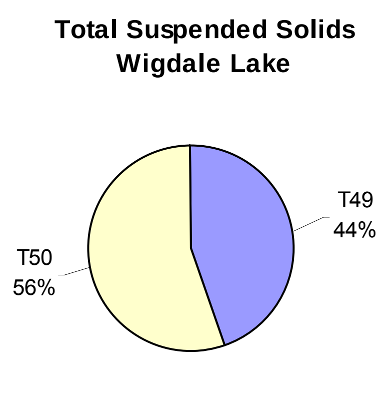


Figure 126. Wigdale Lake Watershed Suspended Solids Loads

Nitrogen Loadings

Wigdale Lake did not have a flowing outlet during the 2003 sampling season. Input loading was measured for the tributaries, and groundwater was estimated. Total nitrogen concentrations are derived from adding TKN concentrations to nitrate-nitrite concentrations. Nitrogen inputs to Wigdale Lake during the 2003 sampling season were insignificant at 672 kg. The total yearly load of nitrogen (672 kg) is retained within the lake, since no nitrogen is lost to tributary outlets. Inputs to Wigdale Lake included gaged tributaries and groundwater (Figure 127). Atmospheric nitrogen was not included in the input estimates. As atmospheric nitrogen enters the lake, it is utilized by different species of algae, therefore, it is impossible to calculate. Of the 672 kg, Site T49 contributed 31 percent and Site T50 contributed 7 percent. Tributary nitrate loads were calculated using the FLUX model.

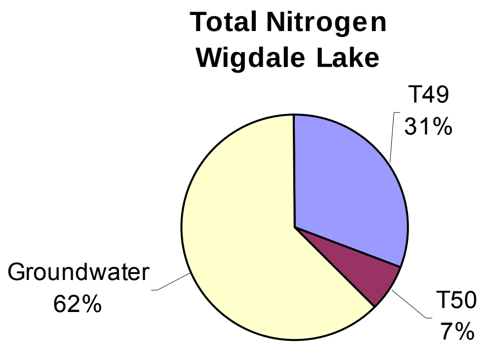


Figure 127. Wigdale Lake Watershed Total Nitrogen Loads

Nitrogen is water soluble which makes it very difficult to estimate groundwater contributions. For the purpose of this study, a total nitrogen concentration of 0.214 mg/L was used for groundwater input. The concentration was averaged from SDGS monitored wells. Groundwater is responsible for 62 percent of the input phosphorus loading since the tributaries were sampled during a dry cycle. The following calculations were used to find the groundwater load:

Hydrologic load converted to m^3:

$$1{,}592.3 \text{ acre-feet} \times 1{,}234 = 1{,}964{,}898 \text{ m}^3$$

Converted m^3 to liters:

$$1{,}964{,}898 \text{ m}^3 \times 1{,}000 = 1{,}964{,}898{,}200 \text{ L}$$

Groundwater phosphorus average concentration multiplied by hydrologic load (L):

$$0.214 \text{ mg/L} \times 1{,}964{,}898{,}200 = 420{,}488{,}214 \text{ mg}$$

Total groundwater nitrogen load converted to kg:

$$420{,}488{,}214 \text{ mg} \div 1{,}000{,}000 = 420.49 \text{ kg}$$

Phosphorus Loadings

Wigdale Lake did not have a flowing tributary outlet during the 2003 sampling season. Inputs to Wigdale Lake averaged 1383.43 kg of phosphorus from April to October. Inputs included gauged tributaries, internal load, groundwater, and precipitation (Figure 128). Of the 1383.434 kg, Site T49 contributed three percent and Site T50 with 0.4 percent. Tributary phosphorus loads were calculated using the FLUX model. The yearly load of phosphorus (1383 kg) is retained within the lake, since no phosphorus is lost to tributary outlets.

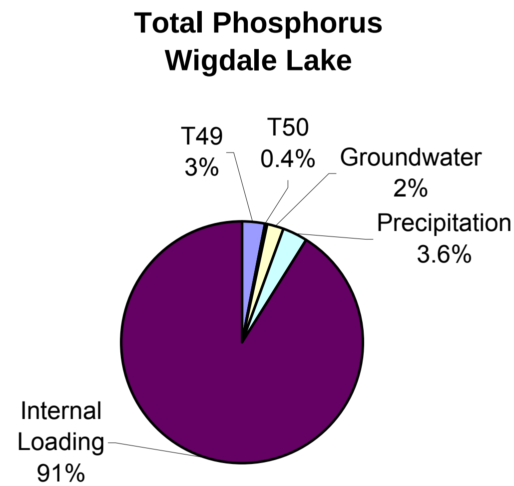


Figure 128. Wigdale Lake Watershed Phosphorus Loads

Groundwater was responsible for two percent of the total phosphorus delivered to the lake. Groundwater contribution was estimated by multiplying the mean total phosphorus concentration (0.014 mg/L) from groundwater samples collected from the SDGS and amount of groundwater discharged into the lake (1,592.3 acre-ft). The following calculations were used to find the groundwater load:

Hydrologic load converted to m^3:

$$1{,}592.3 \text{ acre-ft} \times 1{,}234 = 1{,}964{,}898 \text{ m}^3$$

Converted m^3 to liters:

$$1{,}964{,}898 \text{ m}^3 \times 1{,}000 = 1{,}964{,}898{,}200 \text{ L}$$

Groundwater phosphorus average concentration multiplied by hydrologic load (L):

$$0.014 \text{ mg/L} \times 1{,}964{,}898{,}200 \text{ L} = 27{,}508{,}575 \text{ mg}$$

Total groundwater phosphorus load converted to kg:

$$27{,}508{,}574 \text{ mg} \div 1{,}000{,}000 = 27.51 \text{ kg}$$

The precipitation load (1303.3 acres-ft) was multiplied by 0.03 mg/L, an average phosphorus content of precipitation, to determine the precipitation phosphorus load (Wetzel 1975). Total estimated precipitation concentration was responsible for less than four percent of the total phosphorus load. The following calculations were used to find the precipitation load:

Hydrologic load converted to m^3:

$$1{,}303.29 \text{ acre-ft} \times 1{,}234 = 1{,}608{,}259 \text{ m}^3$$

Converted m^3 to liters:

$$1,608,259 \text{ m}^3 \times 1,000 = 1,608,259,860 \text{ L}$$

Precipitation phosphorus average concentration multiplied by hydrologic load (L):

$$0.03 \text{ mg/L} \times 1,608,259,860 \text{ L} = 48,247,795 \text{ mg}$$

Total precipitation phosphorus load converted to kg:

$$48,247,795 \text{ mg} \div 1,000,000 = 48.25 \text{ kg}$$

The internal loading of phosphorus from the sediment was estimated by calculating the total phosphorus load in the lake and subtracting the other inputs. Internal loading contributed an estimated 91% to the total phosphorus load in Wigdale Lake. Internal loading of phosphorus refers to the release of phosphorus from lake sediments. In shallow lakes, resuspension of bottom sediment can occur from wind action. Figure 129 shows a strong correlation between grab samples of total phosphorus and TSS.

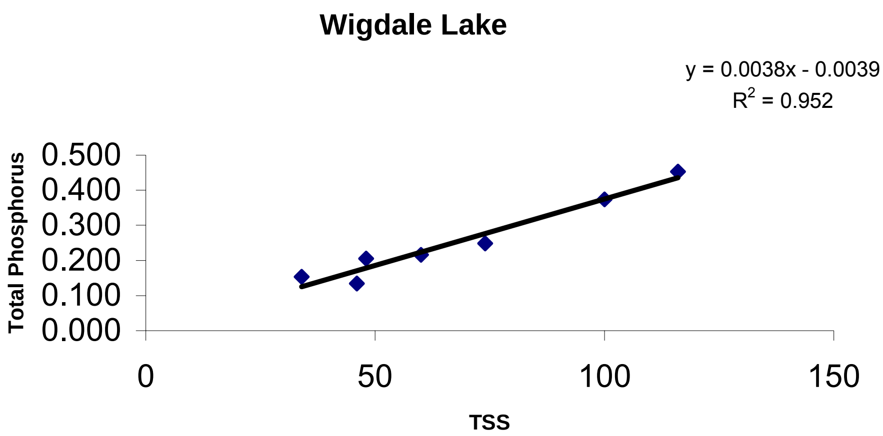


Figure 129. TSS to Total Phosphorus Relationship to Wigdale Lake

In order to estimate the amount of internal phosphorus, total phosphorus was calculated. The following calculations were used to find the total phosphorus amount in Wigdale Lake from April to May:

Volume of the lake:

$$713 \text{ acres} \times 5.58 \text{ ft} = 3,977.1 \text{ acre-ft}$$

Hydrologic load converted to m^3:

$$3,977.1 \text{ acre-ft} \times 1,234 = 4,907,741.4 \text{ m}^3$$

Converted to m^3 to liters:

$$4,907,741.4 \text{ m}^3 \times 1,000 = 4,907,741,400 \text{ L}$$

Average phosphorus concentration multiplied by hydrologic load (L):

$$.227 \text{ mg/L} \times 4{,}907{,}741{,}400\text{L} = 1{,}114{,}057{,}297.8 \text{ mg}$$

Total internal phosphorus load converted to kg:

$$1{,}114{,}057{,}297.8 \div 1{,}000{,}000 = 1{,}114.06 \text{ kg}$$

The total phosphorus concentration amount was calculated for three separate seasons: April to May, June to August, and September to October. The internal phosphorus loading was calculated by subtracting the other inputs from the total phosphorus load. The total phosphorus load also includes the increase of concentration from evaporation. Although internal loading is the vast majority of loading, shrinking lake volume is also playing a role in increasing the phosphorus concentration in the lake. The three internal loads were then averaged. The highest internal load calculated was from September to October with a load of 1,906.3 kg (94%).

Total Dissolved Phosphorus

The inputs of total dissolved phosphorus (Figure 130) to Wigdale Lake were estimated at 37.7 kg. Of the input loading, Site T49 contributed 90 percent with a loading coefficient of 0.011 kg/acre. Site T50 contributed 10 percent of the total loading with a loading coefficient of 0.0022 kg/acre.

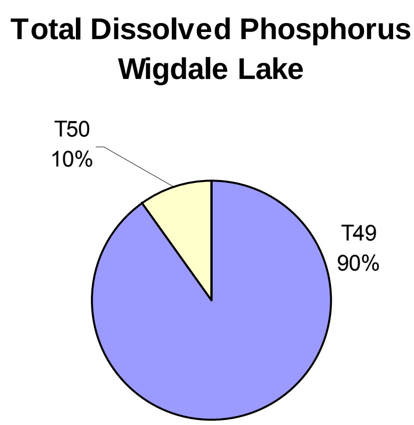


Figure 130. Wigdale Lake Watershed Total Dissolved Phosphorus Loads

Phytoplankton (Algae) Data Summary

Planktonic algae were collected once in June and once in August. However the August sample was not preserved properly and was therefore unusable. The data collected from June consisted of 65 species which represented 50 genera. They were divided into four separate algal divisions – flagellated algae, blue-green algae, diatoms, and non-motile green algae. The most diverse group was the non-motile green algae with 30 species. However, the blue-green algae exhibited the most abundance (Figure 131), with the *aphanocapsa* species being the most dense. Most noxious/nuisance conditions in lakes are produced by just three algae *Anabaena flos-aquae*, *Aphanizomenon flos-aquae*, and *Microcystis aeruginosa*. An oversupply of nutrients, especially phosphorus, will result in the excessive growth of these species. In June, four noxious species were identified, *Anabaena circinalis*, *Anabaena flos-aquae*, *Anabaena subcylindrica*, and *Oscillatoria agardhii* (See Appendix I).

Wigdale Lake - 2003 Algae Assessment

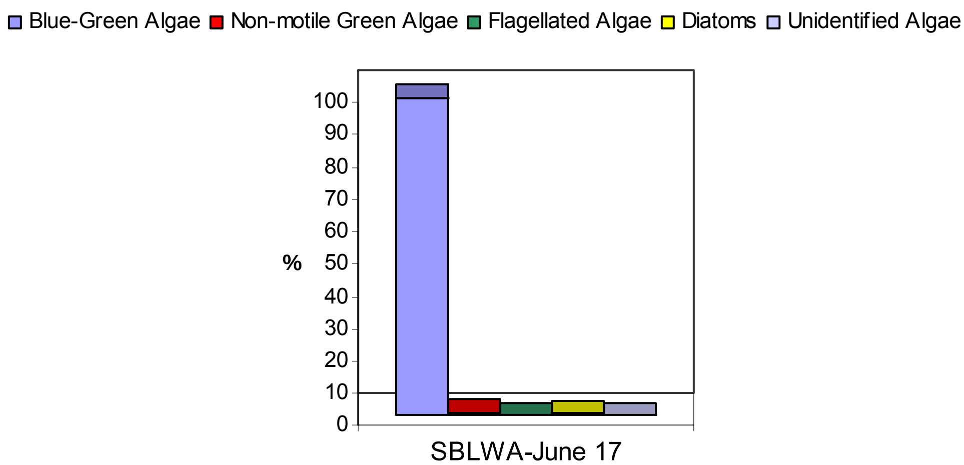


Figure 131. Percentage by Division of Major Algae Groups Collected in Wigdale Lake Source Linkage and Conclusion

Trophic State Index

The trophic state of a lake is a numerical value that ranks its relativity productivity. Developed by Carlson (1977), the Trophic State Index (TSI), allows a lake's productivity to be easily quantified and compared with higher levels of nutrient concentrations. TSI values range from 0 (oligotrophic) to 100 (hypereutrophic). Table 61 describes the TSI trophic levels and numeric ranges that Carlson used to classify lakes productivity. In this index, each increase of 10 units represents a doubling of algal biomass.

Table 61. Carlson Trophic Levels and Numeric Ranges by Category

Trophic Level	Numeric Range
Oligotrophic	0-35
Mesotrophic	36-50
Eutrophic	51-65
Hypereutrophic	66-100

Average values for the trophic levels in Wigdale Lake were calculated and shown in Table 62 for informational purposes. The mean and median for all parameters are categorized as hypereutrophic (Figure 132). Overall, Wigdale has a high TSI value of 80 and can be considered hypereutrophic.

Table 62. Observed Trophic State Index Values Collected in Wigdale Lake

Parameter	Total Phosphorus	Secchi Depth	Chlorophyll-*a*	Parameters Combined
Mean TSI	82.82	82.80	73.89	80.04
Median TSI	82.72	85.29	74.55	78.43
Standard Deviation	0.07	0.07	0.04	0.08

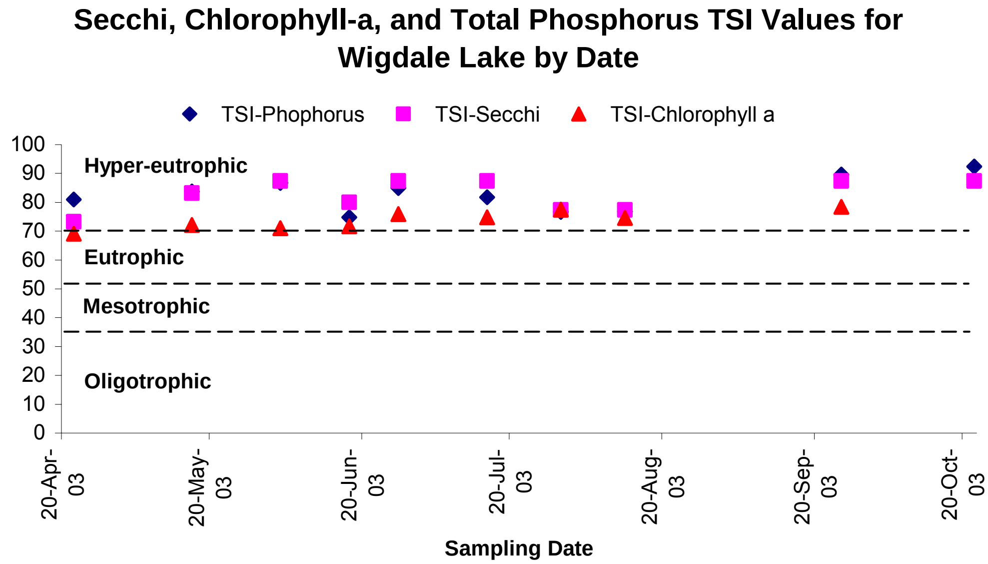


Figure 132. Secchi, Chlorophyll-a, and Total Phosphorus TSI Values Plotted by Carlson Trophic Levels in Wigdale Lake

Based on the beneficial uses of (9) and (10), Wigdale Lake is not assigned TSI numeric value range. Although Wigdale Lake is not required to meet a TSI numeric value range, TSI was calculated for the purpose of comparison to the other lakes within this watershed. The TSI value provides information for the effects of Wigdale Lake flowing into School Lake during high water conditions.

Reduction Prediction based on BATHTUB Model

Inlake responses to watershed nutrient loading reductions were calculated using the BATHTUB model. Although Wigdale Lake is not required to meet a TSI value, reductions may be required for School Lake to meet its beneficial uses. Each lake variable was modeled and shown in Table 63 and Figure 133. See Appendix M for a description of each BATHTUB variable from Table 63. Reductions in phosphorus loading would reduce the TSI value from 74.5 to 66.2. The phosphorus loading can be attributed to sediment internal loading from previous watershed runoff.

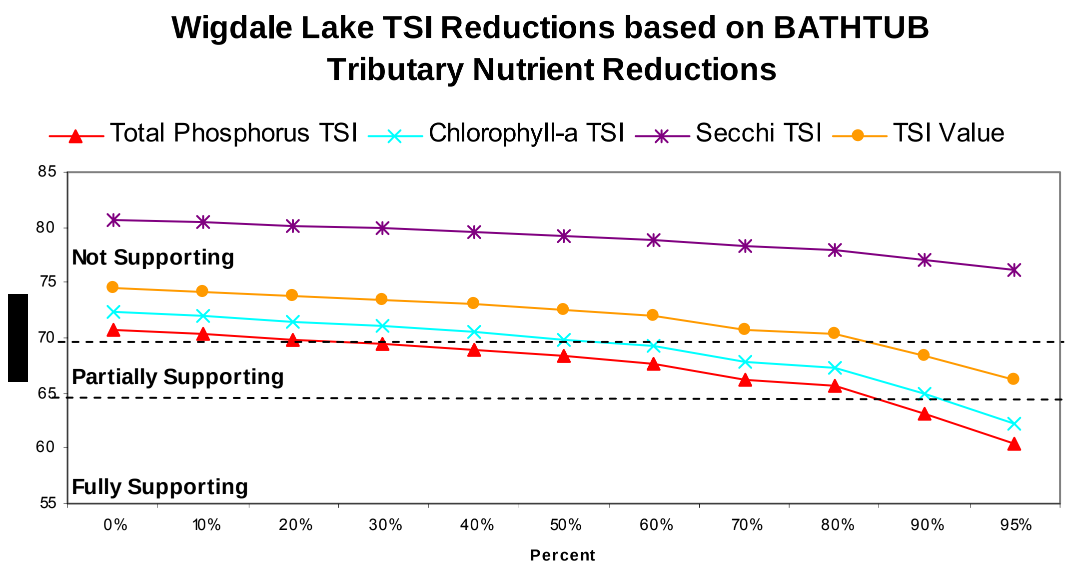


Figure 133. Predicted Trophic State Index Reductions Using the BATHTUB Reduction Model Ranked by Ecoregion 46N Beneficial Use Categories in Wigdale Lake

Table 63. Wigdale Lake Observed and Predicted Watershed Reductions in Nitrogen and Phosphorus Concentrations and Predicted In-Lake Mean TSI Values Using the BATHTUB Model

Variable	Observed Values caluculated using BATHTUB OBSERVED	Condition of the Lake based on current loadings Predicted	Equal Reductions assumed in all subwatersheds, percentages are for total lake load									
			10% Predicted	20% Predicted	30% Predicted	40% Predicted	50% Predicted	60% Predicted	70% Predicted	80% Predicted	90% Predicted	95% Predicted
Total P	251	101.2	98.4	95.5	92.4	89.1	85.6	81.6	74.1	70.7	60.2	49.5
Total N	3841	4781.8	4731.6	4681.3	4631	4580.7	4530.4	4480.2	4429.9	4379.6	4329.3	4304.2
CHL-A	84.8	70.3	67.5	64.6	61.6	58.5	55.1	51.5	44.8	41.8	33.1	25
SECCHI	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
ORGANIC N	3841	1942.9	1878.7	1812.8	1744.7	1673.3	1597.3	1513.8	1360.5	1293.4	1095.8	909.1
ANTILOG PC-1	10025.9	178.6	4303.1	4042.9	3780.3	3512.6	3235.4	2940.8	2427.4	2213.4	1624.7	1126.3
ANTILOG PC-2	9.9	4562.3	9.3	9.2	9	8.8	8.6	8.3	7.8	7.6	6.8	5.9
(N-150)/P	14.7	45.8	46.6	47.5	48.5	49.7	51.2	53.1	57.8	59.8	69.4	83.9
INORGANIC N/P	0	2839	2852.8	2868.4	2886.3	2907.4	2933.2	2966.4	3069.4	3086.2	3233.6	3395.1
FREQ (CHL-a>10)%	99.9	99.8	99.7	99.7	99.6	99.4	99.3	99	98.2	97.7	94.8	87.8
FREQ (CHL-a>20)%	97.8	95.7	95.1	94.3	93.4	92.2	90.8	88.8	83.9	81	69.3	51.9
FREQ (CHL-a>30)%	91.4	85.6	84.1	82.3	80.3	77.8	74.9	71.3	63.1	58.9	44.1	27.2
FREQ (CHL-a>40)%	81.6	72.6	70.3	67.8	65.1	61.9	58.2	53.9	44.9	40.6	27	14.2
FREQ (CHL-a>50)%	70.6	59.5	56.9	54.1	51.1	47.7	43.9	39.6	31.2	27.5	16.5	7.6
FREQ (CHL-a>60)%	59.8	47.8	45.2	42.4	39.5	36.3	32.8	28.9	21.7	18.6	10.3	4.2
TSI-P	83.8	70.7	70.3	69.9	69.4	68.9	68.3	67.6	66.2	65.6	63.2	60.4
TSI-CHLA	74.2	72.3	71.9	71.5	71	70.5	69.9	69.3	67.9	67.2	64.9	62.2
TSI-SEC	81.8	80.6	80.4	80.1	79.9	79.6	79.3	78.9	78.3	78	77	76.1
Mean TSI	79.9	74.5	74.2	73.8	73.4	73	72.5	71.9	70.8	70.3	68.4	66.2

Note: Description of each variable in Appendix M

Point Sources

The City of Goodwin is the only NPDES facility located within the Wigdale Lake watershed. The City of Goodwin is a no discharge facility.

Non-Point Sources (NPS)

Nonpoint sources of concern are those that contribute TSS and nutrients. Since nonpoint sources can be difficult to pinpoint, the following are the possible sources of sediment and nutrients in this watershed. Sediment sources of pollution include agricultural runoff, urban runoff, and eroding stream bed and banks. Sources of phosphorus include human and animal waste, soil erosion, fertilizer runoff, and detergents. Sources of nitrogen are fertilizers, animal wastes and septic systems.

WATER QUALITY GOALS

Water quality goals are based on beneficial uses and the numeric standards assigned to meet those uses. Based on water quality monitoring results, pH was the only parameter found not meeting the numeric standards.

School Lake was listed as an impaired lake because of excessive nutrients, siltation, and noxious aquatic plants, all of which do not have applicable numeric standards. However, lakes can be assessed based on their Trophic State Index (TSI). This takes into account water clarity, nutrient levels, and quality of water.

Excessive Nutrients
Phosphorus is the main nutrient that contributes to excessive algae and weed growth in lakes. Sources of phosphorus include human and animal waste, soil erosion, fertilizer runoff, and detergents. It is estimated that phosphorus levels should be maintained below 0.03 mg/L to prevent algae blooms.

Nitrogen is the second main nutrient contributing to plant growth. Sources of nitrogen are fertilizers, animal wastes, and septic systems. According to the water quality results, nitrogen is not contributing to the problems in these lakes. All inlake samples tested as non-detects.

Of the four lakes assessed, all were considered hypereutrophic. This means these lakes have very high levels of nutrients, and excessive plant and algae growth. As hypereutrophic, these lakes are extremely biologically productive. However, this productivity will continue to increase and speed up the lakes natural processes, becoming detrimental to the aquatic life living there.

Siltation
Excessive siltation can cause an overabundance of phosphorus, due to the sediment releasing phosphorus during periods of anoxia. Phosphorus can also be released after the sediment is resuspended due to wave action. These conditions can be found in School Lake, Bullhead Lake, and Wigdale Lake, all of which are shallow, have little freshwater input, non-existent flushing, and high organic matter.

Noxious Aquatic Plants
All four lakes exhibited noxious aquatic plants. N:P ratios indicate phosphorus limitation. Noxious plant growth can be prevented or at least reduced by lowering the phosphorus loading to the lake. Chlorophyll-*a* concentrations above 40 to 93 ug/L are representative of excessive biomass and would be considered "nuisance bloom" levels. Concentrations in excess of 55 ug/L may indicate hypereutrophic conditions. Higher pH levels can also be an indicator of nuisance levels of algal biomass

MANAGEMENT OPTIONS AND RECOMMENDATIONS

Before considering in-lake management options, any source of external loadings must be dealt with first. If external sources are not reduced before implementing in-lake alternatives, the management plan will likely fail. If it is determined that external sources are not contributing to the water body problems, then in-lake restoration would be the next step.

TMDLs were constructed on a lake by lake basis. Table 64 shows the proposed TMDL list. At this time, 3 TMDLs are proposed, all due to high TSI values. The reports will focus on the lake that was listed in the 305 (b) Water Quality Assessment, and any other lakes not meeting the water quality criteria. The TMDL reports can be found in Appendices Q through T.

Table 64. Proposed TMDL Listing

Proposed TMDLs	
Lake	**Reason**
School Lake	Mean TSI 70.3
Bullhead Lake	Mean TSI 68.9
Round Lake	Mean TSI 65.4
* Lake is fully supporting if Mean TSI is ≤ 65	

BEST MANAGEMENT PRACTICES

External Management of Sediment and Nutrient Sources

Best management practices (BMPs) proposed to control external nutrient and sediment transport from agricultural nonpoint sources are shown in Table 65. These BMPs are options for reducing or eliminating external sources of sediment and nutrients. As indicated by the AnnAGNPS model, the loading of nutrients seems to be the biggest issue (See Results Section).

Table 65. Best Management Practices for TSS and Nutrient Problems

BMP	TSS	Nutrients	Potential Reduction
(1) Feedlot Runoff Containment		X	High
(2) Manure Management		X	High
(3) Grazing Management	X	X	Moderate
(4) Alternative Livestock Watering	X	X	Moderate
(5) Conservation Tillage (30% residue)	X	X	Moderate
(6) No Till	X	X	High
(7) Grassed Waterways	X	X	Moderate
(8) Buffer/Filter Strips	X	X	Moderate
(9) Commercial Fertilizer Management	X	X	Moderate
(10) Wetland Restoration or Creation	X	X	High
(11) Riparian Vegetation Restoration	X	X	High
(12) Conservation Easements	X	X	High
(13) Livestock Exclusion	X	X	High

Note: approximate range of reductions:
Low = 0-25% Moderate = 25-75% High = 75-100%

Most of these BMPs are further explained in Table 66. An explanation of the benefits of using a particular BMP and the reduction that can be achieved when put to use. This table was adapted from an MPCA sources (MPCA 1990).

Table 66. Percent Reduction Achievable by Best Management Practice

BMP	Benefits	Achievable Reduction
Manure Management	• Reduces Nutrient Runoff • Significant Source of Fertilizer	50-100% reduction of nutrient runoff
Buffer/Filter Strips	• Controls sediment, phosphorus, nitrogen, organic matter, and pathogens	50% sediment and nutrient delivery reduction
Conservation Tillage	• Reduces runoff • Reduces wind erosion • More efficient in use of labor, time, fuel, and equipment	30-70% pollutant reduction 50% nutrient loss reduction (depends on residue and direction of rows and contours)
Fencing	• Reduces erosion • Increases vegetation • Stabilized banks • Improves aquatic habitat	Up to 70% erosion reduction
Grassed Waterways	• Reduces gulleys and channel erosion • Reduces sediment associated nutrient runoff • Increases wildlife habitat	10-50% sediment delivery reduction (broad) 0-10% sediment deliver reduction (narrow)
Strip Cropping	• Reduces erosion and sediment loss • Reduces field loss of sediment associated nutrients	High quality sod strips filter out 75% of eroded soil from cultivated strips

Figure 134 is a priority management map showing the areas of the watershed that may be contributing the most to external phosphorus loadings. The shaded areas are the cells found to be contributing more than one percent of the total watershed load during a 10-year rain event. A 10-year rain event would yield approximately 3.8 inches of rain in a 24-hour period. These results are based on AnnAGNPS modeling. The complete listing of phosphorus and nitrogen loadings for each cell can be found in Appendix J.

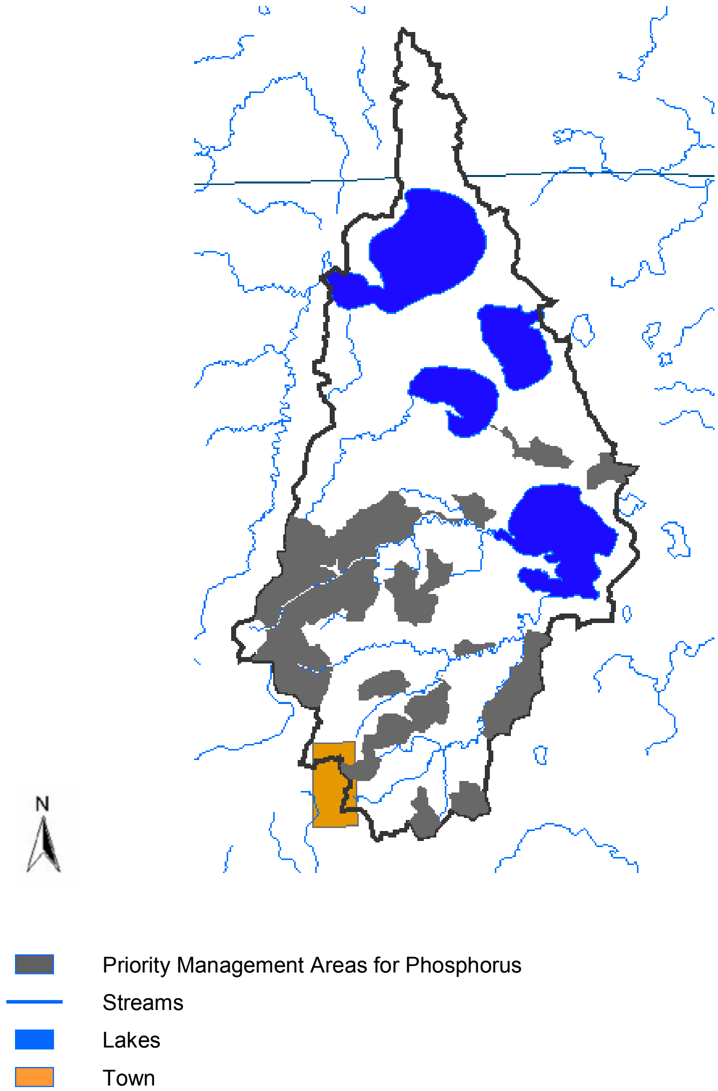


Figure 134. Phosphorus Loadings > 1% of Total Watershed Load Based on a 10-Year Simulation at Current Conditions

Figure 135 is a priority management map showing the areas of the watershed that may be contributing the most to external sediment loadings. The shaded areas are the cells found to be contributing more than one percent of the total watershed load during a 10-year rain event. A 10-year rain event would yield approximately 3.8 inches of rain in a 24-hour period. These results are based on AnnAGNPS modeling. The complete listing of sediment for each cell can be found in Appendix K.

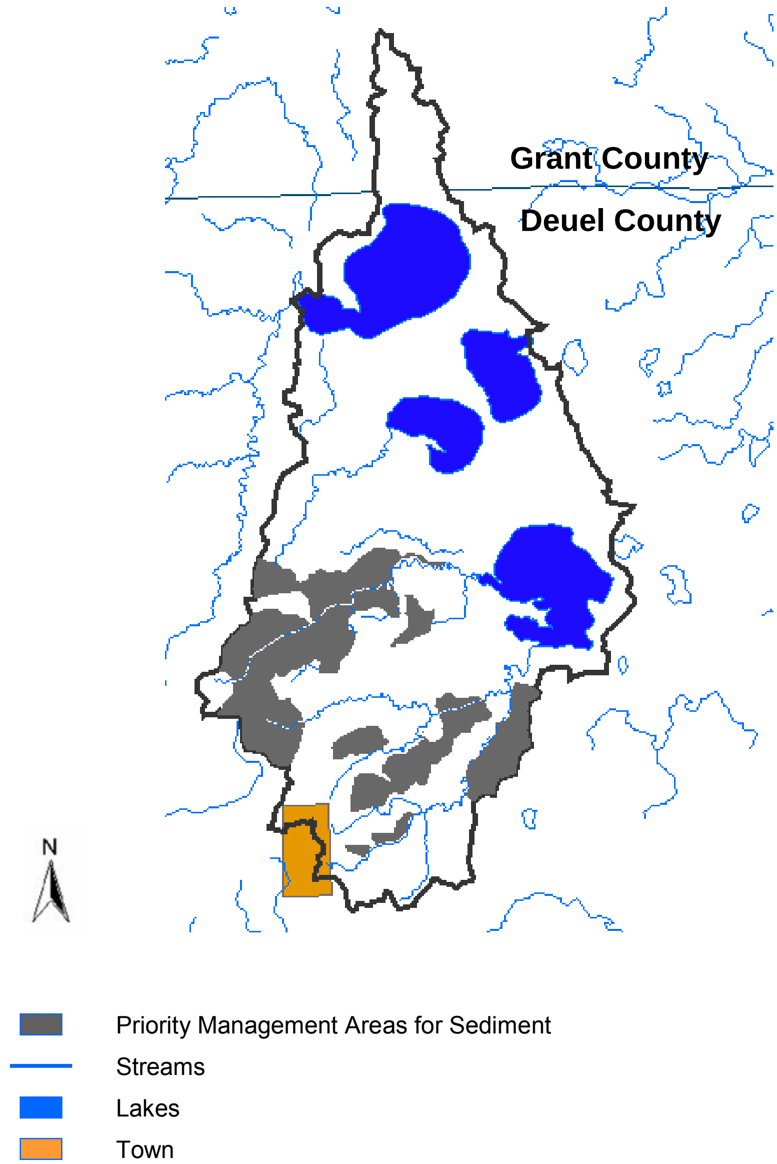


Figure 135. Sediment Loadings > 1% of Total Watershed Load Based on a 10-Year Simulation at Current Conditions

Internal (In-Lake) Management of Sediment and Nutrient Sources

Alternatives for in-lake management of sediment and nutrients are shown in Table 67 (USEPA 1990).

