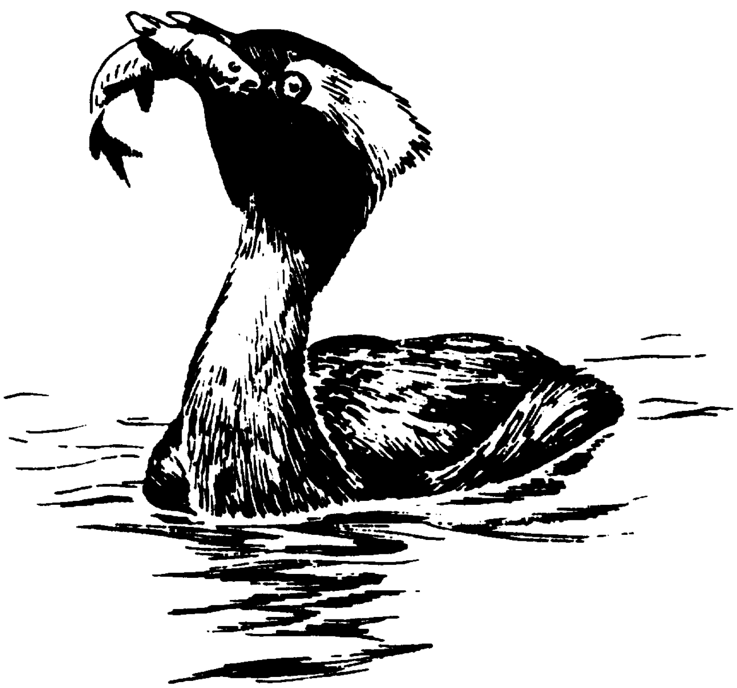
PHASE I
WATERSHED ASSESSMENT
FINAL REPORTS

TWIN LAKE & WILMARTH LAKE



South Dakota Water Resources Assistance Program
Division of Financial & Technical Assistance
South Dakota Department of Environment & Natural Resources
Steven M. Pirner, Secretary

April 2009

SECTION 319 TMDL
ASSESSMENT/PLANNING PROJECT FINAL REPORT

WILMARTH LAKE AND TWIN LAKE WATERSHED ASSESSMENT FINAL REPORT

By

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Sponsor:

Aurora County Conservation District

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

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South Dakota Department of Environment and Natural Resources

South Dakota Department of Game, Fish and Parks

US Environmental Protection Agency

Aurora County Natural Resource Conservation Service

Jerauld County Natural Resource Conservation Service

Sanborn County Natural Resource Conservation Service

Aurora County Farm Service Agency

Jerauld County Farm Service Agency

Sanborn County Farm Service Agency

James River Water Development District

Lower James RC&D

City of Mitchell

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Abbreviations

AFO(s)	Animal Feeding Operation(s)
AnnAGNPS	Annualized Agricultural Non-Point Source Model
ATV	All Terrain Vehicle
BMP(s)	Best Management Practice(s)
° C	Degrees Celsius
CFS	Cubic Feet Per Second
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
GPM	Gallons Per Minute
GPS	Global Positioning System
GRTS	Grant Reporting and Tracking System
MBE/WBE	Minority Business Enterprise/Women Business Enterprise
mg/L	Milligrams Per Liter
NRCS	Natural Resources Conservation Service
PIP	Project Implementation Plan
QA/QC	Quality Assurance/Quality Control
SD DENR	South Dakota Department of Environment and Natural Resources
SDGF&P	South Dakota Department of Game, Fish & Parks
su	Standard Units
TALKA	Total Alkalinity
TDPO4	Total Dissolved Phosphorus

TPO4	Total Phosphorus
TDSOL	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TSI	Trophic State Index
TSOL	Total Solids
TSSOL	Total Suspended Solids
USDA	United States Department of Agriculture
FSA	Farm Service Agency
GIS	Global Information System
NPS	Non Point Source
CST	Central Standard Time
EDNA	Elevation Derivatives for National Applications
DEM	Digital Elevation Map
SSURGO	Soil Survey Geographic Database
NASIS	National Soil Information System
DOQ	Digital Ortho Quad
NLCD	National Land Cover Dataset
EROS	Earth Resource Observation and Science Center
CRP	Conservation Reserve Program

Executive Summary

PROJECT TITLE: Twin Lake/Wilmarth Lake Watershed Assessment Projects

PROJECT START DATE: May 15, 2003
PROJECT COMPLETION DATE: December 2005

FUNDING: TOTAL BUDGET $106,300

TOTAL EPA GRANT:	$64,000
TOTAL EXPENDITURES OF EPA FUNDS	$33,547.22
TOTAL EXPENDITURES OF STATE FEE FUNDS	$12,327.18
TOTAL SECTION 319 MATCH ACCRUED	$23,247.21
BUDGET REVISIONS	None
TOTAL EXPENDITURES	$69,121.61

SUMMARY ACCOMPLISHMENTS

The Twin Lake and Wilmarth Lake Assessment Project began in May 2003 and ended in December 2005 when data collection was complete. Milestones were met for sediment, macrophyte, in-lake water quality monitoring, and tributary stream flow data collection. Milestones for sampling several tributary monitoring sites were not met due to a lack of spring snowmelt and a lack of runoff. Animal feeding operations (AFOs) were identified in the two watersheds and data for each AFO was entered into the AnnAGNPS model. The Aurora County Conservation District was responsible for water quality and biological sample collection, measuring stream velocities and stages at appropriate intervals, assistance with data collection to run the Annualized Agricultural Non-point Source Model (AnnAGNPS), public participation, and reporting of project accomplishments. The South Dakota Department of Environment and Natural Resources (SDDENR) provided technical assistance during the study and SDDENR is responsible for writing the Final Assessment Report.

An EPA Section 319 grant ($64,000) provided 60% of the funding for the Twin/Wilmarth project. The State of South Dakota provided 22% of the required match by awarding a $23,000 Natural Resources Fee Fund grant to the project sponsor. Local matching funds were to be used to meet the remaining 18% of the required match funds ($19,300).

In-lake and tributary water quality monitoring and watershed modeling resulted in the identification of several sources of nonpoint source pollutants affecting the water quality of Twin Lake and Wilmarth Lake. Utilization of Best Management Practices (BMP) through implementation and information/education program will reduce nonpoint source loadings to both Twin Lake and Wilmarth Lake which will result in an improvement to lake trophic status. The primary goal of this project was to determine sources of impairment to the two water bodies and their watersheds, and provide sufficient background data to conduct an implementation project. The goal was successfully achieved and interest has been shown for the development of an implementation project.

The project work plan objectives and activities were presented and compared to the actual accomplishments of the project. Sampling of Twin Lake and Wilmarth Lake began in September of 2003 and continued through September 2004. There were a total of 29 samples collected from Twin Lake and 55 samples collected from Wilmarth Lake. The Project Implementation Plan (PIP) estimated that 91 total samples would be collected from the two lakes. Due to shallow water (less then 10 feet), only surface samples were collected from the two sampling sites on Twin Lake. A total of 84 inlake samples were collected for the two lakes. Likewise, a total of 31 tributary samples were collected from Wilmarth Lake tributaries and 5 tributary samples were collected from the Twin Lake watershed for a total of 36 tributary samples collected for the two lakes.

An additional five blank samples and five duplicate water samples were collected for Quality Assurance/Quality Control purposes. All samples were sent to the South Dakota State Health Laboratory in Pierre for analyses. Discharge measurements were collected and daily stages and stream velocities were recorded at seven tributary sites throughout the project.

Biological sampling for macroinvertebrates, periphyton, and ash-free dry weights was not conducted because of the lack of an effective method that would use the data for impairment quantification and beneficial use attainment.

The results of the sampling effort will enable SDDENR, in cooperation with the Aurora County Conservation District, to develop a Final Assessment Report and TMDLs for the waters studied.

1.0 Introduction

Purpose

The purpose of this assessment was to determine the sources of impairment to Wilmarth Lake and Twin Lake, both located in Day County, South Dakota. Wilmarth Lake and Twin Lake were listed in the South Dakota 303(d) list in the 2000 and 2002 Integrated Reports. The lakes had been experiencing algae blooms and the lakes' Trophic State Indices (TSIs) were deemed high enough to reflect excessive eutrophication. The TSIs were based on Secchi transparency, chlorophyll *a* concentration, and total phosphorus concentration. The Aurora County Conservation District was approached by DENR to be the project sponsor.

General Lake Descriptions

<u>TWIN LAKE</u>
Twin Lake is a 1,512 acre-foot natural lake with a historical surface area of 252 acres located on the border of Sanborn and Jerauld Counties (Figure 1). Twin Lake has a maximum depth of 12 feet, a mean depth of 6 feet, and 3 miles of shoreline. Primary fish species found in Twin Lake consist of walleye, black crappie, and yellow perch. Other species include black bullhead, largemouth bass, smallmouth bass, northern pike, white sucker, bluegill, bigmouth buffalo, common carp, white crappie, and sunfish.

The lake has a number of small, seasonal-type cabins. The South Dakota Department of Game, Fish and Parks owns 50 acres on the western side of the lake while the remaining lake front is privately owned. In the future, the number of lakeshore homes could increase if the private land is offered for sale and developed. If development of Twin Lake's shoreline follows the trend of other recent lake development, large four-season homes will be built on the new development and will eventually replace the small traditional one-season cabins that exist along the lakeshore.

The lake has a small immediate watershed of 1,120 acres with one small unnamed tributary entering the lake from the south and the lake outlet is on the north end of the lake. The lake is also filled or recharged by a spring. During periods of low water, the southern end of the lake becomes separated from the main body by a gravel bar, forming two separate water bodies. Both basins of Twin Lake have a clay-based shoreline. Land use in the watershed is mostly grassland with a small amount of agricultural land.

There are no municipalities or point source discharges in the watershed.

<u>WILMARTH LAKE</u>

Wilmarth Lake is a 103-acre (1,027 acre-foot) man-made lake impoundment located in north central Aurora County (Figure 2). The lake was created by the construction of a man-made dam across Firesteel Creek by the Works Progress Administration (WPA) in 1936. The lake was named for Fred Wilmarth who lived near the lake since 1906. Wilmarth Lake gets its water from west fork of Firesteel Creek and its associated watershed. Outflows exit over the spillway into Firesteel Creek and continue down stream through Lake Mitchell and into the James River. Wilmarth Lake's surface area is 103 acres with a maximum depth of 26 feet and a mean depth of 11 feet. The reservoir has a shoreline length of 3.2 miles.

Primary fish species found in Wilmarth Lake consist of largemouth bass and bluegill. Other species include black bullhead, perch, black crappie, northern pike, and sunfish hybrids.

There are no homes or commercial developments along the shoreline. The majority of the Wilmarth Lake shoreline is not grazed, but the southwestern side of the lake shoreline is grazed to the water's edge with very little riparian buffer and there is obvious erosion taking place.

Wilmarth Lake's 34,812-acre watershed lies in northern Aurora County and southern Jerauld County (Figure 3). The watershed is relatively large with five tributaries and contains numerous intermittent creeks as well as larger tributaries such as the west branch of Firesteel Creek. The west branch of Firesteel Creek is the primary tributary to Wilmarth Lake and drains a mix of agricultural lands with some row crops, some small grains and a majority of grazed rangeland. Winter feeding areas for cattle are common throughout the watershed with several year round feedlot operations present. This watershed receives an annual average precipitation of 20.55 inches per year with approximately 75% of the precipitation occurring during the months of April through September. There are no municipalities or point source discharges in the watershed.

Lake Identification and Location

Lake Name: ***Wilmarth Lake***
State: South Dakota
County: Aurora and Jerauld
Township: 105N
Range: 65W
Sections: 35, 36
Nearest Municipality: White Lake
Latitude: 43.861755
Longitude: -98.579072
Primary Tributary: West Branch Firesteel Creek
HUC Code: 10160011
EPA Region: VIII

Lake Name: ***Twin Lake***
State: South Dakota
County: Sanborn, Jerauld
Township: 106N
Range: 62W, 63W
Sections: 25, 36 30,31
Nearest Municipality: Woonsocket
Latitude: 45.390000
Longitude: -97.361667
Primary Tributary: Small Unnamed
HUC Code: 10160011
EPA Region: VIII

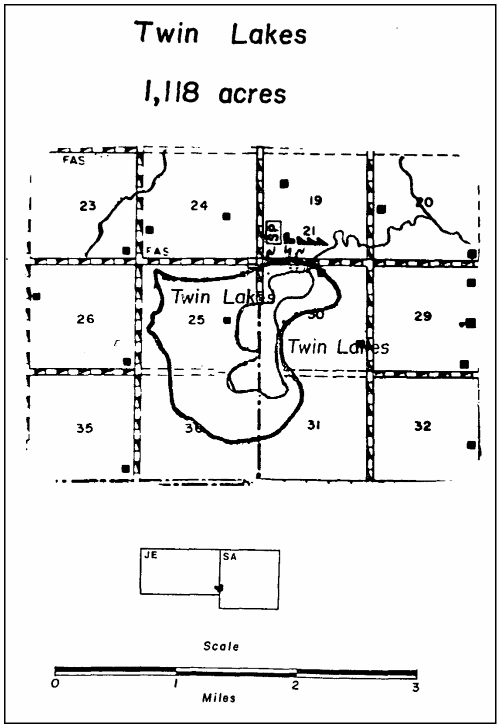


Figure 1. Twin Lake Watershed

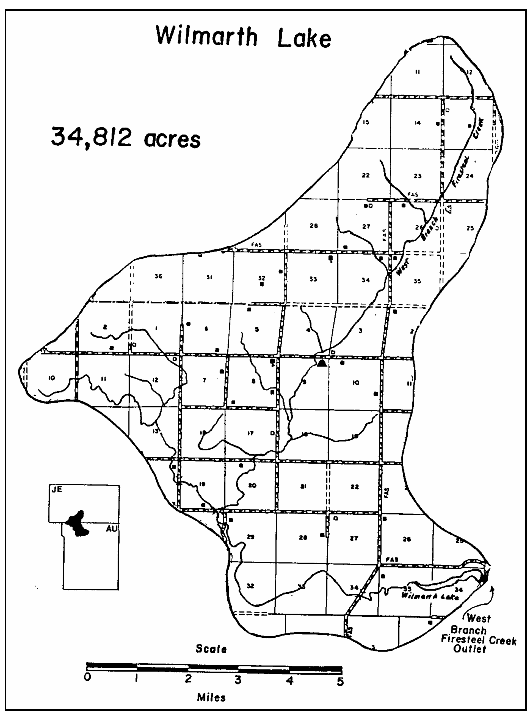


Figure 2. Wilmarth Lake Watershed

Trophic State Comparison

The Trophic State Index (Carlson, 1977) is a numerical value used to compare lake productivity or enrichment. The more productive or nutrient-rich a lake is, the more likely it will have water quality impairments that may prevent it from meeting all of its beneficial uses. High TSI values (51-100) denote lakes that are eutrophic (highly productive) or hyper-eutrophic (excessively productive). Eutrophic and hyper-eutrophic lakes exhibit frequent and severe algal blooms and occasional winter (and sometimes summer) fish kills. Low TSI values (0-50) denote lakes that are comparatively nutrient poor. These lakes typically have water quality that meets all beneficial uses. Table 1 shows a comparison of median TSIs for area lakes and reservoirs combining chlorophyll *a* and Secchi disc transparency based on all available data. The data used to calculate the TSI for each of these lakes was from Project and Statewide Lake Assessment data. The date range was May 15th to September 15th, 2000 through 2007.

Table 1. TSI Comparison for Area Lakes and Reservoirs

Lakes	Nearest Municipality	TSI	Mean Trophic State
Twin Lake	White Lake	77.24	Hyper-eutrophic
Corsica Lake	Corsica	67.13	Hyper-eutrophic
Geddes Lake	Geddes	78.89	Hyper-eutrophic
Reservoirs			
Wilmarth Lake	White Lake	62.18	Eutrophic
Mitchell Lake	Mitchell	57.65	Eutrophic

Beneficial Use Assignment and Water Quality Standards

Each water body within South Dakota is assigned beneficial uses. All waters (both lakes and streams) are designated with the use of fish and wildlife propagation, recreation, and stock watering. Additional uses are assigned by the state based on a beneficial use analysis of each water body. Water quality standards have been defined in South Dakota state statutes in support of these uses. These standards consist of a set of criteria that provide physical and chemical benchmarks from which management decisions can be developed (Table 2).

Wilmarth Lake has been assigned the following beneficial uses:

(4) Warmwater permanent fish life propagation waters;
(7) Immersion recreation waters;
(8) Limited contact recreation waters;
(9) Fish and wildlife propagation, recreation, and stock watering waters;

Twin Lake has been assigned the following beneficial uses:

(5) Warmwater semi-permanent fish life propagation waters;
(7) Immersion recreation waters;
(8) Limited contact recreation waters;
(9) Fish and wildlife propagation, recreation, and stock watering waters;

Table 2. State surface water quality standards for Wilmarth Lake and Twin Lakes

Parameter	Standard	Use Requiring Standard
Alkalinity	< 750 mg/L[1] < 1313 mg/L[2]	(9) Fish, wildlife propagation, recreation and stock watering
Fecal coliform bacteria	< 400 colonies/100 ml < 2,000 colonies/100 ml	(7) Immersion recreation (8) Limited contact recreation
Conductivity	< 4,000 umhos/cm[1] < 7,000 umhos/cm[2]	(9) Fish, wildlife propagation, recreation and stock watering
Undissociated Hydrogen Sulfide	< 0.002 mg/L	(4) Warmwater permanent fish life propagation (5) Warmwater semipermanent fish life propagation
Unionized Ammonia	0.04[1]/1.75 x the criterion	(4) Warmwater permanent fish life propagation (5) Warmwater semipermanent fish life propagation
Nitrate as N	< 50 mg/L[1] or < 88 mg/L[2]	(9) Fish, wildlife propagation, recreation and stock watering
Dissolved Oxygen	$\geq$ 5.0	(4) Warmwater permanent fish life propagation (5) Warmwater semipermanent fish life propagation (7) Immersion recreation (8) Limited contact recreation
pH (standard units)	6.0 - 9.5 6.5 - 9.0	(9) Fish, wildlife propagation, recreation and stock watering (4) Warmwater permanent fish life propagation (5) Warmwater semipermanent fish life propagation
Suspended Solids	< 90 mg/L[1] <158 mg/L[2]	(4) Warmwater permanent fish life propagation (5) Warmwater semipermanent fish life propagation
Total Dissolved Solids	< 2,500 mg/L[1] <4,375 mg/L[2]	(9) Fish, wildlife propagation, recreation and stock watering
Temperature (°F)	< 80°F < 90° F	(4) Warmwater permanent fish life propagation (5) Warmwater semipermanent fish life propagation

[1] 30-day average, [2] daily maximum

Recreational Use

<u>Wilmarth Lake</u>
Recreation and visitation to Wilmarth Lake includes swimming, water skiing, tubing, and jet skiing. None of these activities were observed during the assessment project except for swimming. Fishing appears to be the main recreational use of this water body.

<u>Twin Lake</u>
Twin Lake is a well developed lake with many seasonal cabins and four season homes. The lake appears to have little recreational use other than by adjacent property owners and occasional fishermen. This may be due to shallow water depths in the lake. A larger,

well maintained public use area located on the lake's north shore is home to several camping sites and a vault toilet facility.

Geology

Wilmarth Lake

Wilmarth Lake was built on Firesteel Creek, a small perennial stream whose main tributary flows through the remains of a large melt water channel formed as the stagnant ice of the Late Wisconsin glacier melted. This channel drained snowmelt from atop the Coteau into ancient Lake Dakota, which became the James River basin.

The major associations in the Wilmarth watershed are a mix of many soil associations. There are well-drained to poorly-drained soils in the swales, depressions and other areas on uplands (Houdek-Ethan, Houdek-Dudley-Hoven, and Dudley-Beadle-Jerauld associations in Aurora County; and the Ethan-Houdek-Eakin, and Beadle-Dudley association in Jerauld County). There are well-drained and moderately well-drained soils on rises and side slopes and in swales and other areas on uplands (Highmore-Onita-DeGrey, Eakin-DeGrey, and Eakin-Ethan associations in Aurora County). There are well drained to excessively drained soils in terraces and uplands (Delmont-Enet-Talmo association in Aurora County and the Ethan-Betts association in Jerauld County). Finally there are poorly-drained and moderately well-drained soils in flood plains (Durstein-Bon association in Aurora County).

Twin Lake

The major soil associations found in the Twin Lake watershed are Clarno-Bonilla-Ethan in Sanborn County and the Clarno-Ethan-Prosper association in Jerauld County. These are nearly level to moderately sloping loamy soils, mixed in swales and uplands.

History

Wilmarth Lake

The origin and construction of Wilmarth Lake was a result of a period of dry, poor-growing seasons combined with the Depression and a high rate of unemployment in the surrounding communities. As a response, the people of this area made plans to dam water sources in close proximity to create impoundments that would provide a permanent water supply. The outcome of these projects would also provide habitat for waterfowl as well as recreational facilities for the local people. This was all done in cooperation with the federal government's Works Progress Administration, which was President Roosevelt's Emergency Re-Employment Campaign during the Depression.