Table 67. In-Lake Management Options Effectiveness and Longevity

Management Option	Effectiveness	Longevity
Aluminum Sulfate	High	Moderate
Dredging (entire lake)	Low	High
Dredging (inlets)	High	high
Aeration	Moderate	Moderate
Sediment Oxidation	Moderate	Moderate
Algicides	Moderate	Poor
Food Chain Manipulation	Moderate	Unknown
Herbicides	Moderate	Low
Weed Harvesting	Moderate	Low
Biological Control (weeds)	Moderate	Moderate

Note: approximate range
High = Excellent (75-100%) Low = Poor (0-25%)
Moderate = Fair to Good (25-75%)

Sediment sealing and sediment removal are probably the most highly effective means of reducing nutrients and sediment. However, both are extremely expensive and will not work unless sources of external loadings are reduced first. It is likely that an aluminum sulfate treatment would not work very effectively with these shallow lakes, as wave action alone can break the seal that this chemical makes with the bottom sediment. Biomanipulation and plant management should be attempted before removal of sediment. If dredging is to be considered, then it is recommended that sediment samples be takes beforehand to determine the areas in need of dredging. Dredging of the entire lake is not recommended.

During the study period, large and numerous carp were spotted in Bullhead Lake. Carp can devastate aquatic vegetation, which reduces aquatic invertebrates, and ultimately reduces the necessary habitat to sustain a good population of game fish. Removal of the carp biomass is recommended. This lake is small enough, that electro-shocking may effectively reduce their numbers. This lake is currently stocked with walleye fingerlings, and should continue to be stocked. The large rocks and gravel along the shoreline of this lake provide good spawning habitat, although much of the aquatic plant life along the shoreline has been devastated by carp. Weed beds should be protected and maintained. This lake is fully equipped for recreational uses and therefore the in-lake quality needed to sustain these uses should be improved and maintained. Additionally, the northeast area of Bullhead Lake is occupied by eight summer cabins. It is recommended septic systems be checked to ensure they are in compliance with regulations and ensure any pipes emitting discharge directly to the lake do not contain detergents or other harmful chemicals.

The status of carp in Round Lake and in School Lake is unknown. However, both of these lakes are stocked with northern pike fry.

It is recommended that agricultural animals be excluded from accessing the lakes, particularity at Round Lake and School Lake. Water quality shows a slight difference in dissolved oxygen levels within Round Lake. Site L8 is on the side of the lake with heavier agriculture influence, the water quality shows this site to have approximately a 0.6 mg/L difference in dissolved oxygen from the rest of the lake. School Lake also showed a similar difference from the agriculturally used side of the lake from the rest of the lake.

At a minimum, it is recommended the first 30 meters of bank along the shoreline of all the lakes should have vegetated buffers; although, > 30 meters is preferred. Establishing buffer zones greater than 30 meters around shallow agricultural lakes have shown to increase numbers of zooplankton (Dodson et. al 2004). Zooplankton has shown to suppress phytoplankton and increase macrophyte abundance. Additionally, Round Lake and School Lake are stocked with northern pike fry, which are a good control for zooplankton populations.

Increased nutrient levels have shown to decrease plant community diversity with an increase in dominance of species such has sago pondweed (Moss et. al 1996). Sago pondweed was found scattered in School Lake. In order to determine if sago pondweed occurs in Round Lake and Bullhead Lake, both are recommended for an aquatic plant survey.

The reduction of nutrients to these lakes should alleviate noxious blue-green problems. Algicides can be used, which are effective, but do not maintain their effectiveness for long periods of time. To facilitate the growth of macrophytes and prevent the blue-green algae from dominating, experimental fish free enclosures could be placed in the vulnerable areas to try to re-colonize the beneficial aquatic plants.

Another method for controlling algae blooms is the placement of organic barley straw. As barley straw decomposes it releases chemicals that act like an algicide. It can take up to eight weeks for barley straw to begin working; therefore, placement of the barley straw on top of the ice in the spring can speed up the process. Once in place and active, it can control algae up to 6 months. Research has shown barley straw prohibits algae growth but does not eradicate already present algae. Rate of application is about 225 pounds (5 bales) per surface acre of water (Lembi 2002).

Although, Wigdale Lake in not actually a lake, according to its beneficial uses, it is suggested that reductions of sediment and nutrients within this lake's watershed will positively impact the reduction of nutrient and sediment loadings to School Lake. Due to its shallow depth, its massive amounts of aquatic vegetation, and secluded nature, Wigdale Lake is more of a wetland. This lake is not currently stocked, nor does it have a public access area for boating or fishing. SD GFP game production land and walk-in areas are located to the northwest and southeast of Wigdale Lake.

PUBLIC INVOLVEMENT AND COORDINATION

STATE AGENCIES

The SD DENR was the primary state agency involved in the completion of this assessment. They provided equipment as well as technical assistance throughout the project. They also provided ambient water quality data.

The SD GFP provided the fish stocking information.

FEDERAL AGENCIES

The Environmental Protection Agency (EPA) provided the primary source of funds for the completion of the assessment of the Big Sioux River watershed.

The United States Geological Survey (USGS) provided maps of the area.

The Natural Resource Conservation Service (NRCS) provided technical assistance

LOCAL GOVERNMENTS, OTHER GROUPS, AND GENERAL PUBLIC

The EDWDD provided the sponsorship that made this project possible on a local basis. In addition to providing administrative sponsorship, EDWDD also provided local matching funds and personnel to complete the assessment.

The Deuel County Conservation District as well as the area lakes association provided valuable information concerning the watershed.

Public involvement consisted of individual meetings with landowners that provided information about landuse in the watershed.

OTHER SOURCES OF FUNDS

In addition to funds supplied by the East Dakota Water Development District (EDWDD) and the Environmental Protection Agency (EPA), additional financial support was provided by the Brookings County Conservation District (BCCD) and the South Dakota Conservation Commission (through a grant to BCCD). The inventory of the animal feeding operations and assessment of the potential environmental risk posed by each was work completed by BCCD using these funds in support of the overall project. The inventory and assessment of the AFOs was funded by EPA 319, EDWDD, and the SDCC grant.

ASPECTS OF THE PROJECT THAT DID NOT WORK WELL

Most of the objectives proposed for the project were met with acceptable methods and in a reasonable amount of time. Landuse modeling was behind schedule due to delays of several months in receiving a workable version of the AnnAGNPS program.

The inlets and outlets to these lakes are very intermittent in nature. Due to this fact, we installed automated samplers to collect water samples during rain events. However, there was not enough funding available to install remote devices to alert us of water sample collection or battery depletion. Because of this a few samples were lost in the process.

Bathymetric maps of these lakes were not available at the time of the study. Therefore, these types of maps can be very useful in understanding how a lake functions. Bathymetric maps provide information in determining surface area, maximum length, maximum width, mean width, maximum depth, mean depth, shoreline length, shoreline development, and volume. Simple bathymetric maps are also useful for planning aquatic plant management strategies. Additionally, anglers also utilize these maps for fishing.

Sampling and analysis methods could be improved in future projects by

- winter sampling the lakes for water quality through the ice
- requiring aquatic plant sampling of all lakes involved in the study
- require sediment samples of the lakes (especially if there is suspected phosphorus problem)
- increasing the number of instantaneous discharge measurements at ungaged sites
- use of remote sensing equipment that notifies technicians by dialup modem when a water sample has automatically been taken or notification of low battery life
- having reference sites to compare data with
- having bathymetric maps completed before the project begins
- yearly ambient water quality monitoring so future studies have a good base of data

Overall, data that was gathered during this project was sufficient enough to make a reasonable determination on the condition of these four lakes and to make realistic suggestions for management options. The ultimate goal is to reduce nutrient and sediment levels in the lakes.

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Appendix A.
Water Quality Grab Sample Data

Water Quality in the School Lake Watershed

Site	Site Name	Date	Time	Runoff ?	Stage	Water Temp C°	Air Temp C°	Conductivity µs/cm	Specific Conductivity µs/cm	Salinity ppb	DO mg/L	pH units	Turbidity NTU	Secchi m	Fecal Coliform counts/100 mL	E-Coli mpn/100 mL	Alkalinity-M mg/L	Alkalinity-P mg/L	TSS mg/L	Total Solids mg/L	Dissolved Solids mg/L	VTSS mg/L	Nitrate mg/L	Ammonia mg/L	TKN mg/L	Total PO4 mg/L	Total Dissolved PO4 mg/L
T49	Wigdale Lake Trib (south)	4/10/03	1230	n	1.24	12.2	21.5	568	741	0.4	5.50	8.00	3	-------	-------	-------	299	0.0	24	514	490	8	<0.1	0.24	2.47	0.448	0.315
T49	Wigdale Lake Trib (south)	5/13/03	1015	n	1.26	10.9	16.5	702	962	0.5	8.38	8.17	1	-------	20	6.3	349	0.0	6	708	702	3	<0.1	<0.02	0.59	0.034	0.061
T49	Wigdale Lake Trib (south)	7/5/03	550	y	0.70	21.0	24.0	523	554	-------	7.60	8.62	1	-------	400	261.0	177	3.0	7	421	414	6	<0.1	<0.02	1.89	0.314	0.278
T49	Wigdale Lake Trib (south)	7/21/03	1230	y	0.66	22.9	22.0	1105	1162	0.6	8.10	7.55	6	-------	4600	>2420	155	0.0	7	846	839	6	0.30	0.78	3.25	0.936	0.740
T49	Wigdale Lake Trib (south)	4/20/04	1701	y	0.80	8.9	9.0	512	745	0.4	8.94	7.69	2	-------	20	38.8	149	0.0	6	1251	1245	4	3.50	<0.02	1.96	0.238	0.175
T49	Wigdale Lake Trib (south)	6/9/04	1030	y	1.10	14.3	15.0	593	749	0.4	-------	7.78	0	-------	30	111.0	298	0.0	4	552	548	4	<0.1	<0.02	2.88	0.280	0.261
T50	Wigdale Lake Trib (west)	4/10/03	1200	n	0.40	11.8	20.5	585	785	0.4	11.90	8.41	6	-------	-------	-------	263	0.0	31	578	547	2	<0.1	<0.02	0.81	0.084	0.071
T50	Wigdale Lake Trib (west)	5/13/03	1115	n	0.60	11.5	17.5	770	1032	0.5	9.09	8.34	1	-------	<10	3.0	307	0.0	6	755	749	1	<0.1	<0.02	0.63	0.038	0.032
T50	Wigdale Lake Trib (west)	6/27/03	1918	y	0.93	25.9	32.0	778	795	-------	4.88	8.32	4	-------	3300	2420.0	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
T50	Wigdale Lake Trib (west)	4/21/04	945	y	0.85	7.9	9.1	546	820	0.4	8.05	7.75	3	-------	20	16.1	208	0.0	6	598	592	4	<0.1	<0.02	0.94	0.132	0.089
T50	Wigdale Lake Trib (west)	5/17/04	1500	y	0.45	17.2	19.0	483	568	0.3	7.59	7.58	3	-------	30	45.0	259	0.0	55	701	646	18	<0.1	<0.02	0.90	0.105	0.079
T50	Wigdale Lake Trib (west)	6/1/04	930	y	-------	11.8	13.0	504	678	0.3	5.17	7.12	25	-------	6300	>2420	238	0.0	24	596	572	6	0.40	0.05	3.50	0.755	0.611
T50	Wigdale Lake Trib (west)	6/9/04	1110	y	0.99	14.8	15.0	677	840	0.4		7.97	7	-------	850	1046.0	280	0.0	13	615	602	9	0.10	<0.02	1.53	0.280	0.223
T51	School Lake Trib	4/10/03	1100	n	0.10	7.1	18.0	520	790	0.4	9.00	8.49	4	-------	-------	-------	246	0.0	5	572	567	<1	<0.1	<0.02	0.83	0.056	0.037
T51	School Lake Trib	5/13/03	1215	n	0.40	12.2	16.5	786	1034	0.5	11.50	8.36	3	-------	<10	2.0	294	0.0	8	741	733	4	<0.1	<0.02	0.56	0.029	0.040
T51	School Lake Trib	6/25/03	945	y	0.28	17.7	16.0	560	651	0.3	3.70	7.90	6	-------	9000	>2420	215	0.0	5	475	470	1	<0.1	<0.02	1.34	0.222	0.162
T51	School Lake Trib	4/20/04	2350	y	0.51	8.4	9.0	593	870	0.4	8.14	7.96	6	-------	60	48.7	216	0.0	10	695	685	4	1.00	0.03	1.32	0.301	0.231
T51	School Lake Trib	5/17/04	1430	y	0.25	16.9	23.0	781	924	0.5	20.00	7.47	6	-------	170	126.0	245	0.0	9	733	724	4	0.30	<0.02	1.01	0.190	0.155
T51	School Lake Trib	6/1/04	1015	y	-------	11.8	12.0	629	843	0.4	6.08	7.12	5	-------	360	411.0	232	0.0	9	633	624	4	1.80	<0.02	1.12	0.125	0.080
T51	School Lake Trib	6/9/04	1200	y	0.63	15.0	15.0	686	848	0.4	-------	8.07	2	-------	1800	>2420	252	0.0	5	637	632	5	0.20	<0.02	0.85	0.072	0.047
L3	Bullhead Lake I (north)	4/22/03	1300	n	2.7m	8.7	14.5	520	752	0.4	10.36	9.02	6	0.70	<10	<1	277	7.0	10	541	531	9	<0.1	<0.02	1.40	0.064	0.031
L3	Bullhead Lake I (north)	5/20/03	1045	n	3.1m	13.4	10.0	589	756	0.4	8.81	9.00	12	0.62	<10	3.1	281	12.0	25	547	522	13	<0.1	<0.02	1.37	0.099	0.041
L3	Bullhead Lake I (north)	6/3/03	1345	n	2.75m	16.0	18.0	634	766	0.4	9.19	8.89	18	0.35												0.115	0.042
L3	Bullhead Lake I (north)	6/17/03	1300	n	2.7m	23.9	28.0	737	758	0.4	8.55	8.25	18	0.30	<10	<1	289	18.0	30	545	515	15	<0.1	<0.02	2.28	0.111	0.040
L3	Bullhead Lake I (north)	6/27/03	1235	n	2.7m	18.9	28.0	687	778	0.4	6.22	8.50	24	0.40												0.143	0.058
L3	Bullhead Lake I (north)	7/15/03	1410	n	2.7m	23.2	26.0	729	758	0.4	6.91	9.61	23	0.40	<10	2.0	295	26.0	42	576	534	20	<0.1	<0.02	2.00	0.129	0.020
L3	Bullhead Lake I (north)	7/29/03	1300	n	-------	24.1	27.0	692	705	0.3	8.80	9.07	21	0.30												0.082	0.020
L3	Bullhead Lake I (north)	8/12/03	1230	n	2.5m	25.2	27.0	697	695	0.3	9.90	8.94	11	0.50	<10	<1	267	38.0	20	516	496	12	<0.1	<0.02	1.53	0.075	0.019
L3	Bullhead Lake I (north)	9/23/03	1100	n	2.5m	13.5	18.0	568	728	0.4	8.12	8.82	16	0.45	<10	1.0	281	13.0	28	528	500	15	<0.1	0.05	2.02	0.097	0.017
L3	Bullhead Lake I (north)	10/22/03	1245	n	2.25m	12.4	20.0	585	771	0.4	13.60	8.47	10	0.45	<10	2.0	284	13.0	24	547	523	14	<0.1	<0.02	2.33	0.099	0.017
L4	Bullhead Lake II (south)	4/22/03	1330	n	3.2m	8.8	12.5	520	756	0.4	10.19	9.00	7	0.60	<10	<1	270	5.0	13	542	529	12	<0.1	<0.02	1.34	0.062	0.031
L4	Bullhead Lake II (south)	5/20/03	1100	n	3.4m	13.9	12.5	595	763	0.4	8.82	8.94	14	0.50	<10	3.0	279	12.0	26	554	528	11	<0.1	<0.02	1.78	0.101	0.041
L4	Bullhead Lake II (south)	6/3/03	1330	n	3.1m	16.0	18.0	631	763	0.4	9.08	8.89	20	0.50												0.125	0.024
L4	Bullhead Lake II (south)	6/17/03	1245	n	3.2m	24.0	28.0	738	752	0.4	7.96	8.34	18	0.30	<10	<1	285	26.0	27	548	521	18	<0.1	<0.02	2.01	0.104	0.017
L4	Bullhead Lake II (south)	6/27/03	1220	n	3m	19.1	28.0	689	777	0.4	5.14	8.51	23	0.40							0					0.156	0.061
L4	Bullhead Lake II (south)	7/15/03	1400	n	3m	23.9	26.0	734	754	0.4	6.31	9.66	21	0.60	<10	<1	289	28.0	40	578	538	22	<0.1	<0.02	2.36	0.134	0.020
L4	Bullhead Lake II (south)	7/29/03	1330	n	-------	24.0	28.0	690	706	0.3	6.28	8.98	20	0.35												0.084	0.019
L4	Bullhead Lake II (south)	8/12/03	1300	n	2.9m	23.8	27.0	687	704	0.3	8.14	8.81	15	0.60	<10	<1	272	35.0	27	521	494	17	<0.1	<0.02	1.78	0.099	0.020
L4	Bullhead Lake II (south)	9/23/03	1130	n	2.6m	13.6	18.0	578	739	0.4	8.05	8.85	19	0.38	<10	1.0	283	13.0	29	531	502	17	<0.1	<0.02	2.12	0.104	0.016
L4	Bullhead Lake II (south)	10/22/03	1330	n	2.65m	12.0	19.0	581	774	0.4	10.40	8.40	12	0.55	20.0	<1	293	16.0	24	543	519	14	<0.1	<0.02	2.05	0.097	0.016
L5	Wigdale Lake	4/22/03	1030	n	1.4m	8.4	17.0	326	479	0.2	12.23	9.20	25	0.40	<10	0.9	219	0.0	48	373	325	40	<0.1	<0.02	2.60	0.205	0.062
L5	Wigdale Lake	5/16/03	1000	n	1.37m	14.0	20.0	384	486	0.2	11.38	9.16	38	0.20	<10	2.0	192	6.0	74	405	331	34	<0.1	<0.02	2.40	0.249	0.052
L5	Wigdale Lake	6/3/03	1100	n	1.2m	14.8	17.0	388	483	0.2	8.32	8.67	55	0.15												0.305	0.088
L5	Wigdale Lake	6/17/03	1000	n	1.3m	24.0	26.0	408	416	0.2	7.75	8.67	16	0.25	<10	1.0	145	10.0	46	326	280	30	<0.1	<0.02	2.99	0.134	0.025
L5	Wigdale Lake	6/27/03	1030	n	1.15m	17.7	23.0	369	429	0.2	7.30	8.95	40	0.15												0.271	0.043
L5	Wigdale Lake	7/15/03	1130	n	1.3m	23.2	28.0	347	358	0.2	8.30	9.36	35	0.15	<10	<1	133	33.0	60	327	267	56	<0.1	0.02	3.77	0.216	0.026
L5	Wigdale Lake	7/30/03	1030	n	1.1m	21.8	26.5	328	351	0.2	6.50	10.20	14	0.30												0.152	0.055
L5	Wigdale Lake	8/12/03	1030	n	1.0m	23.1	24.0	339	351	0.2	9.50	9.34	21	0.30	<10	2.0	132	46.0	34	332	298	30	<0.1	<0.02	3.49	0.153	0.076
L5	Wigdale Lake	9/25/03	1230	n	1.0m	11.2	11.5	284	390	0.2	11.42	9.66	50	0.15	<10	1.0	158	13.0	100	411	311	90	<0.1	<0.02	5.35	0.374	0.072
L5	Wigdale Lake	10/22/03	1100	n	.85m	11.9	15.0	352	469	0.2	12.20	8.55	60	0.15	10.0	3.1	189	9.0	116	460	344	80	<0.1	<0.02	6.29	0.453	0.053
L6	School Lake I (east)	4/22/03	1200	n	2.4m	8.8	13.5	397	581	0.3	9.70	8.77	5	1.30	<10	<1	226	0.0	8	420	412	8	<0.1	<0.02	1.02	0.054	0.034
L6	School Lake I (east)	5/16/03	1145	n	-------	13.8	21.0	458	585	0.3	8.70	8.74	12	0.74	<10	<1	164	0.0	12	426	414	8	<0.1	<0.02	1.00	0.061	0.044
L6	School Lake I (east)	6/3/03	1230	n	2.2m	15.5	18.0	497	607	0.3	8.50	8.57	13	0.50												0.095	0.018
L6	School Lake I (east)	6/17/03	1115	n	2.3m	23.9	28.0	581	590	0.3	6.16	8.20	17	0.40	10.0	1.0	162	4.0	32	448	416	24	<0.1	<0.02	1.46	0.089	0.028
L6	School Lake I (east)	6/27/03	1145	n	2.1m	18.4	26.0	508	576	0.3	6.92	8.65	20	0.30							0					0.140	0.017
L6	School Lake I (east)	7/15/03	1445	n	2.1m	24.4	28.0	522	528	0.3	4.85	9.10	22	0.30	<10	1.0	133	11.0	38	442	404	34	<0.1	<0.02	2.38	0.158	0.034
L6	School Lake I (east)	7/30/03	1200	n	2m	23.0	26.5	460	479	0.2	6.70	9.10	25	0.27												0.160	0.018
L6	School Lake I (east)	8/12/03	1130	n	2m	23.0	26.5	456	474	0.2	7.55	8.88	21	0.25	<10	9.8	116	13.0	36	400	364	34	<0.1	<0.02	2.06	0.178	0.014
L6	School Lake I (east)	9/23/03	1200	n	1.7m	13.0	19.0	397	515	0.3	9.46	9.04	18	0.30	<10	2.0	146	12.0	40	429	389	30	<0.1	<0.02	2.17	0.147	0.016
L6	School Lake I (east)	10/23/03	1045	n	1.7m	11.1	9.0	439	597	0.3	8.24	8.24	10	0.50	10.0	<1	169	2.0	38	476	438	18	<0.1	<0.02	1.87	0.104	.0.027

Water Quality in the School Lake Watershed

Site	Site Name	Date	Time	Runoff ?	Stage	Water Temp C˚	Air Temp C˚	Conductivity µs/cm	Specific Conductivity µs/cm	Salinity ppb	DO mg/L	pH units	Turbidity NTU	Secchi m	Fecal Coliform counts/100mL	E-Coli mpn/100 mL	Alkalinity-M mg/L	Alkalinity-P mg/L	TSS mg/L	Total Solids mg/L	Dissolved Solids mg/L	VTSS mg/L	Nitrate mg/L	Ammonia mg/L	TKN mg/L	Total PO4 mg/L	Total Dissolved PO4 mg/L
L7	School Lake II (west)	4/22/03	1130	n	2.2m	8.9	13.0	392	574	0.3	7.26	8.72	4	1.00	<10	<1	306	0.0	9	428	419	8	<0.1	<0.02	1.08	0.054	0.026
L7	School Lake II (west)	5/16/03	1130	n	-------	13.4	21.0	466	598	0.3	9.18	8.70	9	0.65	<10	<1	163	0.0	14	430	416	8	<0.1	<0.02	1.00	0.066	0.040
L7	School Lake II (west)	6/3/03	1215	n	2.3m	15.8	18.0	494	603	0.3	8.80	8.57	13	0.60												0.094	0.014
L7	School Lake II (west)	6/17/03	1130	n	2.1m	24.8	28.0	576	-------	0.3	6.89	8.13	16	0.60	10.0	5.1	162	2.0	32	445	413	20	<0.1	<0.02	1.37	0.089	0.012
L7	School Lake II (west)	6/27/03	1200	n	2.05m	18.4	26.0	504	577	0.3	7.54	8.59	20	0.20												0.139	0.048
L7	School Lake II (west)	7/15/03	1455	n	2.1m	24.0	28.0	517	528	0.3	5.29	9.06	22	0.25	<10	4.1	136	11.0	42	436	394	42	<0.1	<0.02	2.63	0.145	0.030
L7	School Lake II (west)	7/30/03	1230	n	2m	22.8	26.0	463	483	0.2	6.00	9.01	26	0.27												0.178	0.016
L7	School Lake II (west)	8/12/03	1200	n	2m	24.5	27.0	456	460	0.2	9.75	9.10	22	0.25	<10	6.3	112	18.0	42	400	358	32	<0.1	<0.02	2.23	0.167	0.014
L7	School Lake II (west)	9/23/03	1230	n	1.68m	12.9	18.5	400	519	0.3	10.15	9.06	19	0.30	<10	3.1	147	12.0	44	431	387	32	<0.1	<0.02	2.24	0.161	0.020
L7	School Lake II (west)	10/23/03	1100	n	1.6m	10.8	8.5	442	607	0.3	8.25	8.25	12	0.40	<10	5.2	169	1.0	32	472	440	16	<0.1	<0.02	1.83	0.111	0.020
L8	Round Lake I (southwest)	4/22/03	1400	n	1.6m	9.4	15.0	457	650	0.3	11.00	8.82	10	0.65	10.0	9.8	170	0.0	15	500	485	11	<0.1	<0.02	1.22	0.078	0.044
L8	Round Lake I (southwest)	5/20/03	1230	n	1.8m	13.8	11.0	537	688	0.3	9.07	8.44	10	0.60	10.0	20.5	186	2.0	21	541	520	6	<0.1	<0.02	1.08	0.083	0.050
L8	Round Lake I (southwest)	6/4/03	1035	n	1.75m	15.4	19.0	591	725	0.4	8.10	8.63	7	0.90												0.090	0.031
L8	Round Lake I (southwest)	6/18/03	1130	n	1.8m	23.4	23.5	684	706	0.3	8.29	7.81	30	0.70	30.0	8.6	191	5.0	23	549	526	11	<0.1	<0.02	1.24	0.082	0.020
L8	Round Lake I (southwest)	6/27/03	1315	n	1.7m	18.2	24.0	597	686	0.3	9.20	8.59	9	0.60												0.094	0.016
L8	Round Lake I (southwest)	7/15/03	1300	n	1.6m	22.8	23.5	632	662	0.3	6.58	9.54	13	0.60	10.0	2.0	148	12.0	23	520	497	15	<0.1	<0.02	1.52	0.074	0.019
L8	Round Lake I (southwest)	7/29/03	1400	n	1.45m	24.3	26.0	603	612	0.3	4.48	9.01	16	0.50												0.100	0.016
L8	Round Lake I (southwest)	8/13/03	1030	n	1.3m	23.1	22.0	553	575	0.3	7.64	9.12	13	0.50	40.0	12.2	119	18.0	24	479	455	13	<0.1	<0.02	2.01	0.097	0.022
L8	Round Lake I (southwest)	9/23/03	1000	n	1.25m	11.9	15.5	469	624	-------	8.55	8.72	20	0.35	10.0	8.6	148	4.0	48	517	469	32	<0.1	<0.02	2.22	0.188	0.026
L8	Round Lake I (southwest)	10/23/03	1330	n	1.18m	10.7	12.0	511	704	0.3	7.36	8.27	19	0.33	<10	4.1	169	4.0	38	566	528	18	<0.1	<0.02	2.18	0.160	0.044
L9	Round Lake II (north)	4/22/03	1430	n	2.2m	9.0	16.0	445	641	0.3	10.69	8.80	13	0.60	<10	4.1	168	0.0	20	496	476	14	<0.1	<0.02	1.04	0.078	0.036
L9	Round Lake II (north)	5/20/03	1245	n	2.4m	13.7	14.0	529	676	0.3	8.91	8.45	8	0.80	<10	1.0	175	2.0	12	515	503	3	<0.1	<0.02	1.05	0.068	0.048
L9	Round Lake II (north)	6/4/03	1055	n	3.2m	15.4	19.0	571	699	0.3	7.80	8.53	7	0.90												0.072	0.033
L9	Round Lake II (north)	6/18/03	1200	n	2m	23.3	23.5	685	708	0.3	7.99	7.89	10	0.80	10.0	6.3	189	5.0	22	552	530	14	<0.1	<0.02	1.21	0.074	0.019
L9	Round Lake II (north)	6/27/03	1330	n	2.1m	18.4	24.0	607	695	0.3	7.10	8.67	10	0.60							0					0.082	0.023
L9	Round Lake II (north)	7/15/03	1310	n	2.05m	23.2	23.5	663	685	0.3	8.44	9.19	14	0.50	<10	1.0	170	7.0	21	562	541	17	<0.1	<0.02	1.64	0.095	0.017
L9	Round Lake II (north)	7/29/03	1430	n	2m	23.8	28.0	619	633	0.3	8.07	8.90	17	0.40												0.106	0.012
L9	Round Lake II (north)	8/13/03	1100	n	1.8m	23.1	22.0	577	600	0.3	9.08	8.99	16	0.40	<10	12.1	128	15.0	31	494	463	19	<0.1	<0.02	2.22	0.100	0.016
L9	Round Lake II (north)	9/23/03	1030	n	1.78m	12.5	16.0	470	617	0.3	9.30	9.00	17	0.40	<10	2.0	139	10.0	36	501	465	24	<0.1	<0.02	1.85	0.162	0.028
L9	Round Lake II (north)	10/23/03	1315	n	1.65m	11.9	12.5	508	685	0.3	8.70	8.32	13	0.40	<10	1.0	162	7.0	32	546	514	18	<0.1	<0.02	1.62	0.134	0.094

Note: highlighted samples were chlorophyll-a sampling without full water quality sampling

Appendix B.
WQ Field Data Sheet

SD DENR Water Quality Data

Project	School/Bullhead Lakes Watershed Assessment	Agency Code	5387	Storet Number	
Waterbody	School Lake I (east)	Lake ID		**Station ID**	L6
Site Location		Nearest Town			
Latitude		Longitude			

Sample Date | Sample Time | Samplers | Phone #

Type of Sample: ☐ Grab ☐ Integrated ☐ Composite ☐ Duplicate ☐ Blank

Sample Depth: Surface / Bottom / Composite

Field Analyses			
Water Temp (C)		Secchi Disk (m)	
Air Temp (C)		Dissolved Oxygen (mg/L)	
Conductivity (uohm)		pH (su)	
Flow (cfs)		Turbidity (NTU)	

Field Comments

Visual Observations

Precip N L M H Wind C M S Odor Y N

Septic Y N Dead Fish Y N Film Y N

Channel Width | Total Water Depth

Ice Cover | Water Color

Lab Analyses

Bottle A 1 Liter No Preservative	**Bottle B** 1 Liter 2 mL H2SO4	**Bottle C** Na2SO3	**Bottle D** 100 mL .25 mL H2SO4	**Bottle E** Amber glass bottle	**Metals** Plastic qt. cube or Pb/Cu bottle
Alkalinity (mg/L) ☑	Ammonia (mg/L) ☑	Note: 250 mL of sample required if requesting more than one of the following:	TDPO4 (mg/L) ☑	Caffeine ☐	☐ Total
TSOL (mg/L) ☑	NO3-NO2-N (mg/L) ☑	E Coli* ☑			☐ Total Dissolved
TSSOL (mg/L) ☑	TKN (mg/L) ☑	Entercocci* ☐			☐ Total Recoverable
VTSS (mg/L) ☑	Total P (mg/L) ☑	Fecal Coliform* ☑			Al (ug/L) ☐ Pb (ug/L) ☐
TDSOL (mg/L) ☐	COD (mg/L) ☐	* count/100 mL			Sb (ug/L) ☐ Ni (ug/L) ☐
Na (mg/L) ☐					As (ug/L) ☐ Se (mg/L) ☐
K (mg/L) ☐					Ba (ug/L) ☐ Ag (mg/L) ☐
Cl (mg/L) ☐					Be (ug/L) ☐ Ti (mg/L) ☐
SO4 (mg/L) ☐					B (ug/L) ☐ U (mg/L) ☐
BOD (mg/L) ☐					Cr (ug/L) ☐ Vn (mg/L) ☐
CBOD(mg/L) ☐					Cu (ug/L) ☐ Zn (mg/L) ☐
Nitrate (mg/L) ☐					Hg (ug/L) ☐
Fluoride (mg/L) ☐					
pH (su) ☐	Lab Comments				
Cond (umohs ☐					
HCO3 (mg/L) ☐					**1 Liter NaOH**
CO3 (mg/L) ☐					☐ Cn (mg/L)
Hardness (mg/L) ☐					
Ca (mg/L) ☐					
Mg (mg/L) ☐					
Other:					

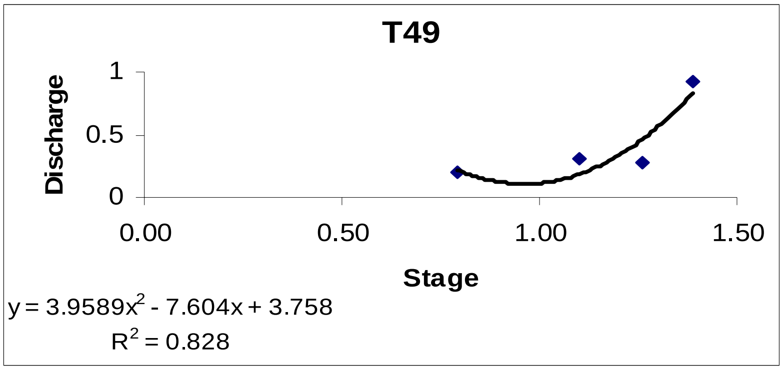
Sample Temp (C) | Date / Time Received | Lab #

Appendix C.
Stage-Discharge Curves

Stage-Discharge Curves

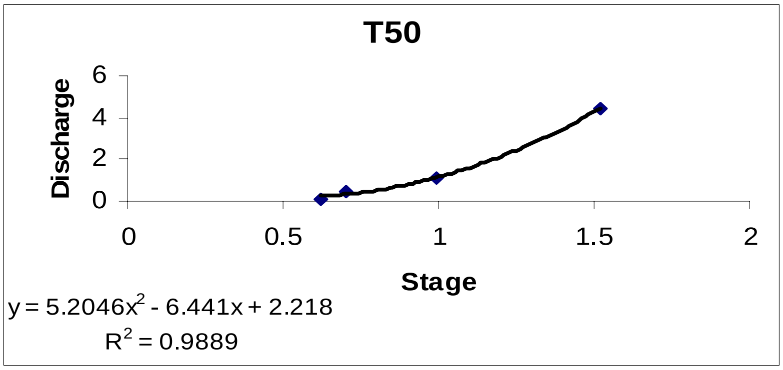
T49

Date	Stage	Discharge
03/21/03	0.79	0.201
06/09/04	1.10	0.309
05/13/03	1.26	0.278
06/11/04	1.39	0.917



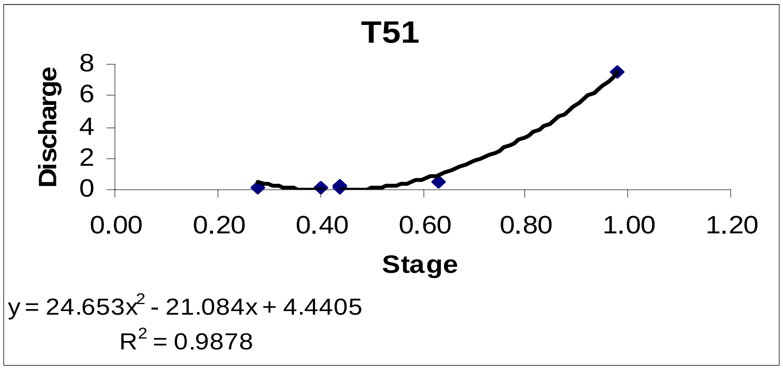
T50

Date	Stage	Discharge
05/16/03	0.62	0.134
03/21/03	0.7	0.49
04/21/04	0.85	0.243
06/09/04	0.99	1.07
06/11/04	1.52	4.446



T51

Date	Stage	Discharge
06/25/03	0.28	0.133
05/16/03	0.40	0.151
03/21/03	0.44	0.145
05/21/03	0.44	0.275
04/21/04	0.51	0.093
06/09/04	0.63	0.448
06/11/04	0.98	7.544



Appendix D.
QA/QC

QA/QC #	Data Type	Site	Name	Date	Time	CFU/100 mL	E-Coli mpn/100mL	Alk-M mg/L	Alk-P mg/L	TSS mg/L	Total Solids mg/L	TDS mg/L	VTSS mg/L	Nitrates mg/L	Ammonia mg/L	TKN mg/L	TPO4 mg/L	TDPO4 mg/L
D100	D1	T50	Wigdale Lake Trib	05/13/03	1115	<10	3	307	0	6	755	749	1	<0.1	<0.02	0.63	0.038	0.032
D100	D2	Dupe		05/13/03	1100	<10	2	304	0	8	758	750	3	<0.1	<0.02	0.77	0.034	0.023
	Absolute Difference					0.00	1.00	3.00	0.00	2	3	1	2	0.00	0.00	0.14	0.004	0.009
	Percent Difference					0.00	33.33	0.98	0.00	25	0	0	67	0.00	0.00	18.18	10.526	28.125
D101	D1	L8	Round Lake I	05/20/03	1230	10.00	21	186	2	21	541	520	6	<0.1	<0.02	1.08	0.083	0.050
D101	D2	Dupe		05/20/03	1145	30.00	44	190	1	14	541	527	3	<0.1	<0.02	1.27	0.082	0.026
	Absolute Difference					20.00	23.00	4.00	1.00	7	0	7	3	0.00	0.00	0.19	0.001	0.024
	Percent Difference					66.67	52.87	2.11	50.00	33	0	1	50	0.00	0.00	14.96	1.205	48.000
D102	D1	L4	Bullhead Lake II	06/17/03	1245	<10	<1	285	26	27	548	521	18	<0.1	<0.02	2.01	0.104	0.017
D102	D2	Dupe		06/17/03	1230	<10	<1	285	26	24	551	527	14	<0.1	<0.02	2.09	0.089	0.014
	Absolute Difference					0.00	0.00	0.00	0.00	3	3	0	4	0.00	0.00	0.08	0.015	0.003
	Percent Difference					0.00	0.00	0.00	0.00	11	1	1	22	0.00	0.00	3.83	14.423	17.647
D104	D1	L8	Round Lake I	07/15/03	1300	10.00	2	148	12	23	520	497	15	<0.1	<0.02	1.52	0.074	0.019
D104	D2	Dupe		07/15/03	1240	10.00	2	144	11	23	517	494	19	<0.1	<0.02	1.67	0.108	0.020
	Absolute Difference					0.00	0.00	4.00	1.00	0	3	3	4	0.00	0.00	0.15	0.034	0.001
	Percent Difference					0.00	0.00	2.70	8.33	0	1	1	21	0.00	0.00	8.98	31.481	5.000
D105	D1	L8	Round Lake I	08/13/03	1030	40.00	12	119	18	24	479	455	13	<0.1	<0.02	2.01	0.097	0.022
D105	D2	Dupe		08/13/03	930	30.00	7	119	17	26	475	449	14	<0.1	<0.02	2.02	0.102	0.035
	Absolute Difference					10.00	4.80	0.00	1.00	2	4	2	1	0.00	0.00	0.01	0.005	0.013
	Percent Difference					25.00	39.34	0.00	5.56	8	1	1	7	0.00	0.00	0.50	4.902	37.143
D107	D1	L5	Wigdale Lake	09/25/03	1230	<10	1	158	13	100	411	311	90	<0.1	<0.02	5.35	0.374	0.072
D107	D2	Dupe		09/25/03	1130	<10	3	159	15	124	408	284	68	<0.1	<0.02	5.47	0.354	0.052
	Absolute Difference					0.00	2.00	1.00	2.00	24	3	27	22	0.00	0.00	0.12	0.020	0.020
	Percent Difference					0.00	66.67	0.63	13.33	19	1	9	24	0.00	0.00	2.19	5.348	27.778
D108	D1	L4	Bullhead Lake II	10/22/03	1330	20.0	<1	293	16	24	543	519	14	<0.1	<0.02	2.05	0.097	0.016
D108	D2	Dupe		10/22/03	1300	<10	2	287	16	23	543	520	13	<0.1	<0.02	2.16	0.098	0.016
	Absolute Difference					20.00	2.00	6.00	0.00	1	0	1	1	0.00	0.00	0.11	-0.001	0.000
	Percent Difference					100.00	100.00	2.05	0.00	4	0	0	7	0.00	0.00	5.09	1.020	0.000
D109	D1	L8	Round Lake I	10/23/03	1330	<10	4.1	169	4	38	566	528	18	<0.1	<0.02	2.18	0.160	0.044
D109	D2	Dupe		10/23/03	1300	<10	5.2	172	4	42	569	527	22	<0.1	<0.02	1.84	0.164	0.074
	Absolute Difference					0.00	1.10	3.00	0.00	4	3	1	4	0.00	0.00	0.34	0.004	0.030
	Percent Difference					0.00	21.15	1.74	0.00	10	1	0	18	0.00	0.00	15.60	2.439	40.541
D110	D1	T50	Wigdale Lake Trib	06/09/04	1110	850.00	1046	280	0	13	615	602	9	0.1000	<0.02	1.53	0.280	0.223
D110	D2	Dupe		06/09/04	1115	960.00	980	280	0	13	614	601	8	0.1000	<0.02	1.56	0.275	0.222
	Absolute Difference					110.00	66.00	0.00	0.00	0	1	1	1	0.00	0.00	0.03	0.005	0.001
	Percent Difference					11.46	6.31	0.00	0.00	0	0	0	11	0.00	0.00	1.92	1.786	0.448

QA/QC #	ID	Date	Time	CFU/ 100mL	E-Coli mpn/100mL	Alk-M mg/L	Alk-P mg/L	TSS mg/L	Total Solids mg/L	VTSS mg/L	Nitrates mg/L	Ammonia mg/L	TKN mg/L	TPO4 mg/L	TDPO4 mg/L
D100	Blank	5/13/03	1030	0	0	0	0	0	0	0	0.000	0.000	0.000	0.011	0.027
D101	Blank	5/16/03	1315	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0.023
D102	Blank	5/20/03	1130	0	0	0	0	1	0	0	0.000	0.000	0.000	0.004	0.020
D103	Blank	6/16/03	930	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0.000
D105	Blank	7/15/03	1230	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0.003
D106	Blank	8/13/03	900	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0.007
D108	Blank	9/25/03	800	0	0	0	0	0	0	0	0.000	0.000	0.000	0.002	0.000
D109	Blank	10/22/03	1315	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0.004
D110	Blank	10/23/03	1300	0	0	0	0	0	0	0	0.000	0.000	0.000	0.009	0.006
D111	Blank	6/9/2004	1130	0	0	0	0	0	0	0	0.100	0.000	0.000	0.000	0.020

Appendix E.
WQ Parameters
FLUX Yearly Loads, Concentrations & CVs

T49

Parameter	Concentration (ppb)	FLUX Load (kg/yr)	CV
SuspSol	10326.23	1048.2	0.369
TotSol	702200.5	71281.7	0.150
DisSol	686493.7	69687.2	0.147
NO2NO3	-------not enough data to run FLUX-------		
NH3N	-------not enough data to run FLUX-------		
Orgntr	-------not enough data to run FLUX-------		
TKN	2038.57	206.9	0.268
TotPO4	417.37	42.4	0.444
TotDisPO4	334.06	33.9	0.420
Fecal	1521790	154479.7	0.899
Ecoli	815771	82810.4	0.877
VTSS	5495.87	557.9	0.176

T50

Parameter	Concentration (ppb)	FLUX Load (kg/yr)	CV
SuspSol	25107.96	1316.7	0.466
TotSol	638947.7	33508.6	0.057
DisSol	613839.8	32191.9	0.055
NO2NO3	-------not enough data to run FLUX-------		
NH3N	-------not enough data to run FLUX-------		
Orgntr	-------not enough data to run FLUX-------		
TKN	846.87	44.4	0.063
TotPO4	97.66	5.1	0.177
TotDisPO4	73.02	3.8	0.123
Fecal	6187	324.5	0.576
Ecoli	1669855	87572.9	0.862
VTSS	6187	324.5	0.576

T51

Parameter	Concentration (ppb)	FLUX Load (kg/yr)	CV
SuspSol	7527.51	23.4	0.21
TotSol	643019.3	1997.9	0.155
DisSol	635491.8	1974.5	0.155
NO2NO3	-------not enough data to run FLUX-------		
NH3N	-------not enough data to run FLUX-------		
Orgntr	-------not enough data to run FLUX-------		
TKN	1080.25	3.4	0.122
TotPO4	184.96	0.6	0.129
TotDisPO4	145.18	0.5	0.113
Fecal	145.18	0.5	0.113
Ecoli	88555860	275153	0.9
VTSS	3015.14	9.4	0.398

Appendix F.
Methodology of the AGNPS Feedlot Model

Feedlot Inventory for the School Lake Watershed Assessment Project

1. Methodology

1.1. Introduction

Objectives outlined in the project summary were to document sources of nonpoint source pollution in the School Lake Watershed to drive a watershed implementation project directed towards improving water quality. Preliminary water quality sampling suggested that impairments to the watershed were in the form of phosphorus and pH. Based on this information, the Brookings County Conservation District drove all township, county, state and interstate roads within the watershed boundaries to locate Animal Feeding Operations (AFOs) and other potential sources of impairments. Since the landuse was largely agricultural, efforts were focused towards un-regulated AFOs which could be a potential source of organic material and nutrient loading during runoff events. Locating and documentation of livestock operations that confined animals became the primary goal. Methods used in the School Lake Watershed Assessment to determine loadings and reductions of nutrients, involved the use of hydrologic zones and flow/load duration intervals. These methods could serve as an integrated measure of runoff between confined livestock operations, manure application and pastured livestock along stream corridors. During large rainfall events, (> 2 inches/24 hours), which is a common occurrence for the area, organic material and fecal coliform bacteria found in the water samples could be the result of all three: confined operations, pastured livestock along stream corridors and manure application. During dry periods, loading from confined operations would be minimal as compared to the potential input from pastured livestock with access to streams and poorly placed manure applications. With this in mind, a key to distinguish between the loading potential of livestock confinement operations vs. pastured livestock and land based manure applications lay in the water quality samples with their respective rainfall data.

1.2. Watershed Delineation

Watershed boundaries were delineated using 1:42,000 topographic maps and ground truthing. Boundary lines were transferred to Arc-View, a computer based software program, to enable future compilation and manipulation of database information spatially. The watershed was later broken down into watersheds using Arc-Info Spatial Analyst with Digital Elevation Models (DEM's) based on the location of lakes and the area that drained into them (See Figure 1). Other layers for the Arc-View database included: Digital Ortho-Quadrangles (DOQ's), Streams, Roads, Soils, Township Boundaries and Section lines.

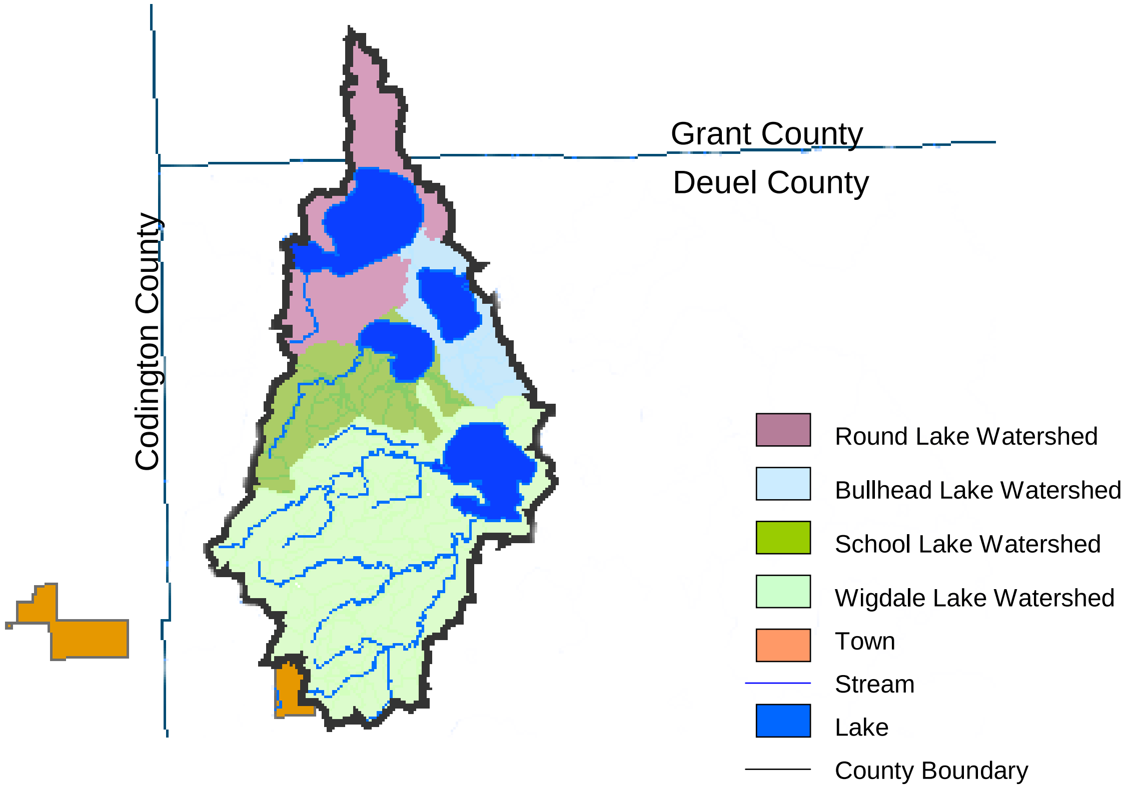


Figure 1. School Lake Watershed Separated into Four Watersheds

1.3. Feedlot Model

All livestock operations within watershed boundaries were highlighted on copies of the latest plat book directories for future contacts. Arc-View was then used to produce an enlarged image (usually on a 1:1,400 scale) of all highlighted operations from 1992 DOQ's that were donated to the project from the Natural Resource Conservation Service (NRCS). These enlarged photos would later serve as templates and data sheets for collection of the operations' information (See Figure 2). Each producer was given a chance to volunteer information about their operation through direct visits, phone calls or letters left in their doors. If a producer was willing to volunteer information for the assessment, they were shown the DOQ printout and asked for data to satisfy inputs for Agricultural Non-Point Source (AGNPS) pollution model's feedlot module.

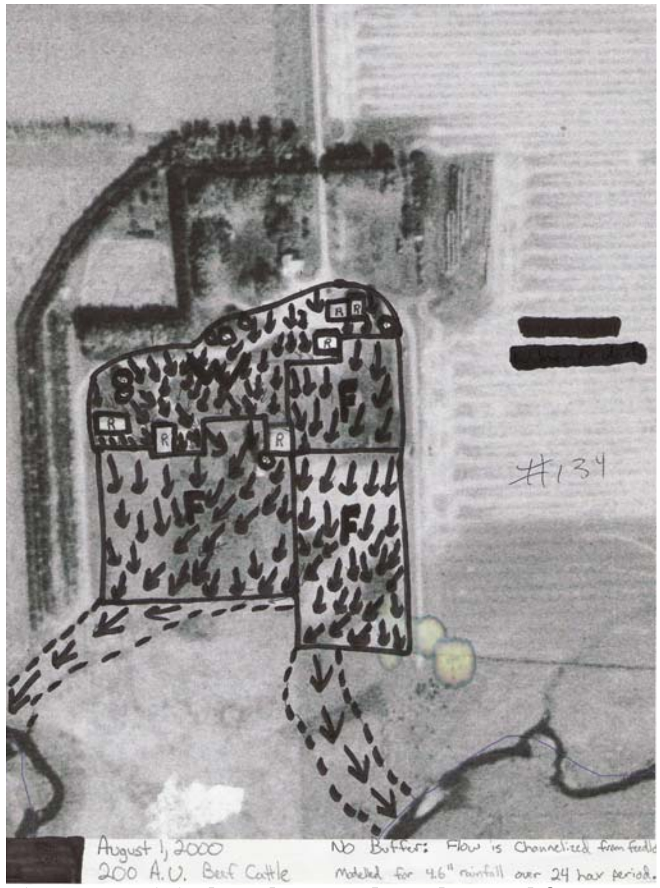


Figure 2. Digital Ortho-Quadrangles used for Operator Surveys

Feeding operations with potential for runoff were assessed using the AGNPS feedlot module. Operations confining <40 animal units (AU's) and exhibiting no potential for runoff were excluded from the model and simply marked on Arc-View as a green dot. There were a few operations confining <40 AU's that were included in the investigation only because they were located within a short distance from a major tributary and exhibited a potential to have runoff occur. Any feeding operation with >40 AU's was modeled using AGNPS. Extra effort was made to contact and interview every producer with a livestock operation personally in the watershed in order to collect good quality information. Gaining trust with producers and access to their operations made this possible.

1.4. Arc-View Model

Geographic Information Systems (GIS) ARC-View was then used to create a watershed distribution map of all operations with their respective information. Four shape files were created to handle the data from the assessments for each of the operations. The first shape file created was the Operator theme. It contained location information as well as summary information that were added back to the theme table after the AGNPS feedlot module was run for all of the operations. The second shape file created was the feedlot theme. It was used to capture the size and number of head each lot contained for each operation. The third shape file was the roof theme. It allowed us to measure the area of roof involved in adding water to the feedlot that AGNPS required as an input. The last shape file was the Watershed theme.

This theme was used to digitize the area and landuse type that comprised the 2a and 3a areas that were also inputs needed in the AGNPS module (See Figure 3).

ArcView Image of Digitized Feedlots

Figure 3. ArcView Image of Digitized Feedlots

Figure 4 shows a simple drawing that illustrates the basic interactions that needed to be taken in consideration when gathering information for the AGNPS feedlot module (USDA AGNPS Feedlot Manual). After digitizing each operation for the operator location; feedlot locations and size; roof area; watershed landuse and size; all required inputs were satisfied for the AGNPS feedlot module.

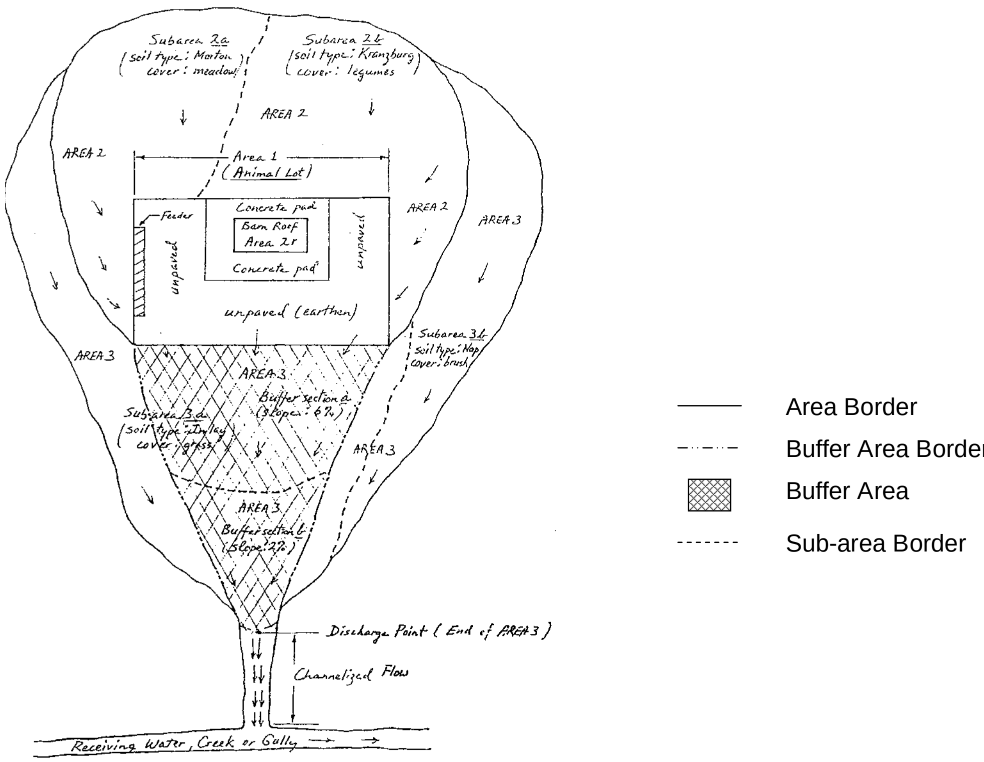


Figure 4. Example of an Animal Lot with Surrounding Watershed

1.5. Combining Arc-View and the AGNPS Feedlot Module

Data was then entered separately for each operation from the Arc-View themes into the AGNPS feedlot module. The module was run to simulate a 25 year 24 hour rainstorm event that was currently a requirement of the general permit for construction of waste storage facilities. Some of the inputs were indexes, so they were standardized to simplify data entry with the thinking that differences in the output would be caused by interactions taking place for each operation's unique situation. After all of the operations were run through AGNPS, the output data was entered back into the operator theme to allow a means of differentiating between feeding operations with a high potential to have runoff from those with little or no potential. AGNPS surface ratings for runoff potential ranged from 0 – 102 for the facilities assessed. AGNPS Phosphorus loading potentials ranged from 0.0 lbs. – 1,574 lbs. for any single animal feeding operation. By using Arc-View, a watershed map could easily be made with feedlots geo-referenced and categorized by a graduated color scheme representing various potential to have runoff occurring. Operations exhibiting low potential were color coded green while intermediate potential sites were given a light green or yellow color. Medium high to high potential operations were color coded orange and red. By coding each operation with a unique value representative of the monitoring site that it eventually flowed to, allowed us to count the number of feedlots in a particular watershed and compare it to water quality data from that point. Depending on runoff potentials of the feedlots affecting any monitoring site, we were able to make a prediction of which sites should exhibit good or poor water quality downstream.

The joining of the AGNPS feedlot module and GIS feedlot databases was used to create a comprehensive watershed model that could simulate various scenarios in order to better predict interactions taking place in the watershed. Managers could use the model as a tool to test “what if” circumstances and make changes to get more desirable outcomes. While working with producers during the implementation phase, simulations could be run to see what effects one might achieve by planning for certain practices (e.g. filters, sediment basins or complete waste management systems). Implementation of best management practices in high pollution potential areas could be the key to improving water quality in the School Lake Watershed.

Appendix G.
Mean, Min, Max, Median, Percent Violation
and
Use Support by Parameter

Mean, Min, Max, Median, Percent Violations & Use Support by Parameter

Water Temperature (C°)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	15	8.9	22.9	13.3	------	------	------
T50	Wigdale Lake Trib (west)	7	14.4	7.9	25.9	11.8	------	------	------
T51	School Lake Trib	7	12.7	7.1	17.7	12.2	------	------	------
L3	Bullhead Lake I (north)	10	17.9	8.7	25.2	17.5	0	0	Full
L4	Bullhead Lake II (south)	10	17.9	8.8	24	17.6	0	0	Full
L5	Wigdale Lake	10	17	8.4	24	16.3	------	------	------
L6	School Lake I (east)	10	17.5	8.8	24.4	17	0	0	Full
L7	School Lake II (west)	10	17.6	8.9	24.8	17.1	0	0	Full
L8	Round Lake I (southwest)	10	17.3	9.4	24.3	16.8	0	0	Full
L9	Round Lake II (north)	10	17.4	9	23.8	16.9	0	0	Full

Air Temperature (C°)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	18	9	24	19	------	------	------
T50	Wigdale Lake Trib (west)	7	18	9.1	32	17.5	------	------	------
T51	School Lake Trib	7	15.6	9	23	16	------	------	------
L3	Bullhead Lake I (north)	10	17.9	10	28	17.5	------	------	------
L4	Bullhead Lake II (south)	10	21.7	12.5	28	22.5	------	------	------
L5	Wigdale Lake	10	20.8	11.5	28	21.5	------	------	------
L6	School Lake I (east)	10	21.6	9	28	23.5	------	------	------
L7	School Lake II (west)	10	21.4	8.5	28	23.5	------	------	------
L8	Round Lake I (southwest)	10	19.2	11	26	20.5	------	------	------
L9	Round Lake II (north)	10	19.9	12.5	28	20.5	------	------	------

Conductivity (µS/cm)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	667	512	1105	581	------	------	------
T50	Wigdale Lake Trib (west)	7	620	483	778	585	------	------	------
T51	School Lake Trib	7	651	520	786	629	------	------	------
L3	Bullhead Lake I (north)	10	644	520	737	661	------	------	------
L4	Bullhead Lake II (south)	10	644	520	738	659	------	------	------
L5	Wigdale Lake	10	353	284	408	350	------	------	------
L6	School Lake I (east)	10	472	397	581	459	------	------	------
L7	School Lake II (west)	10	471	392	576	465	------	------	------
L8	Round Lake I (southwest)	10	563	457	684	572	------	------	------
L9	Round Lake II (north)	10	567	445	685	574	------	------	------

Specific Conductivity (µS/cm)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	819	554	1162	747	0	0	Full
T50	Wigdale Lake Trib (west)	7	788	568	1032	795	0	0	Full
T51	School Lake Trib	7	851	651	1034	848	0	0	Full
L3	Bullhead Lake I (north)	10	747	695	778	757	0	0	Full
L4	Bullhead Lake II (south)	10	749	704	777	755	0	0	Full
L5	Wigdale Lake	10	421	351	486	423	0	0	Full
L6	School Lake I (east)	10	553	474	607	579	0	0	Full
L7	School Lake II (west)	9	550	460	607	574	0	0	Full
L8	Round Lake I (southwest)	10	663	575	725	674	0	0	Full
L9	Round Lake II (north)	10	664	600	708	681	0	0	Full

Salinity (ppt)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	5	0.5	0.4	0.6	0.4	------	------	------
T50	Wigdale Lake Trib (west)	6	0.4	0.3	0.5	0.4	------	------	------
T51	School Lake Trib	7	0.4	0.3	0.5	0.4	------	------	------
L3	Bullhead Lake I (north)	10	0.4	0.3	0.4	0.4	------	------	------
L4	Bullhead Lake II (south)	10	0.4	0.3	0.4	0.4	------	------	------
L5	Wigdale Lake	10	0.2	0.2	0.2	0.2	------	------	------
L6	School Lake I (east)	10	0.3	0.2	0.3	0.3	------	------	------
L7	School Lake II (west)	10	0.3	0.2	0.3	0.3	------	------	------
L8	Round Lake I (southwest)	9	0.3	0.3	0.4	0.3	------	------	------
L9	Round Lake II (north)	10	0.3	0.3	0.3	0.3	------	------	------

Dissolved Oxygen (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	5	7.7	5.5	8.94	8.1	------	------	------
T50	Wigdale Lake Trib (west)	6	7.78	4.88	11.9	7.82	------	------	------
T51	School Lake Trib	6	9.74	3.7	20	8.57	------	------	------
L3	Bullhead Lake I (north)	10	9.05	6.22	13.6	8.81	0	0	Full
L4	Bullhead Lake II (south)	10	8.04	5.14	10.4	8.1	0	0	Full
L5	Wigdale Lake	10	9.49	6.5	12.23	8.91	------	------	------
L6	School Lake I (east)	10	7.68	4.85	9.7	7.9	1	10	Full
L7	School Lake II (west)	10	7.91	5.29	10.15	7.9	0	0	Full
L8	Round Lake I (southwest)	10	8.03	4.48	11	8.2	1	10	Full
L9	Round Lake II (north)	10	8.61	7.1	10.69	8.57	0	0	Full

pH (units)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	7.97	7.55	8.62	7.89	0	0	Full
T50	Wigdale Lake Trib (west)	7	7.93	7.12	8.41	7.97	0	0	Full
T51	School Lake Trib	7	7.91	7.12	8.49	7.96	0	0	Full
L3	Bullhead Lake I (north)	10	8.86	8.25	9.61	8.92	3	30	Not
L4	Bullhead Lake II (south)	10	8.84	8.34	9.66	8.87	1	10	Full
L5	Wigdale Lake	10	9.18	8.55	10.2	9.18	2	20	Full
L6	School Lake I (east)	10	8.73	8.2	9.1	8.76	3	30	Not
L7	School Lake II (west)	10	8.72	8.13	9.1	8.71	4	40	Not
L8	Round Lake I (southwest)	10	8.7	7.81	9.54	8.68	3	30	Not
L9	Round Lake II (north)	10	8.67	7.89	9.19	8.74	1	10	Full

Turbidity (NTU)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	2	0	6	2	------	------	------
T50	Wigdale Lake Trib (west)	7	7	1	25	4	------	------	------
T51	School Lake Trib	7	4	2	6	5	------	------	------
L3	Bullhead Lake I (north)	10	16	6	24	17	------	------	------
L4	Bullhead Lake II (south)	10	17	7	23	19	------	------	------
L5	Wigdale Lake	10	35	14	60	37	------	------	------
L6	School Lake I (east)	10	16	5	25	18	------	------	------
L7	School Lake II (west)	10	16	4	26	18	------	------	------
L8	Round Lake I (southwest)	10	15	7	30	13	------	------	------
L9	Round Lake II (north)	10	12	7	17	13	------	------	------

Fecal Coliform Bacteria (counts/100mL)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	5	1014	20	4600	30	------	------	------
T50	Wigdale Lake Trib (west)	6	1750	ND	6300	440	------	------	------
T51	School Lake Trib	6	1898	ND	9000	265	------	------	------
L3	Bullhead Lake I (north)	7	ND	ND	ND	ND	0	0	Full
L4	Bullhead Lake II (south)	7	ND	ND	20	ND	0	0	Full
L5	Wigdale Lake	7	ND	ND	10	ND	------	------	------
L6	School Lake I (east)	7	ND	ND	10	ND	0	0	Full
L7	School Lake II (west)	7	ND	ND	10	ND	0	0	Full
L8	Round Lake I (southwest)	7	16	ND	40	10	0	0	Full
L9	Round Lake II (north)	7	ND	ND	10	ND	0	0	Full

E. Coli (counts/100mL)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	5	567.4	6.3	>2420	111	------	------	------
T50	Wigdale Lake Trib (west)	6	991.7	3	>2420	545.5	------	------	------
T51	School Lake Trib	6	904.6	2	>2420	268.5	------	------	------
L3	Bullhead Lake I (north)	7	1.2	ND	3.1	1	------	------	------
L4	Bullhead Lake II (south)	7	ND	ND	3	ND	------	------	------
L5	Wigdale Lake	7	1.4	ND	3.1	1	------	------	------
L6	School Lake I (east)	7	2	ND	9.8	1	------	------	------
L7	School Lake II (west)	7	3.4	ND	6.3	4.1	------	------	------
L8	Round Lake I (southwest)	7	9.4	2	20.5	8.6	------	------	------
L9	Round Lake II (north)	7	3.9	1	12.1	2	------	------	------

Alkalinity-M (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	238	149	349	238	0	0	Full
T50	Wigdale Lake Trib (west)	6	259	208	307	261	0	0	Full
T51	School Lake Trib	7	243	515	294	245	0	0	Full
L3	Bullhead Lake I (north)	7	282	267	295	281	0	0	Full
L4	Bullhead Lake II (south)	7	282	270	293	283	0	0	Full
L5	Wigdale Lake	7	167	132	219	158	0	0	Full
L6	School Lake I (east)	7	159	116	226	162	0	0	Full
L7	School Lake II (west)	7	171	112	306	162	0	0	Full
L8	Round Lake I (southwest)	7	162	119	191	169	0	0	Full
L9	Round Lake II (north)	7	162	128	189	168	0	0	Full

Alkalinity-P (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	1	ND	3	ND	------	------	------
T50	Wigdale Lake Trib (west)	6	ND	ND	ND	ND	------	------	------
T51	School Lake Trib	7	ND	ND	ND	ND	------	------	------
L3	Bullhead Lake I (north)	7	18	7	38	13	------	------	------
L4	Bullhead Lake II (south)	7	19	5	35	16	------	------	------
L5	Wigdale Lake	7	17	ND	46	10	------	------	------
L6	School Lake I (east)	7	6	ND	13	4	------	------	------
L7	School Lake II (west)	7	6	ND	18	2	------	------	------
L8	Round Lake I (southwest)	7	6	ND	18	4	------	------	------
L9	Round Lake II (north)	7	7	ND	15	7	------	------	------

Total Suspended Solids (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	9	4	24	7	------	------	------
T50	Wigdale Lake Trib (west)	6	23	6	55	19	------	------	------
T51	School Lake Trib	7	7	5	10	8	------	------	------
L3	Bullhead Lake I (north)	7	26	10	42	25	0	0	Full
L4	Bullhead Lake II (south)	7	27	13	40	27	0	0	Full
L5	Wigdale Lake	7	68	34	116	60	------	------	------
L6	School Lake I (east)	7	29	8	40	36	0	0	Full
L7	School Lake II (west)	7	31	9	44	32	0	0	Full
L8	Round Lake I (southwest)	7	27	15	48	23	0	0	Full
L9	Round Lake II (north)	7	25	12	36	22	0	0	Full

Total Solids (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	715	421	1251	630	------	------	------
T50	Wigdale Lake Trib (west)	6	641	578	755	607	------	------	------
T51	School Lake Trib	7	641	475	741	637	------	------	------
L3	Bullhead Lake I (north)	7	543	516	576	545	------	------	------
L4	Bullhead Lake II (south)	7	545	521	578	543	------	------	------
L5	Wigdale Lake	7	376	326	460	373	------	------	------
L6	School Lake I (east)	7	434	400	476	429	------	------	------
L7	School Lake II (west)	7	435	400	472	431	------	------	------
L8	Round Lake I (southwest)	7	525	479	566	520	------	------	------
L9	Round Lake II (north)	7	524	494	562	515	------	------	------