The state owns over ¾ of the land around the lake, including a boat landing on the northwest end of the lake. The state-owned land has several tree and food plots planted and is used extensively as public hunting ground. Wilmarth Lake was formed behind a man-made earthen dam across Firesteel Creek in 1936. The lake was named for Fred Wilmarth who lived near the lake since 1906. Wilmarth Lake gets its water from the west fork of Firesteel Creek and its associated watersheds. Outflows exit over the spillway into Firesteel Creek and continue downstream through Lake Mitchell and into the James River. The Wilmarth dam was completed in 1936 and the reservoir was nearly full by the end of 1937.

Twin Lake

Twin Lake is a natural prairie pothole lake located on the border of Sanborn and Jerauld counties, SD. In the 1950s and 1960s, locals started developing cabins on the northeast shoreline for recreational purposes. In the following years the development has continued on the north and east and in recent years more cabins and homes have been developed on the southwest corner of the lake. The South Dakota Game, Fish and Parks Department own land on the northwest side of the lake that contains a campground and a boat launch and dock. The park has slight to moderate use, mostly consisting of weekend campers.

Both Wilmarth Lake and Twin Lake have been listed as being impaired and not fully supportive of their beneficial uses. In 2003, the South Dakota Department of Environment and Natural Resources asked the Aurora County Conservation District to sponsor a watershed assessment project for Wilmarth Lake and Twin Lake. The District agreed to sponsor the project which began in May 2003. There were no lake associations or other conservation groups interested in contributing financially to the project; though local support for water quality projects was high in the county. In 2008, the SD DENR and EPA agreed to discontinue the use of TSI as a reason for water quality impairment. However, the target set in the 2005 lake targeting document can still be used as a guide or a goal for lakes within the associated fisher class.

Project Goals, Objectives, and Activities

Planned and Actual Milestones, Products, and Completion Dates

A number of objectives and activities were established to ensure attainment of the project goals. The following objectives and activities were included in the Twin Lake/Wilmarth Lake Watershed Assessment Project.

The goal of the Twin Lake/Wilmarth Lake Assessment Project was to locate and document sources of non-point source pollution in the watersheds and produce TMDL targets and goals for the lakes. Lake restoration strategies will also be recommended for consideration. Since it is no longer being used as an impairment parameter, the TMDL will no longer be written.

Objective 1: Determine Watershed Loadings to Amsden Dam Reservoir.

Task 1. Select a reference site.

Discontinued. The reference site was to be used for comparing macroinvertebrate and periphyton data. This task was dropped from the project because the macroinvertebrate and periphyton sampling was discontinued and there was consequently no need for a reference site.

Objective 2: Determine Loadings to the Lakes.

Task 2. Installation of gauging equipment.

Stage recorders were placed in the field on October 15, 2003. The project personnel maintained the gauging sites and instrumentation, and measured stream velocities at the appropriate times and sent the information to SDDENR for analysis. Five Ott Thalimedes data loggers were placed at five tributary sites to record continuous tributary stage data. Tributary sites are shown in Figure 3 and directions to the sites are given in Table 3. Outlet stage was recorded from the top of the dam's spillway for part of the project, but repeated problems with the equipment resulted in no data. An Ott Thalimedes was then installed below the spillway in ponded water to gage water levels when the lake spilled. Due to extremely low water levels on Wilmarth Lake, the spillway only flowed one time during the project and only two discharges were collected.

Stage recorders were downloaded no more than bi-weekly during the months the equipment was in the field. Stage recorders were removed from the field in November due to freeze-up. No discharge measurements were taken due to a lack of run-off. Stage recording equipment was placed back in the field in April 2004 and removed in October 2004.

The number of stage and flow measurements recorded for each tributary site and outlet for Wilmarth Lake are as follows: outlet site at Wilmarth Lake WLT05 (2), tributary sites WL01 (16), WLT02 (1), WLT03 (12), and WLT04 (22).

The number of stage and flow measurements recorded for each tributary site and outlet for Twin Lake are as follows: outlet site at Twin Lake TLT02 (0), tributary site TLT01 (7). During the project, Twin Lake never spilled thus no measurements were taken at the outlet, TLT02.

Task 3. Determine the annual water discharge at each site.

This task will be included in the hydrologic budget for the lake.

TABLE 3. TRIBUTARY SITE LOCATION DESCRIPTIONS

Site Name	Site Description
TLT01	The tributary entering Twin Lake from the south.
TLT02	The outlet of Twin Lake.

WLT01	The West Branch of Firesteel Creek approximately 7 miles directly north of Wilmarth Lake. Jerauld County Road 236th Street.
WLT02	The West Branch of Firesteel Creek 4 miles west and one mile north of Wilmarth Lake. Aurora County Road 376th Avenue.
WLT03	Side tributary approximately 1/3 mile west of the site WL02. Aurora County Road 242nd Street.
WLT04	The West Branch of Firesteel Creek approximately 1.5 miles directly west of Wilmarth Lake. Aurora County Road 379th Avenue.
WLT05	The outlet of Wilmarth Lake.

Task 4. Collect water chemistry at tributary sites for both lakes.

Water quality samples were collected from five tributary sites in the Wilmarth Lake watershed, and one site in the Twin Lake watershed during the project. The total number of samples collected at each site are as follows: site TLT01 (5 samples), sites WLT01 (9 samples), WLT02 (2 samples), WLT03 (8 samples), WLT04 (10 samples), and WLT05 (2 samples). The projects goal of thirteen samples per site was obtained at two sites, WLT01 and WLT04. These were the only tributary sites with perennial flow during the project period. A total of 36 samples were collected from the tributary sites; 31 from Wilmarth Lake tributaries and five from Twin Lake tributaries.

TABLE 4. PARAMETERS MEASURED FOR TRIBUTARY SAMPLES:

PHYSICAL	CHEMICAL	BACTERIAL	BIOLOGICAL
Air temperature	Total Solids	Fecal Coliform	Chlorophyll *a*
Water temperature	Total Suspended Solids	E. coli	
Discharge	Dissolved oxygen		
Depth	Ammonia		
Visual observations	Un-ionized ammonia		
Water level	Nitrate-nitrite		
	TKN		
	Total phosphorus		
	Total dis. phosphorus		
	Volatile suspended solids		
	Field pH		

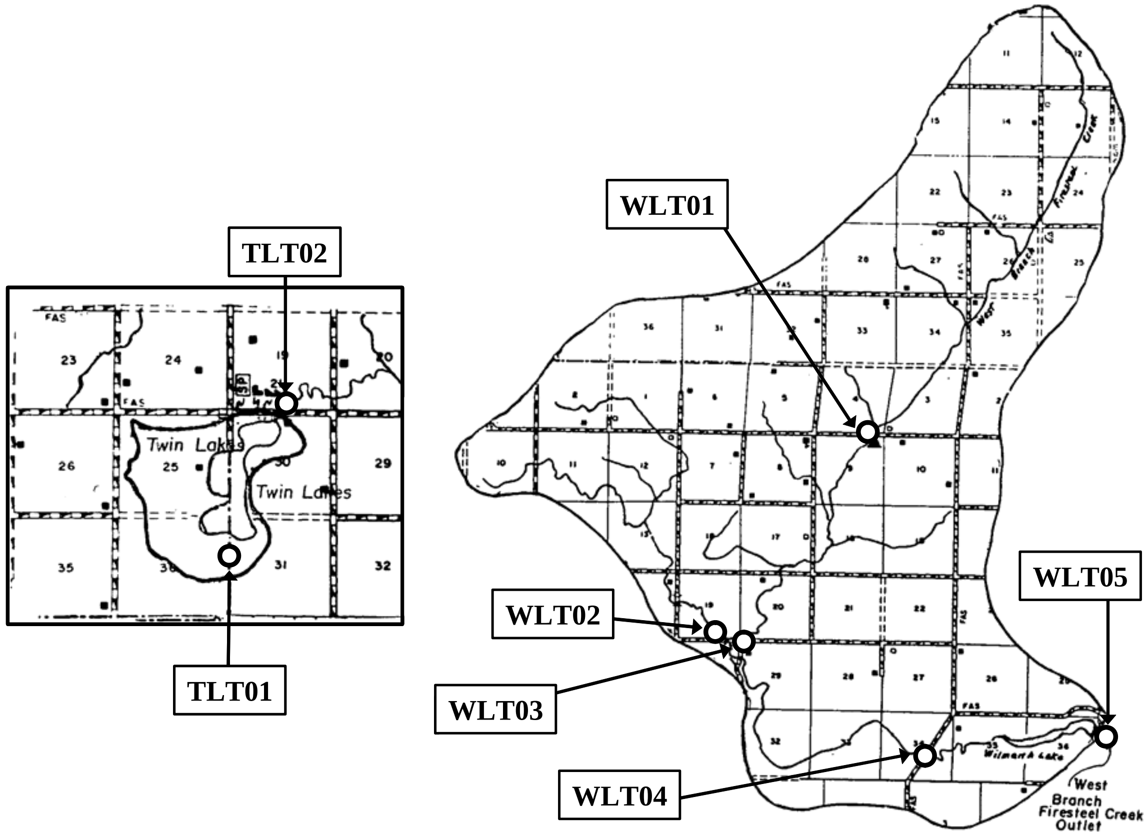


Figure 3. Tributary Sampling Sites.

Task 5. Collection of discrete samples to target nonpoint pollution sources.

Normal sampling and watershed reconnaissance did not reveal any site specific problems in the watersheds, so no discrete samples were collected.

Task 6. Collect biological samples at reference and sampling sites.

The relationships between macroinvertebrate or periphyton metrics, stressors, and the state's beneficial uses were not yet established and it was felt that more research was needed before macroinvertebrate or periphyton metrics are used. At best, a reference site could be used for comparative purposes between sites. But until there is more research relating these metrics to beneficial use attainment these metrics are of limited use.

Objective 3: Inlake Data Collection

Task 7. Inlake water quality sampling

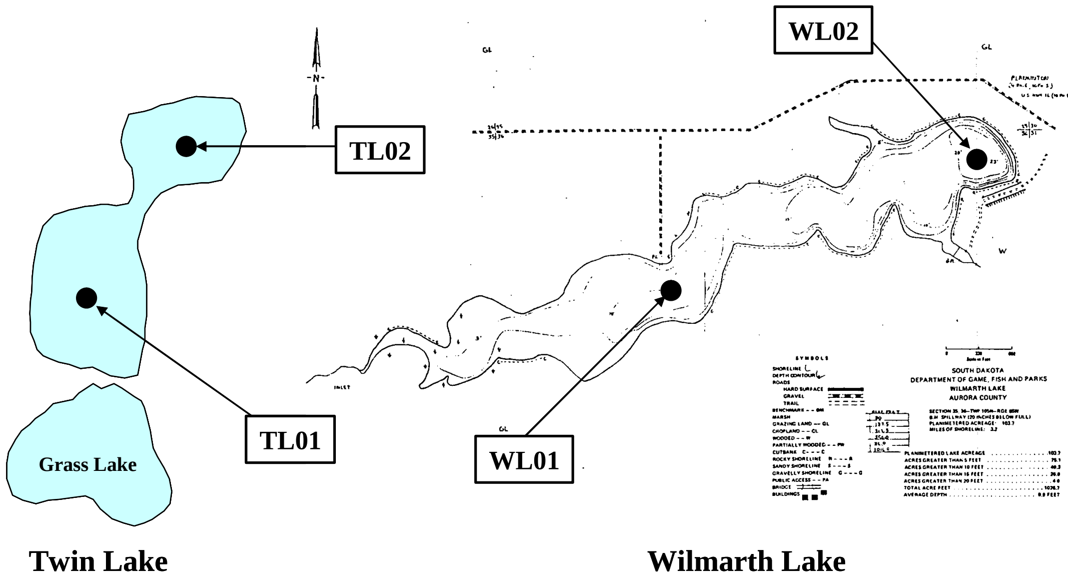


Figure 4. Location of Inlake Sampling Sites.

Lake sampling of Wilmarth Lake began in September 2003 and continued through September 2004. Water temperature and dissolved oxygen measurements were taken at depth intervals so profiles could be made. Due to unsafe ice conditions during the month of December, no further sampling occurred until January 2004 when ice conditions were favorable for sampling. Samples were collected through the ice during the months of January, February; and March. Ice-out occurred early in April allowing in-lake sampling to begin by mid-April. Samples were collected once a month from September 2003 through May 2004. Samples were collected twice monthly during the months of June, July, and August 2004. Two sample sets were collected for QA/QC purposes (sample set = 1 duplicate and 1 blank). A total of 26 bottom samples and 24 surface samples were collected from two in-lake sites, WL01 and WL02 (Figure 4). The project goal was to collect a total of 52 lake samples. Bottom samples were not collected in the February sample. Samples were sent to the South Dakota State Health Lab in Pierre, SD for analysis. Latitude/longitude locations for each sampling site are listed in Table 5 on page 12.

Lake sampling of Twin Lake began in September 2003 and continued through September 2004. Bottom samples were not collected from Twin Lake due to shallow water depths of less than 10 feet at both sampling locations. Water temperature and dissolved oxygen measurements were taken at depth intervals so profiles could be made. Due to unsafe ice conditions during the month of December no further sampling occurred until January 2004. Samples were collected through the ice during the months of January, February, and March. Ice-out occurred early in April allowing lake sampling to begin again mid-April. Samples were collected only once a month from September 2003 through May 2004. Samples were collected twice monthly during June, July, and August 2004. A total of 28 surface samples were collected from two in-lake sites, TL01 and TL02 (Figure 4). Two sample sets were collected for QA/QC purposes (sample set = 1 duplicate and 1 blank). The project goal was to collect a total of 28 in-lake samples. Samples were sent to the South Dakota State Health Lab in Pierre for analysis. Latitude/longitude for each sampling site are given in Table 5.

Table 5. Wilmarth Lake and Twin Lake In-lake Sampling Site Locations and Depth

Waterbody	Sampling Site	Lat/Long	Maximum Depth (meters)
Wilmarth Lake	WL01	43° 86' 40.8" / -98° 57' 20.3"	3.5 m
	WL02	43° 85' 84.4" / -98° 58' 56.6"	6.7 m
Twin Lake	TL01	43° 96' 42.1" / 98° 32' 58.1"	2.5 m
	TL02	43° 95' 85.5" / 98° 33' 18.6"	3.0 m

The list of inlake parameters is found in Table 6. Data for a depth profile was collected at both sites each sample run. The minimum parameters gathered for the profile included depth, water temperature, and dissolved oxygen.

TABLE 6. PARAMETERS MEASURED FOR INLAKE SAMPLES.

Air temperature	Total solids	Fecal coliform	Chlorophyll *a*
Water temperature	Total susp. solids	*E. coli*	
Visual observations	Ammonia		
Depth	Nitrate-nitrite		
Field pH	TKN		
Dissolved oxygen	Total phosphorus		
	Total dis. phosphorus		
	Volatile suspended solids		

Task 8. Macrophyte Survey

A macrophyte survey was done on Wilmarth Lake and Twin Lake in early August of 2004. There were a total of 10 transects for Wilmarth Lake and 20 transects for Twin Lake that were sampled for aquatic plant life. Transects were located by GPS mapping of evenly spaced locations throughout each lake (Figures 5 & 6).

Figure 5. Twin Lake Macrophyte Sampling Locations

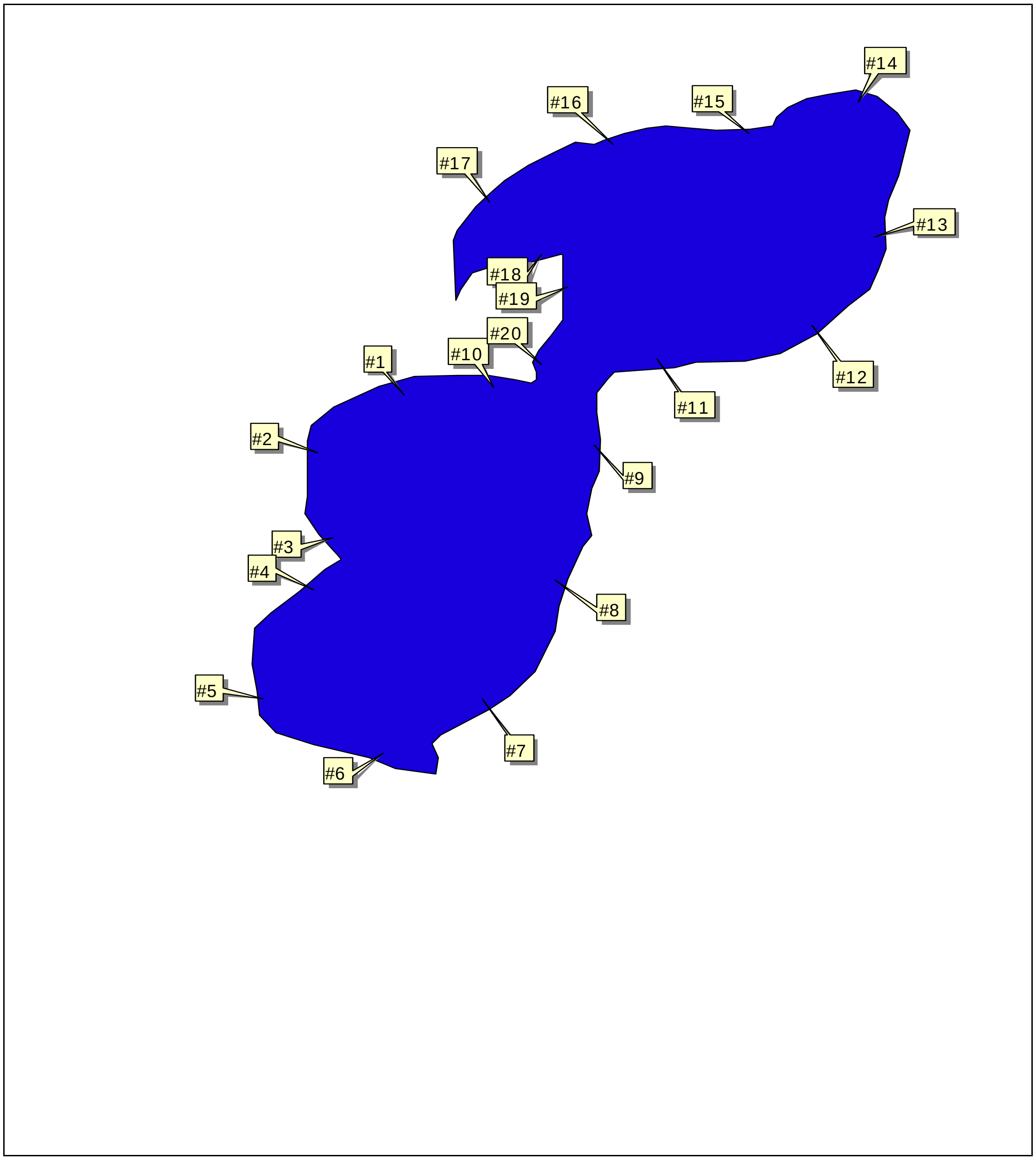
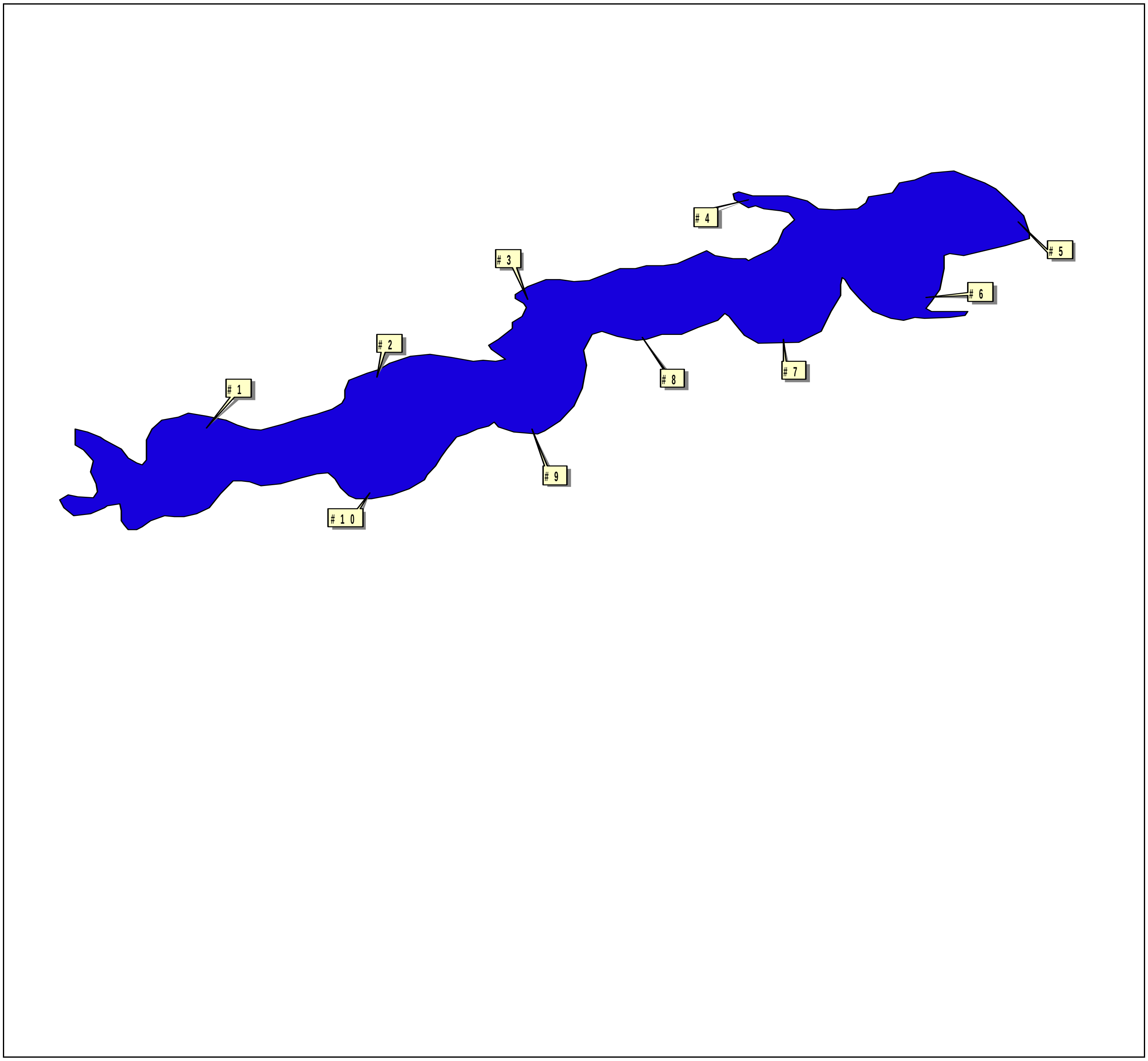


Figure 6. Wilmarth Lake Macrophyte Sampling Locations



Some submergent macrophytes were found in Wilmarth Lake, but no submergent macrophytes were found in Twin Lake in any of the 20 transects sampled, probably due to the very thick algae presence that appeared to be present year around. The thickness and variety of species found in Wilmarth Lake varied at each transect. Only four species were found in Wilmarth Lake, the most common being coontail, some duckweed, *Potomogeton* species, and curlyleaf pondweed.