Total Dissolved Solids (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	706	414	1245	625	0	0	Full
T50	Wigdale Lake Trib (west)	6	618	547	749	597	0	0	Full
T51	School Lake Trib	7	634	470	733	632	0	0	Full
L3	Bullhead Lake I (north)	7	517	496	534	522	0	0	Full
L4	Bullhead Lake II (south)	7	519	494	538	521	0	0	Full
L5	Wigdale Lake	7	308	267	344	311	0	0	Full
L6	School Lake I (east)	7	405	364	438	412	0	0	Full
L7	School Lake II (west)	7	404	358	440	413	0	0	Full
L8	Round Lake I (southwest)	7	497	455	528	497	0	0	Full
L9	Round Lake II (north)	7	499	463	541	503	0	0	Full

Volatile Total Suspended Solids (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	5	3	8	5	------	------	------
T50	Wigdale Lake Trib (west)	6	7	1	18	5	------	------	------
T51	School Lake Trib	7	3	ND	5	4	------	------	------
L3	Bullhead Lake I (north)	7	14	9	20	14	------	------	------
L4	Bullhead Lake II (south)	7	16	11	22	17	------	------	------
L5	Wigdale Lake	7	51	30	90	40	------	------	------
L6	School Lake I (east)	7	22	8	34	24	------	------	------
L7	School Lake II (west)	7	23	8	42	20	------	------	------
L8	Round Lake I (southwest)	7	15	6	32	13	------	------	------
L9	Round Lake II (north)	7	16	3	24	17	------	------	------

Nitrate-Nitrite as Nitrogen (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	0.63	ND	3.5	ND	0	0	Full
T50	Wigdale Lake Trib (west)	6	ND	ND	0.4	ND	0	0	Full
T51	School Lake Trib	7	0.47	ND	1.8	0.2	0	0	Full
L3	Bullhead Lake I (north)	7	ND	ND	ND	ND	0	0	Full
L4	Bullhead Lake II (south)	7	ND	ND	ND	ND	0	0	Full
L5	Wigdale Lake	7	ND	ND	ND	ND	0	0	Full
L6	School Lake I (east)	7	ND	ND	ND	ND	0	0	Full
L7	School Lake II (west)	7	ND	ND	ND	ND	0	0	Full
L8	Round Lake I (southwest)	7	ND	ND	ND	ND	0	0	Full
L9	Round Lake II (north)	7	ND	ND	ND	ND	0	0	Full

Ammonia (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	0.17	ND	0.78	ND	------	------	------
T50	Wigdale Lake Trib (west)	6	ND	ND	0.05	ND	------	------	------
T51	School Lake Trib	7	ND	ND	0.03	ND	------	------	------
L3	Bullhead Lake I (north)	7	ND	ND	0.05	ND	------	------	------
L4	Bullhead Lake II (south)	7	ND	ND	ND	ND	------	------	------
L5	Wigdale Lake	7	ND	ND	0.02	ND	------	------	------
L6	School Lake I (east)	7	ND	ND	ND	ND	------	------	------
L7	School Lake II (west)	7	ND	ND	ND	ND	------	------	------
L8	Round Lake I (southwest)	7	ND	ND	ND	ND	------	------	------
L9	Round Lake II (north)	7	ND	ND	ND	ND	------	------	------

Un-ionized Ammonia (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	0.0031	ND	0.0133	ND	------	------	------
T50	Wigdale Lake Trib (west)	6	ND	ND	0.0001	ND	------	------	------
T51	School Lake Trib	7	0.0001	ND	0.0004	ND	------	------	------
L3	Bullhead Lake I (north)	7	0.001	ND	0.0069	ND	0	0	Full
L4	Bullhead Lake II (south)	7	ND	ND	ND	ND	0	0	Full
L5	Wigdale Lake	7	0.0015	ND	0.0107	ND	0	0	Full
L6	School Lake I (east)	7	ND	ND	ND	ND	0	0	Full
L7	School Lake II (west)	7	ND	ND	ND	ND	0	0	Full
L8	Round Lake I (southwest)	7	ND	ND	ND	ND	0	0	Full
L9	Round Lake II (north)	7	ND	ND	ND	ND	0	0	Full

Total Kjeldahl Nitrogen (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	2.17	0.59	3.25	2.22	------	------	------
T50	Wigdale Lake Trib (west)	6	1.39	0.63	3.5	0.92	------	------	------
T51	School Lake Trib	7	1	0.56	1.34	1.01	------	------	------
L3	Bullhead Lake I (north)	7	1.85	1.37	2.33	2	------	------	------
L4	Bullhead Lake II (south)	7	1.92	1.34	2.36	2.01	------	------	------
L5	Wigdale Lake	7	3.84	2.4	6.29	3.49	------	------	------
L6	School Lake I (east)	7	1.71	1	2.38	1.87	------	------	------
L7	School Lake II (west)	7	1.77	1	2.63	1.83	------	------	------
L8	Round Lake I (southwest)	7	1.64	1.08	2.22	1.52	------	------	------
L9	Round Lake II (north)	7	1.52	1.04	2.22	1.62	------	------	------

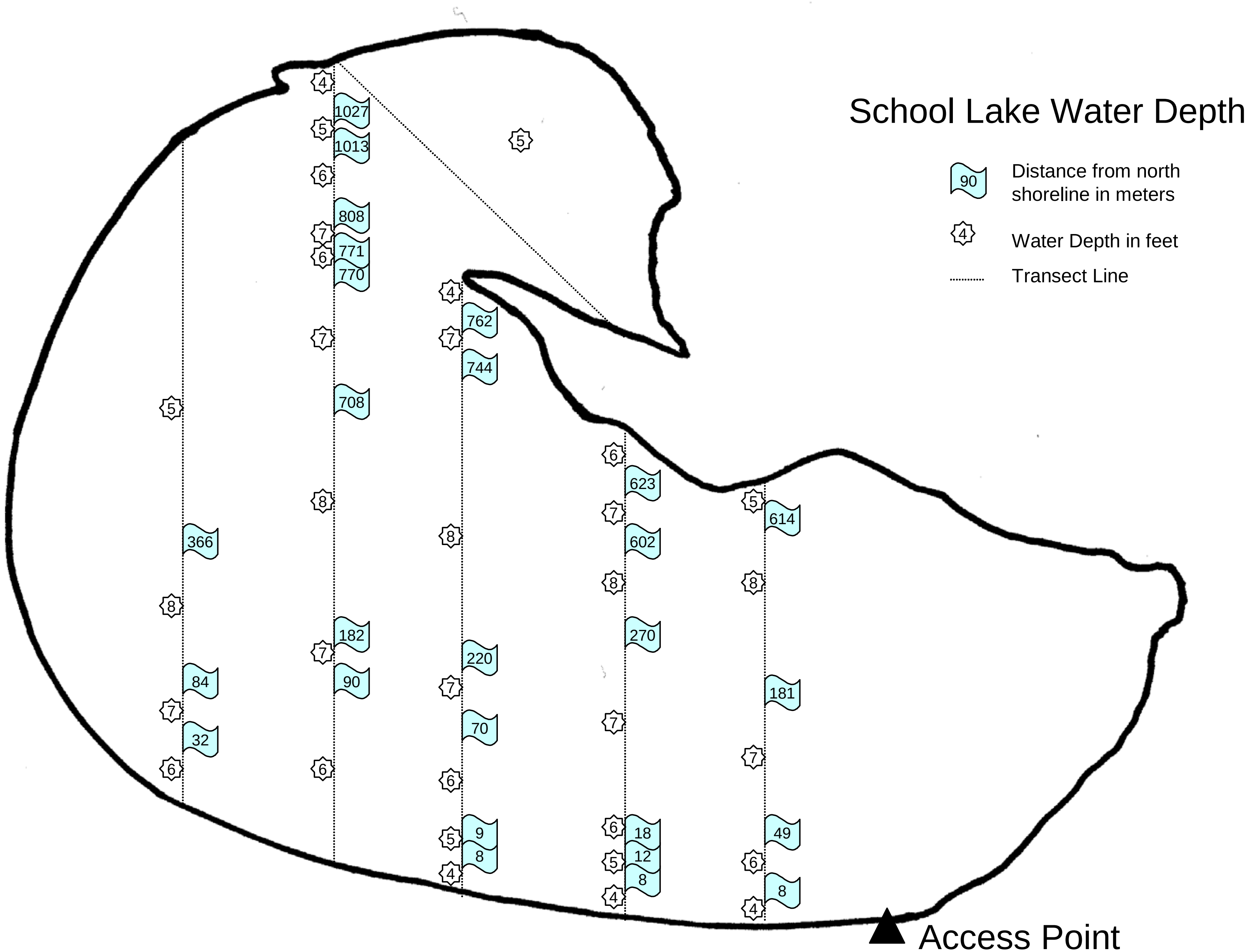
Total Phosphorus (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	0.375	0.034	0.936	0.297	------	------	------
T50	Wigdale Lake Trib (west)	6	0.232	0.038	0.755	0.119	------	------	------
T51	School Lake Trib	7	0.142	0.029	0.301	0.125	------	------	------
L3	Bullhead Lake I (north)	10	0.101	0.064	0.143	0.099	------	------	------
L4	Bullhead Lake II (south)	10	0.107	0.062	0.156	0.103	------	------	------
L5	Wigdale Lake	10	0.251	0.134	0.453	0.233	------	------	------
L6	School Lake I (east)	10	0.119	0.054	0.178	0.122	------	------	------
L7	School Lake II (west)	10	0.12	0.054	0.178	0.125	------	------	------
L8	Round Lake I (southwest)	10	0.105	0.074	0.188	0.092	------	------	------
L9	Round Lake II (north)	10	0.097	0.068	0.162	0.089	------	------	------

Total Dissolved Phosphorus (mg/L)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	6	0.305	0.061	0.74	0.27	------	------	------
T50	Wigdale Lake Trib (west)	6	0.184	0.032	0.611	0.084	------	------	------
T51	School Lake Trib	7	0.107	0.037	0.231	0.08	------	------	------
L3	Bullhead Lake I (north)	10	0.031	0.017	0.058	0.026	------	------	------
L4	Bullhead Lake II (south)	10	0.027	0.016	0.061	0.02	------	------	------
L5	Wigdale Lake	10	0.055	0.025	0.088	0.054	------	------	------
L6	School Lake I (east)	10	0.025	0.014	0.044	0.018	------	------	------
L7	School Lake II (west)	10	0.024	0.012	0.048	0.02	------	------	------
L8	Round Lake I (southwest)	10	0.029	0.016	0.05	0.024	------	------	------
L9	Round Lake II (north)	10	0.033	0.012	0.094	0.026	------	------	------

Secchi Depth (m)									
Site	Name	# of Samples	Mean	Min	Max	Median	Violations of WQ Standards	Percent Violating	Use Support
T49	Wigdale Lake Trib (south)	------	------	------	------	------	------	------	------
T50	Wigdale Lake Trib (west)	------	------	------	------	------	------	------	------
T51	School Lake Trib	------	------	------	------	------	------	------	------
L3	Bullhead Lake I (north)	10	0.4	0.3	0.7	0.4	------	------	------
L4	Bullhead Lake II (south)	10	0.5	0.3	0.6	0.5	------	------	------
L5	Wigdale Lake	10	0.2	0.2	0.4	0.2	------	------	------
L6	School Lake I (east)	10	0.5	0.3	1.3	0.4	------	------	------
L7	School Lake II (west)	10	0.5	0.2	1	0.4	------	------	------
L8	Round Lake I (southwest)	10	0.6	0.3	0.9	0.6	------	------	------
L9	Round Lake II (north)	10	0.6	0.4	0.9	0.6	------	------	------

* ND = non-detect

Appendix H.
School Lake Depth Map


School Lake Water Depth
Distance from north shoreline in meters
Water Depth in feet
Transect Line
Access Point

Appendix I.
Algal Species by Lake

Round Lake

Flagellated	Blue-Green	Diatoms	Non-Motile Green Algae	Unidentified
Chlamydomonas sp.	*Anabaena circinalis*	*Cyclotella meneghiniana*	*Actinastrum hantzschii*	Unidentified algae
Chrysochormulina parva	*Anabaena flos-aquae*	*Cymbella triangulum*	*Ankistrodesmus* sp.	
Cryptomonas sp.	*Anabaena subcylindrica*	*Melosira granulata*	*Closterium aciculare*	
Kephyrion sp.	*Aphanizomenon flos-aquae*	*Nitzschia* sp.	*Coelstrum* sp.	
Mesostigma viridis	*Aphanocapsa* sp.	*Rhizosolenia eriensis*	*Dichotomococcus* sp.	
Phacotus sp.	*Coelosphaerium naegelianum*	*Stephanodiscus minutus*	*Dictyosphaerium pulchellum*	
Rhodomonas minuta	*Cylindrospermum* sp.	Unidentified pennate diatoms	*Elakatothrix* sp.	
Trachelomonas sp.	*Johannesbaptistia pellucida*		*Kirchneriella* sp.	
Unidentified flagellated algae	*Lyngyba contorta*		*Micractinium* sp.	
	Marssoniella elegans		*Oocystis* sp.	
	Merismopedia tenuissima		*Oocystis borgei*	
	Microcystis aeruginosa		*Oocystis parva*	
	Phormidium sp.		*Pediastrum duplex*	
			Quadrigula sp.	
			Selenastrum minimum	
			Staurastrum sp.	

Note: shaded species are considered noxious/nuisance

Bullhead Lake

Flagellated	Blue-Green	Diatoms	Non-Motile Green Algae	Unidentified
Ceratium hirumdinella	*Anabaena circinalis*	*Amphiprora ornata*	*Actinastrum hantzschii*	Unidentified Algae
Chlamydomonas sp.	*Anabaena subsylindrica*	*Cyclotella meneghiniana*	*Ankistrodesmus* sp.	
Chrysochromulina parva	*Anabaenopsis* sp.	*Cymbella triangulum*	*Botryococcus braunii*	
Cryptomonas sp.	*Aphamothece* sp.	*Fragilaric crotonensis*	*Closteriopsis longissima tropica*	
Dinobryon sp.	*Aphanocapsa* sp.	*Melosira ambigua*	*Closterium aciculare*	
Euglena sp.	*Chroococcus* sp.	*Melosira granulata*	*Coelastrum* sp.	
Euglena tripteris	*Chroococcus dispersus*	*Nitzschia* sp.	*Cosmarium* sp.	
Glenodinium sp.	*Cylindrospermum* sp.	*Rhizosolenia eriensis*	*Crucigenia crucifera*	
Glenodinium gymnodinium	*Cylindrospermum minutissimum*	*Stephanodiscus minutus*	*Crucigenia quadrata*	
Glenodinium pernardiforme	*Dactylococcopsis* sp.	*Stephanodiscus niagarae*	*Crucigenia* sp.	
Mallomonas sp.	*Gomphosphaeria* sp.	*Synedra acus*	*Crucigenia tetrapedia*	
Peridinium divergens	*Johannesbaptistia pellucida*		*Dictyosphaerium pulchellum*	
Phacotus sp.	*Lyngbya contorta*		*Elakatothrix* sp.	
Phacus sp.	*Marssoniella elegans*		*Elakatothrix viridis*	
Phacus pleuronectes	*Merismopedia tennissima*		*Geminella* sp.	
Phacus pseudonordstedtii	*Microcystis* sp.		*Golenkinia* sp.	
Platymonas sp.	*Microcystis aeruginosa*		*Kirchneriella* sp.	
Rhodomonas minuta	*Oscillatoria* sp.		*Lagerheimia* sp.	
Trachelomonas sp.	*Oscillatoria agardhii*		*Nephrocytium* sp.	
Unidentified flagellated algae	*Phormidium* sp.		*Oocystis borgei*	
	Phormidium mucicola		*Oocystis parva*	
			Oocystis sp.	
			Oocystis submarina	
			Pediastrum boryanum	
			Pediastrum duplex	
			Pediastrum simplex	
			Pediastrum tetras	
			Scenedesmus abundans	
			Scenedesmus acuminatus	
			Scenedesmus arcuatus	
			Scenedesmus bicaudatus	
			Scenedesmus bijuga	
			Scenedesmus dimorphus	
			Scenedesmus quadricanda	
			Scenedesmus sp.	
			Schroederia judayi	
			Selenastrum minutum	
			Sphaerocystis schroeteri	
			Staurastrum sp.	
			Staurastrum tetracerum	
			Tetraedron caudatum	
			Tetraedron minimum	
			Tetraedron muticum	
			Tetrastrum sp.	
			Tetrastrum elegans	
			Tetrastrum staurogeniaeforme	
			Treubaria sp.	
			Westella botryoides	
			Westella sp.	

Note: shaded species are considered noxious/nuisance

School Lake

Flagellated	Blue-Green	Diatoms	Non-Motile Green Algae	Yellow-Brown Algae	Unidentified Algae
Ceratium hirundinella	*Anabaena circinalis*	*Amphiprora ornata*	*Actinastrum hantzschii*	*Centritractus* sp.	Unidentified Algae
Chlamydomonas sp.	*Anabaena subcylindrica*	*Amphora ovalis*	*Aukistrodesmus* sp.		
Chlorogonium sp.	*Anabaenopsis* sp.	*Cyclotella meneghiniana*	*Botryococcus braunii*		
Chrysochromulina parva	*Aphanocapsa* sp.	*Cymbella triangulum*	*Coelastrum* sp.		
Cryptoglena sp.	*Aphanothece* sp.	*Fragilaria construens*	*Closteriopsis* sp.		
Cryptomonas sp.	*Chroococcus* sp.	*Fragilaria pinnata*	*Closterium aciculare*		
Dinobryon sp.	*Coelosphaerium naegelianum*	*Melosira granulata*	*Cosmarium* sp.		
Dunaliella sp.	*Cylindrospermum* sp.	*Navicula* sp.	*Crucigenia fenestrata*		
Euglena sp.	*Cylindrospermum minutissimum*	*Nitzschia* sp.	*Crucigenia quadrata*		
Euglena polymorpha	*Dactylococcopsis* sp.	*Nitzschia holsatica*	*Crucigenia tetrapedia*		
Euglena tripteris	*Gomphosphaeria* sp.	*Rhizosolenia eriensis*	*Dichotomococcus* sp.		
Glenodinium sp.	*Johannesbaptistia pellucida*	*Stephanodiscus minutus*	*Dictyosphaerium pulchellum*		
Glenodinium gymnodinium	*Lyngbya contorta*	*Surirella* sp.	*Elakatothrix viridis*		
Glenodinium penardiforme	*Merismopedia* sp.	*Synedra acus*	*Geminella* sp.		
Gymmodinium sp.	*Merismopedia elegans*	*Synedra ulna*	*Golenkinia* sp.		
Kephyrion sp.	*Merismopedia tenuissima*		*Kirchneriella* sp.		
Lepocinclis sp.	*Merismopeida* sp.		*Lagerheimia* sp.		
Mallomonas sp.	*Microcystis* sp.		*Nephrocytium* sp.		
Mesostigma sp.	*Microcystis aeruginosa*		*Oocystis* sp.		
Mesostigma viridis	*Oscillatoria agardhii*		*Oocystis borgei*		
Nephroselmis sp.	*Phormidium* sp.		*Oocystis parva*		
Phacotus leuticularis			*Oocystis submarina*		
Phacus sp.			*Pediastrum borganum*		
Phacus helicoides			*Pediastrum duplex*		
Phacus pleuronectus			*Pediastrum simplex*		
Phacus pseudonordstedtii			*Pediastrum tetras*		
Rhodomonas minuta			*Quadrigula* sp.		
Trachelomonas sp.			*Scenedesmus* sp.		
Unidentified flagellated algae			*Scenedesmus abundans*		
			Scenedesmus acuminatus		
			Scenedesmus bicaudatus		
			Scenedesmus bijuga		
			Scenedesmus dimorphus		
			Scenedesmus quadricauda		
			Selenastrum sp.		
			Selenastrum minutum		
			Sphaerocystis schroeteri		
			Staurastrum sp.		
			Staurastrum heterocerum		
			Tetraedron sp.		
			Tetraedron caudatum		
			Tetraedron minimum		
			Tetrastrum elegans		
			Tetrastrum staurogeniaeforme		
			Treubaria sp.		
			Unidentified non-motile algae		

Note: shaded species are considered noxious/nuisance

Wigdale Lake

Flagellated	Blue-Green	Diatoms	Non-Motile Green Algae	Unidentified
Chlamydomonas sp.	*Anabaena circinalis*	*Fragilaria pinnata*	*Actinastrum* sp.	Unidentified algae
Cholrogonium sp.	*Anabaena flos-aquae*	*Melosira granulata*	*Ankistrodesmus* sp.	
Chrysochormulina parva	*Anabaena subcylindrica*	*Navicula* sp.	*Closterium aciculare*	
Cryptomonas sp.	*Anabaenopsis* sp.	*Nitzachia* sp.	*Coelastrum* sp.	
Dinobryon sp.	*Aphanocapsa* sp.	*Nitzschia holsatica*	*Cosmarium* sp.	
Dunaliella sp.	*Chroococlus dispersus*	*Rhizosolenia eriensis*	*Dichotomococcus* sp.	
Euglena sp.	*Dactylococcopsis* sp.	*Stephanodiscus minutus*	*Dictyosphaerium pulihellum*	
Kephyrion sp.	*Johannesbaptistia pellucida*		*Elakatothrix viridis*	
Lepocinclis sp.	*Lyngbya contorta*		*Geminella* sp.	
Nephroselmis sp.	*Merismopedia* sp.		*Kirchneriella* sp.	
Phacotus sp.	*Merismopedia tenuissima*		*Lagerheimia* sp.	
Phacus sp.	*Oscillatoria agardhii*		*Oocystis* sp.	
Phacus pseudonordstedtii	*Phormidium* sp.		*Pediastrum duplex*	
Rhodomonas minuta			*Pediastrum tetras*	
Trachelomonas sp.			*Pediatsrum boryanum*	
Unidentified flagellated algae			*Quadrigula* sp.	
			Scenedesmus sp.	
			Scenedesmus abundans	
			Scenedesmus acuminatus	
			Scenedesmus arcuatus	
			Scenedesmus dimorphus	
			Scenedesmus quadricanda	
			Seleusastrum minutum	
			Staurastrum sp.	
			Tetraedron sp.	
			Tetraedron caudatum	
			Tetraedron minimum	
			Tetrastrum elegrans	
			Tetrastrum staurogeniaseforme	
			Treubaria sp.	

Note: shaded species are considered noxious/nuisance

Appendix J.
AnnAGNPS Results
10-Year Simulation
Phosphorus & Nitrogen

AnnAGNPS Results for a 10-Year Simulation

Current Conditions 10-Year Simulation (sorted by P04 lb/yr)						
Cell	Reach	Area	PO4 lb/yr	% of total	Nitrogen lb/yr	% of total
13202	1320	265	532	8.7	1789	12.7
13552	1355	227	383	6.2	798	5.7
13241	1324	76	209	3.4	130	0.9
13553	1355	193	199	3.2	833	5.9
13523	1352	92	184	3.0	760	5.4
13402	1340	123	173	2.8	552	3.9
13503	1350	101	159	2.6	433	3.1
13342	1334	121	159	2.6	294	2.1
13661	1366	94	138	2.2	483	3.4
13543	1354	56	129	2.1	580	4.1
13401	1340	79	121	2.0	311	2.2
13323	1332	34	118	1.9	485	3.4
13571	1357	75	117	1.9	142	1.0
13542	1354	71	112	1.8	412	2.9
13351	1335	89	108	1.8	186	1.3
13533	1353	93	106	1.7	257	1.8
13471	1347	78	103	1.7	182	1.3
13371	1337	87	99	1.6	156	1.1
13211	1321	81	98	1.6	134	1.0
13291	1329	82	85	1.4	96	0.7
13403	1340	45	83	1.3	333	2.4
13511	1351	79	80	1.3	142	1.0
13063	1306	58	78	1.3	168	1.2
13481	1348	74	78	1.3	174	1.2
13561	1356	76	76	1.2	149	1.1
13141	1314	81	68	1.1	44	0.3
13122	1312	52	68	1.1	48	0.3
13493	1349	68	66	1.1	55	0.4
13051	1305	105	63	1.0	169	1.2
13322	1332	117	58	0.9	249	1.8
13031	1303	80	57	0.9	82	0.6
13681	1368	86	55	0.9	81	0.6
13083	1308	270	54	0.9	53	0.4
13071	1307	83	54	0.9	65	0.5
13043	1304	69	54	0.9	53	0.4
13271	1327	94	53	0.9	71	0.5
13662	1366	232	52	0.8	61	0.4
13691	1369	82	52	0.8	72	0.5
13641	1364	85	47	0.8	116	0.8
13663	1366	232	46	0.7	89	0.6
13411	1341	76	45	0.7	77	0.5
13332	1333	23	44	0.7	71	0.5
13531	1353	75	43	0.7	60	0.4
13301	1330	76	42	0.7	110	0.8
13413	1341	28	41	0.7	74	0.5
13623	1362	203	41	0.7	42	0.3
13651	1365	79	40	0.7	131	0.9
13522	1352	52	39	0.6	139	1.0

Current Conditions 10-Year Simulation (sorted by P04 lb/yr)						
Cell	**Reach**	**Area**	**PO4 lb/yr**	**% of total**	**Nitrogen lb/yr**	**% of total**
13082	1308	251	39	0.6	20	0.1
13683	1368	59	38	0.6	62	0.4
13361	1336	102	38	0.6	19	0.1
13482	1348	22	36	0.6	53	0.4
13682	1368	57	35	0.6	56	0.4
13233	1323	24	35	0.6	181	1.3
13062	1306	14	35	0.6	36	0.3
13263	1326	15	34	0.6	136	1.0
13513	1351	24	33	0.5	117	0.8
13382	1338	222	31	0.5	43	0.3
13483	1348	26	30	0.5	49	0.3
13283	1328	13	29	0.5	91	0.6
13453	1345	19	27	0.4	28	0.2
13372	1337	19	26	0.4	33	0.2
13643	1364	13	25	0.4	32	0.2
13203	1320	183	25	0.4	33	0.2
13502	1350	102	25	0.4	34	0.2
13622	1362	121	25	0.4	25	0.2
13253	1325	16	25	0.4	128	0.9
13222	1322	106	24	0.4	27	0.2
13171	1317	113	22	0.4	20	0.1
13292	1329	17	22	0.4	46	0.3
13362	1336	101	22	0.4	18	0.1
13383	1338	191	21	0.3	39	0.3
13593	1359	107	21	0.3	19	0.1
13472	1347	97	21	0.3	18	0.1
13443	1344	14	20	0.3	20	0.1
13313	1331	19	19	0.3	18	0.1
12973	1297	221	18	0.3	52	0.4
13412	1341	14	18	0.3	27	0.2
13611	1361	88	17	0.3	15	0.1
13142	1314	81	16	0.3	15	0.1
13373	1337	34	16	0.3	10	0.1
13473	1347	48	16	0.3	10	0.1
13061	1306	75	15	0.3	17	0.1
13573	1357	62	15	0.3	10	0.1
13072	1307	23	14	0.2	14	0.1
13642	1364	10	14	0.2	23	0.2
13281	1328	79	13	0.2	19	0.1
13572	1357	60	12	0.2	12	0.1
13011	1301	74	12	0.2	6	0.0
13562	1356	5	11	0.2	56	0.4
13492	1349	26	11	0.2	42	0.3
13532	1353	127	10	0.2	4	0.0
13193	1319	110	10	0.2	13	0.1
13363	1336	99	10	0.2	10	0.1
13232	1323	95	9	0.2	11	0.1
13461	1346	105	9	0.1	8	0.1
13302	1330	12	9	0.1	31	0.2
13563	1356	2	9	0.1	32	0.2

Current Conditions 10-Year Simulation (sorted by P04 lb/yr)						
Cell	Reach	Area	PO4 lb/yr	% of total	Nitrogen lb/yr	% of total
13343	1334	39	8	0.1	7	0.1
13223	1322	57	8	0.1	13	0.1
13633	1363	36	8	0.1	8	0.1
12941	1294	75	8	0.1	1	0.0
13393	1339	4	7	0.1	16	0.1
13242	1324	2	7	0.1	47	0.3
13073	1307	11	7	0.1	9	0.1
12971	1297	80	7	0.1	17	0.1
13601	1360	84	6	0.1	2	0.0
13192	1319	73	6	0.1	8	0.1
13293	1329	6	6	0.1	5	0.0
12981	1298	74	6	0.1	16	0.1
13602	1360	6	6	0.1	16	0.1
13452	1345	30	5	0.1	3	0.0
13352	1335	4	5	0.1	9	0.1
13333	1333	9	5	0.1	2	0.0
13653	1365	5	5	0.1	10	0.1
12942	1294	44	5	0.1	1	0.0
13032	1303	8	4	0.1	5	0.0
12922	1292	28	4	0.1	2	0.0
13273	1327	2	4	0.1	3	0.0
13252	1325	19	4	0.1	5	0.0
13693	1369	6	4	0.1	13	0.1
12972	1297	249	4	0.1	10	0.1
13551	1355	79	3	0.0	1	0.0
13243	1324	13	3	0.0	2	0.0
13303	1330	12	2	0.0	2	0.0
13391	1339	77	2	0.0	1	0.0
13312	1331	25	2	0.0	3	0.0
13692	1369	10	2	0.0	2	0.0
13353	1335	1	2	0.0	2	0.0
13442	1344	11	2	0.0	1	0.0
13603	1360	9	2	0.0	1	0.0
13213	1321	45	1	0.0	1	0.0
13212	1321	34	1	0.0	1	0.0
13632	1363	6	1	0.0	1	0.0
13512	1351	31	1	0.0	1	0.0
13053	1305	6	1	0.0	0	0.0
13282	1328	8	1	0.0	2	0.0
13262	1326	8	1	0.0	2	0.0
13652	1365	2	1	0.0	2	0.0
13462	1346	4	1	0.0	1	0.0
13463	1346	5	0	0.0	0	0.0
13033	1303	5	0	0.0	0	0.0
13583	1358	2	0	0.0	0	0.0
13392	1339	3	0	0.0	0	0.0
13272	1327	2	0	0.0	0	0.0
12912	1291	30	0	0.0	0	0.0
12913	1291	36	0	0.0	0	0.0
12923	1292	27	0	0.0	0	0.0

Current Conditions 10-Year Simulation (sorted by P04 lb/yr)						
Cell	**Reach**	**Area**	**PO4 lb/yr**	**% of total**	**Nitrogen lb/yr**	**% of total**
12932	1293	59	0	0.0	0	0.0
12933	1293	30	0	0.0	0	0.0
12943	1294	94	0	0.0	0	0.0
12952	1295	97	0	0.0	0	0.0
12953	1295	48	0	0.0	0	0.0
12962	1296	46	0	0.0	0	0.0
12963	1296	161	0	0.0	0	0.0
12982	1298	27	0	0.0	0	0.0
12983	1298	155	0	0.0	0	0.0
12992	1299	66	0	0.0	0	0.0
12993	1299	21	0	0.0	0	0.0
13002	1300	25	0	0.0	0	0.0
13003	1300	3	0	0.0	0	0.0
13012	1301	24	0	0.0	0	0.0
13013	1301	1	0	0.0	0	0.0
13022	1302	526	0	0.0	0	0.0
13023	1302	388	0	0.0	0	0.0
13042	1304	42	0	0.0	0	0.0
13052	1305	6	0	0.0	0	0.0
13092	1309	258	0	0.0	0	0.0
13093	1309	109	0	0.0	0	0.0
13103	1310	7	0	0.0	0	0.0
13112	1311	6	0	0.0	0	0.0
13113	1311	15	0	0.0	0	0.0
13121	1312	75	0	0.0	0	0.0
13123	1312	77	0	0.0	0	0.0
13132	1313	157	0	0.0	0	0.0
13133	1313	125	0	0.0	0	0.0
13143	1314	20	0	0.0	0	0.0
13152	1315	147	0	0.0	0	0.0
13153	1315	9	0	0.0	0	0.0
13162	1316	52	0	0.0	0	0.0
13163	1316	15	0	0.0	0	0.0
13172	1317	76	0	0.0	0	0.0
13173	1317	22	0	0.0	0	0.0
13182	1318	203	0	0.0	0	0.0
13183	1318	47	0	0.0	0	0.0
13421	1342	80	0	0.0	0	0.0
13422	1342	2	0	0.0	0	0.0
13432	1343	145	0	0.0	0	0.0
13433	1343	73	0	0.0	0	0.0
13582	1358	13	0	0.0	0	0.0
13591	1359	74	0	0.0	0	0.0
13592	1359	22	0	0.0	0	0.0
13613	1361	7	0	0.0	0	0.0
13672	1367	38	0	0.0	0	0.0
13673	1367	50	0	0.0	0	0.0
Watershed	**Totals**	13494	6151		14088	

** Note: bolded cell numbers are cells with feedlots

Appendix K.
AnnAGNPS Results
10-Year Simulation
Sediment

AnnAGNPS Results for a 10-Year Simulation

Current conditions 10-Year Simulation (sorted by subtotals of sediment tons/year)									
Cell	**Reach**	**Area**	**Clay**	**Silt**	**Sand**	**Sm. Agg.**	**Lg. Agg.**	**Subtotals**	**% of Total**
13202	1320	265	38.69	51.76	33.85	0	0	124.30	12.49
13553	1355	193	22.72	44.35	9.78	0	0	76.85	7.72
13523	1352	92	20.69	39.54	7.41	0	0	67.65	6.80
13552	1355	227	18.57	28.74	7.62	0	0	54.94	5.52
13543	1354	56	16.19	30.80	5.78	0	0	52.78	5.30
13402	1340	123	14.26	26.50	4.74	0	0	45.50	4.57
13661	1366	94	12.95	24.62	4.13	0	0	41.70	4.19
13323	1332	34	11.80	23.76	1.37	0	0	36.93	3.71
13542	1354	71	11.33	21.01	3.42	0	0	35.76	3.59
13503	1350	101	10.09	19.13	3.34	0	0	32.56	3.27
13403	1340	45	8.67	17.41	1.08	0	0	27.16	2.73
13322	1332	117	7.28	13.99	2.99	0	0	24.26	2.44
13401	1340	79	7.05	13.04	2.21	0	0	22.30	2.24
13533	1353	93	6.27	11.77	1.86	0	0	19.90	2.00
13233	1323	24	5.54	9.06	2.28	0	0	16.88	1.70
13342	1334	121	5.27	7.01	3.65	0	0	15.93	1.60
13351	1335	89	4.09	6.46	1.80	0	0	12.36	1.24
13263	1326	15	4.03	6.44	1.78	0	0	12.25	1.23
13481	1348	74	3.79	7.03	1.25	0	0	12.07	1.21
13253	1325	16	3.94	6.33	1.54	0	0	11.80	1.19
13522	1352	52	3.36	6.49	1.37	0	0	11.23	1.13
13371	1337	87	3.54	5.53	1.34	0	0	10.40	1.05
13513	1351	24	3.14	6.03	1.03	0	0	10.20	1.02
13561	1356	76	3.08	5.74	1.00	0	0	9.83	0.99
13651	1365	79	2.99	5.70	0.94	0	0	9.62	0.97
13063	1306	58	3.22	4.20	2.21	0	0	9.62	0.97
13511	1351	79	3.04	5.66	0.92	0	0	9.62	0.97
13471	1347	78	2.94	3.84	2.28	0	0	9.05	0.91
13051	1305	105	2.95	3.87	2.07	0	0	8.89	0.89
13301	1330	76	2.59	4.09	1.00	0	0	7.69	0.77
13031	1303	80	2.13	3.38	2.06	0	0	7.58	0.76
13283	1328	13	2.51	3.90	1.03	0	0	7.44	0.75
13062	1306	14	1.48	2.11	3.13	0	0	6.71	0.67
13332	1333	23	1.89	2.65	1.46	0	0	5.99	0.60
13211	1321	81	1.98	2.52	1.38	0	0	5.88	0.59
13641	1364	85	1.86	2.37	1.44	0	0	5.67	0.57
13242	1324	2	1.50	2.95	0.68	0	0	5.12	0.51
13562	1356	5	1.58	3.21	0.21	0	0	5.00	0.50
13291	1329	82	1.75	2.58	0.63	0	0	4.96	0.50
13071	1307	83	1.35	2.08	1.24	0	0	4.68	0.47
13411	1341	76	1.32	1.79	1.56	0	0	4.67	0.47
13482	1348	22	1.19	2.03	1.42	0	0	4.64	0.47
13571	1357	75	1.45	1.88	1.09	0	0	4.42	0.44
13492	1349	26	1.16	2.34	0.18	0	0	3.68	0.37
13483	1348	26	1.17	2.33	0.15	0	0	3.64	0.37
13292	1329	17	1.11	1.80	0.49	0	0	3.40	0.34
13413	1341	28	1.08	1.42	0.82	0	0	3.31	0.33
13241	1324	76	1.45	1.48	0.25	0	0	3.17	0.32
13122	1312	52	0.87	1.34	0.85	0	0	3.07	0.31

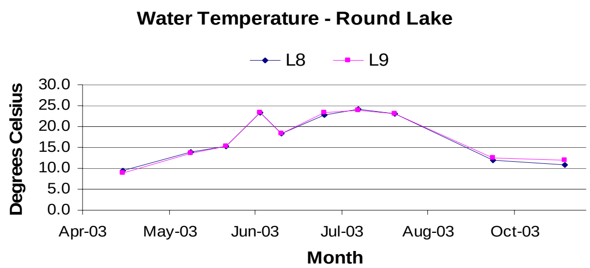
Current conditions 10-Year Simulation (sorted by subtotals of sediment tons/year)									
Cell	**Reach**	**Area**	**Clay**	**Silt**	**Sand**	**Sm. Agg.**	**Lg. Agg.**	**Subtotals**	**% of Total**
13141	1314	81	1.00	1.28	0.56	0	0	2.84	0.28
13563	1356	2	0.86	1.77	0.06	0	0	2.69	0.27
13382	1338	222	0.73	1.30	0.55	0	0	2.58	0.26
13043	1304	69	0.64	1.09	0.82	0	0	2.54	0.26
13383	1338	191	0.68	1.35	0.35	0	0	2.38	0.24
13681	1368	86	0.69	0.92	0.74	0	0	2.34	0.24
13271	1327	94	0.70	1.17	0.38	0	0	2.25	0.23
13602	1360	6	0.53	0.92	0.78	0	0	2.23	0.22
13662	1366	232	0.60	0.82	0.79	0	0	2.21	0.22
13531	1353	75	0.68	1.13	0.37	0	0	2.19	0.22
13683	1368	59	0.64	0.86	0.69	0	0	2.18	0.22
13453	1345	19	0.59	1.00	0.59	0	0	2.18	0.22
13663	1366	232	0.62	1.23	0.30	0	0	2.15	0.22
13302	1330	12	0.64	0.85	0.47	0	0	1.95	0.20
13682	1368	57	0.54	0.72	0.58	0	0	1.83	0.18
13203	1320	183	0.50	0.89	0.36	0	0	1.75	0.18
13372	1337	19	0.52	0.82	0.22	0	0	1.57	0.16
13691	1369	82	0.53	0.64	0.30	0	0	1.47	0.15
13643	1364	13	0.56	0.67	0.20	0	0	1.43	0.14
13412	1341	14	0.42	0.86	0.06	0	0	1.33	0.13
13393	1339	4	0.35	0.76	0.09	0	0	1.20	0.12
13642	1364	10	0.36	0.49	0.32	0	0	1.17	0.12
13281	1328	79	0.33	0.58	0.23	0	0	1.15	0.12
13623	1362	203	0.26	0.35	0.35	0	0	0.96	0.10
13083	1308	270	0.25	0.35	0.35	0	0	0.95	0.10
13222	1322	106	0.26	0.35	0.34	0	0	0.95	0.10
12973	1297	221	0.24	0.35	0.35	0	0	0.94	0.09
13502	1350	102	0.25	0.34	0.34	0	0	0.93	0.09
13223	1322	57	0.25	0.45	0.19	0	0	0.89	0.09
13693	1369	6	0.24	0.32	0.17	0	0	0.74	0.07
13653	1365	5	0.21	0.43	0.06	0	0	0.70	0.07
13072	1307	23	0.20	0.29	0.14	0	0	0.63	0.06
13073	1307	11	0.16	0.27	0.17	0	0	0.61	0.06
13193	1319	110	0.16	0.32	0.09	0	0	0.58	0.06
13622	1362	121	0.15	0.21	0.21	0	0	0.56	0.06
13443	1344	14	0.17	0.35	0.02	0	0	0.54	0.05
13061	1306	75	0.14	0.19	0.19	0	0	0.51	0.05
13352	1335	4	0.17	0.22	0.11	0	0	0.50	0.05
13082	1308	251	0.11	0.18	0.18	0	0	0.47	0.05
13192	1319	73	0.09	0.18	0.05	0	0	0.33	0.03
13032	1303	8	0.08	0.13	0.08	0	0	0.29	0.03
13313	1331	19	0.09	0.18	0.01	0	0	0.29	0.03
13493	1349	68	0.09	0.18	0.01	0	0	0.28	0.03
13232	1323	95	0.07	0.14	0.04	0	0	0.25	0.02
13252	1325	19	0.06	0.09	0.09	0	0	0.24	0.02
12971	1297	80	0.05	0.07	0.07	0	0	0.20	0.02
13572	1357	60	0.05	0.07	0.07	0	0	0.19	0.02
13633	1363	36	0.05	0.07	0.07	0	0	0.19	0.02
13473	1347	48	0.05	0.11	0.02	0	0	0.18	0.02
13171	1317	113	0.05	0.07	0.07	0	0	0.18	0.02

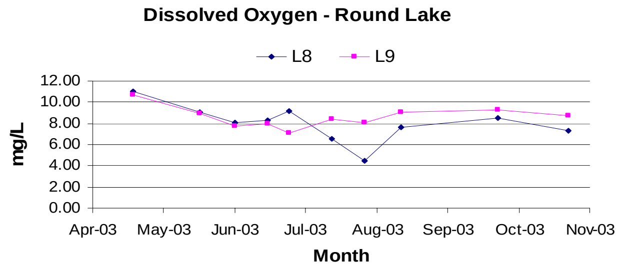
Current conditions 10-Year Simulation (sorted by subtotals of sediment tons/year)									
Cell	**Reach**	**Area**	**Clay**	**Silt**	**Sand**	**Sm. Agg.**	**Lg. Agg.**	**Subtotals**	**% of Total**
13593	1359	107	0.05	0.07	0.07	0	0	0.18	0.02
12981	1298	74	0.05	0.07	0.07	0	0	0.18	0.02
13573	1357	62	0.04	0.06	0.07	0	0	0.17	0.02
13472	1347	97	0.05	0.06	0.06	0	0	0.17	0.02
13282	1328	8	0.05	0.10	0.01	0	0	0.16	0.02
13142	1314	81	0.04	0.06	0.06	0	0	0.15	0.02
13362	1336	101	0.04	0.06	0.05	0	0	0.15	0.01
13011	1301	74	0.03	0.06	0.06	0	0	0.14	0.01
13293	1329	6	0.05	0.07	0.02	0	0	0.14	0.01
13461	1346	105	0.04	0.07	0.02	0	0	0.13	0.01
13611	1361	88	0.03	0.04	0.04	0	0	0.12	0.01
13262	1326	8	0.04	0.07	0.01	0	0	0.11	0.01
13343	1334	39	0.03	0.04	0.04	0	0	0.11	0.01
13312	1331	25	0.03	0.06	0.02	0	0	0.11	0.01
13652	1365	2	0.03	0.04	0.02	0	0	0.09	0.01
12922	1292	28	0.02	0.03	0.03	0	0	0.08	0.01
13353	1335	1	0.02	0.03	0.02	0	0	0.07	0.01
13363	1336	99	0.02	0.04	0.01	0	0	0.07	0.01
13452	1345	30	0.01	0.02	0.02	0	0	0.06	0.01
13273	1327	2	0.02	0.02	0.01	0	0	0.05	0.01
13361	1336	102	0.02	0.03	0	0	0	0.05	0.00
12972	1297	249	0.02	0.03	0.01	0	0	0.05	0.00
13303	1330	12	0.01	0.02	0.01	0	0	0.04	0.00
13243	1324	13	0.01	0.01	0.01	0	0	0.04	0.00
13632	1363	6	0.01	0.01	0.01	0	0	0.03	0.00
13692	1369	10	0.01	0.01	0.01	0	0	0.03	0.00
13442	1344	11	0.01	0.01	0.01	0	0	0.02	0.00
12941	1294	75	0.01	0.01	0.01	0	0	0.02	0.00
13462	1346	4	0.01	0.01	0	0	0	0.02	0.00
12942	1294	44	0	0.01	0.01	0	0	0.02	0.00
13373	1337	34	0	0.01	0.01	0	0	0.01	0.00
13603	1360	9	0	0.01	0.01	0	0	0.01	0.00
13463	1346	5	0	0.01	0	0	0	0.01	0.00
13532	1353	127	0	0	0	0	0	0.01	0.00
13333	1333	9	0	0	0	0	0	0.01	0.00
13272	1327	2	0	0	0	0	0	0.00	0.00
13601	1360	84	0	0	0	0	0	0.00	0.00
13551	1355	79	0	0	0	0	0	0.00	0.00
13033	1303	5	0	0	0	0	0	0.00	0.00
13212	1321	34	0	0	0	0	0	0.00	0.00
13213	1321	45	0	0	0	0	0	0.00	0.00
12912	1291	30	0	0	0	0	0	0.00	0.00
12913	1291	36	0	0	0	0	0	0.00	0.00
12923	1292	27	0	0	0	0	0	0.00	0.00
12932	1293	59	0	0	0	0	0	0.00	0.00
12933	1293	30	0	0	0	0	0	0.00	0.00
12943	1294	94	0	0	0	0	0	0.00	0.00
12952	1295	97	0	0	0	0	0	0.00	0.00
12953	1295	48	0	0	0	0	0	0.00	0.00
12962	1296	46	0	0	0	0	0	0.00	0.00

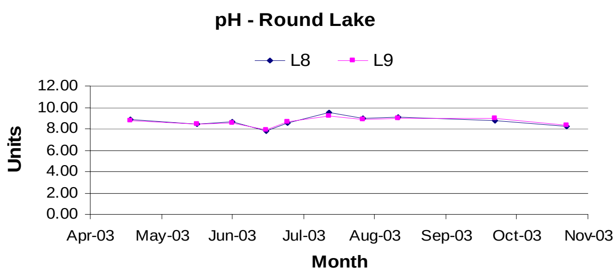
Current conditions 10-Year Simulation (sorted by subtotals of sediment tons/year)									
Cell	**Reach**	**Area**	**Clay**	**Silt**	**Sand**	**Sm. Agg.**	**Lg. Agg.**	**Subtotals**	**% of Total**
12963	1296	161	0	0	0	0	0	0.00	0.00
12982	1298	27	0	0	0	0	0	0.00	0.00
12983	1298	155	0	0	0	0	0	0.00	0.00
12992	1299	66	0	0	0	0	0	0.00	0.00
12993	1299	21	0	0	0	0	0	0.00	0.00
13002	1300	25	0	0	0	0	0	0.00	0.00
13003	1300	3	0	0	0	0	0	0.00	0.00
13012	1301	24	0	0	0	0	0	0.00	0.00
13013	1301	1	0	0	0	0	0	0.00	0.00
13022	1302	526	0	0	0	0	0	0.00	0.00
13023	1302	388	0	0	0	0	0	0.00	0.00
13042	1304	42	0	0	0	0	0	0.00	0.00
13052	1305	6	0	0	0	0	0	0.00	0.00
13053	1305	6	0	0	0	0	0	0.00	0.00
13092	1309	258	0	0	0	0	0	0.00	0.00
13093	1309	109	0	0	0	0	0	0.00	0.00
13103	1310	7	0	0	0	0	0	0.00	0.00
13112	1311	6	0	0	0	0	0	0.00	0.00
13113	1311	15	0	0	0	0	0	0.00	0.00
13121	1312	75	0	0	0	0	0	0.00	0.00
13123	1312	77	0	0	0	0	0	0.00	0.00
13132	1313	157	0	0	0	0	0	0.00	0.00
13133	1313	125	0	0	0	0	0	0.00	0.00
13143	1314	20	0	0	0	0	0	0.00	0.00
13152	1315	147	0	0	0	0	0	0.00	0.00
13153	1315	9	0	0	0	0	0	0.00	0.00
13162	1316	52	0	0	0	0	0	0.00	0.00
13163	1316	15	0	0	0	0	0	0.00	0.00
13172	1317	76	0	0	0	0	0	0.00	0.00
13173	1317	22	0	0	0	0	0	0.00	0.00
13182	1318	203	0	0	0	0	0	0.00	0.00
13183	1318	47	0	0	0	0	0	0.00	0.00
13391	1339	77	0	0	0	0	0	0.00	0.00
13392	1339	3	0	0	0	0	0	0.00	0.00
13421	1342	80	0	0	0	0	0	0.00	0.00
13422	1342	2	0	0	0	0	0	0.00	0.00
13432	1343	145	0	0	0	0	0	0.00	0.00
13433	1343	73	0	0	0	0	0	0.00	0.00
13512	1351	31	0	0	0	0	0	0.00	0.00
13582	1358	13	0	0	0	0	0	0.00	0.00
13583	1358	2	0	0	0	0	0	0.00	0.00
13591	1359	74	0	0	0	0	0	0.00	0.00
13592	1359	22	0	0	0	0	0	0.00	0.00
13613	1361	7	0	0	0	0	0	0.00	0.00
13672	1367	38	0	0	0	0	0	0.00	0.00
13673	1367	50	0	0	0	0	0	0.00	0.00
Totals		13494	311.309	533.679	150.474	0	0	995.46	

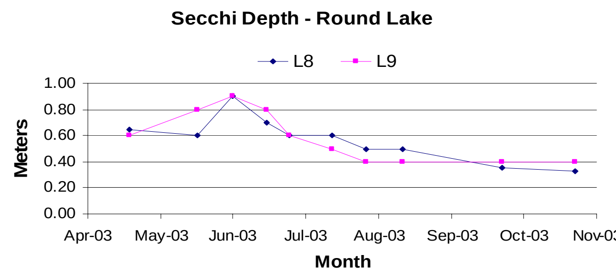
** Note: bolded cell numbers are cells with feedlots

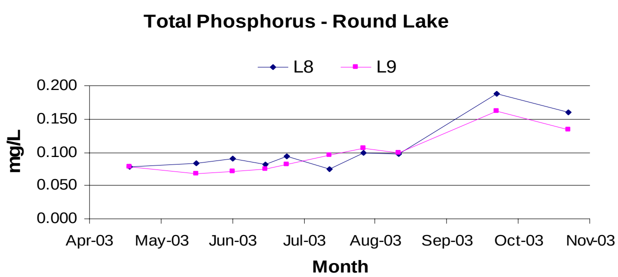
Appendix L.
Round Lake WQ Graphs

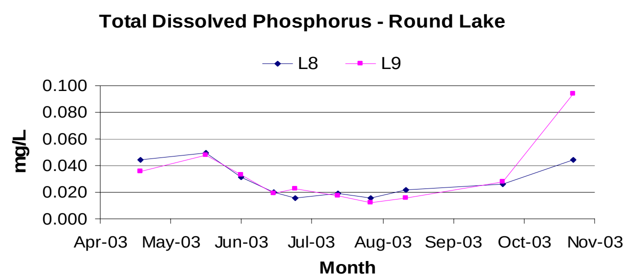

Water Temperature - Round Lake
L8
L9
Degrees Celsius
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Oct-03
Month

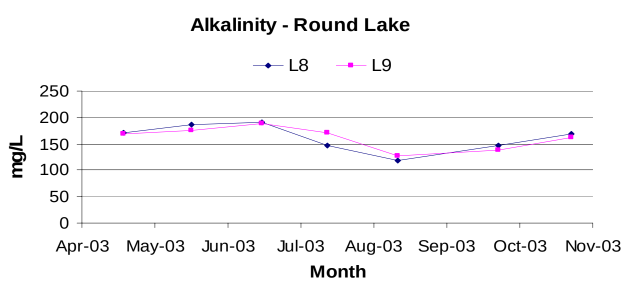

Dissolved Oxygen - Round Lake
L8
L9
mg/L
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

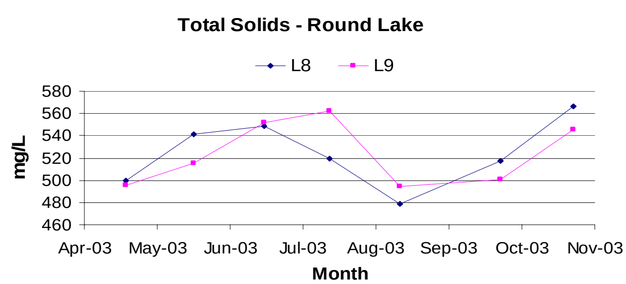

pH - Round Lake
L8
L9
Units
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

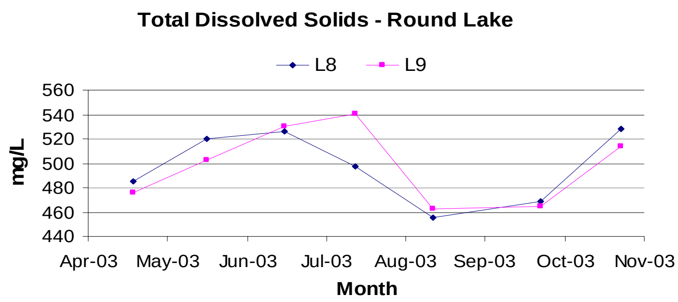

Secchi Depth - Round Lake
L8
L9
Meters
1.00
0.80
0.60
0.40
0.20
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

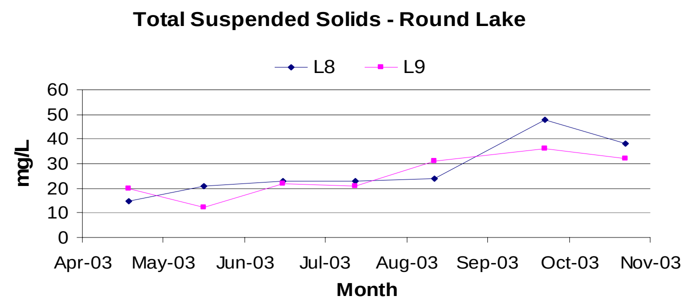

Total Phosphorus - Round Lake
L8
L9
mg/L
0.200
0.150
0.100
0.050
0.000
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

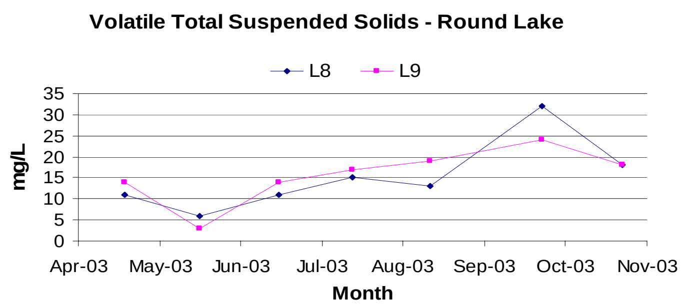

Total Dissolved Phosphorus - Round Lake
L8
L9
mg/L
0.100
0.080
0.060
0.040
0.020
0.000
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

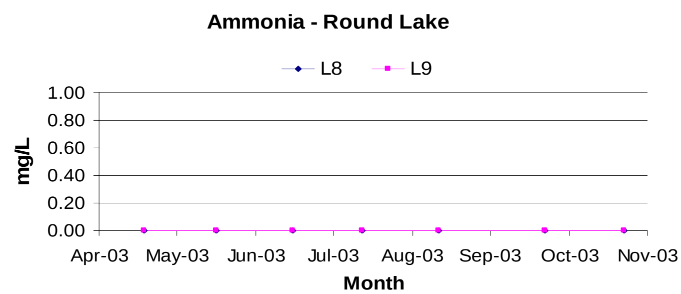

Alkalinity - Round Lake
L8
L9
mg/L
250
200
150
100
50
0
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

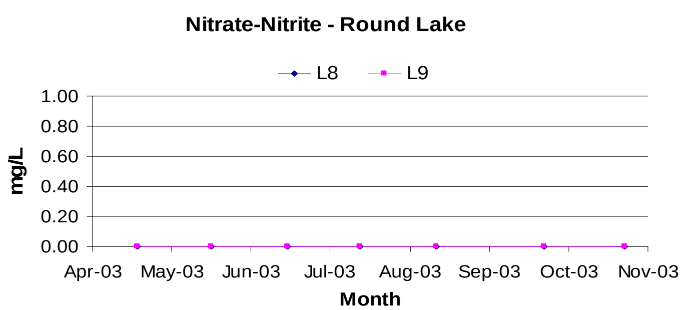

Total Solids - Round Lake
L8
L9
mg/L
580
560
540
520
500
480
460
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

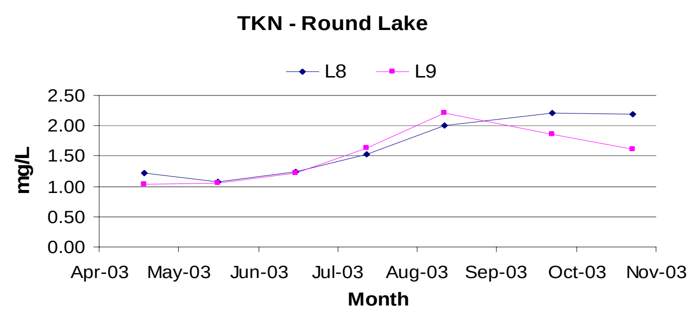

Total Dissolved Solids - Round Lake
L8
L9
mg/L
560
540
520
500
480
460
440
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month


Total Suspended Solids - Round Lake
L8
L9
mg/L
60
50
40
30
20
10
0
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month


Volatile Total Suspended Solids - Round Lake
L8
L9
mg/L
35
30
25
20
15
10
5
0
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month


Ammonia - Round Lake
L8
L9
mg/L
1.00
0.80
0.60
0.40
0.20
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

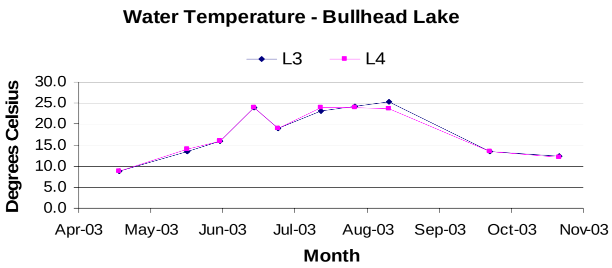

Nitrate-Nitrite - Round Lake
L8
L9
mg/L
1.00
0.80
0.60
0.40
0.20
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

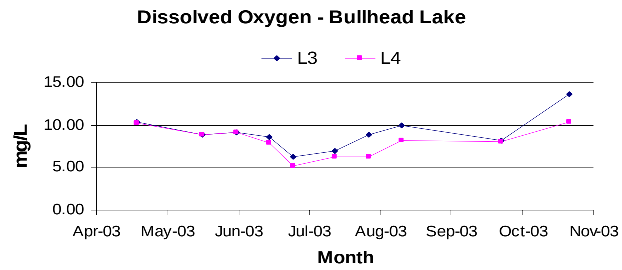

TKN - Round Lake
L8
L9
mg/L
2.50
2.00
1.50
1.00
0.50
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

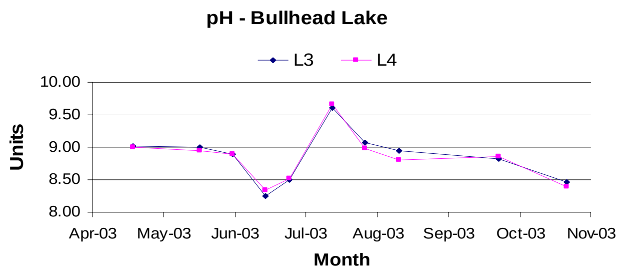
Appendix M.
BATHTUB Variables and Description

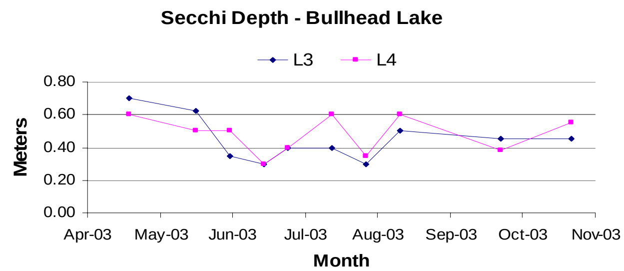
Variable	Units	Explanation
Total P (ppb)	mg/m^3	Pool Mean Phosphorus Concentration
Total N (ppb)	mg/m^3	Pool Mean Nitrogen Concentration
Chl-A (ppb)	mg/m^3	Pool Mean Chlorophyll a Concentration
Secchi (m)	m	Pool Mean Chlorophyll a Concentration
Organic N (ppb)	mg/m^3	Pool Mean Organic Nitrogen Concentration
Antilog PC-1	----	First principal component of reservoir response.Measure of nutrient supply.
		< 50 = Low Nutrient Supply and Low Eutrophication potential
		> 500 = High nutrient supply and High Eutrophication potential
Antilog PC-2	----	Second principal component of reservoir response variables.
		Nutrient association with organic vs. inorganic forms; related to light-limited areal productivity.
		Low: PC-2 < 4 = Turbidity dominated, light-limited, low nutrient response.
		High: PC-2 > 10 = Algae-dominated, light unimportant, high nutrient response.
(N-150)/P	----	(Total N - 150)/ Total P ratio. Indicator of limiting nutrient.
		Low: (N-150)/P < 10-12 nitrogen limited
		High: (N-150)/P > 12-15 phosphorus limited
Inorganic N/P	---	Inorganic nitrogen / Ortho-phosphorus ratio. Indicator of limiting nutrient
		Low : N/P < 7-10 Nitrogen limited
		High: N/P > 7-10 Phosphorus limited
Freq (Chl-a >10) %	---	Algal nuisance frequencies or bloom frequencies. Estimated from mean chlorophyll a.
		Percent of time during growing season that Chl a exceeds 10, 20, 30, 40, 50, or 60 ppb
		Related to risk or frequency of use impairment.
TSI	----	Trophic State Indices (Carlson 1977)
		Calculated from Phosphorus, Chlorophyll a, and Secchi Depths
		TSI < 40 Oligotrophic
		41 < TSI < 50 Mesotrophic
		51 < TSI < 70 Eutrophic
		TSI > 70 Hypereutrophic

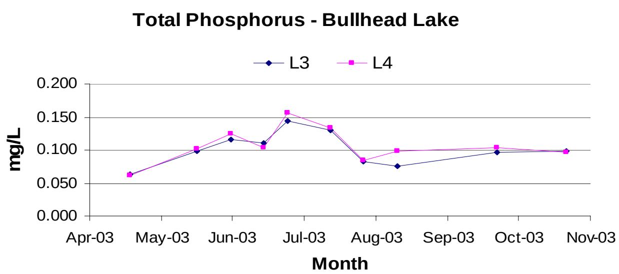
Appendix N.
Bullhead Lake WQ Graphs

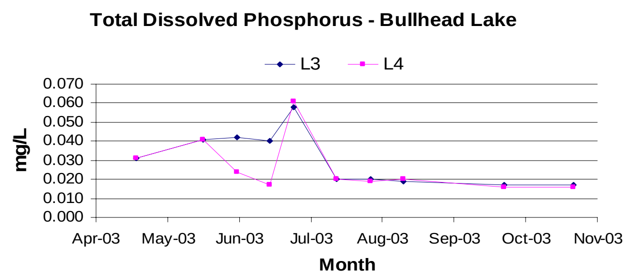

Water Temperature - Bullhead Lake
L3
L4
Degrees Celsius
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

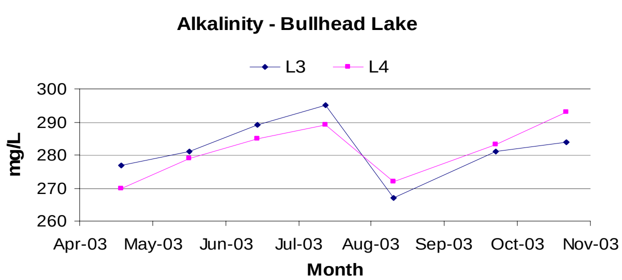

Dissolved Oxygen - Bullhead Lake
L3
L4
mg/L
15.00
10.00
5.00
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

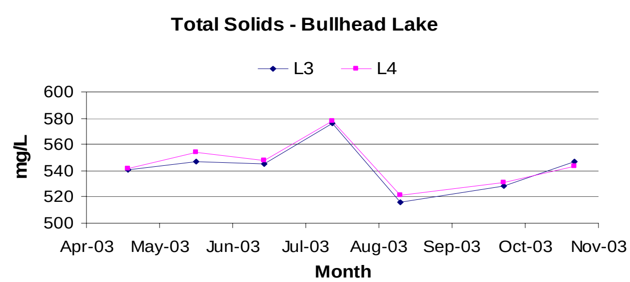

pH - Bullhead Lake
L3
L4
Units
10.00
9.50
9.00
8.50
8.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

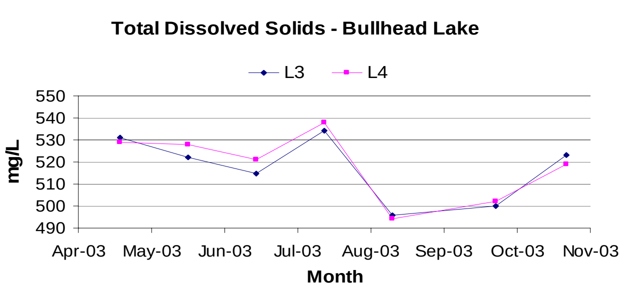

Secchi Depth - Bullhead Lake
L3
L4
Meters
0.80
0.60
0.40
0.20
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

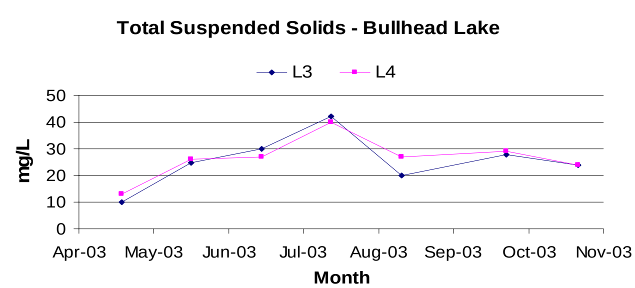

Total Phosphorus - Bullhead Lake
L3
L4
mg/L
0.200
0.150
0.100
0.050
0.000
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

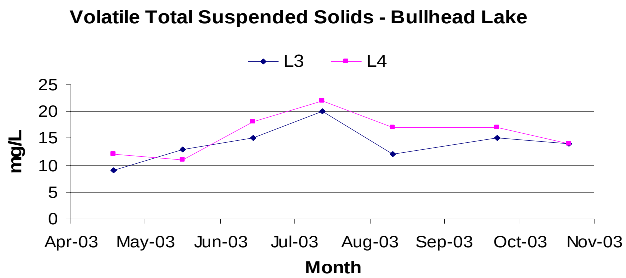

Total Dissolved Phosphorus - Bullhead Lake
L3
L4
mg/L
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

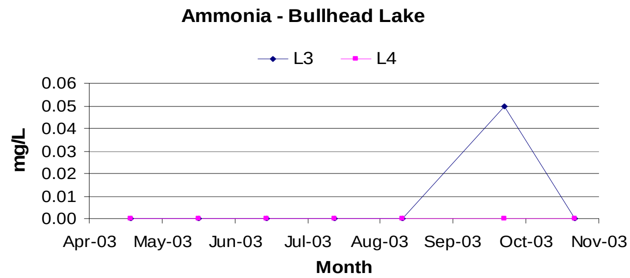

Alkalinity - Bullhead Lake
L3
L4
mg/L
300
290
280
270
260
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

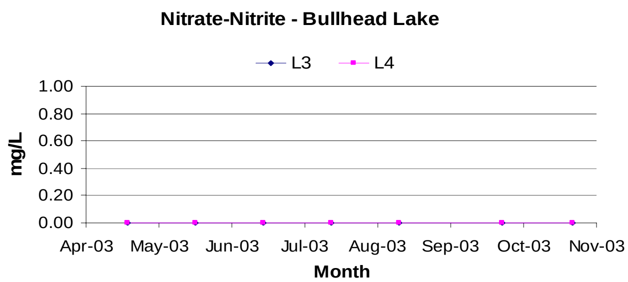

Total Solids - Bullhead Lake
L3
L4
mg/L
600
580
560
540
520
500
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

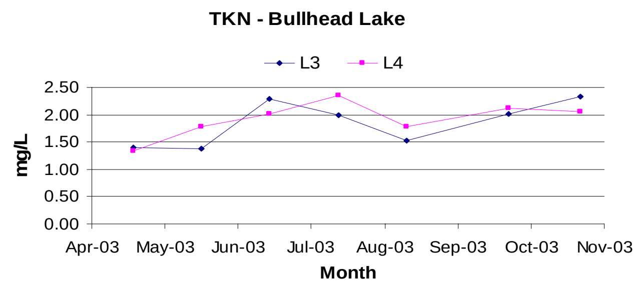

Total Dissolved Solids - Bullhead Lake
L3
L4
mg/L
550
540
530
520
510
500
490
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month