The *average* maximum depth for growth of submergent macrophytes in Wilmarth Lake was 2.4 meters. The *maximum* depth for growth was 3 meters and the minimum depth being 0 meters. The average Secchi depth for all transects sampled was 0.646 meter. The maximum Secchi depth reading was 1.6 meters and the minimum was 0.2 meter.

Twin Lake had no depths of colonization. The average Secchi depth was 0.1 meter.

Buffer zone vegetation densities were noted, but plant identification on upland areas were not included. Vegetative protection on the shoreline of Wilmarth Lake were optimal in most areas. There were several areas that had erosion problems; one due to damming of a creek and the other due to cattle influence on the bank structure. Twin Lake's shoreline was mostly ranked as optimal with the exception of a few areas where cabins and homes along the lakeshore have tried to maintain private beach areas.

Task 9. Elutriate Sampling

One elutriate sample set to include receiving water was collected from each lake during the project period. The sample set consisted of three composite receiving water samples and three composite mud samples. The subsample sites were equally spaced along the longest fetch of the lakes. Parameters analyzed for the elutriate samples were a standard set of contaminants and metals as agreed upon between the State Health Lab and DENR Water Resource Assistance Program. The elutriate samples were collected with a Petite Ponar and sent to the State Laboratory in Pierre for analysis. Results of those tests are illustrated in Table 7 and Table 8 below.

Table 7. Wilmarth Lake Elutriate Sample Results

Elutriate Test Toxins	amount detected
Alachlor	<.100 ug/l
Chlordane	<.500 ug/l
Endrin	<.500 ug/l
Heptachlor	<.400 ug/l
Heptachlor Epoxide	<.500 ug/l
Toxaphene	<.100
Aldrin	<.500 ug/l
Diedrin	<.500 ug/l
PCB	<.100 ug/l
Diazinon	<.500 ug/l
DDD	<.500 ug/l
DDT	<.500 ug/l
DDE	<.800 ug/l
Beta BHC	<.500 ug/l
Gamma BHC	<.500 ug/l
Alpha BHC	<.500 ug/l
Mercury	<0.1 ug/l
Lead	<0.1 ug/l
Arsenic	0.008 mg/l

Table 8. Twin Lake Elutriate Sample Results

Elutriate Test Toxins	amount detected
Alachlor	<.100 ug/l
Chlordane	<.500 ug/l
Endrin	<.500 ug/l
Heptachlor	<.400 ug/l
Heptachlor Epoxide	<.500 ug/l
Toxaphene	<.100
Aldrin	<.500 ug/l
Diedrin	<.500 ug/l
PCB	<.100 ug/l
Diazinon	<.500 ug/l
DDD	<.500 ug/l
DDT	<.500 ug/l
DDE	<.800 ug/l
Beta BHC	<.500 ug/l
Gamma BHC	<.500 ug/l
Alpha BHC	<.500 ug/l
Mercury	<0.1 ug/l
Lead	<0.1 ug/l
Arsenic	0.006 mg/l

Task 10. Historical sedimentation determination

DENR staff, along with the project coordinator, collected water and sediment depth data through the ice to determine the accumulated sediment in the lakes. Staff used GIS mapping to determine the volume of sediment in the lakes.

A sediment survey was conducted on Wilmarth Lake in December 2003, and on Twin Lake in January 2004. Water depth and sediment depth were measured using a 5/8”X20’ long steel probe. The probe was lowered through holes in the ice until the soft sediment was reached, giving a water depth. Then the probe was pushed through the soft sediment until it reached a solid substrate, giving a sediment depth. There were measurements logged at 36 predetermined locations on Wilmarth Lake and 39 on Twin Lake, which were located on a grid using a Global Positioning System.

The completed survey revealed an average sediment depth of 3 feet in Wilmarth Lake and 2 feet in Twin Lake. The maximum sediment depth observed was 8 feet in Wilmarth Lake and 5 feet in Twin Lake. The volume of sediment in Wilmarth Lake is approximately 5,100,000 cubic yards and 4,200,000 cubic yards in Twin Lake.

Objective 4: QA/QC

Task 11. QA/QC Procedures for data collection

Field water quality samples were collected in accordance with Standard Operating Procedures for Field Samplers distributed by the South Dakota Non-point Source Program. Replicate and blank samples were collected during the course of the project to provide defendable proof that sample data were collected in a scientific and reproducible manner. A minimum of 10 percent of all water quality samples needed to be QA/QC. There were a total of 120 samples collected from the Wilmarth Lake and its tributaries, and Twin Lake and its tributaries. Five blank samples and five replicate samples were collected during the project. Given that 120 samples were collected during the project, at least 12 QA sets (12 blanks and 12 replicate samples) should have been collected to meet the 10% requirement. There was a miscommunication in the correct number of QA/QC samples to be collected. It was thought that 10% total number QA/QC samples were needed for the number of sample sets instead of the total number of samples collected.

Objective 5: AnnAGNPS Watershed Model Evaluation

Task 12. AnnAGNPS model data collection

AnnAGNPS is a data intensive watershed model that routes sediment and nutrients through a watershed by utilizing land uses and topography. The watershed is broken up into cells of varying sizes based on topography. Each cell is then assigned a primary land use and soil type. Best Management Practices (BMPs) are then simulated by altering the land use in the individual cells and reductions in nutrient and sediment loads are calculated at the outlet to the watershed.

Project personnel collected all information required to run the AGNPS simulation model. DENR will use this model to identify critical areas of nonpoint source pollution to the surface waters in the Wilmarth Lake watershed. DENR will produce an AGNPS report to be incorporated in the final assessment report.

Due to a very small watershed and minimal runoff, the AnnAGNPS model was not used for the Twin Lake watershed.

Objective 6: Public Participation

Task 13. Public meetings, news releases

Public involvement consisted of individual meetings with landowners as well as monthly board meetings with Aurora County Conservation District that were open to the public which provided an opportunity for the general public to be informed of the project activities. An informational booth was set up at the Wessington Springs Farm and Home

Show to help get word out about the project and to answer any questions from the general public.

Objective 7: Reporting

Task 14. Sponsor's reporting duties

The Aurora County Conservation District, the project sponsor, was responsible for reporting on the progress of the watershed assessments. The conservation district completed and submitted two annual and two semi-annual GRTS, and two MBE/WBE procurement reports to SD DENR. The district also submitted 12 payment vouchers with documentation of project expenses and incurred local match and in-kind contributions.

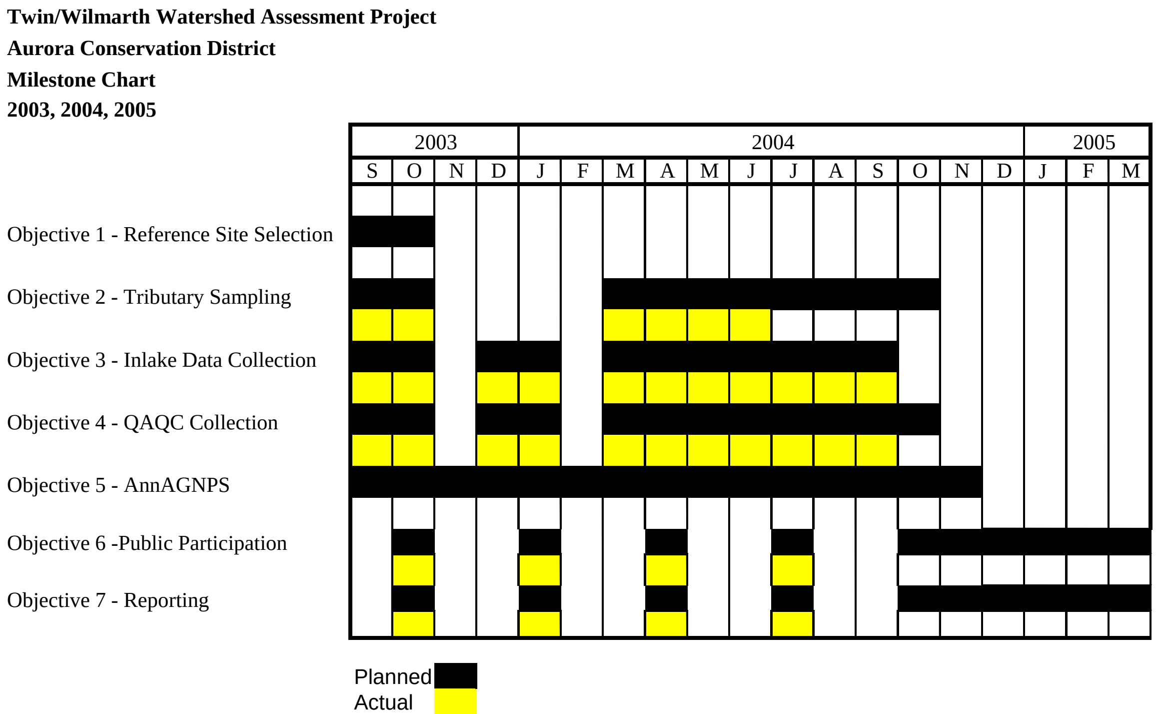
Task 15. Department's reporting duties

The project officer with DENR ensured all semi-annual and annual reports were sent to the Department's GRTS reporting officer. The Department was responsible for writing a final report for the lake assessments, including hydrologic, sediment and nutrient budgets for the watersheds. The final reports include the results of AnnAGNPS modeling of the Wilmarth watershed that were used in conjunction with the water quality and hydrologic budget to determine critical areas in the watershed. The feasible management practices were compiled into a list of recommendations for the development of an implementation project(s) that are included in the final project report. The TMDL targets and goals are included in this Final Assessment Report.

2.1 Planned and Actual Milestones, Products, and Completion Dates

A summary of the project's milestones and completion dates is presented in Table 9. Objective 1, selecting a reference site, was discontinued. Objective 2, tributary sampling, was on time. Objective 3, lake sampling, was on time. Objective 4, the QA/QC effort was on time but not enough samples were collected due to a misunderstanding of how many samples needed to be collected. Objective 5, the AnnAGNPS modeling, was delayed due to staff work load of running the model for other projects. Objective 6, outreach, was completed and on time. Objective 7, final report preparation, was delayed because other reports were prepared and written by staff.

Table 9. Milestone Chart



2.2 Evaluation of Goal Achievement and Relationship to the State NPS Management Plan

The goal of the Twin Lake/Wilmarth Lake Watershed Assessment Project was to determine and document sources of non-point source pollution in the watersheds and produce TMDL targets and goals for Twin Lake and Wilmarth Lake. Lake restoration strategies are recommended for consideration.

Because Twin Lake and Wilmarth Lake were both on the 303(d) list in the South Dakota Integrated Report, this assessment project was deemed necessary and was an integral part of the state's NPS Management Program. Completion of the project goals should lead to a watershed-wide implementation project, another integral part of the state's NPS Program.

3.0 Monitoring Results

Tributary Sampling Schedule

Water samples were collected at all five stream monitoring sites for Wilmarth Lake and from one of the two stream sites for Twin Lake from September 2003 through June 2004. All samples were collected using the grab sample method. Water samples were then filtered, preserved, and packed in ice for shipping to the State Health Laboratory in Pierre, SD, for analysis.

The Laboratory analyzed the following parameters:

Fecal Coliform Counts
Total Solids
Total Suspended Solids
Nitrate
Total Phosphorus
Total Dissolved Phosphorus
E. coli Bacteria Counts
Alkalinity
Total Dissolved Solids
Ammonia
Total Kjeldahl Nitrogen (TKN)
Volatile Total Suspended Solids
Un-ionized Ammonia

Personnel conducting the sampling at each of the sites recorded visual observations of weather and tributary characteristics:

Precipitation
Odor
Water Depth
Water Color
Wind Speed
Film
Ice Cover
Dead Fish

Parameters measured in the field by sampling personnel were:

Stream stage and flow
Air Temperature
Field pH
Water Temperature
Dissolved Oxygen

Tributary Flow Calculations

A total of five tributary monitoring sites were selected for Wilmarth Lake and its tributaries and two for Twin Lake. Of the 7 monitoring sites, five sites were in-stream, and two outlet sites located below the lake outlets. The stream sites were selected to determine which portions of the watershed were contributing the greatest amount of nutrient and sediment load to Wilmarth Lake and Twin Lake. The stream sites were all equipped with Ott Thalimedes float level-type stage recorders. Water stages were monitored and recorded to the nearest $1/100^{th}$ of a foot at each of the seven sites. A Marsh-McBirney Model 201D flow meter was used in conjunction with stage recorders to measure flows at various water levels in the watersheds. The stages and flows were to be used to create a stage-to-discharge table for each monitoring site but problems with the recorders delivered marginal data at best. Instead of using the marginal data collected to calculate stage-to-discharge tables, the U.S Geological Survey (USGS) derived Elevation Derivatives for National Applications or EDNA stream-flow model was used to provide an estimate of mean annual stream flow for Firesteel Creek.

Mean annual stream flow for Firesteel Creek above Wilmarth Lake was estimated based on hydrologic model results and historic stream gage records. The U.S Geological Survey (USGS) derived Elevation Derivatives for National Applications (EDNA) stream flow model was also used to estimate mean annual stream flow for Firesteel Creek above Wilmarth Lake. Historic stream flow data (>50 years) available from an upstream USGS gage station on Firesteel Creek was used to test the accuracy of the EDNA model. Mean annual stream flow was calculated from the USGS gage data and compared to the EDNA result at the same station location. The EDNA model was found to overestimate the mean annual stream flow by 59% in comparison to the measured data at the USGS gage station. As a result, the mean annual stream flow estimate generated by EDNA for Firesteel Creek above Wilmarth Lake was reduced by 59% to compensate for error. The median from the phosphorus and nitrogen concentration data was applied to this estimate of mean annual stream flow to calculate annual loadings. WLT01 data was not included in the median phosphorus or nitrogen calculations due to its small drainage and its relative location in the northernmost part of the watershed. The concentrations observed there were not considered representative of what was actually reaching Wilmarth Lake.

Tributary Site Summary

As discussed in the AnnAGNPS section of this report, the top 40% of the watershed's cells that generate the highest loadings per acre had the potential to contribute as much as 70% of the annual load. Limiting cells to the top 20% in the watershed, these same cells have the potential to contribute as much as 50% of the annual load. The critical areas in the map on page 46 (Figure 14) should be used in a "check here first" manner during any conservation implementation projects. Protecting them through conservation management will provide the greatest protection for Wilmarth Lake.

Watershed Overview

Runoff from 1,118 acres, springs, and rainfall are the primary sources of water entering Twin Lake. Runoff from 34,812 acres and rainfall are the primary sources of water entering Wilmarth Lake. The amount of groundwater entering the lakes is unknown at this time, but the amount of groundwater entering Twin Lake is said to be significant.

Subwatersheds

WLT01

Site WLT01 was located on an intermittent stream four miles north and three and one-fourth miles west of the Wilmarth Lake outlet (figure 3). An OTT Thalimedes data logger was placed on the north side of the road next to the culvert to record stream stage. Flows were measured approximately ten feet upstream of this culvert where the channel narrowed. Nine (9) water quality samples and sixteen (16) stage and flow measurements were recorded at this site.

WLT02

Site WLT02 was located on an intermittent stream one mile north and five and one-half miles west of the Wilmarth Lake outlet (figure 3). An OTT Thalimedes data logger was placed on the north side of the road next to the culvert to record stream stage. Flows were measured approximately ten feet upstream of this culvert where the channel narrowed. Only two (2) water quality samples and one (1) stage and flow measurement were recorded at this site.

WLT03

Site WLT03 was located on an intermittent stream one mile north and five miles west of the Wilmarth Lake outlet (figure 3). An OTT Thalimedes data logger was placed on the north side of the road next to the culvert to record stream stage. Flows were measured approximately ten feet upstream of this culvert where the channel narrowed. Eight (8) water quality samples and twelve (12) stage and flow measurements were recorded at this site.

WLT04

Site WLT04 was located on an intermittent stream one-half mile south and two and one-half miles west of the Wilmarth Lake outlet (figure 3). An OTT Thalimedes data logger was placed on the east side of the road next to the culvert to record stream stage. Flows were measured approximately ten feet upstream of this culvert where the channel narrowed. Ten (10) water quality samples and twenty-two (22) stage and flow measurements were recorded at this site.

WLT05

This tributary site is located below the outlet of the Wilmarth Lake (figure 3). Water quality samples and flows were collected and recorded 100 yards east (below) of the spillway where the stream channel narrowed before crossing a road. Two (2) water quality samples and two (2) stage and flow measurements were taken at this site. Only two measurements were taken at this site because Wilmarth Lake was drawn down several feet at the beginning of the project in order for construction to begin on the damaged spillway. The lake level remained low during construction. Once construction was complete, the lake was allowed to fill again, and it spilled only one time during the project period.

TLT01

Site TLT01 was located on an intermittent stream on the south end of Twin Lake (figure 3). An OTT Thalimedes data logger was placed on the west side of the road in the ditch next to the fence. Flows were measured in the road ditch where the stream channel was narrowest. Five (5) water quality samples and seven (7) stage and flow measurements were recorded at this site during two separate runoff events.

TLT02

Site TLT02 was located on the north end of Twin Lake (outlet) (figure 3). An OTT Thalimedes data logger was placed on the south side of the highway in the ditch next to the fence. There were no flows or samples collected from this site during the project period because the Twin Lake outlet never spilled.

Upper Firesteel Creek has the beneficial uses of (9) Fish and Wildlife Propagation and Stock watering; and (10) Irrigation. Based on the water quality results from the tributaries, no numeric water quality standards were violated for the beneficial uses assigned. All the data collected from the Wilmarth Lake tributaries is located in appendix A of this report.

Water Budget

Due to a very small watershed and minimal runoff from the Twin Lake watershed, a water budget was not calculated. The lake level of Twin Lake is heavily influenced by spring-fed water loading.

According to model results, Wilmarth Lake had a total water load, to include precipitation, of 2,513.2 acre-feet on an annual basis from its tributaries. Wilmarth Lake spillway was under construction at the time of the assessment which required the contractor to pump the lake down to an elevation low enough to complete the work on the spillway. With the lake pumped down approximately several feet, it was not practical to try to determine how much of the annual water load flowed over the spillway due to refilling of the lake. Wilmarth Lake only spilled twice during the assessment once the lake level was back up to the outlet elevation.

Tributary Load Calculations

Twin Lake

Due to a very small watershed and minimal runoff from the Twin Lake watershed, a tributary load was not calculated. The vast majority of nutrient loading to the lake is from internal loading. It should be noted that nutrient loading could also be influenced by lakeside cabins with septic tanks and drain fields.

Wilmarth Lake

The average annual flow (2,351 acre-feet) was applied to the median phosphorus and average nitrogen concentrations (0.46 mg/L and 2.6 mg/L, respectively) to estimate an annual phosphorus and nitrogen load to Wilmarth Lake. The average annual phosphorus load to Wilmarth Lake was estimated at 2,966 lbs. The model calculated 2,626.4 lbs. of phosphorus would have left the lake through the spillway leaving 339.6 lbs. of phosphorus in the lake. The average annual nitrogen load to Wilmarth Lake was estimated at 17,467 lbs. The model calculated 7,812.1 lbs. would have left the lake through the spillway leaving 9,654.9 lbs. of nitrogen in the lake.