Total Suspended Solids - Bullhead Lake
L3
L4
mg/L
50
40
30
20
10
0
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

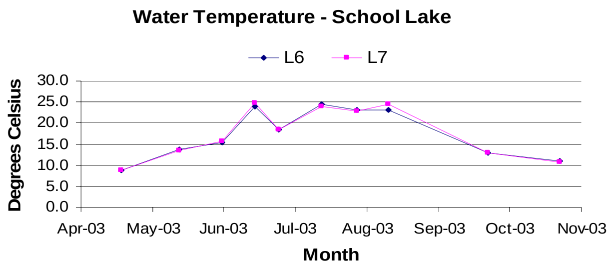

Volatile Total Suspended Solids - Bullhead Lake
L3
L4
mg/L
25
20
15
10
5
0
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

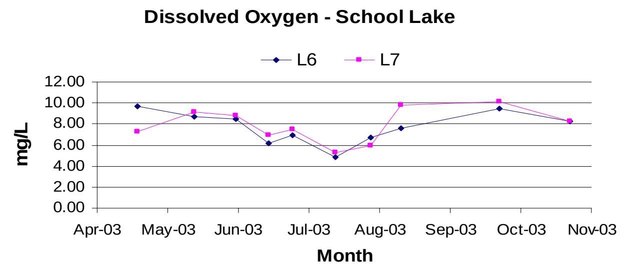

Ammonia - Bullhead Lake
L3
L4
mg/L
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

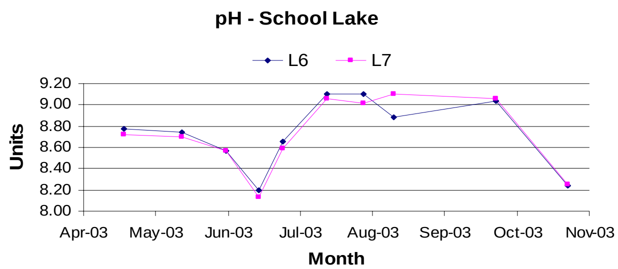

Nitrate-Nitrite - Bullhead Lake
L3
L4
mg/L
1.00
0.80
0.60
0.40
0.20
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

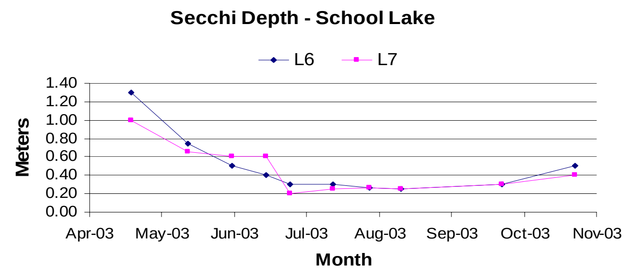

TKN - Bullhead Lake
L3
L4
mg/L
2.50
2.00
1.50
1.00
0.50
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

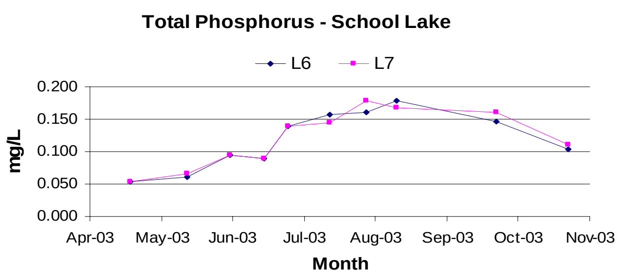
Appendix O.
School Lake WQ Graphs

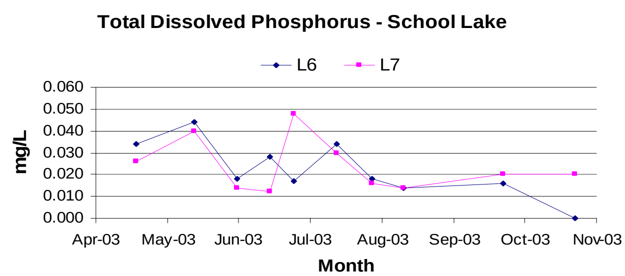

Water Temperature - School Lake
L6
L7
Degrees Celsius
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

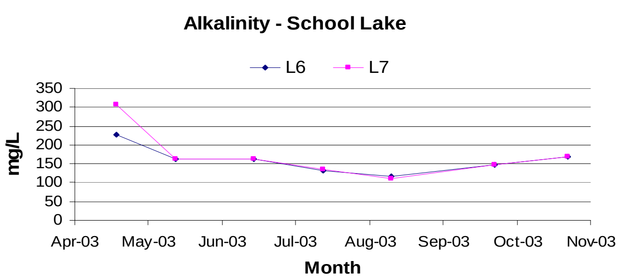

Dissolved Oxygen - School Lake
L6
L7
mg/L
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

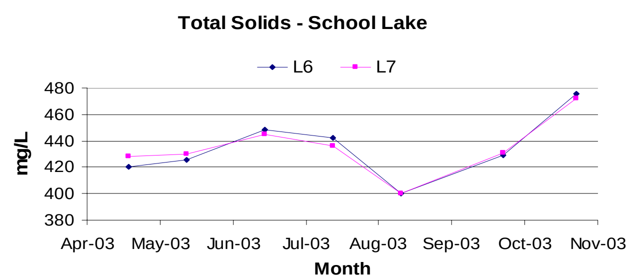

pH - School Lake
L6
L7
Units
9.20
9.00
8.80
8.60
8.40
8.20
8.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

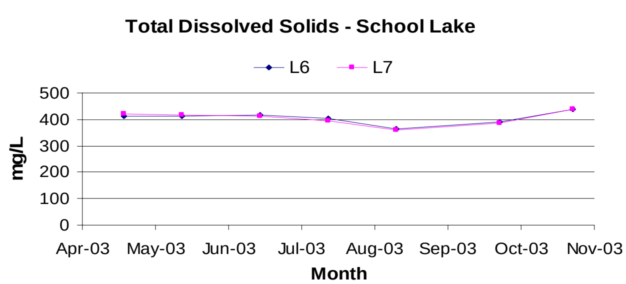

Secchi Depth - School Lake
L6
L7
Meters
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

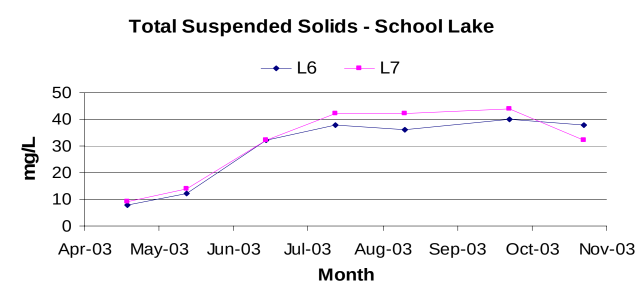

Total Phosphorus - School Lake
L6
L7
mg/L
0.200
0.150
0.100
0.050
0.000
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

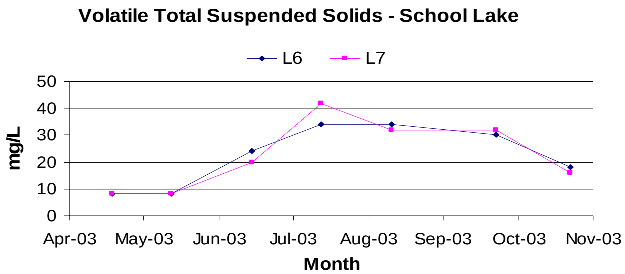

Total Dissolved Phosphorus - School Lake
L6
L7
mg/L
0.060
0.050
0.040
0.030
0.020
0.010
0.000
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

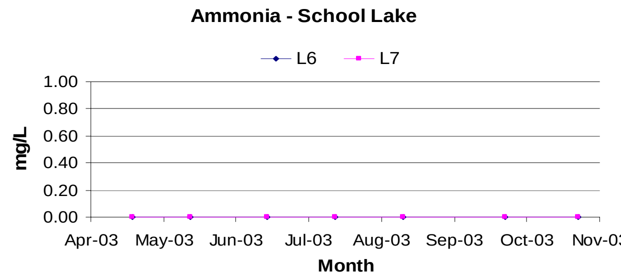

Alkalinity - School Lake
L6
L7
mg/L
350
300
250
200
150
100
50
0
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

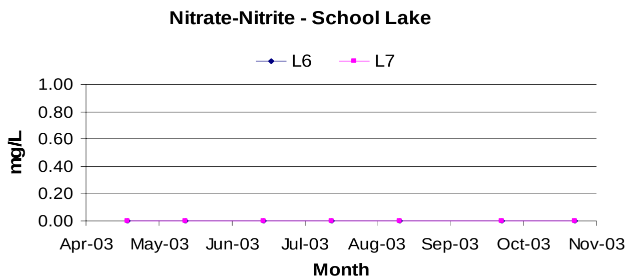

Total Solids - School Lake
L6
L7
mg/L
480
460
440
420
400
380
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

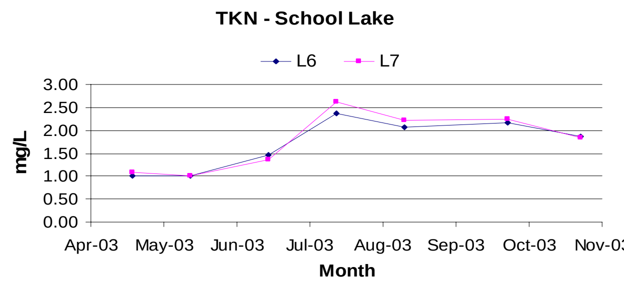

Total Dissolved Solids - School Lake
L6
L7
mg/L
500
400
300
200
100
0
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month


Total Suspended Solids - School Lake
L6
L7
mg/L
50
40
30
20
10
0
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

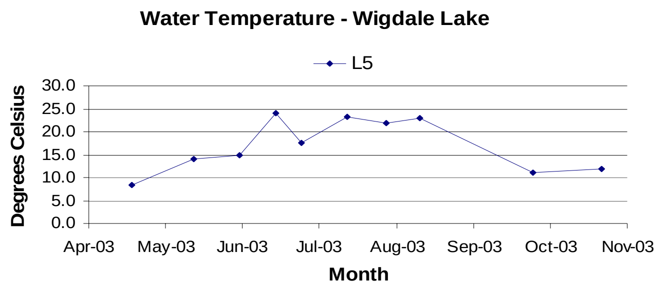

Volatile Total Suspended Solids - School Lake
L6
L7
mg/L
50
40
30
20
10
0
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

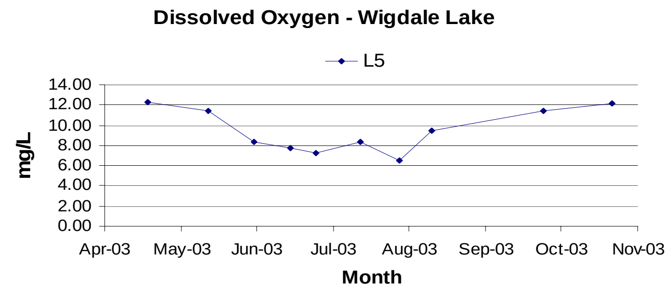

Ammonia - School Lake
L6
L7
mg/L
1.00
0.80
0.60
0.40
0.20
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

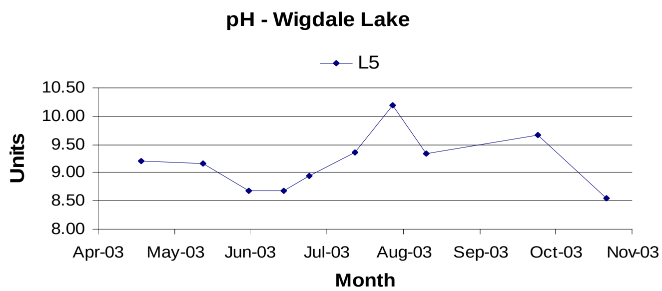

Nitrate-Nitrite - School Lake
L6
L7
mg/L
1.00
0.80
0.60
0.40
0.20
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

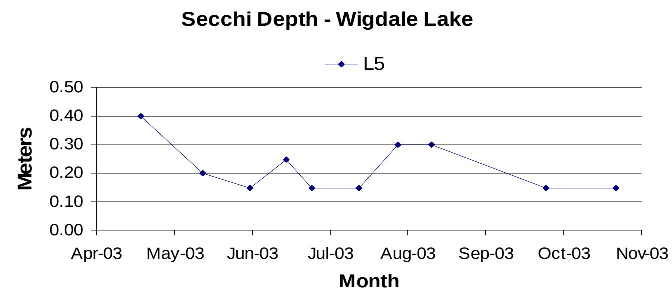

TKN - School Lake
L6
L7
mg/L
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Month

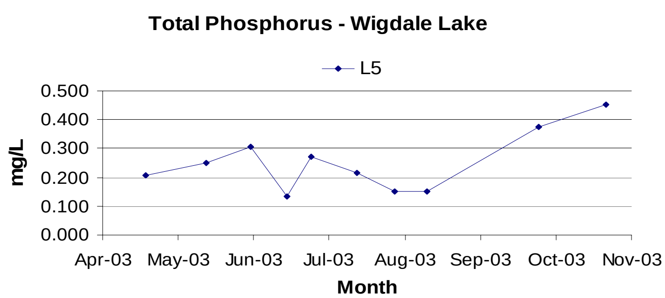
Appendix P.
Wigdale Lake WQ Graphs

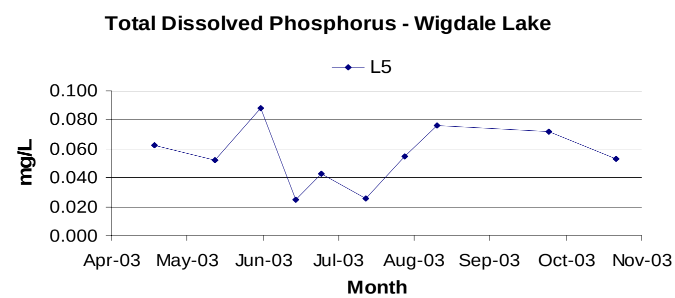

Water Temperature - Wigdale Lake
L5
Degrees Celsius
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03
Month

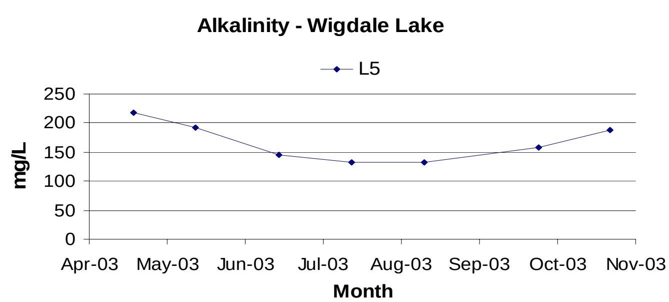

Dissolved Oxygen - Wigdale Lake
L5
mg/L
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03
Month

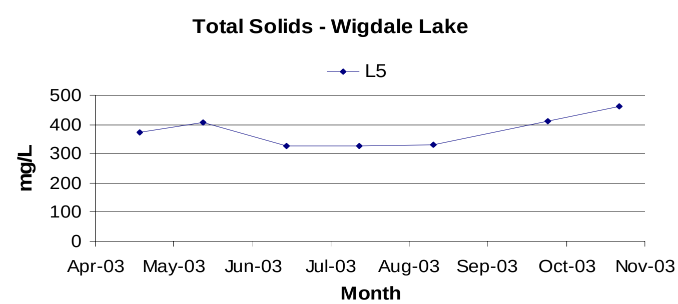

pH - Wigdale Lake
L5
Units
10.50
10.00
9.50
9.00
8.50
8.00
Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03
Month

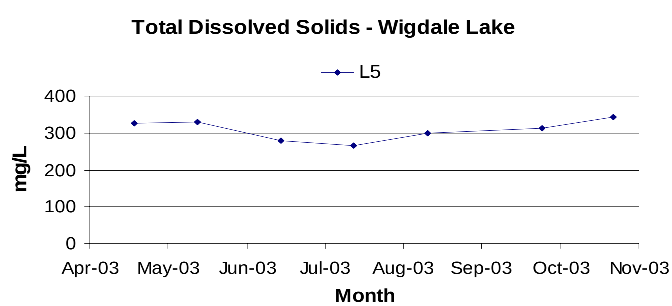

Secchi Depth - Wigdale Lake
L5
Meters
0.50
0.40
0.30
0.20
0.10
0.00
Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03
Month

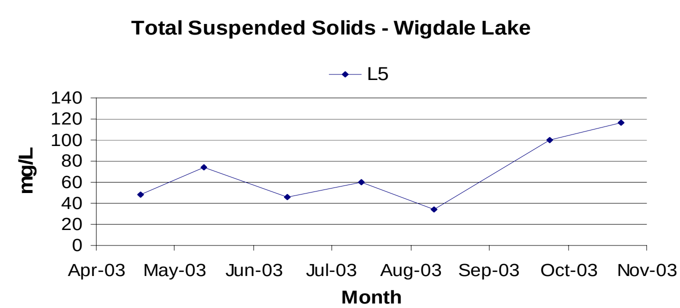

Total Phosphorus - Wigdale Lake
L5
mg/L
0.500
0.400
0.300
0.200
0.100
0.000
Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03
Month

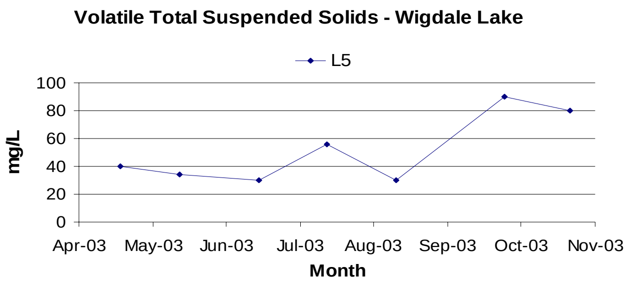

Total Dissolved Phosphorus - Wigdale Lake
L5
mg/L
0.100
0.080
0.060
0.040
0.020
0.000
Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03
Month

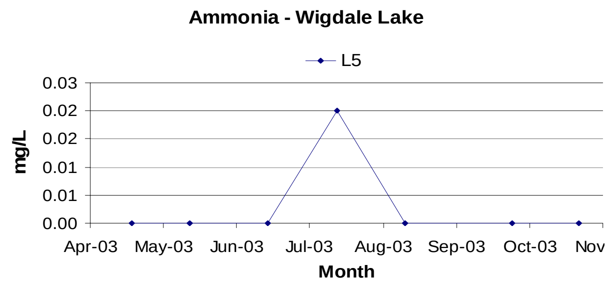

Alkalinity - Wigdale Lake
L5
mg/L
250
200
150
100
50
0
Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03
Month

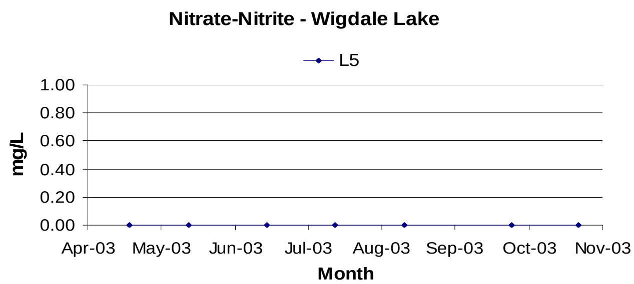

Total Solids - Wigdale Lake
L5
mg/L
500
400
300
200
100
0
Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03
Month

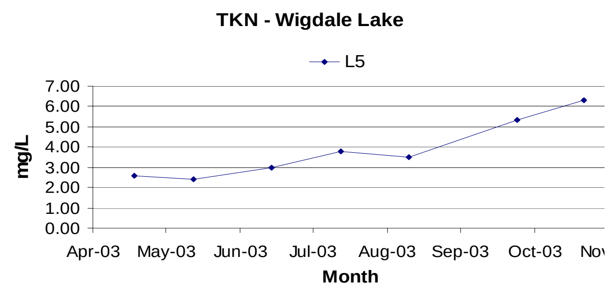

Total Dissolved Solids - Wigdale Lake
L5
mg/L
400
300
200
100
0
Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03
Month


Total Suspended Solids - Wigdale Lake
L5
mg/L
140
120
100
80
60
40
20
0
Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03
Month


Volatile Total Suspended Solids - Wigdale Lake
L5
100
80
60
40
20
0
mg/L
Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03
Month


Ammonia - Wigdale Lake
L5
0.03
0.02
0.02
0.01
0.01
0.00
mg/L
Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov
Month


Nitrate-Nitrite - Wigdale Lake
L5
1.00
0.80
0.60
0.40
0.20
0.00
mg/L
Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03
Month


TKN - Wigdale Lake
L5
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
mg/L
Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov
Month

TOTAL MAXIMUM DAILY LOAD EVALUATION
TSI Trend (Total Phosphorus)

for

Bullhead Lake

(HUC 10170202)

Deuel County, South Dakota

East Dakota Water Development District
Brookings, South Dakota

September 2005

Bullhead Lake Total Maximum Daily Load

Waterbody Type:	Lake
303(d) Listing Parameter:	Total Phosphorus (TSI Trend)
Designated Uses:	Warmwater Semi-permanent Fish Life Propagation Immersion Recreation Limited Contact Recreation Fish and Wildlife Propagation, Recreation and Stock Watering
Size of Waterbody:	571 acres
Size of Watershed:	3,374 acres
Water Quality Standards:	Narrative and Numeric
Indicators:	Water Chemistry
Analytical Approach:	Models including AnnAGNPS and BATHTUB
Location:	HUC Code: 10170202
Goal (BATHTUB based):	
Total Phosphorus	47 percent reduction in Total Phosphorus (47.1 kg/yr)
pH	By reducing total phosphorus, pH levels will improve
Target (BATHTUB based):	
Total Phosphorus	TSI 62.4, mean TSI 64.9 (53.3 kg/yr)
pH	≥ 6.5 to ≤ 9.0 pH units per grab sample

Objective

The intent of this summary is to clearly identify the components of the TMDL submittal to support adequate public participation and facilitate the US Environmental Protection Agency (EPA) review and approval. The TMDL was developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by EPA.

Introduction

Bullhead Lake is a 571-acre natural lake with a watershed of approximately 3,374 acres. This lake is located within the Big Sioux River Basin (HUC 10170202) in northwestern Deuel County, South Dakota.

This lake is included as part of the School-Bullhead Lakes Watershed Assessment Project. The entire study area for this project is also outlined in Figure 1.

The watershed of this lake lies within Deuel County as shown by the shaded region in Figure 2.

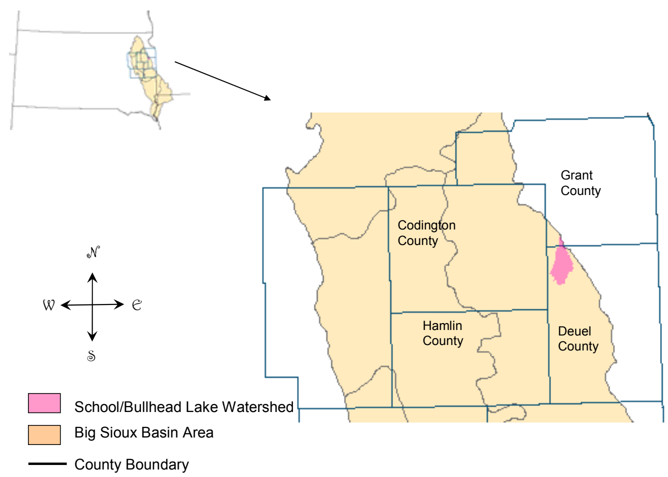


Figure 1. Location of the School-Bullhead Lakes Watershed

This lake was identified in the 1998 South Dakota 303(d) Waterbody List for TMDL development due to excessive nutrients, siltation, and noxious aquatic plants.

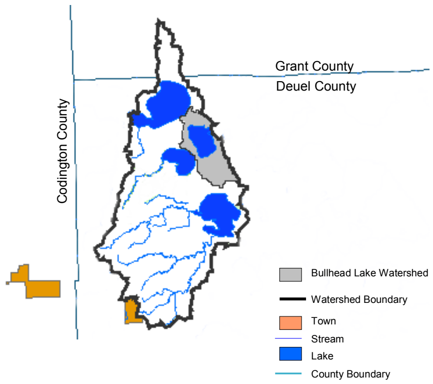


Figure 2. Location of the Bullhead Lake Watershed

Information supporting this listing was derived from statewide ambient monitoring data and the 1996 305(b) report. Furthermore, the School-Bullhead Lakes Watershed Assessment Project found this lake is not meeting the water quality criteria due to excessive nutrients. Although no aquatic plant survey was completed, there was excessive algae growth including the presence of several species of nuisance blue-green algae.

Problem Identification

Two in-lake monitoring sites were setup on Bullhead Lake, L3 (north) and L4 (south) (Figure 3). Water quality sampling at these sites indicate excessive phosphorus and high pH levels. Noxious species of algae were found in both the June and August samples. Chlorophyll-*a* samples averaged 35.13 ppb.

The watershed area shown in Figure 2 drains approximately 47 percent grass/grazing land and cropland acres. There were no monitored inlets or outlets and no municipalities are located in this area.

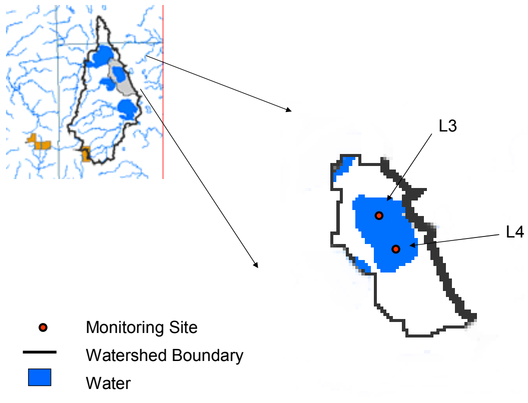


Figure 3. Bullhead Lake Monitoring Sites

Total phosphorus load to Bullhead Lake is 100.4 kg annually. Of the total load, groundwater contribution is estimated at 2.2 kg, precipitation contribution is 41.4 kg, and nonpoint source contribution is 56.8 kg. The absence of stream influence may indicate contributions from non-point sources, such as ungaged runoff and internal loading, or from point sources, such as drainage pipes. Total phosphorus loads will need to be reduced by 47 percent. This reduction was calculated from ungaged runoff which requires a reduction of 47 kg/yr (or 83 percent of the total nonpoint source contribution) to meet the numeric mean Trophic State Index (TSI) of 64.9 and to fully support the lake's beneficial uses.

A total of 20 phosphorus and 20 pH samples were taken from the two monitoring locations (L3 and L4). Of the 20 pH samples, four of the samples (20 percent) were violating the water quality standards. This 20 percent indicates that this lake is not meeting the water quality criteria for its beneficial uses. The exceedences in pH levels is believed to be attributed to excessive algae growth which uses the acidic dissolved carbon dioxide in the water for its life processes and in-turn causes the pH of the water to rise.

Additionally, excessive algae growth is likely caused by the high levels of nutrients within the lake from current and previous watershed runoff. In this case, Bullhead Lake is a phosphorus limited lake which indicates algal growth is likely being caused by excessive phosphorus in the water (See Table 1). If the phosphorus concentrations can be controlled then the excessive algae growth will be suppressed.

Table 1. Total Phosphorus and Chlorophyll a Means for Bullhead Lake

	Total Phosphorus (ppb)	Chlorophyll-a (ppb)
April-May	82	13
June-August	104	42
September-October	101	36

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

Bullhead Lake has been assigned beneficial uses by the state of South Dakota Surface Water Quality Standards regulations (See page 10 of the Assessment Report). Along with these assigned uses are narrative and numeric criteria that define the desired water quality of this lake. These criteria must be maintained for the lake to satisfy its assigned beneficial uses, which are listed below:

- Warmwater semipermanent fish propagation
- Limited contact recreation
- Immersion recreation
- Fish and wildlife propagation, recreation and stock watering

Individual parameters, including the lake's mean TSI value, determine the support of beneficial uses and compliance with standards. This lake experiences nutrient enrichment and nuisance algal blooms which are typical signs of the eutrophication process. This lake was originally identified in the 1998 Dakota Waterbody List as partially supporting its beneficial uses warmwater semipermanent fish life propagation, and fish and wildlife propagation, recreation, and stock watering.

Administrative Rules of South Dakota Article 74:51 contains numeric and narrative standards to be applied to the surface waters (i.e. streams, lakes) of the state. It contains language that prohibits the existence of materials causing pollutants to form, visible pollutants, taste and odor producing materials, and nuisance aquatic life.

If adequate numeric criteria are not available, alternate measures to assess the trophic status of a lake are taken. This alternate method uses the mean Trophic State Index (Carlson 1977) which incorporates a combination of Secchi depth, chlorophyll-*a*, and total phosphorus concentrations.

The SD DENR has developed an EPA-approved protocol that establishes desired TSI levels for lakes based on their ecoregion location (SD DENR 2000). Table 2 shows the protocol used to assess impairment and determine a numeric target for Bullhead Lake.

Table 2. Ecoregion 46N Beneficial Use Category and Carlson TSI Numeric Ranges by Category

Ecoregion (46N) Beneficial Use Category	TSI Numeric Range
Fully supporting	≤ 65
Partially supporting	≥ 65.01 - ≤ 70
Non-supporting	≥ 70.01

Bullhead Lake currently has a BATHTUB modeled total phosphorus TSI of 67.8, a chlorophyll-*a* TSI of 66.6, and a Secchi TSI of 71.6, which calculates to an average TSI of 68.7. Observed values are worse, with a total phosphorus TSI of 71.1, a chlorophyll-*a* TSI of 65.7, a Secchi TSI of 71.1, and an overall mean TSI of 69.3, which is indicative of increased levels of primary productivity.

Additionally, water samples were obtained using SD DENR standard operating procedures and the results were compared to the applicable water quality criteria. Four of the 20 pH samples were higher than the numeric standard levels (≥ 6.5 to ≤ 9.0 pH units) allowed per grab sample.

Recommended specific TSI parameters for Bullhead Lake are 62.4 for total phosphorus, 62.8 for chlorophyll-*a*, and 69.5 for Secchi depth. The TMDL numeric target will reduce total phosphorus loading to Bullhead Lake, lowering the mean TSI to 64.9.

This phosphorus reduction will reduce algal blooms and consequently lower pH levels.

Pollutant Assessment

Point Sources

There are no point source pollutants of concern in this watershed.

Nonpoint Sources

Nonpoint and background sources of pollution in the Bullhead Lake Watershed were estimated using BATHTUB and AnnAGNPS modeling.

Under current conditions, total nonpoint source loadings of total phosphorus from the watershed into Bullhead Lake was estimated to be 56.8 kg, and were attributed to ungaged runoff. Reductions were based only on ungaged runoff since background can not be reduced. The required reduction of ungaged runoff load of total phosphorus (47 kg) was subtracted from the total phosphorus TMDL (100.4 kg) to determine background source loading. The remaining total phosphorus loading (53.3 kg) was attributed to 2.2 kg/yr for groundwater contribution, 9.7 kg/yr for ungaged runoff, and 41.4 kg/yr for precipitation contribution in the Bullhead Lake Watershed.

Internal lake sources of phosphorus should also be considered for reduction. Internal loading was estimated to contribute 91 percent of the total phosphorus level in Bullhead Lake (See page 99 of the Assessment Report). Improvements to the riparian areas, including vegetation management will also improve the TSI values.

Linkage Analysis

Water quality data was collected at two in-lake monitoring. Samples were collected according to South Dakota's EPA approved Standard Operating Procedures for Field Samplers. Water samples were sent to the State Health Laboratory in Pierre, South Dakota, for analysis. Quality assurance/quality control samples were collected on 10% of the samples according to South Dakota's EPA approved Non-point Source Quality Assurance/Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed in the assessment final report.

In addition to water quality monitoring, data was collected to complete a watershed landuse model. The AnnAGNPS model was used to identify areas contributing to potential nutrient and sediment loads. More information about AnnAGNPS results can be found in the Results section and Appendices J and K of the Assessment Report.

Areas of higher nutrient and sediment loads within the Bullhead Lake watershed are shown in Figures 4 and 5. This data is based on current conditions over a 10-year simulation period. Details regarding nutrient and sediment loads contributed by each AnnAGNPS cell can be found in Attachment 1.

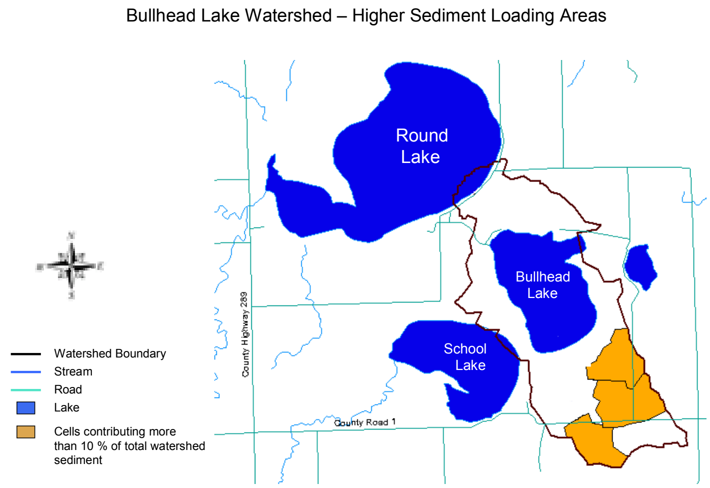


Figure 4. Higher Nutrient Loading Areas in the Bullhead Lake Watershed

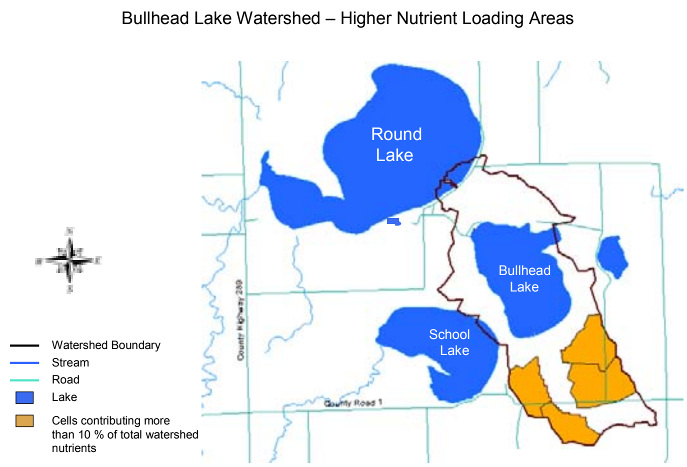


Figure 5. Higher Sediment Loading Areas in the Bullhead Lake Watershed

The impacts of phosphorus reductions on the condition of Bullhead Lake were calculated using the BATHTUB. The BATHTUB predicted a reduction of 83 percent (47 kg/yr) of the current total phosphorus ungaged runoff load (56.8 kg/yr) to reduce the average TSI value from 68.7 to 64.9. Reductions to meet the TMDL could be achieved by implementing BMPs such as shoreline stabilization, riparian management, private waste systems, and fertilizer reduction. Internal lake sources of phosphorus should also be considered, even though the ungaged runoff would accomplish the goal of this TMDL.