In-Lake Water Quality Parameters

Inlake Sampling Schedule

Lake sampling of Wilmarth Lake and Twin Lake began in September 2003 and continued through September 2004. Both water bodies were usually sampled in the morning hours, Twin Lake from 8:00 to 9:30 AM and Wilmarth Lake from 10:00 AM to 12:00 PM (CST) the same day. There were two pre-selected sampling sites on each water body. Water samples were collected once a month during the months of September through May and twice monthly June through August. Only surface samples were taken from Twin Lake due to its depth of less than 10 feet. Water samples were taken to the Aurora County Conservation District office where they were filtered, preserved, and packed in ice for shipping to the State Health Lab in Pierre, SD. Lake water quality data for Wilmarth Lake and Twin Lake are given in Appendices A and B.

The Laboratory analyzed the following parameters:

Fecal Coliform Bacteria
Total Solids
Ammonia
Total Kjeldahl Nitrogen (TKN)
Total Volatile Suspended Solids
E coli/Enterococci
Alkalinity
Total Suspended Solids
Nitrate
Total Phosphorus
Total Dissolved Phosphorus

Personnel conducting the sampling at each in-lake site recorded visual observations of the following weather and lake characteristics:

Precipitation
Odor
Film
Ice Cover
Wind Speed
Dead Fish
Water Color

Parameters measured in the field by sampling personnel were:

Water Temperature
Dissolved Oxygen
Field pH
Secchi Depth
Air Temperature
Sample Depth
Total Water Depth

Water Temperature

Water temperature is of great importance to any aquatic ecosystem as it can affect chemical and biological processes. Many organisms are temperature sensitive. Blue-green algae tend to dominate the warmer waters of summer while green algae and diatoms are more prevalent in the cooler waters of spring and fall. Water temperature also affects physical/chemical processes. Cooler water has the capacity to hold more dissolved oxygen than warm water. Warm water can also increase the un-ionized fraction of ammonia that, if high enough, can cause fish kills.

Wilmarth Lake

Surface water temperature in Wilmarth Lake exhibited little variation from site WL01 to WL02. The highest surface temperature recorded was 25.1 ^{o} C at site WL01 on July 13,

2004. This is below the state standard that requires a maximum temperature of equal to or less than 26.7^{o} C. The single lowest surface water temperature of 3.3° C was recorded just below the surface of the ice at site WL01 on February 18, 2004. There was a mild thermal stratification observed at site WL02 in July 2004. The temperature difference from surface to bottom was 4.1° C. Site WL02 was located at the lake's deepest part of 7.8 meters (26 feet). No stratification was observed at site WL01 due to its shallow depth of 2.4 meters (8 feet).

Twin Lake

Surface water temperature in Twin Lake exhibited little variation from site TL01 to TL02. The highest surface temperature of 25.53^{o} C was recorded at sampling site TL01 on July 13, 2004. This reading is below the state standard that requires a maximum temperature of equal to or less than 32.2^{o} C. The single lowest surface water temperature 2.0° C was recorded just below the ice on January 14, 2004 at site TL02. On this date, the highest dissolved oxygen level in Twin Lake was recorded at 14.81 mg/L possibly due to lots of over wintering of Oscillatoria near the ice boundary producing excessive oxygen. There was no thermal stratification observed during the project, probably due to Twin Lake's shallow depth and the fact that wind and wave action kept the lake's water column mixed.

Surface water temperatures for both Wilmarth Lake and Twin Lake showed seasonal variations that are consistent with their geographic location in the Northern Great Plains, steadily increasing in spring and summer and consistently decreasing in fall and winter (Figures 7 and 8). It can be expected that during most years, lake surface temperatures will be within a few degrees of those observed during the project on their respective dates.

Figure 7. Wilmarth Lake Daily Average Surface Water Temperature

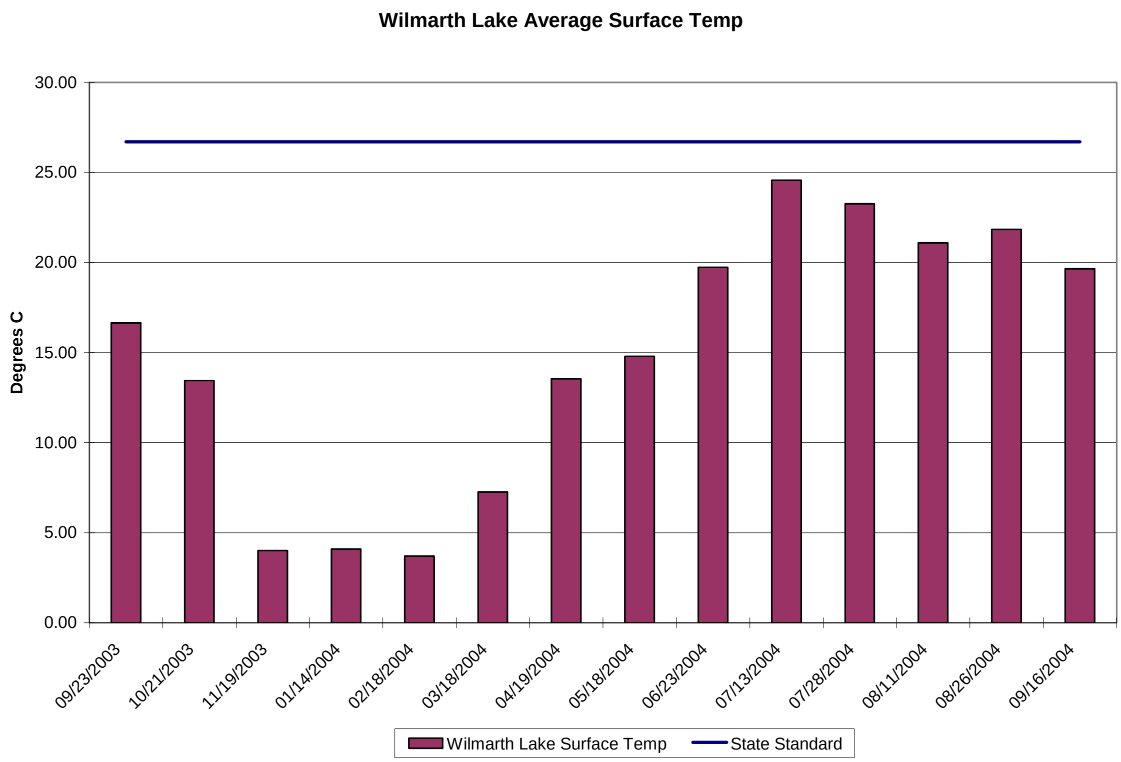
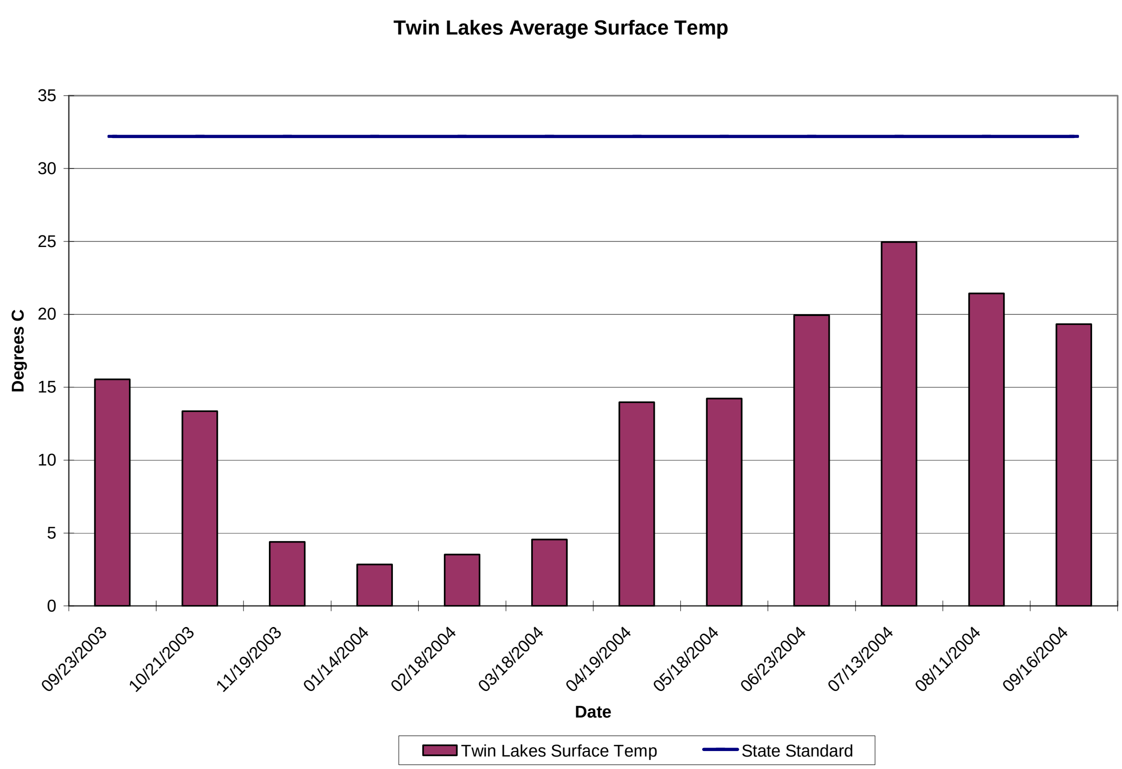


Figure 8. Twin Lake Daily Average Surface Water Temperature



Dissolved Oxygen

Dissolved oxygen (DO) is one of the more important water quality parameters in regard to the health and diversity of aquatic organisms in a lake. Lakes with more oxygen concentrations throughout the year are more likely to have a diverse population of aquatic organisms than lakes with low oxygen concentrations. Lakes with poor DO usually lack diversity and stability, and are dominated by a few hardy species.

Many factors can influence DO concentrations in a water body. Daily and seasonal fluctuations in DO may occur in response to algal and bacterial action (Bowler, 1998). As algae photosynthesize during daylight hours, they produce oxygen that raises the concentration in the epilimnion. As photosynthesis ceases at night, respiration utilizes available oxygen causing a decrease in DO concentration. During winters when heavy snow covers ice, light penetration in a lake may be reduced to the point that photosynthesis ceases and algae and aquatic macrophytes cannot produce enough oxygen to keep up with consumption (respiration) rates. This can result in oxygen depletion that may lead to a winter fish kill.

Dissolved oxygen concentrations can also affect chemical parameters in a lake. When anoxic conditions form in a lake's benthic zone or bottom due to the complete lack of DO; dissolved phosphorus, ammonia, hydrogen sulfide and other undesirable substances are released from lake sediments into the water column. Dissolved phosphorus can contribute to algal growth when stratified lakes turn over or shallow non-stratified lakes are mixed by wind. Ammonia and hydrogen sulfide can be toxic to aquatic organisms if present in sufficient concentrations.

<u>Wilmarth Lake</u>
Dissolved oxygen levels in Wilmarth Lake at site WL01 ranged from 6.49 mg/L to 15.7 mg/L on the surface and 2.5 mg/L to 16.5 mg/L on the bottom. DO levels at site WL02 ranged from 7.52 mg/L to 12.3 mg/L on the surface and 1.4 mg/L to 12.6 mg/L at or near the bottom. The highest surface DO levels of 15.73 mg/L. (WL01) and 12.3 mg/L. (WL02) were recorded during the winter months when the water is colder and able to hold more DO. Five DO levels fell below the state standard of 5.0 mg/L in five bottom samples collected from sites WL01 and WL02 (Figures 9 & 10). The five bottom DO levels recorded below state standards ranged from 1.4 mg/L to 4.8 mg/L. These low DO levels were recorded during a slight thermal stratification observed during the months of June, July, and August 2004. The lake may have stratified during this period due to algal blooms and/or the dark-stained water in the reservoir at that time. Elevated levels of total phosphorus in July indicate the reservoir's benthic zone at site WL01and WL02 were anoxic. As stated above, anoxic conditions will release phosphorus from a lake's sediment. Although DO levels were low at or near the bottom of site WL01 and WL02 during June and July 2005, the remainder of the reservoir's water column had DO levels sufficient enough to meet state standards and maintain a healthy fishery. All DO levels recorded during the project for Wilmarth Lake are given in Appendix A.

Figure 9. WL01 Surface and Bottom Dissolved Oxygen Concentrations

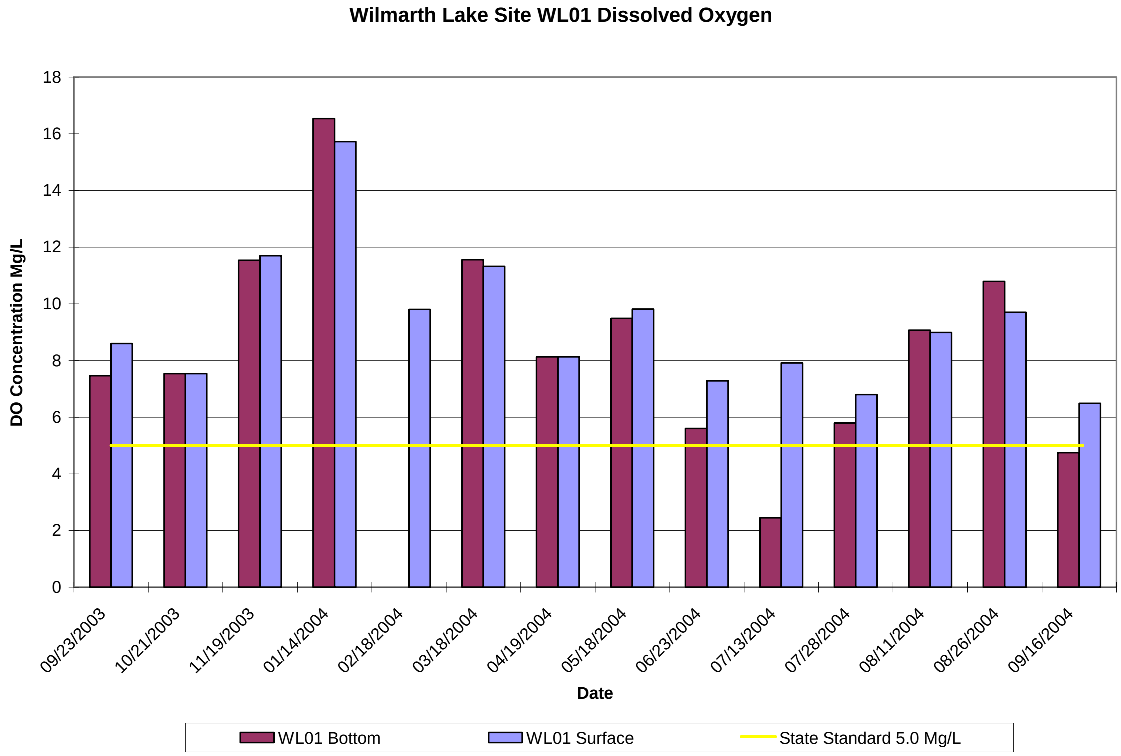
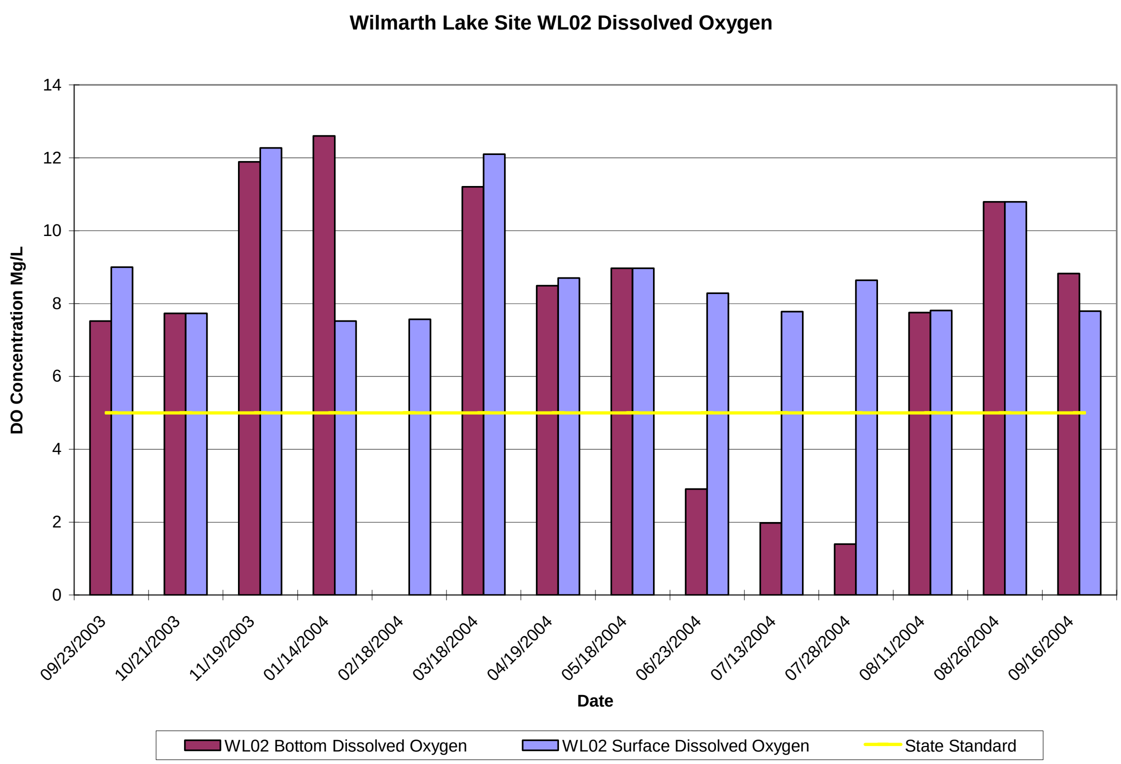
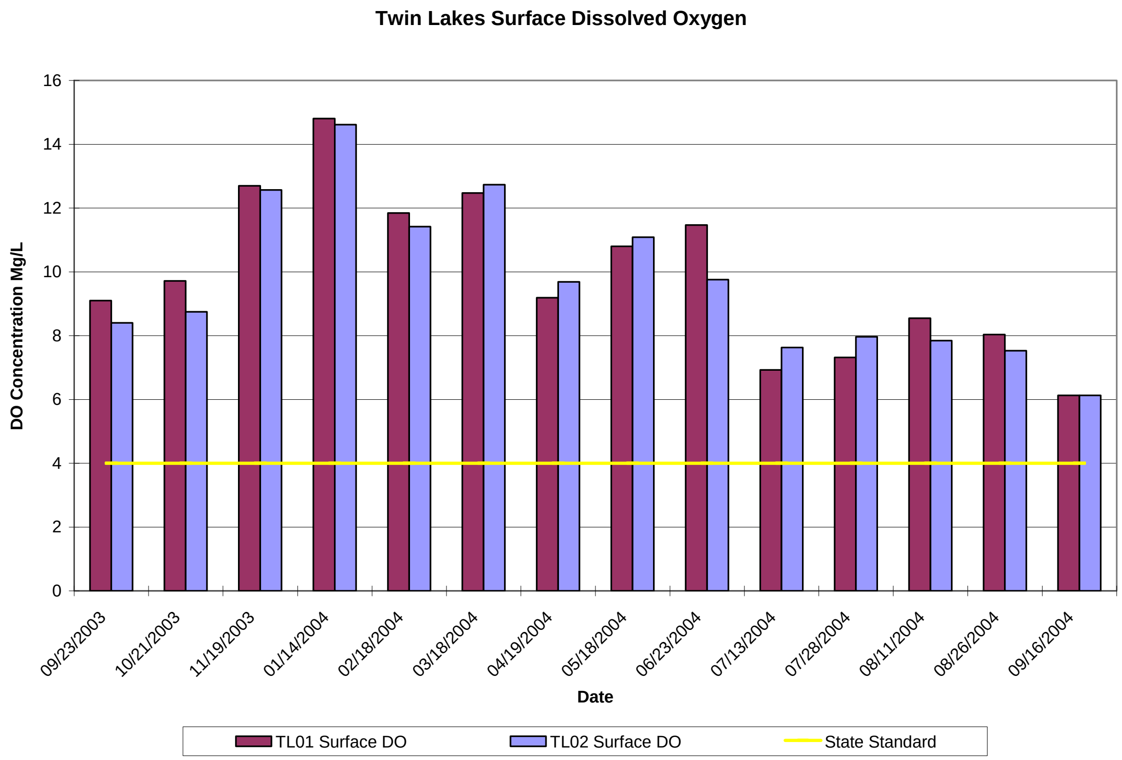


Figure 10. WL02 Surface and Bottom Dissolved Oxygen Concentrations



Twin Lake
Dissolved oxygen levels in Twin Lake at site TL01 ranged from 6.1 mg/L to 14.8 mg/L on the surface. DO levels at site TL02 ranged from 6.1 mg/L to 14.6 mg/L on the surface. The highest surface DO levels of 14.8 mg/L. (TL01) and 14.6 mg/L. (TL02) were recorded in January 2004 during winter months when lake water is colder and able to hold more DO. There were no DO concentrations at either site on Twin Lake that fell below the state standard of 4.0 mg/L (Figure 11). All DO levels recorded during the project for Twin Lake are given in Appendix B.

Figure 11. TL01 and TL02 Surface Dissolved Oxygen Concentrations



pH

pH is a measure of free hydrogen ions (H+) or potential hydrogen. Simply stated, it indicates the balance between acids and bases in a water body. pH is measured on a logarithmic scale between 0 and 14 and is recorded as standard units (su). Each pH point represents a 10-fold increase or decrease in hydrogen ion concentration. At neutrality (pH of 7) acid ions (H+) equal the base ions (OH-). Values less than 7 are considered acidic (more H+ ions) and greater than 7 are basic (more OH- ions).

Biological and chemical processes in a lake or reservoir can increase pH while photosynthesis increases pH. The decomposition of organic matter in a lake's benthos releases carbon dioxide into the water column. This carbon dioxide reacts with the water and is converted to carbonic acid, decreasing a lake's pH. The extent to which this process affects pH is determined by a lake's alkalinity. High alkalinity (>200 mg/L.) in a water body represents a considerable buffering capacity that will reduce any large fluctuations in pH caused by decomposition. Most aquatic plants and organisms (especially fish) are sensitive to acidity and will not survive at a pH below 6.0 su.

The state standard for pH on both Wilmarth Lake and Twin Lake is 6.5 to 9.0 su. On August 26, 2004, Wilmarth Lake exceeded state pH standards with two pH readings at site WL02 which is the deepest part of the lake. Due to depths greater then 20 feet, it is hard to imagine the pH being the same (9.02) at the surface and the bottom. Thus, it is believed the pH probe was getting bad or the pH probe was not calibrated. No other exceedences of pH were experienced at Wilmarth Lake.

<u>Twin Lake</u>
Surface pH measurement in Twin Lake ranged from 6.13 to 8.71 with an average pH of 7.66. There were no bottom pH measurements taken due to the lake's shallow depth. No seasonal variations in the lake's measured pH were observed.

On January 14, 2004, Twin Lake exceeded state pH standards with one pH reading of 6.13 su at site TL01. On the same date and 15 minutes sooner, a pH reading of 6.7 was collected at site TL02, a very short distance from site TL01. Though pH levels were below standard at one site, there was refuge in the lake for fish to gather where the pH was above standard. Due to the shallow depth of Twin Lake, only surface measurements were collected.

<u>Wilmarth Lake</u>
Surface pH measurements in Wilmarth Lake ranged from 7.3 to 9.02 with an average pH of 8.23. Bottom pH measurements ranged from 7.3 to 9.02 with an average pH of 8.14. No seasonal variations in the lake's measured pH were observed.

All pH measurements taken during the project for Wilmarth Lake are given in Appendix A, and Appendix B for Twin Lake.

Alkalinity

Alkalinity measures the water's capacity to neutralize acids. Alkalinity exists due to the complex interaction of several compounds in water that include bicarbonates, carbonates, and hydroxides. In natural environments alkalinity usually ranges from 20 to 200 mg/L (Lind,1985) and is dependant on local soils. An alkalinity of >100 mg/L will buffer changes in a lake's pH caused by increased or decreased acids.

<u>Twin Lake</u>
The alkalinity in Twin Lake varied from a minimum concentration of 90 mg/L in August to a maximum concentration of 153 mg/L recorded in February. The average alkalinity was 113 mg/L.

Secchi Depth

Secchi depth is a measure of lake transparency or clarity. Secchi depth is measured using a Secchi disk, a 20 cm (8 in) metal or plastic disk with alternating black and white colored quadrants. The disk is lowered into the water until it is no longer visible. The point where the disk disappears is called the Secchi depth. Secchi depth is measured in meters or feet, usually by attaching a measuring tape to the disk. Secchi depth is one of the parameters used to determine the Trophic State Index (TSI) of a water body. The TSI of a lake indicates whether the body is nutrient-rich or nutrient-poor. Low Secchi depth measurements are typically due to algal blooms or high suspended sediments and may indicate a eutrophic or hyper-eutrophic TSI.

Twin Lake

The deepest Secchi depth readings for Twin Lake were recorded in January and February 2004. Secchi depths were recorded at 0.8 meter (2.6 feet) at site TL01 and 0.8 meter at site TL02. The lowest Secchi depth recorded was 0.1 meter (.33 foot) which occurred in August 2004 at both inlake sites. The increased turbidity observed at both sampling sites on this date was due to a large algal bloom in the lake and possible wind and wave action stirring bottom sediments in the shallow lake. Secchi depths decreased from June through August as algal growth increased. Secchi depths improved through the fall and winter months, as expected.

Wilmarth Lake

In November 2003, Secchi depth was greatest in Wilmarth Lake at 2.0 meters (6.5 feet). The lowest Secchi depth was 0.38 meter (1.6 ft.) recorded in September of 2003. These low depths were a result of an extensive algal bloom observed across the entire lake. Secchi depths in Wilmarth Lake followed the expected seasonal trends with lower Secchi depths observed during the summer months when algal production is highest, to greater Secchi depths recorded during the winter months when algal production is low.

Nitrogen

Nitrogen was analyzed in three forms: nitrate/nitrite, ammonia, and Total Kjeldahl Nitrogen (TKN). From these three forms, total, organic, and inorganic nitrogen may be calculated. Nitrogen compounds are major cellular components of organisms. Because its availability may be less than the biological demand, environmental sources may limit productivity in freshwater ecosystems. Nitrogen is difficult to manage because it is highly soluble and very mobile. In addition, some blue-green algae fix atmospheric nitrogen, adding it to the nutrient supply in the lake.

Ammonia is a form of nitrogen produced by bacterial decomposition. This nutrient is readily available for plant growth, especially algae. Ammonia is produced by decaying organic matter in a lake's benthos and by bacterial conversion of other nitrogen compounds found in the lake. Decomposing bacteria in a lake's sediment and some blue-green algae species in the water column are able to convert free nitrogen (N^2) to ammonia. Algae can assimilate several forms of nitrogen; however their growth rate will greatly increase when ammonia is available (Wetzel, 1983). Animal feeding operations and anhydrous fertilizer applied on cropland are two possible sources of ammonia from watershed runoff. The South Dakota State Health Laboratory cannot detect ammonia levels below 0.02 mg/L.

Twin Lake

Ammonia concentrations in Twin Lake surface samples ranged from below the detection limit of 0.02 mg/L on several dates to 2.99 mg/L in February 2004. The high spikes of ammonia during the winter months can be related to bio degradation of algal biomass and other organic material near the sediment water interface. There were no calculated total ammonia nitrogen as N violations for Twin Lake during the project period. Therefore, the ammonia levels in Twin Lake were at levels required to sustain a healthy fishery.

Wilmarth Lake

Ammonia concentrations in Wilmarth Lake surface samples ranged from below the detection limit of 0.02 mg/L on several dates to 0.26 mg/L in November 2003. Bottom samples ranged from below the detection limit on several dates to 1.46 mg/L in July 2004. Ammonia concentrations in Wilmarth Lake were highest near the bottom in July. These elevated ammonia levels can be related to low oxygen concentrations from decomposition of organic sediments, primarily aquatic macrophytes and algae. There were no calculated total ammonia nitrogen as N violations for Wilmarth Lake during the project period. Therefore, the ammonia levels in Wilmarth Lake were at levels required to sustain a healthy fishery.

Total Phosphorus

Phosphorus is one of the macronutrients required for primary production. When compared with carbon, nitrogen, and oxygen, it is typically the least abundant (Wetzel, 2001). Total phosphorus is the sum of all attached and dissolved phosphorus in the lake. The attached phosphorus is directly related to the amount of total suspended solids present. An increase in the amount of suspended solids increases the fraction of attached phosphorus. Phosphorus loading to lakes can be of an internal or external nature. External loading refers to surface runoff over land, dust, and precipitation.
Internal loadings of phosphorus can occur when oxygen concentrations near the sediment surface approach zero (anoxia). Phosphorus, ammonia and other compounds are released from the sediment under anoxic conditions. If a lake is stratified, phosphorus can accumulate in the deeper waters of stratified lakes and can suddenly become available to support algae growth after the water column is mixed by wind or fall turnover. Wilmarth Lake may have exhibited stratification for a short period of time in July 2004 at site WL02, but Twin Lake remained un-stratified throughout the assessment study.

Twin Lake

Total P concentration in surface waters of Twin Lake ranged from 0.052 mg/L on January 14, 2004 to 0.153 mg/L on June 23, 2004. Mean lake total phosphorus in surface samples was 0.11 mg/L.

Twin Lake had a small amount external loading of phosphorus due to a very small watershed that diverted small amounts of water. This resulted in mainly internal loadings of total phosphorus throughout the project period. Internal loadings of phosphorus from sediment release may have occurred due to decomposition of organic matter at the bottom of the lake. Oxygen levels remained relatively high while phosphorus concentrations were slightly elevated in samples taken in the fall, winter, and early spring months.

Wilmarth Lake

Wilmarth Lake concentrations of total phosphorus were notably higher during the summer and fall months. The mean total phosphorus concentration during the assessment was 0.48 mg/L. Concentrations ranged from 0.113 mg/L on May 18, 2004 to 1.51 mg/L on July 28, 2004 at site WL02 which can be attributed to watershed loading from runoff events paired with internal loading. This is a sufficient amount of phosphorus to support algae blooms which have been typical of Wilmarth Lake in recent years. As algae floats up from the bottom, total phosphorus in the water column increases. There was evidence that low oxygen levels in Wilmarth Lake near the bottom in June and July 2004 likely caused some release of phosphorus from the sediment.

Total Dissolved Phosphorus

Total dissolved phosphorus is the unattached portion of the total phosphorus load. It is found in solution but readily binds to soil particles when they are present. Total dissolved phosphorus, including soluble reactive phosphorus, is more readily available to plant life.

Twin Lake

Total dissolved phosphorus concentrations in surface samples ranged from 0.013 mg/L on June 23, 2004 to 0.20 mg/L on August 26, 2004. The mean concentration during the assessment was 0.026 mg/L. Total dissolved phosphorus was NOT the dominant fraction of phosphorus throughout the assessment. Though Twin Lake is considered phosphorus limited, it averaged 23% dissolved phosphorus as a fraction of total phosphorus in the water column during the assessment.

Wilmarth Lake

Total dissolved phosphorus concentrations in surface samples from Wilmarth Lake ranged from 0.052 mg/L on March 18, 2004 to 1.40 mg/L on July 28, 2004.

Percent total dissolved phosphorus averaged 84.5% of total phosphorus with the remaining 15.5% in total phosphorus form. Total dissolved phosphorus was the dominant fraction of total phosphorus during the assessment.

For most of the assessment, 80% to 90% of the phosphorus was in suspension as dissolved phosphorus, readily available for aquatic plant life. Rapid growth of algae in late July and August 2004 converted much of the dissolved phosphorus into biomass as indicated by a large increase in chlorophyll during this same time.

Fecal Coliform Bacteria

Fecal coliform bacteria are found in the waste of warm-blooded animals. Some common types of bacteria are *E. coli*, S*almonella*, and *Streptococcus*, which are associated with livestock, wildlife, and human waste (Novotny, 1994). Fecal coliform is used as an indicator to determine if pathogens may be present in a waterbody.

Twin Lake and Wilmarth Lake are listed for the beneficial use of immersion recreation which requires that no fecal coliform single sample exceed 400 colonies/100mL or the 30-day geometric mean (consisting of at least 5 samples) be no more then 200 colonies /100mL. There were no samples that exceeded the state standard during the monitoring process of this project. Only one sample exceeded detection limits (10 colonies per 100 mL) for Twin Lake and Wilmarth Lake. The remaining fecal coliform samples were non-detect or below 10 colonies per 100 mL.

Chlorophyll *a*

The average chlorophyll-*a* concentration for Twin Lake during the project was 85.0 mg/L with values ranging from 17.2 mg/L (January 2004) to 213.5 mg/L (August 2004). An increase in chlorophyll was observed during the summer months and into early fall (July - October) attributable to blue-green algal blooms observed in the upper level of the water column.

The average chlorophyll-*a* concentration for Wilmarth Lake during the project was 29.4 mg/L with values ranging from 1.3 mg/L (November 2003) to 95.0 mg/L (August 2004). An increase in chlorophyll was observed during the month of August 2004 attributable to blue-green algal blooms observed in the upper level of the water column in Wilmarth Lake. Some blue-green algae (not all) are nitrogen fixers and can grow in the absence of nitrogen provided there is adequate phosphorous available. Wilmarth Lake is nitrogen limited and has highly elevated phosphorous levels providing ideal conditions for blue-green algae growth. Twin Lake on the other hand is phosphorus limited with lower levels of phosphorus and nitrogen, but Twin Lake has high enough phosphorus levels to support heavy algal bio-mass with the community dominated by blue-green algae (Downing, 2001).

Limiting Nutrients

Four primary nutrients are required for cellular growth in organisms. Two of these nutrients are phosphorus and nitrogen. Nitrogen is difficult to limit in aquatic environments due to its highly soluble nature. Phosphorus is easier to control making it the primary nutrient targeted for reduction when attempting to control lake eutrophication. The ideal ratio of nitrogen to phosphorus for aquatic plant growth is 10:1 (EPA, 1994). Ratios higher than 10 indicate a phosphorus-limited system. Those that are less than 10 represent nitrogen-limited systems.

Twin Lake is considered phosphorus-limited though there is significant phosphorus in the system to sustain algal growth. The average nitrogen-to-phosphorus ratio for Twin Lake was 34:1 during the project period. All the sampled nutrient ratios did not vary far from the calculated average. All samples showed consistent phosphorus limitations. The greatest difference was seen in April 2004 when the ratio jumped to 49.1:1. The smallest ratio was recorded in June 2004 at 22.5:1.

Wilmarth Lake is considered nitrogen-limited though there is sufficient amount of organic nitrogen (TKN) in the system. The average nitrogen-to-phosphorus ratio for Wilmarth Lake was 4.7:1 during the project period. Surface samples had relatively close ratios to the lake's overall average except for spring samples which were considerably higher or over just over the ratio for phosphorus limitations. The greatest difference was seen in May 2003 when the ratio jumped to 9.9:1, nearly the ideal ratio of nitrogen-to-phosphorus. The smallest ratio was recorded in August 2003 at 1.63:1.

Trophic State Index

Trophic state refers to the degree of primary production within a lake and its relation to nutrient enrichment and water clarity. The Trophic State Index (TSI) developed by Carlson (1977) is a commonly used and widely accepted method for quantifying the trophic state of lakes. The TSI transforms measures of total phosphorus (nutrient), chlorophyll-*a* (algal biomass), and Secchi depth (water clarity) using linear regression models and logarithmic transformation to produce unitless index scores typically ranging from 0-100. The greater the index score, the more primary production, phosphorus and correspondingly lower water clarity waterbodies are expected to exhibit. Carlson (1977) assigned numeric ranges to classify the trophic state of a waterbody (Table 10).

Table 10. Trophic state categories established by Carlson (1977).

Trophic State Classification	TSI Numeric Range
Oligotrophic	0-35
Mesotrophic	36-50
Eutrophic	51-65
Hyper-eutrophic	66-100

Lakes with TSI values less than 35 are considered to be oligotrophic and contain very small amounts of nutrients, low primary production and are very clear. Lakes that obtain a score of 36 to 50 are considered to be mesotrophic and have more nutrients and primary production than oligotrophic lakes. Eutrophic lakes have a score between 50 and 65 and have moderately high nutrients and are susceptible to algae blooms and reduced water clarity. Hyper-eutrophic lakes have scores greater than 65 and contain excessive nutrients, sustainable nuisance algae blooms and poor water clarity.

The three TSI indices are expected to be interrelated as a function of the regression models. Therefore, it is assumed that any one of the three indices could be used to classify the trophic state of a waterbody. When the TSI is presented as an average or median value it is imperative that the indices are interrelated. Carlson (1991) suggests that if any TSI parameter deviates significantly ($\pm$ 5 TSI points) from the chlorophyll TSI (main measure of primary production) then that parameter is contributing to the misclassification of the trophic state.

The South Dakota DENR, Water Resource Assistance Program (WRAP) uses the median of Secchi depth transparency and chlorophyll-*a* TSI to measure the trophic state of lakes and reservoirs. Many lakes in South Dakota are considered non phosphorus limited and have sufficient phosphorus (>0.02 mg/L) to support excessive algae growth (Downing et al. 2001). As a result, the phosphorus TSI was eliminated from the median index calculation to avoid misclassification (Carlson 1991).

To characterize the trophic state of Wilmarth Lake it is necessary to examine differences between the trophic state indices. Secchi and chlorophyll-a TSI values are relatively similar while the phosphorus TSI deviates significantly from both TSI parameters, (Table 11). Wilmarth Lake contains significant supplies and receives a significant amount of annual phosphorus loading from the watershed, leading to the high phosphorus TSI values. Some significant deviation did occur between monthly Secchi and chlorophyll TSI values (Table 11).

Table 11. Wilmarth Lake growing season TSI values for all parameters.

Site	Month	TSI Secchi	TSI Phosphorus	TSI Chlorophyll
WL01	August	60.0	101.7	68.3
WL01	August	65.1	99.1	71.8
WL02	August	63.2	100.9	75.2
WL02	August	67.4	100.5	75.2
WL01	July	60.0	97.1	62.2
WL01	July	58.6	99.3	60.5
WL02	July	63.2	97.9	55.4
WL02	July	63.2	97.1	62.4
WL01	June	57.4	95.0	69.2
WL02	June	58.6	96.9	60.7
WL01	May	56.2	69.2	
WL02	May	60.0	72.4	
WL01	September	73.2	96.9	62.0
WL01	September	63.2	98.6	
WL02	September	74.0	97.8	62.4
WL02	September	55.1	99.0	63.6

An ordination graph derived from Carlson (1991) was generated to examine potential environmental factors associated with variation between the trophic state indices (Figure 12). Again, Wilmarth Lake displays non phosphorus limitation as depicted by the negative deviation from the X-axis. It is also apparent that during the growing season some deviation occurs between Secchi and Chlorophyll TSI. This is indicated by left-right deviation from the center Y- axis. On three occasions the Secchi TSI deviated negatively from the Chlorophyll TSI indicating the potential for non-algal turbidity. In other instances, the chlorophyll TSI was higher than the Secchi TSI (right side of Y-axis). This particular deviation could arise if large particles, such as blue-green algae dominate and transparency is typically less affected by these larger particles. Deviations to the right may also occur if zooplankton grazing removes smaller particles (i.e. diatoms and green algae) and leaves only larger species. In some instances, Secchi and chlorophyll TSI were interrelated as indicated by the points along the Y-axis.

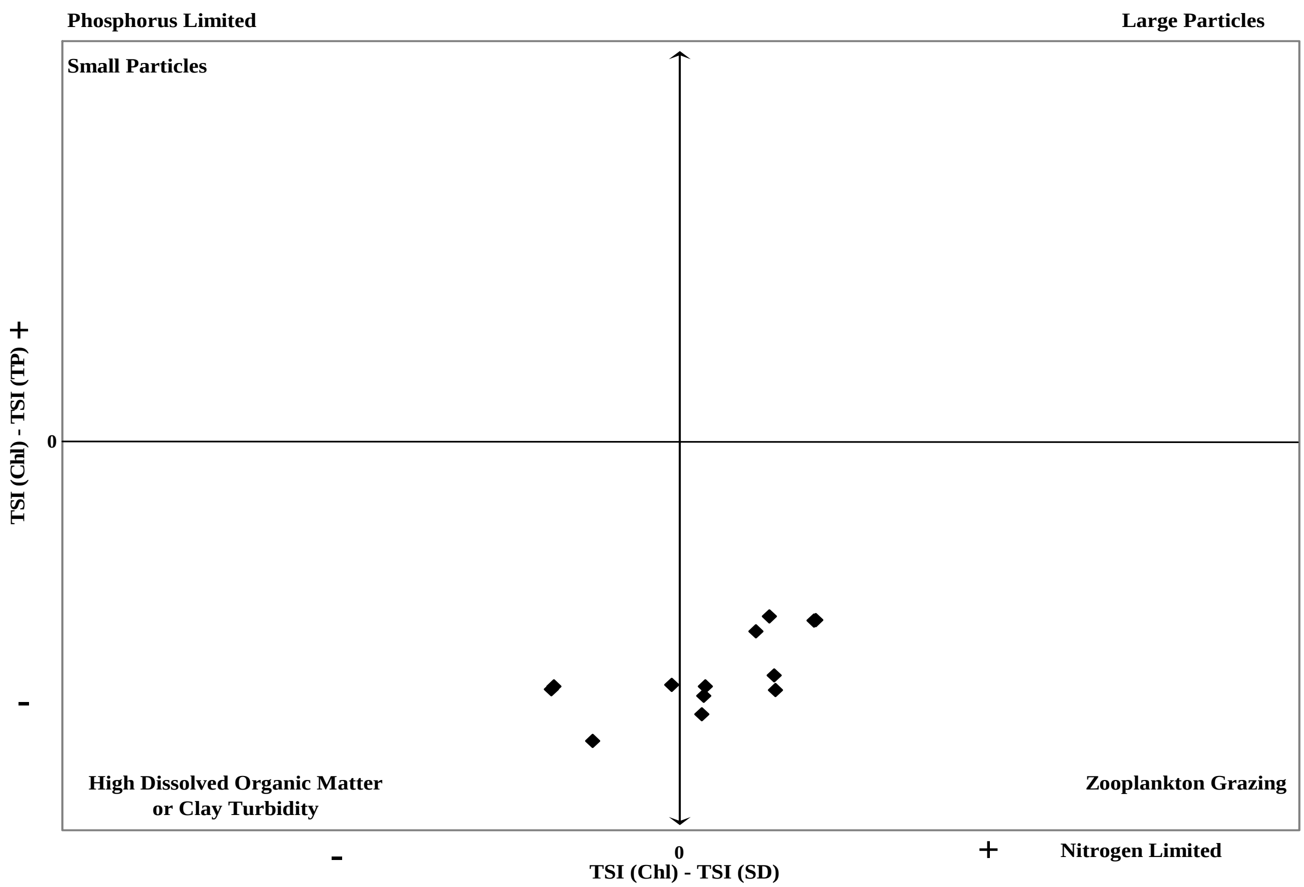


Figure 12. Ordination graph depicting environmental factors associated with variation in the trophic state indices of Wilmarth Lake.