TMDL and Allocations

TMDL

Total phosphorus (kg) = 47 % reduction

	0 kg/yr	(WLA)
+	9.7 kg/yr	(LA)
+	43.6 kg/yr	(Background)
+	Implicit	(MOS)
	53.3 kg/yr	(TMDL)

Wasteload Allocations (WLAs)

There are no point source pollutants of concern in this watershed. Therefore, the "wasteload allocation" component of this TMDL is considered a zero value. The TMDL is considered wholly included within the "load allocation" component.

Load Allocations (LAs)

Load allocations account for the portion of the TMDL assigned to non-point sources. Natural background constitutes 43.5 kg/yr of the total and the remainder of the LA is assigned to the ungaged runoff that is likely to contribute phosphorus at rates above the natural background. An 83 percent reduction of external phosphorus load from ungaged runoff may be achieved through the implementation of BMPs including no tillage cropping practices and riparian buffers.

Inlake total phosphorus reductions to improve TSI should also be considered for Bullhead Lake. Aluminum sulfate treatments would not be a viable option to control internal phosphorus as mean lake depth is 2.83 m. However, biomanipulation and plant management strategies may be the best options to control internal phosphorus. Dredging could be considered, but it is recommended sediment samples be taken beforehand to determine which areas sediment should be removed. Dredging of the entire lake is not recommended. See Management Options and Recommendations section of the Assessment Report for further information.

Additionally, a total phosphorus load reduction would be the primary means in attaining water quality standards for pH and to control algal biomass.

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in temperature, precipitation and agricultural practices. To determine seasonal differences, Bullhead Lake phosphorus and chlorophyll-*a* samples were separated into spring (April to May), summer (June to August), and fall (September to October). This TMDL targets the most productive part of the year (June to August). Not only is this the period of peak recreational use, but it is also the period during which most impairments are occurring.

Margin of Safety

The margin of safety (MOS) is a portion of the loading capacity that is set aside to prevent the exceedence of a water quality standard as a means of accounting for the uncertainty involved in developing a TMDL. The MOS for this TMDL is implicit, meaning all total phosphorus reductions were calculated based on extremely conservative estimations built into the model and conservative total phosphorus reduction percentages using best professional judgment.

Critical Conditions

Based upon the 2003 assessment data, nutrient loading to Bullhead Lake is most severe late spring (May-June) and impairments usually result mid to late summer (July-August) because of warmer water temperatures and increased algal growth.

Follow-Up Monitoring

Bullhead Lake should continue to be monitored through the statewide lake assessment project and the South Dakota Game, Fish and Parks normal lake survey to monitor and evaluate long-term trophic status, biological communities, and ecological trends.

Periodically during the implementation project and then once it is completed, monitoring will be necessary to ensure TSI values improve and the goals of this TMDL are met. Recurrent water quality sampling at the original monitoring sites is suggested.

Public Participation

Efforts taken to gain public education, review, and comment during development of the TMDL involved:

1. East Dakota Water Development District public board meetings
2. Individual contact with landowners in the watershed

Comments from these public meetings and comments have been taken into consideration in the development of the Bullhead Lake TMDL.

Implementation Plan

The East Dakota Water Development District is working with the South Dakota DENR and various stakeholders to initiate an implementation project, which is estimated to begin in 2006. Deuel County Conservation District is expected to request 319 funding in late 2005 with project assistance being available in 2006.

Bullhead Lake							
Current Conditions 10-Year Simulation (sorted by P04 lb/ac/yr)							PO4
Cell	Reach	Area	PO4 lb/yr	% of total	Nitrogen lb/yr	% of total	lb/ac/yr
13013	1301	1	0	0	0	0	2.46
13022	1302	526	0	0	0	0	1.33
13023	1302	388	0	0	0	0	0.78
13042	1304	42	0	0	0	0	0.71
13052	1305	6	0	0	0	0	0.60
13033	1303	5	0	0	0	0	0.58
13053	1305	6	1	0	0	0	0.21
13032	1303	8	4	1	5	1	0.19
13061	1306	75	15	5	17	3	0.07
13062	1306	14	35	11	36	7	0.00
13043	1304	69	54	17	53	10	0.00
13031	1303	80	57	19	82	15	0.00
13051	1305	105	63	20	169	32	0.00
13063	1306	58	78	25	168	32	0.00
Bullhead Lake Watershed Totals		**1385**	**308**	**100**	**530**	**100**	

Bullhead Lake										
Current conditions 10-Year Simulation (sorted by subtotals of sediment tons/acre/year)										
Cell	Reach	Area	Clay	Silt	Sand	Sm. Agg.	Lg. Agg.	Subtotals	% of total	tons/ac/yr
13062	1306	14	1.48	2.11	3.13	0	0	6.71	18.64	0.47
13063	1306	58	3.22	4.20	2.21	0	0	9.62	26.73	0.16
13031	1303	80	2.13	3.38	2.06	0	0	7.58	21.05	0.09
13051	1305	105	2.95	3.87	2.07	0	0	8.89	24.68	0.08
13032	1303	8	0.08	0.13	0.08	0	0	0.29	0.81	0.04
13043	1304	69	0.64	1.09	0.82	0	0	2.54	7.06	0.04
13061	1306	75	0.14	0.19	0.19	0	0	0.51	1.42	0.01
13033	1303	5	0	0	0	0	0	0.00	0.00	0.00
13013	1301	1	0	0	0	0	0	0.00	0.00	0.00
13022	1302	526	0	0	0	0	0	0.00	0.00	0.00
13023	1302	388	0	0	0	0	0	0.00	0.00	0.00
13042	1304	42	0	0	0	0	0	0.00	0.00	0.00
13052	1305	6	0	0	0	0	0	0.00	0.00	0.00
13053	1305	6	0	0	0	0	0	0.00	0.00	0.00
Bullhead Lake Watershed Totals		1385	11	15	11	0	0	36	100	

TOTAL MAXIMUM DAILY LOAD EVALUATION
TSI Trend (Total Phosphorus)

for

Round Lake

(HUC 10170202)

Deuel County, South Dakota

East Dakota Water Development District
Brookings, South Dakota

September 2005

Round Lake Total Maximum Daily Load

Waterbody Type:	Lake
303(d) Listing Parameter:	Total Phosphorus (TSI Trend)
Designated Uses:	Warmwater Marginal Fish Life Propagation Immersion Recreation Limited Contact Recreation Fish and Wildlife Propagation, Recreation and Stock Watering
Size of Waterbody:	1,161 acres
Size of Watershed:	4,903 acres
Water Quality Standards:	Narrative and Numeric
Indicators:	Water Chemistry
Analytical Approach:	Models including AnnAGNPS and BATHTUB
Location:	HUC Code: 10170202
Goal (BATHTUB based):	
Total Phosphorus	11 percent reduction in Total Phosphorus (21.5 kg/yr)
pH	By reducing total phosphorus, pH levels will improve
Target (BATHTUB based):	
Total Phosphorus	TSI 66.8, mean TSI 66.1 (173.8 kg/yr), Additional internal load reductions required to bring mean TSI below ≤ 65
pH	≥ 6.0 to ≤ 9.0 pH units per grab sample

Objective

The intent of this summary is to clearly identify the components of the TMDL submittal to support adequate public participation and facilitate the US Environmental Protection Agency (EPA) review and approval. The TMDL was developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by EPA.

Introduction

Round Lake is a 1,161-acre natural lake with a watershed of approximately 4,903 acres. This lake is located within the Big Sioux River Basin (HUC 10170202) in northwestern Deuel County, South Dakota (a small portion of the area also lies within southwestern Grant County).

This lake is included as part of the School-Bullhead Lakes Watershed Assessment Project. The entire study area for this project is outlined in Figure 1.

The watershed of this lake lies within Deuel County as shown by the shaded region in Figure 2.

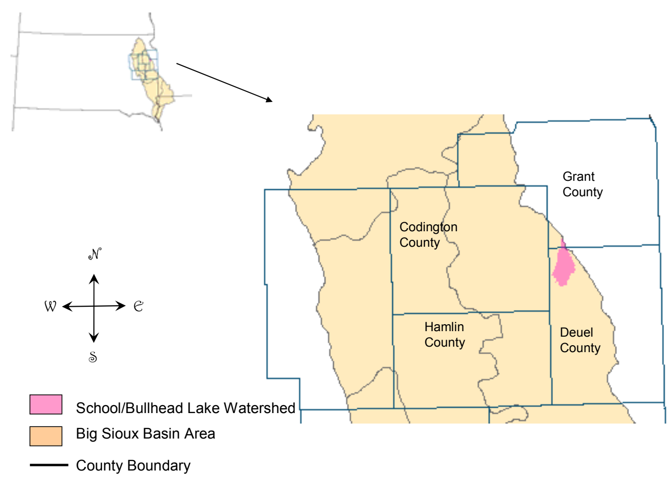


Figure 1. Location of the School-Bullhead Lakes Watershed

The School-Bullhead Lakes Watershed Assessment Project identified Round Lake for TMDL development due to not meeting the numeric mean Trophic State Index (TSI) and not meeting water quality criteria for pH.

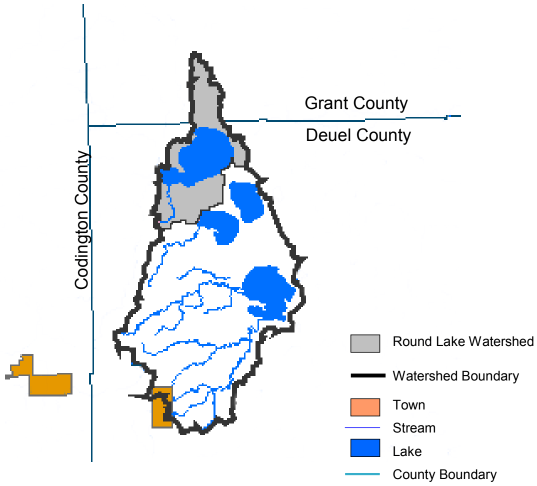


Figure 2. Location of the Round Lake Watershed

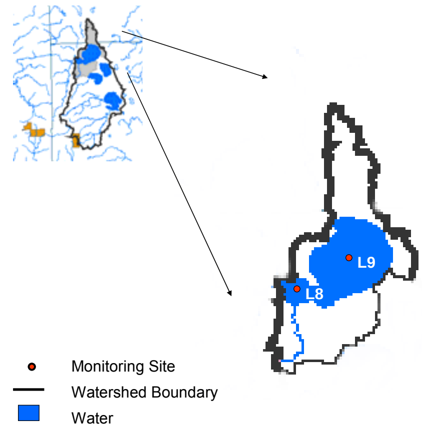


Figure 3. Round Lake Monitoring Sites

Information supporting this listing was derived from East Dakota Water Development District monitoring data. Excessive nutrients is the reason this lake is not meeting its water quality criteria. Appendix A summarizes the water quality data collected during the period of April to October of 2003. Although no aquatic plant survey was completed, there was excessive algae growth including several species of nuisance blue-green algae present.

Problem Identification

Two in-lake monitoring sites were setup on Round Lake, L8 (southwest) and L9 (north) (Figure 3). Water quality sampling at these sites indicate excessive phosphorus and high pH levels. Noxious species of algae were found in both June and August samples. Chlorophyll-*a* samples averaged 25.83 ppb.

The watershed area shown in Figure 2 drains approximately 70 percent grass/grazing land and cropland acres. There were no monitored inlets or outlets and no municipalities are located within this area.

During heavy rainfall/flood years, School Lake and Bullhead Lake may drain into Round Lake. However, due to the dry conditions during the time of this assessment, Round Lake was not influenced by any other water bodies. The outlet to Round Lake is Willow Creek. This Creek was assessed during the North-Central Big Sioux River Watershed Assessment Project which is still in progress. Preliminary results show Willow Creek is not supporting for the parameters of fecal coliform bacteria and dissolved oxygen.

A total of 20 phosphorus and 20 pH samples were taken from the two monitoring locations (L8 and L9). Of the 20 pH samples, four of the samples (20 percent) were violating the water quality standards. This 20 percent indicates that this lake is not meeting the water quality criteria for its beneficial uses. The exceedences in pH levels is believed to be attributed to excessive algae growth which uses the acidic dissolved carbon dioxide in the water for its life processes and in-turn causes the pH of the water to rise.

Additionally, excessive algae growth is likely caused by the high levels of nutrients within the lake. In this case, Round Lake is a phosphorus limited lake. Therefore, increases in phosphorus should yield increases in algal mass (See Table 1). If the phosphorus concentrations can be controlled then the excessive algae growth will be suppressed.

Table 1. Total Phosphorus and Chlorophyll a Means for Round Lake

	Total Phosphorus (ppb)	Chlorophyll-a (ppb)
April-May	77	7
June-August	89	27
September-October	175	54

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

Round Lake has been assigned beneficial uses by the state of South Dakota Surface Water Quality Standards regulations (See page 10 of the Assessment Report). Along with these assigned uses are narrative and numeric criteria that define the desired water quality of this lake. These criteria must be maintained for the lake to satisfy its assigned beneficial uses, which are listed below:

- Warmwater marginal fish propagation
- Limited contact recreation
- Immersion recreation
- Fish and wildlife propagation, recreation and stock watering

Individual parameters, including the lake's mean TSI value, determine the support of beneficial uses and compliance with standards.

Administrative Rules of South Dakota Article 74:51 contains numeric and narrative standards to be applied to the surface waters (i.e. streams, lakes) of the state. It contains language that prohibits the existence of materials causing pollutants to form, visible pollutants, taste and odor producing materials, and nuisance aquatic life.

If adequate numeric criteria are not available, alternate measures to assess the trophic status of a lake are taken. This alternate method uses the mean Trophic State Index (Carlson 1977) which incorporates a combination of Secchi depth, chlorophyll-*a*, and total phosphorus concentrations.

The SD DENR has developed an EPA-approved protocol that establishes desired TSI levels for lakes based on their ecoregion location (SD DENR 2000). Table 2 shows the protocol was used to assess impairment and determine a numeric target for Round Lake.

Table 2. Ecoregion 46N Beneficial Use Category and Carlson TSI Numeric Ranges by Category

Ecoregion (46N) Beneficial Use Category	TSI Numeric Range
Fully supporting	≤ 65
Partially supporting	≥ 65.01 - ≤ 70
Non-supporting	≥ 70.01

Round Lake currently has a BATHTUB modeled total phosphorus TSI of 69.7, a chlorophyll-*a* TSI of 62.7, and a Secchi TSI of 68, which calculates to an average TSI of 66.8. Observed values for total phosphorus TSI is 70.7, for chlorophyll-*a* TSI 62.5, for Secchi TSI 67.9, and an overall mean TSI of 67.1, which is indicative of increased levels of primary productivity.

Additionally, water samples were obtained using SD DENR standard operating procedures and the results were compared to the applicable water quality criteria. Four of the 20 pH samples were higher than the numeric standard levels (≥ 6.0 to ≤ 9.0 pH units) allowed per grab sample.

Recommended specific TSI parameters for Round Lake are 69.7 for total phosphorus, 62.7 for chlorophyll-*a*, and 68 for Secchi depth. These reductions are achievable but will not improve the health of the lake to a fully supporting TSI value.

This phosphorus reduction will reduce algal blooms and consequently lower pH levels.

Pollutant Assessment

Point Sources

There are no point sources of pollutants of concern in this watershed.

Nonpoint Sources

Nonpoint and background sources of pollution in the Round Lake Watershed were estimated using BATHTUB and AnnAGNPS modeling.

Round Lake TSI values were determined by assuming School Lake and Bullhead Lake were contributing to the total phosphorus loads. School Lake and Bullhead Lake are contributing 53.6 kg/yr of total phosphorus (27 percent of the total contribution). Groundwater contribution is estimated at 0.7 kg/yr (< 1 percent), while precipitation is estimated to contribute 141 kg/yr (72 percent). Groundwater and precipitation contributions can not be reduced, so a 95 percent reduction (21.5 kg/yr) of the contribution from School Lake and Bullhead Lake would not decrease the TSI. It is assumed an internal loading of phosphorus from the sediment is increasing the inlake levels of phosphorus. A reduction of the internal load is assumed to decrease the TSI value one to two points, improving the lake's condition enough to fully support its beneficial uses.

A TSI value of 65 would need to be achieved for Round Lake to be fully supporting. Therefore, internal phosphorus sediment loading should also be considered. Internal loading was estimated to contribute 84 percent of the total phosphorus level in Round Lake (See page 82 of the Assessment Report). Improvements to riparian areas, including vegetation management, will also improve the TSI values.

Linkage Analysis

Water quality data was collected at two in-lake monitoring. Samples were collected according to South Dakota's EPA approved Standard Operating Procedures for Field Samplers. Water samples were sent to the State Health Laboratory in Pierre, South Dakota, for analysis. Quality assurance/quality control samples were collected on 10% of the samples according to South Dakota's EPA approved Non-point Source Quality Assurance/Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed in the assessment final report.

In addition to water quality monitoring, data was collected to complete a watershed landuse model. The AnnAGNPS model was used to identify areas contributing to potential nutrient and sediment loads. More information about Ann AGNPS results can be found in the Results section and Appendices J and K of the Assessment Report.

Areas of higher nutrient and sediment loads within the Bullhead Lake watershed are shown in Figures 4 and 5. This data is based on current conditions over a 10-year simulation period. Details regarding nutrient and sediment loads contributed by each AnnAGNPS cell can be found in Attachment 1.

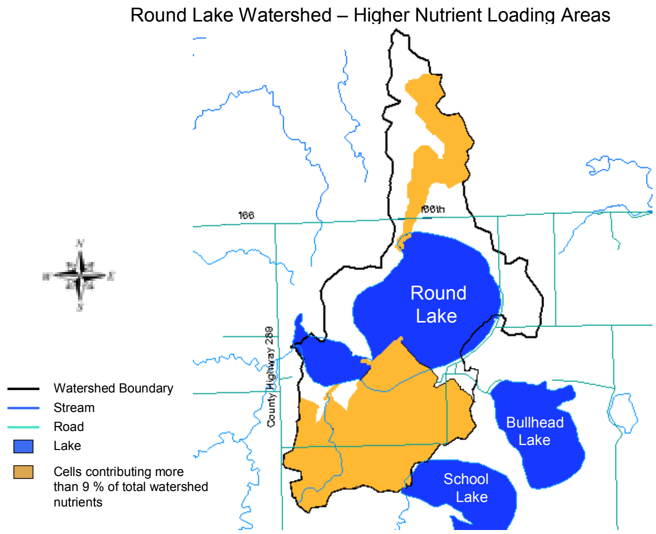


Figure 4. Higher Nutrient Loading Areas in the Round Lake Watershed

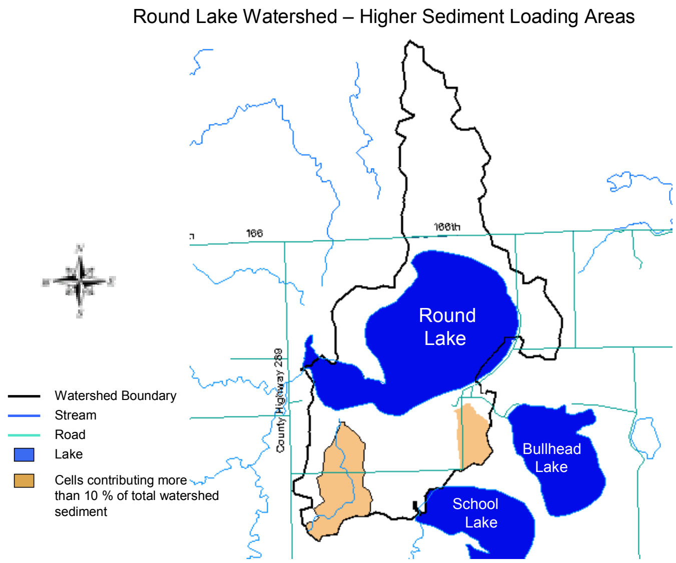


Figure 5. Higher Sediment Loading Areas in the Round Lake Watershed

Using the BATHTUB model, with the assumption School Lake and Bullhead Lake do flow into Round Lake, total phosphorus load to Round Lake is estimated to be 195.3 kg annually. The absence of stream influence may indicate contributions from non-point sources, such as runoff, or point sources, such as drainage pipes. The BATHTUB model calculated total phosphorus contribution from School Lake and Bullhead Lake. A reduction of 11 percent (21.5 kg/yr from School Lake and Bullhead Lake) was predicted, reducing the average TSI value from 66.8 to 66.1. Reductions needed to meet this TMDL, and the TMDLs of School Lake and Bullhead Lake, can be achieved by implementing BMPs such as shoreline stabilization, grazing management, riparian management, and fertilizer reduction. This reduction alone will not improve the lake enough to fully support its beneficial uses; therefore, reductions of internal lake sources of phosphorus should also be considered. A reduction of internal phosphorus is assumed to lower the TSI value and would accomplish the goal of this TMDL.

TMDL and Allocations

TMDL

Total phosphorus (kg) = 11 % reduction

	0 kg/yr	(WLA)
+	32.1 kg/yr	(LA)
+	141.7 kg/yr	(Background)
+	Implicit	(MOS)
	173.8 kg/yr	(TMDL)

Wasteload Allocations (WLAs)

There are no point source pollutants of concern in this watershed. Therefore, the "wasteload allocation" component of this TMDL is considered a zero value. The TMDL is considered wholly included within the "load allocation" component.

Load Allocations (LAs)

Load allocations account for the portion of the TMDL assigned to non-point sources. Natural background constitutes 141.7 kg/yr of the total and the remainder of the LA is assigned to runoff likely to contribute phosphorus at rates above natural background. An 11 percent reduction of external phosphorus load from ungaged runoff may be achieved through the implementation of BMPs including animal exclusion, no-tillage cropping practices, and riparian buffers.

Inlake total phosphorus reductions to improve TSI should also be considered for Round Lake to meet its beneficial uses. Aluminum sulfate treatments would not be a viable option to control internal phosphorus as mean lake depth is 1.83 m. However, biomanipulation and plant management strategies may be the best options to control internal phosphorus. Dredging could be considered, but it is recommended sediment samples be taken beforehand to determine which areas sediment should be removed. Dredging of the entire lake is not recommended. See Management Options and Recommendations section of the Assessment Report for further information.

Additionally, a total phosphorus load reduction would be the primary means in attaining water quality standards for pH and to control algal biomass.

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in temperature, precipitation and agricultural practices. To determine seasonal differences, Round Lake phosphorus and chlorophyll-*a* samples were separated into spring (April to May), summer (June to August), and fall (September to October). This TMDL targets the most productive part of the year (September to October). Not only is this the period of peak recreational use, but it is also the period during which most impairments are occurring.

Margin of Safety

The margin of safety (MOS) is a portion of the loading capacity that is set aside to prevent the exceedence of a water quality standard as a means of accounting for the uncertainty involved in developing a TMDL. The MOS for this TMDL is implicit, meaning all total phosphorus reductions were calculated based on extremely conservative estimations built into the model and conservative total phosphorus reduction percentages using best professional judgment.

Critical Conditions

Based upon the 2003 assessment data, nutrient loading to Round Lake is most severe during late summer (August) and impairments usually result during early fall (September) due increased algal growth.

Follow-Up Monitoring

Round Lake should continue to be monitored by the South Dakota Game, Fish and Parks normal lake survey and also added to the statewide lake assessment project to monitor and evaluate long-term trophic status, biological communities, and ecological trends.

Periodically during the implementation project and then once it is completed, monitoring will be necessary to ensure TSI values improve and the goals of this TMDL are met. Recurrent water quality sampling at the original monitoring sites is suggested.

Public Participation

Efforts taken to gain public education, review, and comment during development of the TMDL involved:

1. East Dakota Water Development District public board meetings
2. Individual contact with landowners in the watershed

Comments from these public meetings have been taken into consideration in the development of the Round Lake TMDL.

Implementation Plan

The East Dakota Water Development District is working with the South Dakota DENR and various stakeholders to initiate an implementation project, which is estimated to begin in 2006. Deuel County Conservation District is expected to request 319 funding in late 2005 with project assistance being available in 2006.

Round Lake							
Current Conditions 10-Year Simulation (sorted by P04 lb/acre/yr)							PO4
Cell	**Reach**	**Area**	**PO4 lb/yr**	**% of total**	**Nitrogen lb/yr**	**% of total**	**lb/ac/yr**
13693	1369	6	4	1	13	2	0.68
13683	1368	59	38	9	62	11	0.65
13071	1307	83	54	13	65	12	0.65
13681	1368	86	55	13	81	15	0.64
13691	1369	82	52	12	72	13	0.63
13682	1368	57	35	8	56	10	0.62
13072	1307	23	14	3	14	3	0.61
13073	1307	11	7	2	9	2	0.61
13083	1308	270	54	13	53	10	0.20
13692	1369	10	2	0	2	0	0.20
12922	1292	28	4	1	2	0	0.16
13011	1301	74	12	3	6	1	0.16
13082	1308	251	39	9	20	4	0.16
12942	1294	44	5	1	1	0	0.10
12941	1294	75	8	2	1	0	0.10
12973	1297	221	18	4	52	9	0.08
12971	1297	80	7	2	17	3	0.08
12981	1298	74	6	1	16	3	0.08
12972	1297	249	4	1	10	2	0.01
12912	1291	30	0	0	0	0	0.00
12913	1291	36	0	0	0	0	0.00
12923	1292	27	0	0	0	0	0.00
12932	1293	59	0	0	0	0	0.00
12933	1293	30	0	0	0	0	0.00
12943	1294	94	0	0	0	0	0.00
12952	1295	97	0	0	0	0	0.00
12953	1295	48	0	0	0	0	0.00
12962	1296	46	0	0	0	0	0.00
12963	1296	161	0	0	0	0	0.00
12982	1298	27	0	0	0	0	0.00
12983	1298	155	0	0	0	0	0.00
12992	1299	66	0	0	0	0	0.00
12993	1299	21	0	0	0	0	0.00
13002	1300	25	0	0	0	0	0.00
13003	1300	3	0	0	0	0	0.00
13012	1301	24	0	0	0	0	0.00
13672	1367	38	0	0	0	0	0.00
13673	1367	50	0	0	0	0	0.00
Round Lake Watershed Totals		**2818**	**417**	**100**	**552**	**100**	

Round Lake

Current conditions 10-Year Simulation (sorted by subtotals of sediment tons/acre/year)

Cell	Reach	Area	Clay	Silt	Sand	Sm. Agg.	Lg. Agg.	Subtotals	% of total	tons/ac/yr
13693	1369	6	0.24	0.32	0.17	0	0	0.74	4.08	0.13
13071	1307	83	1.35	2.08	1.24	0	0	4.68	25.98	0.06
13073	1307	11	0.16	0.27	0.17	0	0	0.61	3.37	0.06
13683	1368	59	0.64	0.86	0.69	0	0	2.18	12.13	0.04
13682	1368	57	0.54	0.72	0.58	0	0	1.83	10.18	0.03
13681	1368	86	0.69	0.92	0.74	0	0	2.34	13.01	0.03
13072	1307	23	0.20	0.29	0.14	0	0	0.63	3.52	0.03
13691	1369	82	0.53	0.64	0.30	0	0	1.47	8.14	0.02
12973	1297	221	0.24	0.35	0.35	0	0	0.94	5.21	0.00
13083	1308	270	0.25	0.35	0.35	0	0	0.95	5.26	0.00
12922	1292	28	0.02	0.03	0.03	0	0	0.08	0.45	0.00
13692	1369	10	0.01	0.01	0.01	0	0	0.03	0.14	0.00
12971	1297	80	0.05	0.07	0.07	0	0	0.20	1.10	0.00
12981	1298	74	0.05	0.07	0.07	0	0	0.18	0.98	0.00
13011	1301	74	0.03	0.06	0.06	0	0	0.14	0.79	0.00
13082	1308	251	0.11	0.18	0.18	0	0	0.47	2.59	0.00
12942	1294	44	0	0.01	0.01	0	0	0.02	0.08	0.00
12941	1294	75	0.01	0.01	0.01	0	0	0.02	0.12	0.00
12972	1297	249	0.02	0.03	0.01	0	0	0.05	0.27	0.00
12912	1291	30	0	0	0	0	0	0.00	0.00	0.00
12913	1291	36	0	0	0	0	0	0.00	0.00	0.00
12923	1292	27	0	0	0	0	0	0.00	0.00	0.00
12932	1293	59	0	0	0	0	0	0.00	0.00	0.00
12933	1293	30	0	0	0	0	0	0.00	0.00	0.00
12943	1294	94	0	0	0	0	0	0.00	0.00	0.00
12952	1295	97	0	0	0	0	0	0.00	0.00	0.00
12953	1295	48	0	0	0	0	0	0.00	0.00	0.00
12962	1296	46	0	0	0	0	0	0.00	0.00	0.00
12963	1296	161	0	0	0	0	0	0.00	0.00	0.00
12982	1298	27	0	0	0	0	0	0.00	0.00	0.00
12983	1298	155	0	0	0	0	0	0.00	0.00	0.00
12992	1299	66	0	0	0	0	0	0.00	0.00	0.00
12993	1299	21	0	0	0	0	0	0.00	0.00	0.00
13002	1300	25	0	0	0	0	0	0.00	0.00	0.00
13003	1300	3	0	0	0	0	0	0.00	0.00	0.00
13012	1301	24	0	0	0	0	0	0.00	0.00	0.00
13672	1367	38	0	0	0	0	0	0.00	0.00	0.00
13673	1367	50	0	0	0	0	0	0.00	0.00	0.00
Round Lake Watershed Totals		**2818**	**5**	**7**	**5**	**0**	**0**	**18**	**97**	

TOTAL MAXIMUM DAILY LOAD EVALUATION
TSI Trend (Total Phosphorus)

for

School Lake

(HUC 10170202)

Deuel County, South Dakota

East Dakota Water Development District
Brookings, South Dakota

September 2005

School Lake Total Maximum Daily Load

Waterbody Type:	Lake
303(d) Listing Parameter:	Total Phosphorus (TSI Trend)
Designated Uses:	Warmwater Marginal Fish Life Propagation Immersion Recreation Limited Contact Recreation Fish and Wildlife Propagation, Recreation and Stock Watering
Size of Waterbody:	221 acres
Size of Watershed:	3,892 acres
Water Quality Standards:	Narrative and Numeric
Indicators:	Water Chemistry
Analytical Approach:	Models including AnnAGNPS and BATHTUB
Location:	HUC Code: 10170202
Goal (BATHTUB based):	
Total Phosphorus	47 percent reduction in Total Phosphorus (53.7 kg/yr)
pH	By reducing total phosphorus, pH levels will improve
Target (BATHTUB based):	
Total Phosphorus	TSI 64.5, mean TSI 64.9 (60.3 kg/yr)
pH	≥ 6.0 to ≤ 9.0 pH units per grab sample

Objective

The intent of this summary is to clearly identify the components of the TMDL submittal to support adequate public participation and facilitate the US Environmental Protection Agency (EPA) review and approval. The TMDL was developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by EPA.

Introduction

School Lake is a 221-acre natural lake with a watershed of approximately 3,892 acres. This lake is located within the Big Sioux River Basin (HUC 10170202) in northwestern Deuel County, South Dakota.

This lake is included as part of the School-Bullhead Lakes Watershed Assessment Project. The entire study area for this project is outlined in Figure 1.

The watershed of this lake lies within Deuel County as shown by the shaded region in Figure 2.

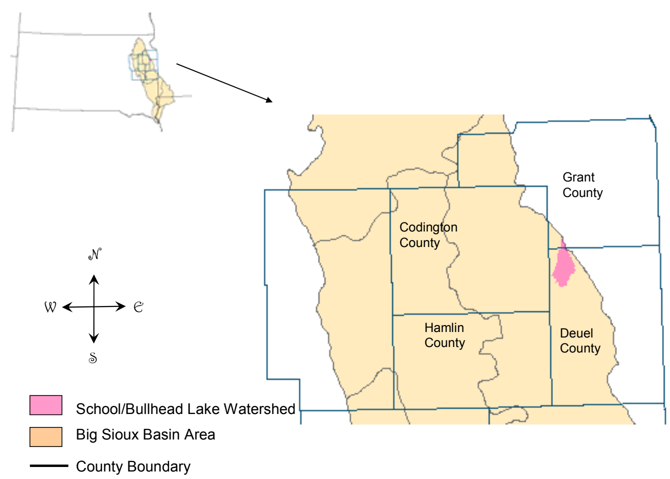


Figure 1. Location of the School-Bullhead Lakes Watershed

This lake was initially identified in the 1998 South Dakota 303(d) Waterbody list for TMDL development due to excessive nutrients, siltation, and noxious aquatic plants. This lake was most recently identified in the 2004 Integrated Waterbody List for TMDL development due to TSI trend.

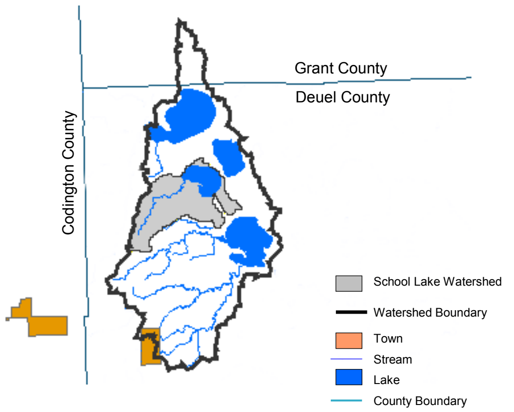


Figure 2. Location of the School Lake Watershed

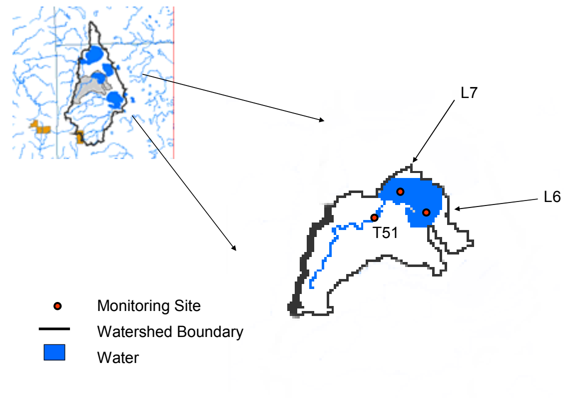


Figure 3. School Lake Monitoring Sites

Information supporting this listing was derived from statewide ambient monitoring data and the 1996 305(b) report. Furthermore, the School-Bullhead Lakes Watershed Assessment Project identified School Lake for TMDL development due to not meeting the numeric mean Trophic State Index (TSI) and not meeting water quality criteria for pH.

Although no noxious aquatic plants were found, there was excessive algae growth including several species of nuisance blue-green algae present.

Problem Identification

Two in-lake monitoring sites were setup on School Lake, L6 (east) and L7 (west) (Figure 3). Water quality sampling at these sites indicate excessive phosphorus and high pH levels. Noxious species of algae were found in both the June and August samples. Chlorophyll-*a* samples averaged 49.84 ppb.

The watershed area shown in Figure 2 drains approximately 90 percent grass/grazing land and cropland acres. No municipalities are located in this area.

The inlet of School Lake (monitoring site T51) was assessed for water quality. This inlet was found to be meeting its numeric criteria for its beneficial uses.

During heavy rainfall/flooding years, School Lake may drain into Round Lake. However, due to the dry conditions during the time of this assessment, this was not observed.

Total phosphorus load to School Lake is 114 kg annually. Of the total load, groundwater contribution is estimated at 2.1 kg/yr, precipitation contribution is 39.3 kg/yr, and nonpoint sources are 72.6 kg/yr. The inlet to School Lake was not taken into consideration when calculating the phosphorus loading due to its intermittent nature.

Non-point sources (such as ungaged runoff and sediment loading) or point sources (such as drainage pipes) may also be contributing to the phosphorus load. A 47 percent reduction in phosphorus load is required to improve TSI. This reduction was calculated from ungaged runoff which requires a reduction of 53.7 kg/yr (or 74 percent of the total nonpoint source contribution) to meet the numeric mean Trophic State Index (TSI) of 64.9 to fully support the lake's assigned beneficial uses.

A total of 20 phosphorus and 20 pH inlake samples were taken from the two monitoring locations (L6 and L7). Of the 20 pH samples, seven of the samples (35 percent) were violating the water quality standards. This 35 percent indicates that this lake is not meeting the water quality criteria for its beneficial uses. The exceedences in pH levels is believed to be attributed to excessive algae growth which uses the acidic dissolved carbon dioxide in the water for its life processes which in-turn causes the pH of the water to rise.

Additionally, excessive algae growth is likely caused by high levels of nutrients within the lake. In this case, School Lake is a phosphorus limited lake. Therefore, increases in phosphorus should yield increases in algal mass (See Table 1). If the phosphorus concentrations can be controlled, then excessive algae growth will be suppressed.

Table 1. Total Phosphorus and Chlorophyll a Means for School Lake

	Total Phosphorus (ppb)	Chlorophyll-a (ppb)
April - May	60	10
June - August	136	66
September - October	130	49

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

School Lake has been assigned beneficial uses by the state of South Dakota Surface Water Quality Standards regulations (See page 10 of the Assessment Report). Along with these assigned uses are narrative and numeric criteria that define the desired water quality of this lake. These criteria must be maintained for the lake to satisfy its assigned beneficial uses, which are listed below:

- Warmwater marginal fish propagation
- Limited contact recreation
- Immersion recreation
- Fish and wildlife propagation, recreation and stock watering

Individual parameters, including the lake's mean TSI value, determine the support of beneficial uses and compliance with standards. This lake experiences nutrient enrichment and nuisance algal blooms which are typical signs of the eutrophication process.

Administrative Rules of South Dakota Article 74:51 contains numeric and narrative standards to be applied to the surface waters (i.e. streams, lakes) of the state. It contains language that prohibits the existence of materials causing pollutants to form, visible pollutants, taste and odor producing materials, and nuisance aquatic life.

If adequate numeric criteria are not available, alternate measures to assess the trophic status of a lake are taken. This alternate method uses the mean Trophic State Index (Carlson 1977) which incorporates a combination of Secchi depth, chlorophyll-*a*, and total phosphorus concentrations.

The SD DENR has developed an EPA-approved protocol that establishes desired TSI levels for lakes based on their ecoregion location (SD DENR 2000). Table 2 shows the protocol that was used to assess impairment and determine a numeric target for School Lake.

Table 2. Ecoregion 46N Beneficial Use Category and Carlson TSI Numeric Ranges by Category

Ecoregion (46N) Beneficial Use Category	TSI Numeric Range
Fully supporting	≤ 65
Partially supporting	≥ 65.01 - ≤ 70
Non-supporting	≥ 70.01

School Lake currently has a BATHTUB modeled total phosphorus TSI of 70, a chlorophyll-*a* TSI of 71.3, and a Secchi TSI of 70, which calculates to an average TSI of 70.4. Observed values for total phosphorus TSI is 73.2, for chlorophyll-*a* TSI 69.9, for Secchi TSI 70.9, and an overall mean TSI of 71.3, which is indicative of increased levels of primary productivity.

Additionally, water samples were obtained using SD DENR standard operating procedures and the results were compared to the applicable water quality criteria. Seven of the 20 pH samples were higher than the numeric standard levels (≥ 6.0 to ≤ 9.0 pH units) allowed per grab sample.

Recommended specific TSI parameters for School Lake are 64.5 for total phosphorus, 65.8 for chlorophyll-*a*, and 64.5 for Secchi depth. The TMDL numeric target will reduce total phosphorus loading to School Lake lowering the mean TSI to 64.9. A phosphorus reduction will reduce algal blooms and consequently lower pH levels.

Pollutant Assessment

Point Sources

There are no point source pollutants of concern in this watershed.

Nonpoint Sources

Nonpoint and background sources of pollution in the School Lake Watershed were estimated using BATHTUB and AnnAGNPS modeling.

Under current conditions, total nonpoint source loadings of total phosphorus from the watershed of School Lake was estimated to be 72.6 kg, and were attributed to ungaged runoff. Reductions were based only on ungaged runoff since the background can not be reduced. The required reduction of ungaged runoff load of total phosphorus (53.7 kg) was subtracted from the total phosphorus TMDL (114 kg) to determine background source loading. The remaining total phosphorus loading (60.3 kg) was attributed to 2.1 kg/yr for groundwater contribution, 18.9 kg/yr for ungaged runoff, and 39.3 kg/yr for precipitation contribution in the School Lake Watershed.

Internal lake sources of phosphorus should also be considered for reduction. Internal loading was estimated to contribute 70 percent of the total phosphorus level in School Lake (See page 116 of the Assessment Report). Improvements to the riparian areas, including vegetation management will also improve TSI values.

Linkage Analysis

Water quality data was collected at two in-lake monitoring and one inlet site. Samples were collected according to South Dakota's EPA approved Standard Operating Procedures for Field Samplers. Water samples were sent to the State Health Laboratory in Pierre, South Dakota, for analysis. Quality assurance/quality control samples were collected on 10% of the samples according to South Dakota's EPA approved Non-point Source Quality Assurance/Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed in the assessment final report.

In addition to water quality monitoring, data was collected to complete a watershed landuse model. The AnnAGNPS model was used to identify areas contributing to potential nutrient and sediment loads. More information about AnnAGNPS results can be found in the Results section and Appendices J and K of the Assessment Report. Areas of higher nutrient and sediment loads within School Lake watershed are shown in Figures 4 and 5. This data is based on current conditions over a 10-year simulation period. Details regarding nutrient and sediment loads contributing by each AnnAGNPS cell can be found in Attachment 1.

School Lake Watershed – Higher Nutrient Loading Areas

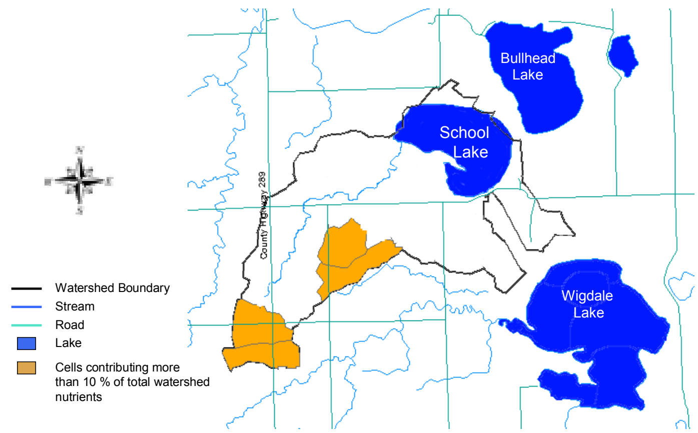


Figure 4. Higher Nutrient Loading Areas in the School Lake Watershed

School Lake Watershed – Higher Sediment Loading Areas

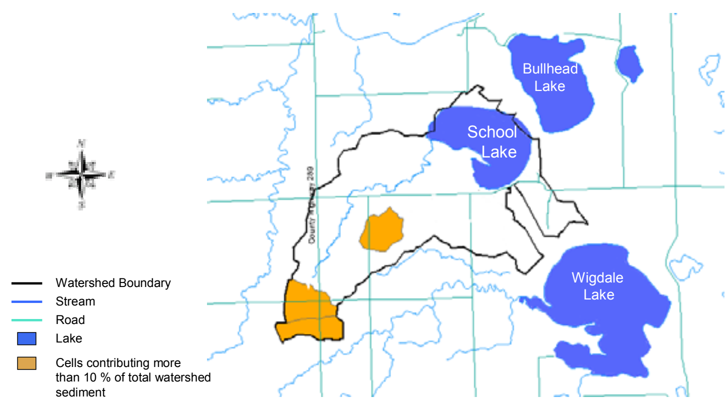


Figure 5. Higher Sediment Loading Areas in the School Lake Watershed

The impacts of phosphorus reductions on the condition of School Lake were calculated using the BATHTUB. The BATHTUB predicted a reduction of 74 percent (53.7 kg/yr) of the current total phosphorus ungaged runoff load (72.6 kg/yr), to reduce the average TSI value from 70.4 to 64.9. Reductions to meet the TMDL can be achieved by implementing BMPs such as shoreline stabilization, grazing management, riparian management, and fertilizer reduction. Internal lake sources of phosphorus should also be considered, even though the ungaged runoff would accomplish the goal of this TMDL.

TMDL and Allocations

TMDL

Total phosphorus (kg) = 47 % reduction

	0 kg/yr	(WLA)
+	18.9 kg/yr	(LA)
+	41.4 kg/yr	(Background)
+	Implicit	(MOS)
	60.3 kg/yr	(TMDL)

Wasteload Allocations (WLAs)

There are no point source pollutants of concern in this watershed. Therefore, the "wasteload allocation" component of this TMDL is considered a zero value. The TMDL is considered wholly included within the "load allocation" component.

Load Allocations (LAs)

Load allocations account for the portion of the TMDL assigned to non-point sources. Natural background constitutes 41.4 kg/yr of the total and the remainder of the LA is assigned to the ungaged runoff that is likely to contribute phosphorus at rates above the natural background. A 74 percent reduction of external phosphorus load from ungaged runoff may be achieved through the implementation of BMPs including animal exclusion, no-tillage cropping practices, and riparian buffers.

In-lake total phosphorus reduction to improve TSI should also be considered for School Lake. Aluminum sulfate treatments would not be a viable option to control internal phosphorus as School Lake has a mean depth of 2.03 m. However, biomanipulation and plant management strategies may be the best options to control internal phosphorus. Dredging could be considered but it is recommended sediment samples be taken beforehand to determine which areas sediment should be removed. Dredging of the entire lake is not recommended. See Management Options and Recommendations section of the Assessment Report for further information.

Additionally, a total phosphorus load reduction would be the primary means in attaining water quality standards for pH and to control algal biomass.

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in temperature, precipitation and agricultural practices. To determine seasonal differences, School Lake phosphorus and chlorophyll-*a* samples were separated into spring (April to May), summer (June to August), and fall (September to October). This TMDL targets the most productive part of the year (June to August). Not only is this the period of peak recreational use, but it is also the period during which most impairments are occurring.

Margin of Safety

The margin of safety (MOS) is a portion of the loading capacity that is set aside to prevent the exceedence of a water quality standard as a means of accounting for the uncertainty involved in developing a TMDL. The MOS for this TMDL is implicit, meaning all total phosphorus reductions were calculated based on extremely conservative estimations built into the model and conservative total phosphorus reduction percentages using best professional judgment.

Critical Conditions

Based upon the 2003 assessment data, nutrient loading to School Lake is most severe during late spring and impairments usually result during mid to late summer because of warmer water temperatures and increased algal growth. Phosphorus load from the ungaged runoff occurs during spring runoff from April to late May.

Follow-Up Monitoring

School Lake should continue to be monitored through the statewide lake assessment project and the South Dakota Game, Fish and Parks normal lake survey to monitor and evaluate long-term trophic status, biological communities, and ecological trends.

Periodically during the implementation project and then once it is completed, monitoring will be necessary to ensure TSI values improve and the goals of this TMDL are met. Recurrent water quality sampling at the original monitoring sites is suggested.

Public Participation

Efforts taken to gain public education, review, and comment during development of the TMDL involved:

1. East Dakota Water Development District public board meetings
2. Individual contact with landowners in the watershed

Comments from these public meetings have been taken into consideration in the development of the School Lake TMDL.

Implementation Plan

The East Dakota Water Development District is working with the South Dakota DENR and various stakeholders to initiate an implementation project, which is estimated to begin in 2006. Deuel County Conservation District is expected to request 319 funding in late 2005 with project assistance being available in 2006.

School Lake							
Current Conditions 10-Year Simulation (sorted by P04 lb/ac/yr)							PO4
Cell	**Reach**	**Area**	**PO4 lb/yr**	**% of total**	**Nitrogen lb/yr**	**% of total**	**lb/ac/yr**
13562	1356	5	11	2	56	4	2.19
13643	1364	13	25	4	32	2	1.94
13661	1366	94	138	21	483	36	1.47
13642	1364	10	14	2	23	2	1.42
13122	1312	52	68	10	48	4	1.31
13602	1360	6	6	1	16	1	1.07
13561	1356	76	76	12	149	11	1.00
13653	1365	5	5	1	10	1	0.89
13641	1364	85	47	7	116	9	0.56
13652	1365	2	1	0	2	0	0.53
13651	1365	79	40	6	131	10	0.51
13662	1366	232	52	8	61	5	0.22
13633	1363	36	8	1	8	1	0.22
13622	1362	121	25	4	25	2	0.20
13623	1362	203	41	6	42	3	0.20
13632	1363	6	1	0	1	0	0.20
13593	1359	107	21	3	19	1	0.20
13611	1361	88	17	3	15	1	0.20
13663	1366	232	46	7	89	7	0.20
13603	1360	9	2	0	1	0	0.18
13601	1360	84	6	1	2	0	0.08
13583	1358	2	0	0	0	0	0.07
13092	1309	258	0	0	0	0	0.00
13093	1309	109	0	0	0	0	0.00
13103	1310	7	0	0	0	0	0.00
13112	1311	6	0	0	0	0	0.00
13113	1311	15	0	0	0	0	0.00
13123	1312	77	0	0	0	0	0.00
13582	1358	13	0	0	0	0	0.00
13591	1359	74	0	0	0	0	0.00
13592	1359	22	0	0	0	0	0.00
13613	1361	7	0	0	0	0	0.00
School Lake Watershed Totals		**2135**	**651**	**100**	**1331**	**100**	

School Lake

Current conditions 10-Year Simulation (sorted by subtotals of sediment tons//acre/year)

Cell	Reach	Area	Clay	Silt	Sand	Sm. Agg.	Lg. Agg.	Subtotals	% of total	tons/ac/yr
13562	1356	5	1.58	3.21	0.21	0	0	5.00	5.75	0.98
13661	1366	94	12.95	24.62	4.13	0	0	41.70	47.93	0.44
13602	1360	6	0.53	0.92	0.78	0	0	2.23	2.56	0.40
13653	1365	5	0.21	0.43	0.06	0	0	0.70	0.80	0.14
13561	1356	76	3.08	5.74	1.00	0	0	9.83	11.29	0.13
13651	1365	79	2.99	5.70	0.94	0	0	9.62	11.06	0.12
13642	1364	10	0.36	0.49	0.32	0	0	1.17	1.34	0.12
13643	1364	13	0.56	0.67	0.20	0	0	1.43	1.64	0.11
13641	1364	85	1.86	2.37	1.44	0	0	5.67	6.51	0.07
13122	1312	52	0.87	1.34	0.85	0	0	3.07	3.52	0.06
13652	1365	2	0.03	0.04	0.02	0	0	0.09	0.11	0.05
13662	1366	232	0.60	0.82	0.79	0	0	2.21	2.54	0.01
13663	1366	232	0.62	1.23	0.30	0	0	2.15	2.47	0.01
13633	1363	36	0.05	0.07	0.07	0	0	0.19	0.21	0.01
13623	1362	203	0.26	0.35	0.35	0	0	0.96	1.10	0.00
13622	1362	121	0.15	0.21	0.21	0	0	0.56	0.64	0.00
13632	1363	6	0.01	0.01	0.01	0	0	0.03	0.03	0.00
13593	1359	107	0.05	0.07	0.07	0	0	0.18	0.20	0.00
13603	1360	9	0	0.01	0.01	0	0	0.01	0.01	0.00
13611	1361	88	0.03	0.04	0.04	0	0	0.12	0.14	0.00
13601	1360	84	0	0	0	0	0	0.00	0.00	0.00
13092	1309	258	0	0	0	0	0	0.00	0.00	0.00
13093	1309	109	0	0	0	0	0	0.00	0.00	0.00
13103	1310	7	0	0	0	0	0	0.00	0.00	0.00
13112	1311	6	0	0	0	0	0	0.00	0.00	0.00
13113	1311	15	0	0	0	0	0	0.00	0.00	0.00
13123	1312	77	0	0	0	0	0	0.00	0.00	0.00
13582	1358	13	0	0	0	0	0	0.00	0.00	0.00
13583	1358	2	0	0	0	0	0	0.00	0.00	0.00
13591	1359	74	0	0	0	0	0	0.00	0.00	0.00
13592	1359	22	0	0	0	0	0	0.00	0.00	0.00
13613	1361	7	0	0	0	0	0	0.00	0.00	0.00
School Lake Watershed Totals		2135	27	48	12	0	0	87	100	

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
1595 Wynkoop Street
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Phone 800-227-8917
http://www.epa.gov/region08

SEP 2 2008

Ref: 8EPR-EP

Steven M. Pirner
Secretary
South Dakota Department of Environment & Natural Resources
Joe Foss Building
523 East Capitol
Pierre, SD 57501-3181

Re: TMDL Approvals
School Lake; SD-BS-L-SCHOOL_01
Legion Lake; SD-CH-L-LEGION_01

Dear ~~Mr. Pirner~~ Steve:

We have completed our review of the total maximum daily loads (TMDLs) as submitted by your office for the waterbodies listed in the enclosure to this letter. In accordance with the Clean Water Act (33 U.S.C. 1251 *et. seq.*), we approve all aspects of the TMDLs as developed for the water quality limited waterbodies as described in Section 303(d)(1). Based on our review, we feel the separate elements of the TMDLs listed in the enclosed table adequately address the pollutants of concern as given in the table, taking into consideration seasonal variation and a margin of safety.

Some of the TMDLs listed in the enclosed table may be for waters not found on the State's current Section 303(d) waterbody list. The Environmental Protection Agency understands that such waters would have been included on the list had the State been aware, at the time the list was compiled, of the information developed in the context of calculating these TMDLs. This information demonstrates that the non-listed water is, in fact, a water quality limited segment in need of a TMDL. The State need not include these waters that have such TMDLs associated with them on its next Section 303(d) list for the pollutant covered by the TMDL.

Thank you for submitting these TMDLs for our review and approval. If you have any questions, the most knowledgeable person on my staff is Vern Berry and may be reached at 303-312-6234.

Sincerely,

Carol L. Campbell

Carol L. Campbell
Assistant Regional Administrator
Office of Ecosystems Protection
and Remediation

Enclosures

ENCLOSURE 1

APPROVED TMDLs

2 Pollutant TMDLs completed
1 cause addressed from the 2008 303(d) list
0 Determinations made that no pollutant TMDL was needed

Waterbody Name & AU ID	TMDL Parameter/ Pollutant (303(d) list cause)	Water Quality Goal/Endpoint	TMDL WLA / LA / MOS	Supporting Documentation (not an exhaustive list of supporting documents)
School Lake* SD-BS-L-SCHOOL_01	Phosphorus (TSI); pH impairment documented in the assessment report**	Secchi – chlorophyll-*a* TSI ≤ 68.4	LC = 87.2 kg/yr LA = 87.2 kg/yr WLA = 0 kg/yr MOS = Implicit	■ Watershed Assessment Final Report and TMDL, School Lake, Deuel County, South Dakota (SD DENR, August 2005)
Legion Lake* SD-CH-L-LEGION_01	Phosphorus	Secchi – chlorophyll-*a* TSI ≤ 53.0	LC = 7.3 kg/yr LA = 7.3 kg/yr WLA = 0 kg/yr MOS = Implicit	■ Section 319 Nonpoint Source Pollution Control Program Assessment/Planning Project Final Report, Legion Lake, Custer County, South Dakota (SD DENR, April 2008)
	pH	The pH impairment will be addressed in a future report and/or TMDL and Legion Lake will remain on the 303(d) list for pH. It is expected that the BMPs needed to control phosphorus loading will improve the pH readings in the lake, but natural sources are also suspected of contributing to high pH readings and will be investigated further.		

* Indicates that the waterbody has been included on the State's Section 303(d) list of waterbodies in need of TMDLs.
** Improvements in the pH readings in School Lake can be achieved through reduction of organic loading to the lake as a result of proposed BMP implementation. The TMDL contains a linkage analysis between phosphorous loading and pH in lakes and reservoirs.
LC = loading capacity; WLA = wasteload allocation; LA = load allocation; MOS = margin of safety
TMDL = LC = $\sum$WLAs + $\sum$LAs + MOS

ENCLOSURE 3

EPA REGION VIII TMDL REVIEW FORM

Document Name:	**Legion Lake Watershed Assessment Final Report**
Submitted by:	**Gene Stueven, SD DENR**
Date Received:	**June 19, 2008**
Review Date:	**July 15, 2008**
Reviewer:	**Vern Berry, EPA**
Formal or Informal Review?	**Formal – Final Approval**

This document provides a standard format for EPA Region 8 to provide comments to the South Dakota Department of Environment and Natural Resources on TMDL documents provided to the EPA for either official formal or informal review. All TMDL documents are measured against the following 11 review criteria:

1. Water Quality Impairment Status
2. Water Quality Standards
3. Water Quality Targets
4. Significant Sources
5. Technical Analysis
6. Margin of Safety and Seasonality
7. Total Maximum Daily Load
8. Allocation
9. Public Participation
10. Monitoring Strategy
11. Restoration Strategy

Each of the 11 review criteria are described below to provide the rational for the review, followed by EPA's comments. This review is intended to ensure compliance with the Clean Water Act and also to ensure that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Water Quality Impairment Status

Criterion Description – Water Quality Impairment Status
TMDL documents must include a description of the listed water quality impairments. While the 303(d) list identifies probable causes and sources of water quality impairments, the information contained in the 303(d) list is generally not sufficiently detailed to provide the reader with an adequate understanding of the impairments. TMDL documents should include a thorough description/summary of all available water quality data such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and/or appropriate water quality standards.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Legion Lake is a 9 acre man-made lake impoundment located in north-central Custer County, South Dakota. Galena Creek is the main tributary that flows into the reservoir and is located within the Middle Cheyenne-Spring sub-basin of the Cheyenne River Basin. It is listed on South Dakota's 2006 303(d) list as impaired (SD-CH-L-LEGION_01) for trophic state index (TSI) and pH, and on the 2008 303(d) list for pH, due to nonpoint sources and ranked as priority 1 (i.e., high priority) for TMDL development. The watershed is approximately 2,050 acres and drains predominantly evergreen forest and recreational areas. Legion Lake was included on South Dakota's 2006 303(d) list based on data collected prior to the Legion Lake assessment report being finalized (dated December 2007). When this recent data is added to the existing data Legion Lake is currently meeting the State's TSI target which corresponds with the coldwater marginal fish life propagation designated beneficial use of the lake. The pH impairment will be addressed in a future report and/or TMDL and Legion Lake will remain on the 303(d) list for pH. It is expected that the BMPs needed to control phosphorus loading will improve the pH readings in the lake, but natural sources are also suspected of contributing to high pH readings and will be investigated further.

2. Water Quality Standards

Criterion Description – Water Quality Standards
The TMDL document must include a description of all applicable water quality standards for all affected jurisdictions. TMDLs result in maintaining and attaining water quality standards. Water quality standards are the basis from which TMDLs are established and the TMDL targets are derived, including the numeric, narrative, use classification, and antidegradation components of the standards.

☒ Satisfies Criterion
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☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
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SUMMARY – Legion Lake was listed as impaired for TSI which is a surrogate measure used to determine whether the narrative standards are being met. South Dakota has applicable narrative standards that may be applied to the undesirable eutrophication of lakes. Data from Legion Lake indicates potential problems with nutrient enrichment and nuisance algal blooms, which are typical signs of the eutrophication process. The narrative standards being implemented in this TMDL are:

> "*Materials which produce nuisance aquatic life may not be discharged or caused to be discharged into surface waters of the state in concentrations that impair a beneficial use or create a human health problem.*" (See ARSD §74:51:01:09)

> "*All waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities.*" (See ARSD §74:51:01:12)

Other applicable water quality standards are included on pages 2 - 4 of the assessment report.

3. Water Quality Targets

Criterion Description – Water Quality Targets

Quantified targets or endpoints must be provided to address each listed pollutant/water body combination. Target values must represent achievement of applicable water quality standards and support of associated beneficial uses. For pollutants with numeric water quality standards, the numeric criteria are generally used as the TMDL target. For pollutants with narrative standards, the narrative standard must be translated into a measurable value. At a minimum, one target is required for each pollutant/water body combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include targets representing water column sediment such as TSS, embeddeness, stream morphology, up-slope conditions and a measure of biota).

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SUMMARY – Water quality targets for this TMDL are based on interpretation of narrative provisions found in State water quality standards. In June 2005, SD DENR published *Targeting Impaired Lakes in South Dakota*. This document proposed targeted median growing season Secchi disk/chlorophyll *a* Trophic State Index (TSI) values for each beneficial use designation category. In South Dakota algal blooms can limit contact and immersion recreation beneficial uses. Also algal blooms can deplete oxygen levels which can affect aquatic life uses. SD DENR considers several algal species to be nuisance aquatic species. TSI measurements can be used to estimate how much algal production may occur in lakes. Therefore, TSI is used as a measure of the narrative standard in order to determine whether beneficial uses are being met. Legion Lake is classified as a coldwater marginal fishery. The TSI target for coldwater marginal fisheries is a median Secchi disk / chlorophyll $a \leq 53.0$

The actual Secchi disk / chlorophyll *a* TSI for Legion Lake during the period of the assessment was 50.4. However, Legion Lake continues to experience internal phosphorus loading from its sediments and external phosphorus loading from its watershed which has caused increasing eutrophication. The water quality data collected for the December 2007 assessment report was collected during a period of drought so the Secchi disk / chlorophyll *a* TSI of 50.4 may not be representative of a typical year. Therefore, the TMDL recommends that BMPs be implemented to achieve lake phosphorus concentrations at a level that allows the lake to maintain or improve its trophic state.

The water quality target for this TMDL is: **maintain a growing season median Secchi disk -chlorophyll *a* TSI at or below 53.0.**

4. Significant Sources

Criterion Description – Significant Sources

TMDLs must consider all significant sources of the stressor of concern. All sources or causes of the stressor must be identified or accounted for in some manner. The detail provided in the source assessment step drives the rigor of the allocation step. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each significant source when the relative load contribution from each source has been estimated. Ideally, therefore, the pollutant load from each significant source should be quantified. This can be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach can be employed so long as the approach is clearly defined in the document.

☒ Satisfies Criterion
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SUMMARY – The TMDL identifies the major sources of phosphorus as coming from nonpoint source forest and recreational landuses within the watershed. There are no known point source contributions in this watershed. Water quality loading was calculated for each gauged subwatershed using the FLUX modeling program to determine the approximate loading from the watershed. Possible sources include domestic sewage, detergents, fertilizers and animal waste. Also, a portion of the total phosphorus load originates from lake bottom sediment.

5. Technical Analysis

Criterion Description – Technical Analysis

*TMDLs must be supported by an appropriate level of technical analysis. It applies to **all** of the components of a TMDL document. It is vitally important that the technical basis for **all** conclusions be articulated in a manner that is easily understandable and readily apparent to the reader. Of particular importance, the cause and effect relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and allocations needs to be supported by an appropriate level of technical analysis.*

☒ Satisfies Criterion
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SUMMARY – The technical analysis addresses linkage between the water quality target and the identified sources of nutrients, and describes the models or methods used to derive the TMDL loads that will ensure that the water quality standards are met. To determine the cause and effect relationship between the water quality target and the identified sources various models and loading analysis were utilized.

The FLUX model was used to facilitate the analysis and reduction of tributary inflow and outflow nutrient and sediment loadings for Legion Lake. Phosphorus export coefficients were calculated for each subwatershed and were used to define critical nonpoint source pollution areas within the watershed. The BATHTUB program was used to estimate water and nutrient balances and identify factors controlling algal production. The model was also used to determine the nutrient load reduction required for Legion Lake to support its beneficial uses.

The Acidification and Alkalinity section of the assessment report (pp. 35 – 36) discusses the pH data and impairment. Management practices recommended to reduce phosphorus loads, thereby reducing algae growth, are expected to also reduce the pH of Legion Lake to a level that meets the applicable water quality criteria. However, the high pH is also attributed, in part, to natural sources. This report does not include a strategy to control these natural sources; therefore the pH impairment will be addressed in a future report and/or TMDL.

6. Margin of Safety and Seasonality

Criterion Description – Margin of Safety and Seasonality

A margin of safety (MOS) is a required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving water body (303(d)(1)(c)). The MOS can be implicitly expressed by incorporating a margin of safety into conservative assumptions used to develop the TMDL. In other cases, the MOS can be built in as a separate component of the TMDL (in this case, quantitatively, a TMDL = WLA + LA + MOS). In all cases, specific documentation describing the rational for the MOS is required.

Seasonal considerations, such as critical flow periods (high flow, low flow), also need to be considered when establishing TMDLs, targets, and allocations.

☒ Satisfies Criterion
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☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing BMPs that can be tailored to seasonal needs.

7. TMDL

Criterion Description – Total Maximum Daily Load
TMDLs include a quantified pollutant reduction target. According to EPA regulations (see 40 CFR 130.2(i)). TMDLs can be expressed as mass per unit of time, toxicity, % load reduction, or other measure. TMDLs must address, either singly or in combination, each listed pollutant/water body combination.

- ☒ Satisfies Criterion
- ☐ Satisfies Criterion. Questions or comments provided below should be considered.
- ☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
- ☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
- ☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The TMDL established for Legion Lake is a 7.3 kg/yr (0.022 kg/day) total phosphorus load to the lake. This is the "measured load" which is based on the flow and concentration data collected during the period of the assessment. Since the annual loading varies from year-to-year, this TMDL is considered a long term average percent reduction in phosphorus loading. Data collected for the assessment report indicate that Legion Lake is currently meeting the State's TSI target for coldwater marginal fish life propagation. Therefore the TMDL load for total phosphorus is equal to the current loading rate in order to maintain the current trophic state. However, BMPs are recommended to reduce phosphorus loads and improve or maintain the trophic state because Legion Lake is only narrowly meeting the TSI target.

The SD DENR believes that describing the load as an annual load is more realistic and protective of the waterbody. Most phosphorus based eutrophication models use annual phosphorus loads, and seasonality and unpredictable precipitation patterns make a daily load unrealistic. EPA recognizes that, under the specific circumstances, the state may deem the annual load the most appropriate timeframe (i.e., the TSI water quality target is based on an interpretation of narrative water quality standards which naturally does not include an averaging period). EPA notes that the Legion Lake TMDL calculations for phosphorus include an approximated daily load derived by EPA's method contained in the Technical Support Document for Water Quality-Based Toxics Control. The daily load expression is identified as a static daily maximum load, but will typically not match the actual phosphorus load reaching the lake on a given day.

8. Allocation

> ***Criterion Description – Allocation***
>
> *TMDLs apportion responsibility for taking actions or allocate the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or dividing of responsibility. A performance based allocation approach, where a detailed strategy is articulated for the application of BMPs, may also be appropriate for nonpoint sources. Every effort should be made to be as detailed as possible and also, to base all conclusions on the best available scientific principles.*
>
> *In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).*

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – This TMDL addresses the need to achieve reductions in nutrients to attain water quality goals in Legion Lake. The allocations in the TMDL include a "load allocation" attributed to recreational nonpoint sources. There are no known point source contributions in this watershed. Possible sources include domestic sewage, detergents, fertilizers and animal waste. Phosphorus loading reductions can be achieved by implementing the various BMPs that are outlined in the Conclusions and Recommendations section (pp. 52 – 54) of the report.

9. Public Participation

> ***Criterion Description – Public Participation***
>
> *The fundamental requirement for public participation is that all stakeholders have an opportunity to be part of the process. Notifications or solicitations for comments regarding the TMDL should clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for review, a copy of the comments received by the state should be also submitted to EPA..*

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
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☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The State's submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through public meetings in the watershed and has had individual contact with residents in the watershed. Also, the draft TMDL was posted on the State's internet site to solicit comments during the public notice period. The level of public participation is found to be adequate.

10. Monitoring Strategy

> ***Criterion Description – Monitoring Strategy***
>
> *TMDLs may have significant uncertainty associated with selection of appropriate numeric targets and estimates of source loadings and assimilative capacity. In these cases, a phased TMDL approach may be necessary. For Phased TMDLs, it is EPA's expectation that a monitoring plan will be included as a component of the TMDL documents to articulate the means by which the TMDL will be evaluated in the field, and to provide supplemental data in the future to address any uncertainties that may exist when the document is prepared.*

- ☐ Satisfies Criterion
- ☐ Satisfies Criterion. Questions or comments provided below should be considered.
- ☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
- ☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
- ☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Legion Lake will continue to be monitored through the statewide lake assessment project. Post-implementation monitoring will be necessary to assure the TMDL has been reached and maintenance of the beneficial use occurs.

11. Restoration Strategy

> ***Criterion Description – Restoration Strategy***
>
> *At a minimum, sufficient information should be provided in the TMDL document to demonstrate that if the TMDL were implemented, water quality standards would be attained or maintained. Adding additional detail regarding the proposed approach for the restoration of water quality is not currently a regulatory requirement, but is considered a value added component of a TMDL document.*

- ☐ Satisfies Criterion
- ☐ Satisfies Criterion. Questions or comments provided below should be considered.
- ☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
- ☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
- ☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The South Dakota DENR will work with a local watershed group to initiate BMP implementation in the Legion Lake watershed. Implementation of various best management practices will be necessary to meet or maintain the current water quality and TMDL targets/goals.