Chlorophyll is the best indicator of primary production (algae biomass) while Secchi provides a measure of water clarity. The trophic state dynamics of Wilmarth Lake are such that primary production is not always significantly impacting the water clarity. In other instances, the water clarity is not always being impacted by primary production (e.g., non algal turbidity). Therefore, it was determined that the cumulative median (middle value) of Secchi-chlorophyll TSI would provide the best descriptor of trophic state for Wilmarth Lake. The median Secchi-chlorophyll TSI for Wilmarth Lake is 62.5, which classifies the lake as eutrophic. This is also consistent with the individual median calculations of both parameters (Table 12). The median phosphorus TSI value was several orders of magnitude higher than the median Secchi and chlorophyll TSI. Significant phosphorus reductions (internal and external) are warranted to improve the trophic state of Wilmarth Lake.

Table 12. Wilmarth Lake median growing season TSI by parameter 2003-2004.

Parameter	2003-2004
Median Growing Season TSI Secchi-Chlorophyll	62.5
Median Growing Season TSI Secchi	61.6
Median Growing Season TSI Chlorophyll	62.5
Median Growing Season TSI Phosphorus	97.9

Reduction Response Modeling

Inlake phosphorus reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model (Walker, 1999). Trophic state responses were modeled using incremental reductions in phosphorus loading to the lake. The average annual phosphorus loading for upper Firesteel Creek was derived by applying the average phosphorus concentration to the average annual flow estimated from historic gage records and the USGS EDNA model.

BATHTUB contains numerous mathematical models that simulate the response of inlake limnology (phosphorus, chlorophyll-*a* and Secchi depth) based on watershed phosphorus loading. The model initially produces a standardized output of observed inlake conditions based on lake morphology attributes, inlake water quality and watershed phosphorus load. A series of parameter models are selected in combination to best imitate the observed conditions. These “best fit” models simulate the expected trophic state (TSI) responses to general reductions in watershed phosphorus loading.

The model observed the median inlake Secchi-chlorophyll TSI at 64.3. A combination of models were used to get the expected TSI, in the presence of the current annual phosphorus load, as close to the observed median TSI value as possible. The best fit models indicated a median Secchi-chlorophyll TSI of 66.9 with the current annual phosphorus load. The difference between the observed and expected (2.6 points) median

TSI was relatively close indicating that the models were capable of simulating the trophic state response with reductions in phosphorus load.

The average annual phosphorus load from upper Firesteel Creek was decreased in increments of 10% to simulate the respective trophic state response of Wilmarth Lake. The expected median Secchi-chlorophyll TSI was adjusted by 2.6 points to compensate for the difference exhibited by the observed TSI. Table 13 depicts the estimated shifts in median TSI Secchi-chlorophyll from incremental phosphorus reductions from the upper Firesteel Creek watershed.

The Twin Lake watershed is made up of two small tributaries of which only one tributary produced enough runoff to collect a set of samples. The BATHTUB model was not run for Twin Lake due to its very small watershed and a lack of tributary data collected during the assessment.

Table 13. Output generated by the BATHTUB model depicting percent phosphorus reductions from the Firesteel Creek watershed to derive estimated shifts in Wilmarth Lake median TSI Secchi-chlorophyll.

Parameter	0%	10%	20%	30%	33%	40%	50%	60%	70%	80%	86%	90%	99%
Total Phosphorus (mg/m^3)	405.5	365.3	325.1	284.9	272.8	244.7	204.5	164.3	124.1	83.8	59.7	43.6	7.5
Total Nitrogen (mg/m^3)	1206.1	1206.1	1206.1	1206.1	1206.1	1206.1	1206.1	1206.1	1206.1	1206.1	1206.1	1206.1	1206.1
Composite Nutrient (mg/m^3)	86.0	85.6	85.0	84.1	83.8	82.8	80.8	77.6	71.8	60.7	49.4	39.1	7.4
Chlorophyll-a (mg/m^3)	51.5	51.3	51.0	50.6	50.4	49.9	48.9	47.3	44.2	37.9	31.0	24.2	3.2
Secchi (meters)	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	1.0	1.2	1.5	6.3
Organic Nitrogen (mg/m^3)	1337.2	1332.3	1325.5	1315.9	1312.2	1301.5	1279.0	1240.9	1170.7	1027.6	869.5	715.3	235.6
Total Dissolved Phosphorus (mg/m^3)	89.5	89.1	88.6	87.8	87.5	86.7	84.9	81.9	76.5	65.3	53.0	40.9	3.5
Antilog PC-1 (principle Components)[2]	1831.9	1816.3	1795.0	1764.9	1753.4	1720.7	1652.6	1541.6	1349.3	1002.9	686.3	438.7	18.2
Antilog PC-2 (principle Components)[3]	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.9	15.9	15.9	15.9	12.3
(Total Nitrogen-150)/Total Phosphorus	2.6	2.9	3.2	3.7	3.9	4.3	5.2	6.4	8.5	12.6	17.7	24.2	141.6
Inorganic nitrogen/Phosphorus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	9.6	49.7	180.0	243.1
Turbidity 1/M (1/Secchi-0.025* Chlorophyll-a)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Mixed Layer Depth * Turbidity	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Mixed Layer Depth * Secchi	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.5	2.4	2.1	1.7	1.4	0.3
Chlorophyll-*a* * Secchi	37.7	37.7	37.6	37.6	37.6	37.6	37.5	37.5	37.3	36.9	36.3	35.3	20.0
Mean Chlorophyll-a / Total Phosphorus	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.4
Frequency (Chlorophyll-a > 10)%	99.0	99.0	99.0	98.9	98.9	98.9	98.8	98.6	98.2	96.7	93.5	86.8	1.6
Frequency (Chlorophyll-a > 20)%	88.8	88.7	88.5	88.2	88.1	87.8	87.2	85.9	83.4	76.5	65.4	50.0	0.1
Frequency (Chlorophyll-a > 30)%	71.3	71.1	70.7	70.3	70.1	69.6	68.4	66.4	62.4	52.7	39.8	25.6	0.0
Frequency (Chlorophyll-a > 40)%	53.9	53.6	53.3	52.7	52.5	51.9	50.6	48.4	44.1	34.6	23.5	13.2	0.0
Frequency (Chlorophyll-a > 50)%	39.6	39.4	39.0	38.5	38.3	37.7	36.5	34.4	30.5	22.5	14.0	7.0	0.0
Frequency (Chlorophyll-a > 60)%	28.9	28.7	28.3	27.9	27.7	27.2	26.2	24.4	21.1	14.7	8.4	3.8	0.0
Carlson TSI-(Phosphorus)	90.7	89.2	87.6	85.7	85.0	83.5	80.9	77.7	73.7	68.0	63.1	58.6	33.1
Carlson TSI-(Chlorophyll-a)	69.3	69.2	69.2	69.1	69.1	69.0	68.8	68.4	67.8	66.3	64.3	61.9	42.0
Carlson TSI-(Secchi)	64.5	64.5	64.4	64.3	64.2	64.1	63.8	63.4	62.4	60.4	57.7	54.6	33.6
Median TSI Secchi-chlorophyll-a	66.9	66.8	66.8	66.7	66.6	66.5	66.3	65.9	65.1	63.3	61.0	58.2	37.8
Corrected TSI Median TSI Secchi-chlorophyll-a	64.3	64.2	64.2	64.1	64	63.9	63.7	63.3	62.5	60.7	58.4	55.6	35.2

To graphically depict how the median Secchi-chlorophyll TSI responded to reductions in phosphorus from the upper Firesteel Creek watershed an in-lake reduction curve was generated (Figure 13).

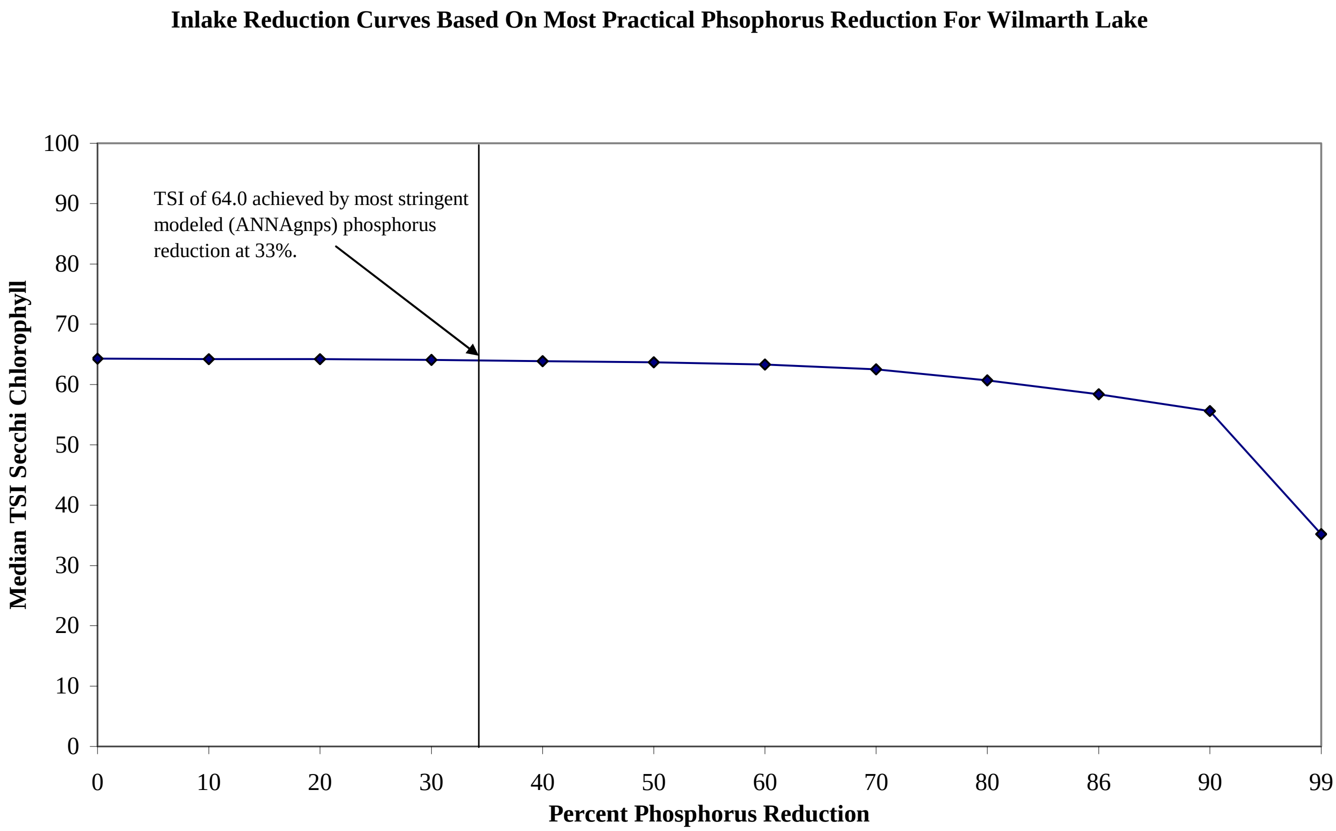


Figure 13. Median Secchi-chlorophyll TSI reduction response based on warmwater permanent fish life propagation target for Wilmarth Lake.

Significant phosphorus reductions are required to improve the trophic state of Wilmarth Lake. Modeled reductions suggest minimal improvement in TSI until a watershed phosphorus reduction in excess of 80 % is achieved (Figure 13). The magnitude of this phosphorus reduction is not achievable based on socioeconomic restraints, watershed specific phosphorus reduction attainability and modeled reductions. As a result, a TSI target of 64.0 was recommended based on the most stringent modeled (AnnAGNPS) phosphorus reduction attainability. While this target will not likely improve the overall trophic state of Wilmarth Lake it should help maintain the current eutrophic condition. Wilmarth Lake is currently meeting its beneficial uses based on numeric criteria and the recommended phosphorus reductions would likely help maintain this support status. Additional phosphorus reductions are also recommended from internal loading to aid in improving the overall trophic state of Wilmarth Lake.

OTHER MONITORING

Annualized Agricultural Non-Point Source Model (AnnAGNPS)

AnnAGNPS is a data intensive watershed model that routes sediment and nutrients through a watershed by utilizing land uses and topography. The watershed is broken up into cells of varying sizes based on topography. Each cell is then assigned a primary land use and soil type. Best Management Practices (BMPs) are then simulated by altering the land use in the individual cells and reductions in sediment and nutrient output are calculated at the outlet to the watershed.

The input data set for AnnAGNPS Pollutant Loading Model consists of 33 sections of data which can be supplied by the user in a number of ways. This model execution utilized; digital elevation maps (DEMs) to determine cell and reach geometry, SSURGO soil layers to determine primary soil types and the associated NASIS data tables for each soils properties, and primary land use based on the Digital Ortho Quads (DOQs). Landuse data was obtained from the modified NLCD maps developed by SDDENR in cooperation with the EROS Datacenter. Additional detail on cropping rotations and grass condition were added through utilizing Farm Service Agency (FSA) records and through some ground truthing. Climate data was generated using a synthetic weather generator based on climate information from the two closest stations, Huron and Pierre. Mean annual precipitation for this watershed is about 16.7 inches.

Table 14. 25-Year Simulated Model Response

	Run #	Water		Sediment		Phosphorus	
Calibration Target		0.8	inches runoff	91	mg/L	0.75	mg/L
Calibrated Model	1	0.754	inches runoff	108	mg/L	0.70	mg/L
% Difference		6%		19%		7%	
Calibrated Model Loads	1	2216	Acre Feet	326	Tons	4207	Lbs
Without Feeding Areas	2	2216	Acre Feet	326	Tons	4030	Lbs
Feeding Area Contribution	2-1	0	Acre Feet	0	Tons	177	Lbs
% Feeding Area		0%		0%		4%	
Presettlement	3	980	Acre Feet	3	Tons	2831	Lbs
	3-1	1236	Acre Feet	323	Tons	1376	Lbs
% Difference		56%		99%		33%	
Range Good	4	2177	Acre Feet	322	Tons	4135	Lbs
Range Poor	5	4233	Acre Feet	732	Tons	7769	Lbs
Rangeland Acres		19212	Acres	19212	Acres	19212	Acres
Average/Acre	(5-4)/ Acres			0.021	Tons/ Acre	0.189	Lbs/ Acre
Crops No till	6	2117	Acre Feet	260	Tons	3731	Lbs
Cropland Acres		16042	Acres	16042	Acres	16042	Acres
Average/Acre	(6-1)/ Acres			0.004	Tons/ Acre	0.030	Lbs/ Acre

It is important to note that these model results are based on 25 years of simulated data with precipitation ranging from 15 to 27 inches per year. None of these represent the project period but are instead representations of what may typically occur on any given year. When analyzed as an average annual load, it provides a risk analysis for practices in the watershed.

Comparisons between the model results and the water quality data will be difficult to make due to drought conditions experienced in the watershed. Through the use of the USGS EDNA website and USGS gauges located downstream on Firesteel Creek, annual runoff from this watershed was estimated to be 0.8 inch annually. The model was calibrated to 0.754 inch of water, which was within 6% of the target. The model simulations are located in Table 14.

The first simulation completed was the model calibration which may be considered the watershed in its current condition. This is a best estimation of the current land use practices applied to the soils and slopes of the watershed to obtain nutrient and sediment loss from individual cells as well as the watershed as a whole. Some default values were incorporated in this step, such as rangeland condition, which was simulated in a condition. Actual range conditions in the watershed did vary from this condition and would require analysis on a tract-by-tract basis during the implementation of any activities targeted at their improvement. Cropland acres were defaulted to minimum tillage practices consisting primarily of spring tillage prior to planting with a conventional planter. Actual tillage practices vary considerably between producers and would require a detailed analysis to determine the benefits of the BMP prior to its implementation on any individual tract within the watershed. Successful calibration of water, sediment, and phosphorus yields was obtained. Nitrogen was not a primary concern in the analysis of this watershed as it is the most difficult nutrient to calibrate and thus was not calibrated for this simulation.

The second simulation was to simply remove all of the feeding areas from the model. This resulted in a 4% reduction in the phosphorus loading to the lake, or an estimated reduction of 160 pounds per year. There were a total of 13 feeding areas located within the watershed. Due to the small number of operators, a map indicating locations and priorities will not be added to this document. It will be stored at SD DENR and used for the direction of any implementation activities that occur within the watershed.

The third simulation completed involved simulating the watershed as it may have been prior to settlement (Run #3 labeled pre-settlement). Grass conditions similar to mixed grass prairie or CRP were applied to all of the non-water cells in the watershed. Sediment reduction was calculated to be approximately 99% while phosphorus was 33%. These percentages may be primarily attributed to the cropland acres as there is little difference between the current condition simulation and the one simulating the pastures in good condition. It is unlikely that obtaining reductions of this magnitude are possible and they should **NOT** to be used as a TMDL or restoration goal, but are only a reference point from where implementation targets may begin development.

The fourth and fifth simulations involved modeling the watershed with both good and poor quality rangeland conditions. This was done in order to determine what might be expected from the implementation of activities that result in improving the condition of rangeland acres. As an average, an acre of improved rangeland in the Wilmarth Lakewatershed will result in a 42 pound per year reduction of sediment and a 0.2 pound per acre reduction in phosphorus.

The sixth simulation consisted of modeling the watershed with all crop fields managed as no-till systems. The reductions from this scenario were smaller than what may be typically seen for many watersheds in the state. It is expected that many fields are currently under conservation management and that beyond the addition of riparian buffers, additional benefits from no-till systems may have limited benefits.

The final simulations were completed modeling the watershed in a monoculture of grass in good and poor condition as well as in crops under minimum and no-till management. The results of these simulations were rank-ordered to develop a protection area priority map. The map in Figure 14 depicts the portions of the watershed that are most critical to the protection of the lake. The top 40% of the watershed's cells that generate the highest loadings per acre had the potential to contribute as much as 70% of the annual load. Limiting cells to the top 20% in the watershed, these same cells have the potential to contribute as much as 50% of the annual load. The critical areas in the map should be used in a "check here first" manner during any conservation implementation projects. Protecting them through conservation management will provide the greatest protection for Wilmarth Lake.

The AnnAGNPS model was not run on the Twin Lake watershed due to its very small size. Nearly all of the watershed is currently in grass and to simulate the watershed in any other manner, other than grass, did not seem feasible.

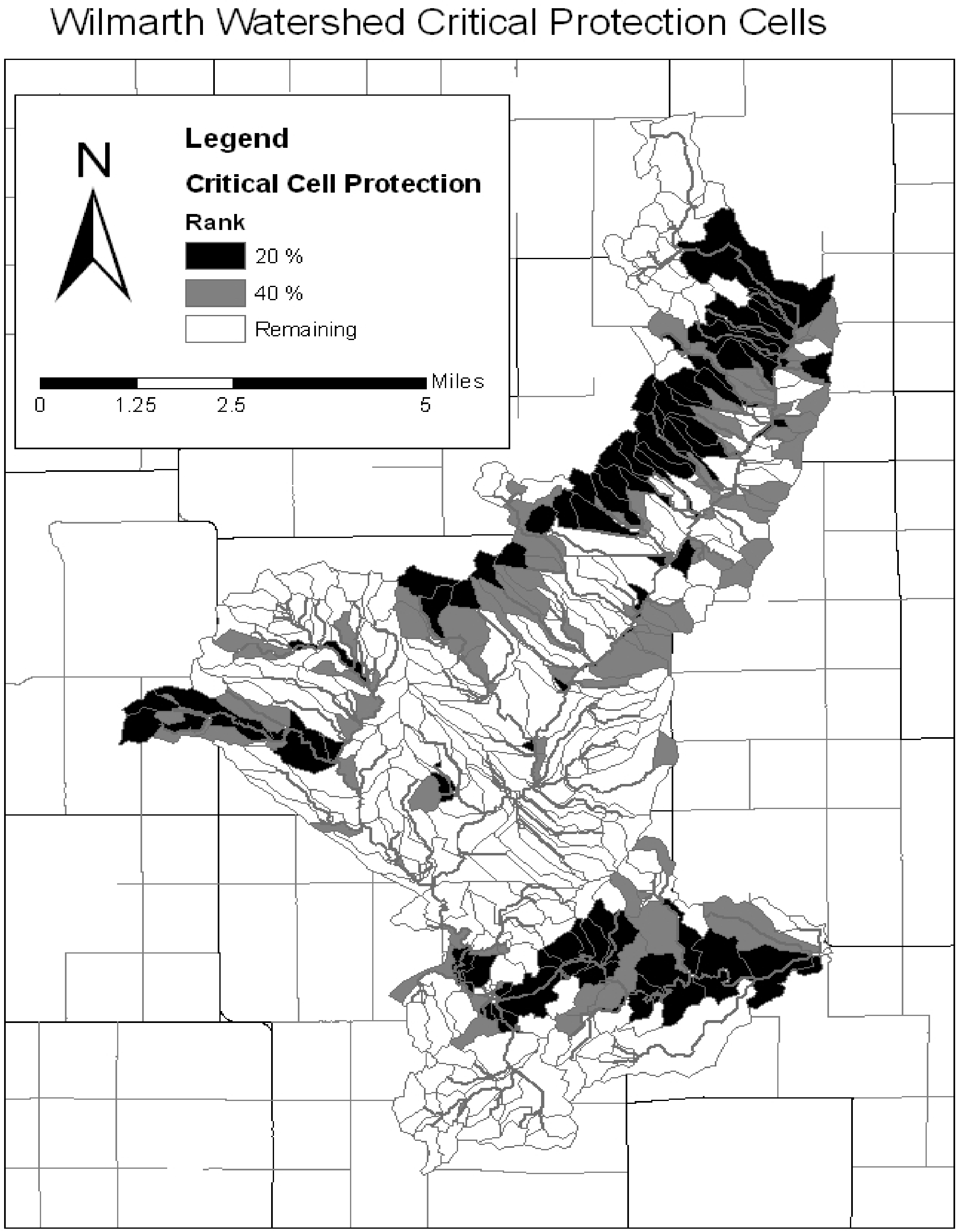


Figure 14. Wilmarth Watershed Critical Protection Cells

BIOLOGICAL MONITORING

Fishery

Twin Lake

The fish community in Twin Lake was sampled in 2006. Trap net catch and gill net catch were the methods used for gathering fish. A final report was published on the findings of the study and may be obtained from the South Dakota Department of Game, Fish and Parks (SDGF&P). The report shows dates, times, growth and condition rates, abundance, size, species of fish and management recommendations. Twin Lake is considered a major fishery in the area.

Results indicated a fish community resembling that of a lake managed under the panfish option. Black crappie and bluegill populations dominate the Twin Lake fishery, but large populations of bigmouth buffalo are also present. Other fish found during the study include walleye, black bullhead, green sunfish, common carp, white sucker, hybrid sunfish, northern pike, shortnose gar, yellow perch, and white crappie. Due to poor reproduction of some fish species such as walleye and black crappie, SDGF&P frequently stocks the lake with fingerlings to maintain a good fishery. State fishing regulations apply to the lake.

Wilmarth Lake

The fish community in Wilmarth Lake was sampled in 2007. Electro-fishing was the method used for gathering fish. A final report was published on the findings of the study and may be obtained from the South Dakota Department of Game, Fish and Parks .The report shows dates, times, growth and condition rates, abundance, size, species of fish and management recommendations. Wilmarth Lake is also considered a major fishery in the area.

Results indicated a fish community resembling that of a lake managed under the panfish option. Bluegill, black bullhead, and largemouth bass populations dominate the Wilmarth Lake fishery, but large populations of other fish species are also present. Other fish found during the study include black crappie, green sunfish, hybrid sunfish, northern pike, and yellow perch. Due to good reproduction rates of some fish species such as bluegill and largemouth bass, SDGF&P does not stock the lake with fingerlings. If natural reproduction does not continue to maintain the current fish population, fingerlings will be stocked in Wilmarth Lake. State fishing regulations apply to the lake.

Threatened and Endangered Species

According to Doug Backlund, SDGF&P, there are documented cases where threatened or endangered species were present in the Twin Lake watershed in past years to include the long eared owl, black tern, northern river otter, and regal fritillary butterfly. None of these species were encountered during the study.

There are documented cases where threatened or endangered species were present in the Wilmarth Lake watershed to include the long eared owl, Merlin raptor, Plains Top

Minnow, Downy Gentian perennial flower, Rough rattlesnake-root flower, Bald Eagle, Loggerhead Shrike, Northern River Otter, Northern Mockingbird, Topeka Shiner, Black crowned Night-heron, and Plains Spotted Skunk. None of these species were encountered during the study.

The US Fish and Wildlife Service listed the whooping crane and bald eagle as species that could potentially be found in the area, though none of these species were encountered during the study.

Twin Lake Planktonic Algae

Six composited surface water samples were collected mid-lake at two widely separated sites during the summers of 2001, 2002, and 2005 as part of the annual statewide lake surveys established in 1979. A total of 83 algal taxa were identified, not including several “unidentified algae” categories. Species richness (the number of algal taxa observed) in Twin Lake was rated “above average” when compared to 15 other recently monitored small state lakes of 200 acres or less which had a mean of 73 algal taxa. The presence of moderately saline water (TDS >3000) appears not to have noticeably reduced the number of algal species inhabiting this water body, although most taxa were present in small numbers.

Non-motile green algae (Chlorophyta) represented the most diverse group of algae in Twin Lake with 26 species followed by blue-green algae (Cyanophyta) with 22 taxa. Less diverse algal groups were flagellated (motile) algae, comprising five phyla, with 19 taxa and diatoms with 16 identified taxa.

The bulk of the annual summer phytoplankton populations consisted almost exclusively of only one species of blue-green algae, *Oscillatoria* (*Planktothrix*) *agardhii* (Table 15). This dominance dates back to at least 2001 when on 25 June and 13 August it comprised 80% of the total algae community.

The preeminence of *O. agardhii* over other nuisance blue-greens that are dominant in a number of other monitored state lakes, for example *Aphanizomenon flos-aquae,* may indicate a greater abundance of usable nitrogen (NO3, NO2, and ammonia) in Twin Lake than in some other state lakes where *Aphanizomenon* is dominant. *Oscillatoria* cannot fix (utilize) atmospheric or dissolved molecular nitrogen (N2) like *Aphanizomenon* and is therefore as highly dependent on a sufficient supply of usable nitrogen being available as green algae or diatoms. Recent (2005) summer densities of *O. agardhii* were extremely high and similar to those reported for Lake Andes.

Diatoms made up only 1.3% of total algae numbers and 6.7% of the biovolume during this survey (Table 15). It is not unusual for diatoms to be abundant during summer in some other eutrophic state lakes. Diatoms benefit from the mixing of the water column during summer in shallow eutrophic lakes such as Twin Lake (mean depth: 6 ft.). However, some literature indicates that silicate (SiO2) limitation commonly occurs in eutrophic lakes that probably have a plentiful supply of most other plant nutrients. Under those conditions, silicate supplies may be rapidly depleted in the spring to remain at low levels for the rest of the growing season. Silicates are the building blocks for diatom frustules without which diatom growth cannot continue or proceeds at a slow pace even though other nutrients are still present in sufficient concentrations to promote rapid growth.

Non-motile green algae occurred in relatively moderate numbers for most of the survey. They comprised 2.4% of total algal density and 2.6% of biovolume for the monitoring study (Tables 15 and 16). Planktonic green algae appear to be at a competitive disadvantage in alkaline lakes with high pH (> 8). Alkaline lakes tend to favor the growth of blue-green algae due to the low levels of free dissolved carbon dioxide (CO2) in those types of waters which blue-greens are able to utilize more efficiently. Twin Lake is not a typical alkaline water body but may be placed in a group of moderately saline sulfate lakes in eastern South Dakota where sodium and/or magnesium ions may also be abundant (e.g. Lake Cochrane).

Limited sampling during this assessment suggested there may be considerable year-to-year variation in the annual algae populations of Twin Lake. The 2002 summer population size was less than 10% of those recorded for the years 2001 and 2005. It may be that rainfall in the watershed, runoff into the lake, and, therefore, nutrient loading was considerably less in 2002 than during 2001 and 2005. It may also be significant that the latter year had the highest algal densities and biovolume recorded for Twin Lake to date.

Wilmarth Lake Planktonic Algae

Six composited surface water samples were collected at two widely separated sites during the summer of 1998, 2002, and 2006 as part of the annual state-wide lake assessments established in 1979. Of the six samples, five yielded usable data for analysis. A total of 71 algal taxa were identified not including three “unidentified algae” categories.

Species richness(the number of taxa observed) in Lake Wilmarth was rated “average” when compared to 15 other recently monitored small state lakes of 200 acres or less which had a mean of 73 algal taxa. Although a considerable number of species was identified in Lake Wilmarth during the monitoring process, only 4 blue-green taxa made up nearly 80% of the average algae population for those three years (Table 17).

Non-motile green algae (Chlorophyta) and motile(flagellated)algae within five phyla, represented the most diverse groups in Lake Wilmarth with 21 species each, followed by diatoms with 15 taxa and blue-green algae (Cyanophyta) represented by 14 species.

The filamentous blue-green *Oscillatoria*(Planktothrix)*agardhii* was the most abundant taxon collected during the assessments (Table 18) owing almost entirely to a single bloom of this species estimated at 137,060 cells/ml on 31 July 2002. Summer blooms of blue-green algae do not appear to be uncommon in this eutrophic reservoir and date back to at least 1979 when blooms of *Aphanizomenon* (93,104 cells/ml) and *Microcystis aeruginosa*

(155,175 cells/ml) were recorded in late July (Koth,1981). The more recent statewide assessments, however, failed to detect any large blooms other than the one observed in July 2002. For most sampling dates, algae populations, including those of nuisance blue-green algae, were in the low to moderate range, especially in 2006, for a highly eutrophic water body such as Lake Wilmarth.

Flagellated (motile) algae were numerically dominant or co-dominant in three of five samples collected in Wilmarth Lake during the course of three annual statewide lake assessments. Being able to swim is of great advantage to an alga inhabiting a lake water column. Therefore, it is unclear why free-swimming algae are not more frequently the dominant planktonic forms in most situations. Under ice where water movement is slight, motile algae have a substantial advantage over non-motile forms that require water turbulence created by wind/wave action to remain suspended in the water column. In statewide lake surveys flagellated algae were frequently the most numerous taxa in winter under ice cover. In spring, they were the most common algae collected from smaller water bodies with some degree of wind protection such as Hayes, Waggoner, Dante Lake and some other small state lakes.

Table 15. Twin Lake Algae Species

Project Algae Species List

Twin Lake: 2001, 2002, 2005. 6 samples total

#	Algae Species	Avg Density cells/ml	Avg % Density	# samples	Algae Type
1	Oscillatoria agardhii	904055	81.6	6	Blue-Green (filament)
2	Pseudanabaena sp.	49729	4.5	2	Blue-Green (filament)
3	Anabaena subcylindrica ?	45813	4.1	3	Blue-Green (filament)
4	Oscillatoria sp.	21667	2.0	2	Blue-Green (filament)
5	Aphanocapsa sp.	19237	1.7	6	Blue-Green (colonial)
6	Raphidiopsis sp. ?	15822	1.4	2	Blue-Green (filament)
7	Cylindrospermopsis raciborskii	13011	1.2	2	Blue-Green (filament)
8	Anabaena sp.	9475	0.8	3	Blue-Green (filament)
9	Oscillatoria limnetica	8317	0.8	2	Blue-Green (filament)
10	Lyngbya limnetica	6742	0.6	1	Blue-Green (filament)
11	Anabaena oscillarioides ?	5800	0.5	1	Blue-Green (filament)
12	Unidentified algae	1623	0.2	6	unidentified
13	Unidentified flagellated algae	740	0.1	6	unidentified
14	Kirchneriella sp.	662	0.1	4	Green
15	Marssionella elegans	635	0.1	3	Blue-Green (colonial)
16	Oocystis sp.	605	0.0	6	Green (colonial)
17	Aphanocapsa elachista	580	0.0	1	Blue-Green (colonial)
18	Chrysochromulina parva	482	0.0	4	Flagellated algae
19	Dictyosphaerium pulchellum	363	0.0	5	Green (colonial)
20	Anabaenopsis sp.	360	0.0	2	Blue-Green (filament)
21	Scenedesmus acuminatus	274		4	Green (colonial)
22	Chaetoceros elmorei	248		4	Diatom (centric)
23	Cyclotella meneghiniana	222		6	Diatom (centric)
24	Actinastrum hantzschii	181		3	Green (colonial)
25	Nephrocytium sp. ?	180		2	Green (colonial)
26	Nitzschia sp.	170		4	Diatom (pennate)
27	Ankistrodesmus sp.	156		5	Green
28	Stephanodiscus minutus	137		3	Diatom (centric)
29	Anabaena circinalis	123		2	Blue-Green (filament)
30	Dactylococcopsis sp. ?	120		1	Blue-Green
31	Chromulina sp.	107		3	Flagellated algae

32	Rhodomonas minuta	91	5	Flagellated algae
33	Cryptomonas sp.	81	6	Flagellated algae
34	Selenastrum minutum	72	1	Green (colonial)
35	Scenedesmus quadricauda	70	4	Green (colonial)
36	Scenedesmus dimorphus	55	2	Green (colonial)
37	Merismopedia tenuissima	53	1	Blue-Green (colonial)
38	Unidentified green algae	50	2	unidentified
39	Unidentified centric diatoms	42	1	Diatom (centric)
40	Aphanizomenon sp. ?	42	1	Blue-Green (filament)
41	Closterium aciculare	35	2	Green
42	Stephanodiscus sp.	33	1	Diatom (centric)
43	Microcystis sp.	31	1	Blue-Green (colonial)
44	Closteriopsis sp.	30	3	Green
45	Nitzschia paleacea	27	1	Diatom (pennate)
46	Cosmarium depressum	24	1	Green
47	Chlamydomonas sp.	22	3	Flagellated algae
48	Chroococcus dispersus	22	1	Blue-Green (colonial)
49	Microcystis incerta	20	1	Blue-Green (colonial)
50	Quadrigula sp.	18	2	Green (colonial)
51	Trachelomonas sp.	15	5	Flagellated algae
52	Pediastrum duplex	14	3	Green (colonial)
53	Treubaria sp.	8	2	Green
54	Spermatozopsis sp.	8	2	Flagellated algae
55	Phacus pleuronectes	7	1	Flagellated algae
56	Glenodinium sp.	6	5	Flagellated algae
57	Sphaerocystis schroeteri	5	1	Green (colonial)
58	Dunaliella sp. ?	5	1	Flagellated algae
59	Synedra acus	5	3	Diatom (pennate)
60	Entomoneis paludosa	4	2	Diatom (pennate)
61	Nitzschia reversa	4	2	Diatom (pennate)
62	Coelastrum sp.	4	1	Green (colonial)
63	Coscinodiscus rothii	3	1	Diatom (centric)
64	Euglena sp.	3	2	Flagellated algae
65	Phacus helicoides	3	2	Flagellated algae
66	Crucigenia quadrata	3	1	Green (colonial)
67	Cosmarium sp.	2	2	Green
68	Fragilaria capucina	2	1	Diatom (pennate)
69	Lepocinclis sp.	2	2	Flagellated algae
70	Euglena oxyuris	2	1	Flagellated algae
71	Characium limneticum	2	2	Green
72	Staurastrum gracile	2	1	Green
73	Nitzschia aciculare	2	1	Diatom (pennate)
74	Stephanodiscus niagarae	1	2	Diatom (centric)
75	Entzia acuta ?	1	1	Flagellated algae
76	Pediastrum tetras	1	1	Green (colonial)
77	Tetraedron sp.	1	2	Green

78	Phacus sp.	1	1	Green
79	Spirulina sp.	< 1	1	Blue-Green (filament)
80	Staurastrum sp.	< 1	1	Green
81	Ceratium hirundinella	< 1	1	Flagellated algae
82	Carteria sp.	< 1	1	Flagellated algae
83	Glenodinium gymnodinium	< 1	1	Flagellated algae
84	Amphora ovalis	< 1	1	Diatom (pennate)
85	Gomphonema sp.	< 1	1	Diatom (pennate)
86	Surirella ovalis	< 1	1	Diatom (pennate)
87	Closterium sp.	< 1	1	Green

Table 16. Twin Lake Algal Density

Twin Lake Algae Density (cells/ml) and Biovolume (um3/ml)

Date	Algae Group	cells / ml	%	um3 / ml	%
25-Jun-01	Flagellated Algae	2,064	0.2	73,975	0.2
	Dinoflagellates	2	0.0	10,516	0.0
	Blue-Green Algae	886,383	99.6	40,632,013	99.6
	Diatoms	83	0.0	44,543	0.1
	Non-Motile Green Algae	118	0.0	11,324	0.0
	Unidentified Algae	1,490	0.2	44,700	0.1
Total		**890,140**		**40,817,071**	
13-Aug-01	Flagellated Algae	589	0.0	32,700	0.0
	Dinoflagellates	2	0.0	13,300	0.0
	Blue-Green Algae	1,329,050	99.9	63,643,050	99.7
	Diatoms	273	0.0	106,550	0.2
	Non-Motile Green Algae	190	0.0	23,250	0.0
	Unidentified Algae	180	0.0	5,400	0.0
Total		**1,330,284**		**63,824,250**	
24-Jun-02	Flagellated Algae	3,713	21.5	426,070	32.7
	Dinoflagellates	6	0.0	4,200	0.3
	Blue-Green Algae	7,438	43.0	187,880	14.4
	Diatoms	1,121	6.5	465,280	35.7
	Non-Motile Green Algae	1,853	10.7	124,389	9.6
	Unidentified Algae	3,170	18.3	95,100	7.3
Total		**17,301**		**1,302,919**	
22-Jul-02	Flagellated Algae	1,350	1.0	486,270	7.3
	Dinoflagellates	4	0.0	2,800	0.0
	Blue-Green Algae	122,510	94.1	5,568,862	83.4
	Diatoms	1,122	0.9	243,440	3.6
	Non-Motile Green Algae	3,535	2.7	329,196	4.9
	Unidentified Algae	1,660	1.3	49,800	0.8
Total		**130,181**		**6,680,368**	

21-Jun-05	Flagellated Algae	1,030	0.1	201,800	0.3
	Dinoflagellates	5	0.0	15,000	0.0
	Blue-Green Algae	1,567,227	98.9	66,047,666	97.7
	Diatoms	2,400	0.2	532,800	0.8
	Non-Motile Green Algae	10,420	0.7	726,250	1.1
	Unidentified Algae	2,860	0.2	85,800	0.1
Total		**1,583,942**		**67,609,316**	
19-Jul-05	Flagellated Algae	662	0.0	26,550	0.0
	Dinoflagellates	19	0.0	13,300	0.0
	Blue-Green Algae	2,697,309	99.9	162,071,505	99.9
	Diatoms	466	0.0	51,080	0.0
	Non-Motile Green Algae	798	0.0	78,970	0.0
	Unidentified Algae	380	0.0	11,400	0.0
Total		**2,699,634**		**162,252,805**	

Table 17. Wilmarth Lake Algae Species

Project Algae Species List

Lake Wilmarth:1998, 2002, 2006 — 5 samples total

#	Algae Species	Avg Density cells/ml	Avg % Density	# samples	Algae Type
1	Oscillatoria agardhii	27548	62.9	3	Blue-Green (filament)
2	Anabaena circinalis	4467	10.2	2	Blue-Green (filament)
3	Unidentified algae	3446	7.9	5	unidentified
4	Aphanocapsa sp.	1722	3.9	3	Blue-Green (colonial)
5	Unidentified flagellated algae	1546	3.5	5	unidentified
6	Rhodomonas minuta	1100	2.5	5	Flagellated algae
7	Aphanizomenon flos-aquae	946	2.2	3	Blue-Green (filament)
8	Cyclotella meneghiniana	875	2.0	3	Diatom(colonial)
9	Cryptomonas sp.	421	1.0	5	Flagellated algae
10	Microcystis sp.	218	0.5	1	Blue-Green (colonial)
11	Oocystis sp.	156	0.4	3	Green(colonial)
12	Stephanodiscus hantzschii	130	0.3	2	Diatom(centric)
13	Anabaena spiroides crassa	120	0.3	1	Blue-Green(filament)
14	Synura uvella	98	0.2	1	Flagellated algae
15	Anabaena sp.	91	0.2	3	Blue-Green (filament)
16	Chlamydomonas sp.	82	0.2	3	Flagellated algae
17	Microcystis aeruginosa	58	0.1	1	Blue-Green (colonial)
18	Characium limneticum	55	0.1	4	Green
19	Sphaerocystis schroeteri	51	0.1	4	Green (colonial)
20	Characium sp.	50	0.1	1	Green

21	Pediastrum duplex	43	0.1	2	Green (colonial)
22	Scenedesmus sp.	40	0.1	2	Green (colonial)
23	Anabaena flos-aquae	40	0.1	1	Blue-Green(filament)
24	Chrysochromulina parva	31	0.1	4	Flagellated algae
25	Coelastrum sp.	26	0.1	2	Green (colonial)
26	Bicoeca euplanktonica	26	0.1	1	Flagellated algae
27	Cocconeis placentula	24	0.0	1	Diatom(pennate)
28	Microcystis incerta	24	0.0	1	Blue-Green(colonial)
29	Kirchneriella sp.	24	0.0	2	Green(colonial)
30	Melosira granulata	22	0.0	5	Diatom(filament)
31	Trachelomonas sp.	22		3	Flagellated algae
32	Coelastrum cambricum	22		1	Green(colonial)
33	Oscillatoria sp.	20		1	Blue-Green(filament)
34	Ceratium hirundinella	17		3	Flagellated algae
35	Chromulina sp.	16		1	Flagellated algae
36	Platymonas elliptica	16		1	Flagellated algae
37	Trachelomonas volvocina	15		1	Flagellated algae
38	Nitzschia sp.	15		3	Diatom(pennate)
39	Closterium aciculare	15		3	Green
40	Fragilaria crotonensis	13		2	Diatom(filament)
41	Micractinium pusillum	13		1	Green(colonial)
42	Chlorococcum sp.	12		2	Green(colonial)
43	Pandorina morum	10		2	Flagellated algae
44	Lyngbya sp.	10		1	Blue-Green(filament)
45	Stephanodiscus niagarae	9		4	Diatom (centric)
46	Stephanodiscus minutus	8		1	Diatom(centric)
47	Micractinium sp.	8		1	Green(colonial)
48	Dictyosphaerium pulchellum	7		1	Green(colonial)
49	Chrysococcus rufescens	6		1	Flagellated algae
50	Schroederia judayi	5		2	Green
51	Cylindrospermopsis raciborskii	5		1	Blue-Green (filament)
52	Closterium sp.	4		2	Green
53	Botryococcus braunii	4		1	Green
54	Nitzschia acicularis	3		1	Diatom(pennate)
55	Euglena sp.	3		3	Flagellated algae
56	Unidentified green algae	2		1	Green
57	Glenodinium sp.	2		1	Flagellated algae
58	Tetraedron sp.	2		1	Green
59	Cocconeis sp.	2		3	Diatom(pennate)
60	Asterionella formosa	2		1	Diatom(pennate)
61	Fragilaria capucina	2		1	Diatom (pennate)
62	Anabaenopsis sp.	2		1	Blue-Green(filament)
63	Oocystis borgei	2		1	Green(colonial)
64	Glenodinium gymnodinium	1		3	Flagellated algae
65	Staurastrum sp.	1		2	Green

66	Gomphonema sp.	1	1	Diatom (pennate)
67	Euglena oxyuris	< 1	1	Flagellated algae
68	Carteria sp.	< 1	2	Flagellated algae
69	Phacus sp.	< 1	1	Flagellated algae
70	Euglena ehrenbergii	< 1	1	Flagellated algae
71	Lepocinclis sp.	< 1	1	Flagellated algae
72	Closteriopsis sp.	< 1	1	Green
73	Navicula cryptocephala	< 1	1	Diatom (pennate)
74	Epithemia sp.	< 1	1	Diatom (pennate)

Table 18. Wilmarth Lake Algal Density

Lake Wilmarth Algae Density (cells/ml) and Biovolume (um3/ml)

Date	Algae Group	cells / ml	%	um3 / ml	%
23-Jun-98	Flagellated Algae	10,032	28.0	1,803,520	36.4
	Dinoflagellates	54	0.2	398,208	8.0
	Blue-Green Algae	9,011	24.5	95,613	1.9
	Diatoms	5,132	14.0	1,934,930	39.0
	Non-Motile Green Algae	837	2.3	376,229	7.6
	Unidentified Algae	11,720	31.9	351,600	7.1
Total		**36,786**		**4,960,100**	
03-Aug-98	Flagellated Algae	2,512	25.5	262,800	41.0
	Dinoflagellates	0			
	Blue-Green Algae	1,326	13.4	117,292	18.3
	Diatoms	137	1.4	82,510	12.9
	Non-Motile Green Algae	1,001	10.2	23,250	3.6
	Unidentified Algae	4,880	49.5	155,234	24.2
Total		**9,856**		**641,086**	
31-Jul-02	Flagellated Algae	985	0.6	202,650	2.0
	Dinoflagellates	6	0.0	52,080	0.5
	Blue-Green Algae	159,451	98.9	9,568,760	96.5
	Diatoms	62	0.0	25,120	0.2
	Non-Motile Green Algae	520	0.3	58,682	0.6
	Unidentified Algae	240	0.2	7,200	0.1
Total		**161,264**		**9,914,492**	
13-Jun-06	Flagellated Algae	1,660	65.2	127,875	27.3
	Dinoflagellates	1	0.0	9,816	2.1
	Blue-Green Algae	350	13.8	10,600	2.3
	Diatoms	143	5.6	284,155	60.7
	Non-Motile Green Algae	310	12.2	33,000	7.0
	Unidentified Algae	80	3.1	2,400	0.5
Total		**2,544**		**467,846**	
19-Jul-06	Flagellated Algae	1,768	20.9	101,845	6.8
	Dinoflagellates	46	0.5	444,720	29.6

	Blue-Green Algae	6,214	73.5	830,477	55.2
	Diatoms	79	0.9	91,410	6.1
	Non-Motile Green Algae	41	0.5	26,065	1.7
	Unidentified Algae	310	3.7	9,300	0.6
Total		**8,458**		**1,503,817**	

QUALITY ASSURANCE REPORTING

Two lake *replicate* QA/QC sample **sets** and 8 lake sample **sets** were collected in Twin Lake during the project period for an overall QA/QC percentage of 25 percent of all inlake samples collected. Due to a lack of runoff, no tributary samples were collected from TLT02 and only three tributary samples were collected from TLT01 which resulted in no collection of QA/QC samples for the Twin Lake watershed.

One lake replicate QA/QC sample and 32 lake samples were collected in Wilmarth Lake during the project period for an overall QA/QC percentage of 3 percent of all inlake samples collected. Two tributary QA/QC *replicate* samples and 15 samples were collected in the watershed for an overall QA/QC control of 13%. Parameters tested for include alkalinity, ammonia, nitrate, TKN, fecal coliform, E. coli, total solids, total suspended solids, volatile total suspended solids, total phosphorus, and total dissolved phosphorus. Total solids, total dissolved solids, total suspended solids, and volatile total suspended solids concentrations can vary considerably because of variations in sample collection and natural variation. Variations in field sampling techniques, preparation and that the samples are replicate and not duplicate may be some reasons for slight differences. Complete test results for replicates and blanks may be found in the following tables.

Table 19. Twin Lake Duplicates and Blanks

Depth	Date	Site	Type	Talka	DO	Fecal	TKN	Ammonia	Nitrogen	pH	TP04	TDP04	TSOL	TSSOL
SURFACE	07/13/2004	TL01	Blank	<6	<7	<10	<0.23	<0.02	<0.1		<0.002	0.006	<7	4
SURFACE	07/13/2004	TL01	Grab	107	6.93	<10	3.19	0.04	<0.1	7.22	0.142	0.024	2675	38
SURFACE	07/13/2004	TL01	Replicate Grab	106	6.93	10	2.99	0.04	<0.1	7.22	0.134	0.023	2678	38
Percent Difference				1%	0%	0%	6%	0%	0%	0%	6%	4%	4%	0%
SURFACE	09/16/2004	TL01	Blank	<6		<10	<0.23	<0.02	<0.1		<0.002	<0.002	<7	<1
SURFACE	09/16/2004	TL01	Grab	101	6.13	<10	4.52	0.40	<0.1	7.74	0.121	0.015	2622	35
SURFACE	09/16/2004	TL01	Replicate Grab	102	6.13	<10	4.65	0.40	<0.1	7.74	0.125	0.016	2658	37
Percent Difference				1%	0%	0%	3%	0%	0%	0%	4%	6%	1%	5%
***Average* Percent Difference**				1%	0%	0%	4.5%	0%	0%	0%	5%	5%	3%	3%

The July 13, 2004 QA/QC sample at TL01 detected a difference in alkalinity, TKN, TDP04, and TSOL between sample and replicate. These differences are probably due to natural variation. The blank sample detected TDP04 and TSSOL in the sample. The presence of TDP04 in the blank sample is probably the result of a poorly rinsed sample bottle or the presence of phosphorus in the distilled water used, or a small amount of organic matter in the sample, which in return caused TSSOL to be detected.

The September 16, 2004 QA/QC sample detected slight differences in alkalinity, TKN, TP04, TDP04, TSOL, and TSSOL between the sample and the replicate. These differences are probably due to natural variation.

Table 20. Wilmarth Lake and Tributary Duplicates and Blanks

Depth	Date	Site	Type	Talka	DO	Fecal	TKN	Ammonia	Nitrogen	pH	TP04	TDP04	TSOL	TSSOL
SURFACE	03/19/2004	WL01	Blank	<6			<0.23	<0.02	<0.1		<0.002	<0.002	<7	<1
SURFACE	03/19/2004	WLT04	Replicate Grab	197	11.46		2.15	<0.02	<0.1	8.42	0.364	0.201	1188	12
SURFACE	03/19/2004	WLT04	Grab	195	11.46		2.18	<0.02	<0.1	8.42	0.360	0.203	1189	15
Percent Difference				1%	0%		0%	0%	0%	0%	0%	0%	0%	20%
SURFACE	05/18/2004	WLT01	Blank	<6		<10	<0.23	<0.02	<0.1		<0.002	0.004	<7	<1
SURFACE	05/18/2004	WLT01	Replicate Grab	164	9.03	2200	2.52	<0.02	0.2	8.06	1.30	1.21	1199	16
SURFACE	05/18/2004	WLT01	Grab	164	9.03	1080	2.64	<0.02	0.2	8.06	1.30	1.21	1201	17
Percent Difference				0%		51%	5%	0%	0%	0%	0%	0%	1%	6%
BOTTOM	07/13/2004	WL01	Blank	<6			<0.23	<0.02	0.1		<0.002	0.008	<7	<1
BOTTOM	07/13/2004	WL01	Replicate Grab	200	2.45		1.29	<0.02	<0.1	8.07	0.648	0.568	952	12
BOTTOM	07/13/2004	WL01	Grab	200	2.45		1.36	<0.02	<0.1	8.07	0.663	0.570	958	11
Percent Difference				0%	0%		5%	0.10%	0%	0%	2%	0%	0%	8%
***Average* Percent Difference**				0.33%	0%	51%	3%	0.04%	0%	0%	2%	3%	1%	20%

The March 19, 2004 QA/QC sample at WLT04 detected an increase in TSSOL and alkalinity between the sample and the replicate. The blank sample had not detection for any of the parameters tested. The slight difference in TSSOL and alkalinity are probably due to natural variation. There were no detections in the blank sample.

The May 18, 2004 QA/QC sample at WLT01 detected quite a difference in fecal coliform bacteria, and only a small difference in TKN, TSOL, and TSSOL between the sample and the replicate. These differences are probably due to natural sample variation. However, the blank sample detected TDP04 was present (.004 mg/L) in the sample. This detection is probably due to a poorly rinsed sample bottle or the distilled water used could have contained a small amount of phosphorus.

The July 13, 2004 QA/QC sample at WL01 detected a slight increase in TKN and TP04 between the sample and the replicate. These differences are probably due to natural sample variation. Once again, the blank sample detected the presence of nitrogen and TDP04 in the sample. This detection is probably due to a poorly rinsed sample bottle or the distilled water used could have contained a small amount of phosphorus and nitrogen.

Public Involvement and Coordination

State Agencies

The South Dakota Department of Environment and Natural Resources (DENR) was the primary lead advocate state agency involved in the completion of this assessment. DENR provided equipment as well as technical assistance throughout the entire project. DENR administered the 319 funds ($64,000) for the project, provided $23,000 in state "fee" funds and provided technical assistance. SDDENR also took the lead in the AnnAGNPS modeling effort, and is responsible for preparing the Final Assessment Report and TMDLs.

The South Dakota Department of Game, Fish and Parks (GF&P) aided in the completion of the assessment by providing a complete report on the condition of the fishery in Twin Lake and Wilmarth Lake.

Federal Agencies

The Environmental Protection Agency (EPA) provided the primary source of 319 funds for the completion of the Twin Lake and Wilmarth Lake Assessments.

The Natural Resource Conservation Service (NRCS) provided technical assistance for the assessment coordinator.

The Farms Service Agency provided land use information for the AnnAGNPS model used for watershed modeling.

Local Governments; Industry, Environmental, and other Groups, and Public-at-Large

The Aurora County Conservation District contributed financially to the project and provided the sponsorship that made this project possible. District personnel conducted the water quality sampling, stream velocity measurements, stream stage recording, data compilation, and local outreach.

Aspects of the Project That Did Not Work Well

All of the objectives proposed for the project were met in an acceptable time frame, with the exception of the macroinvertebrate survey. The number of tributary samples collected during the project was less than proposed, but adequate for the completion of the report. The number of tributary samples was reduced because of a lack of moisture during the project period. The outlet of Twin Lake never flowed and the tributary sites flowed only after high intensity rain events. The outlet to Wilmarth Lake only flowed once after a high intensity rain.

There was a misunderstanding of the number of QA/QC samples needed to meet the 10% requirement. QA/QC samples were collected for 10% of the sample "sets" rather then 10% of the "total" number of samples.

Future Activity Recommendations

The Wilmarth Lake watershed is void of urban influences with no concentrations of housing development in the watershed. Possibilities for future implementation of Best Management Practices (BMPs) will relate to agricultural activities. Near the inlet of Wilmarth Lake, the landowner installed one mile of buffer along the creek during the assessment. Another area of concern is on the southwest end of Wilmarth Lake where a producer is currently watering livestock in Wilmarth Lake, resulting in bank erosion and decreased lake water quality.

All of the large feedlots in the Wilmarth watershed have ag-waste systems in place already. However, there are a few smaller operations in close proximity of the West Branch of Firesteel Creek that could benefit from feedlot relocation or some type of animal waste system.

The Twin Lake watershed appears to have problems stemming from a mixture of urban and agricultural sources. There are quite a few cabins and homes on the lake that have septic tanks and/or drain fields. Dye testing septic systems would be necessary in an implementation project to determine if leaching to the lake is a problem.

The small watershed of just over 1,000 acres was primarily grass during the assessment with only small parcel of land being farmed. Converting the cropland to grass would be beneficial to the lake's water quality.

It is believed the results of the assessment will justify seeking additional 319 funds for a 319 Implementation Project, providing various BMPs for both watersheds.

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Appendix A. Wilmarth Lake Water Quality Data

RelativeDepth	SampleDate	Station ID	Alk mg/L	Secchi meter	DO mg/L	E. Coli #/100mL	Fecal #/100mL	TKN mg/L	Ammonia mg/L	Nitrate mg/L	pH s.u.	Total Phos mg/L	Dis Phos mg/L	Sp Cond umol/C	H2o Temp ^{0}C	Tot Sol mg/L	TSS mg/L	TVSS mg/L
SURFACE	09/16/2004	TWINWILTL01	102	0.2	6.13	<1	<10	4.65	0.40	<0.1	7.74	0.125	0.016	2524	19.14	2658	37	28
SURFACE	08/11/2004	TWINWILTL01	90	0.2	8.55	<1	<10	4.31	<0.02	<0.1		0.143	0.046	2937	20.57	2731	47	35
SURFACE	06/22/2004	TWINWILTL01	112	.2	11.47	3.1	<10	3.39	0.45	<0.1	7.97	0.153	0.014	3005	19.68	2608	31	19
SURFACE	09/16/2004	TWINWILTL01	101	0.2	6.13	<1	<10	4.52	0.40	<0.1	7.74	0.121	0.015	2524	19.14	2622	35	28
SURFACE	07/13/2004	TWINWILTL01	107	.2	6.93	3.1	<10	3.19	0.04	<0.1	7.22	0.142	0.024	3071	25.53	2675	38	27
SURFACE	08/26/2004	TWINWILTL01	94	0.1	8.04	1.0	<10	3.86	<0.02	<0.1	8.02	0.131	0.020	2448	22.17	2702	41	34
SURFACE	05/18/2004	TWINWILTL01	112	.4	10.80	5.2	10	2.81	0.76	<0.1	8.71	0.073	0.015	2378	14.13	2644	20	14
SURFACE	07/28/2004	TWINWILTL01	92	0.2	7.32	1.0	<10	4.05	<0.02	<0.1	7.74	0.142	0.019	3088	23.34	2741	44	41
SURFACE	04/19/2004	TWINWILTL01	132	.4	9.19	30.1	20	4.47	1.75	<0.1	8.07	0.092	0.015	2428	13.82 C	2687	23	1
SURFACE	09/16/2004	TWINWILTL02	101	0.2	6.13	<1	<10	4.23	0.50	<0.1	7.71	0.122	0.016	2549	19.51	2658	34	28
SURFACE	08/11/2004	TWINWILTL02	90	0.2	7.85	<1	<10	3.96	<0.02	<0.1		0.131	0.017	2970	20.95	2714	40	31
SURFACE	06/22/2004	TWINWILTL02	115	.3	9.76	1.0	10	3.39	0.80	<0.1	8.11	0.102	0.013	3062	20.20	2602	21	14
SURFACE	07/13/2004	TWINWILTL02	104	0.4	7.63	7.4	10	2.70	0.20	<0.1	7.55	0.102	0.020	3079	25.20	2674	31	23
SURFACE	07/28/2004	TWINWILTL02	95	0.2	7.97	<1	<10	4.07	<0.02	<0.1	8.00	0.123	0.021	3120	23.80	2728	41	36
SURFACE	08/26/2004	TWINWILTL02	94	0.1	7.53	<1	10	4.12	<0.02	<0.1	8.16	0.124	0.018	2452	22.08	2701	39	33
SURFACE	04/19/2004	TWINWILTL02	132	.4	9.69	2.0	<10	4.48	1.79	<0.1	8.08	0.101	0.016	2441	14.13 C	2673	21	11
SURFACE	05/18/2004	TWINWILTL02	117	.4	11.09	8.6	<10	3.17	0.88	0.1	8.60	0.072	0.014	2395	14.31	2646	19	14
SURFACE	05/18/2004	TWINWILTLT01	162		6.31	866	570	2.90	<0.02	<0.1		1.58	1.22	1417	12.12	1670	132	20
SURFACE	05/17/2004	TWINWILTLT01	100		6.61	>2420	3300	2.37	0.21	<0.1	7.35	1.39	0.978	828	10.58 C	950	31	8
SURFACE	05/16/2004	TWINWILTLT01	50		7.29			1.88	0.08	0.1	8.26	0.800	0.534	400	12.43	463	82	16
SURFACE	06/22/2004	TWINWILWL01	134	1.2	7.29	3.0	<10	1.47	<0.02	0.1	8.24	0.543	0.583	1205	19.48	880	6	5
BOTTOM	05/18/2004	TWINWILWL01	217	1.3	9.49			1.14	<0.02	<0.1	8.73	0.101	0.059	1421	14.48	1368	11	5
SURFACE	07/28/2004	TWINWILWL01	210	1.1	6.80	3.1	<10	1.59	0.02	<0.1	8.25	0.733	0.678	1319	23.08	961	11	11
SURFACE	05/18/2004	TWINWILWL01	214	1.3	9.82	17.3	40	1.07	<0.02	<0.1	8.63	0.091	0.062	1448	15.08	1358	11	6
SURFACE	07/13/2004	TWINWILWL01	200	1.0	7.92	1.0	<10	1.35	<0.02	<0.1	8.07	0.629	0.586	1319	25.10	952	12	9
BOTTOM	08/11/2004	TWINWILWL01	215	1.0	9.07			2.48	<0.02	<0.1		0.860	0.708	1277	20.97	985	24	14
SURFACE	09/16/2004	TWINWILWL01	219	0.8	6.49	3.1	<10	1.91	0.14	<0.1	8.66	0.698	0.614	1115	19.07	960	14	6
BOTTOM	04/19/2004	TWINWILWL01	212	0.8	8.13			1.37	<0.02	<0.1	7.95	0.128	0.079	1429	13.76 C	1377	9	1
BOTTOM	07/28/2004	TWINWILWL01	210	1.1	5.80			1.64	0.02	<0.1	8.34	0.754	0.672	1312	22.86	956	10	10
SURFACE	08/11/2004	TWINWILWL01	215	1.0	8.99	3.1	<10	1.99	<0.02	<0.1		0.866	0.715	1278	21.01	973	17	8
BOTTOM	09/16/2004	TWINWILWL01	226	0.8	4.75			1.77	0.17	<0.1	8.61	0.703	0.610	1106	18.71	959	13	5
SURFACE	04/19/2004	TWINWILWL01	212	0.8	8.13	4.1	<10	1.34	<0.02	<0.1	7.89	0.125	0.082	1432	13.88 C	1378	10	<1
BOTTOM	08/26/2004	TWINWILWL01	223	0.7	10.79			1.81	<0.02	<0.1	8.82	0.734	0.617	1069	21.14	997	20	8
SURFACE	08/26/2004	TWINWILWL01	222	0.7	9.70	2.0	<10	1.76	<0.02	<0.1	8.82	0.772	0.632	1066	21.55	1000	21	12
BOTTOM	06/22/2004	TWINWILWL01	187		5.60			1.39	0.03	0.1	8.20	0.638	0.561	1312	18.74	878	5	5
BOTTOM	07/13/2004	TWINWILWL01	200	1.0	2.45			1.36	<0.02	<0.1	8.07	0.663	0.570	1319	22.54	958	11	8
BOTTOM	04/19/2004	TWINWILWL02	214	1.0	8.49			1.24	<0.02	<0.1	7.96	0.102	0.064	1396	13.15 C	1370	10	2
SURFACE	07/13/2004	TWINWILWL02	200	.8	7.78	5.2	<10	1.34	0.06	<0.1	8.15	0.665	0.575	1293	24.05	957	12	8
BOTTOM	07/13/2004	TWINWILWL02	200	.8	1.98			1.36	0.32	<0.1	8.28	0.700	0.628	1204	19.94	967	8	5
BOTTOM	07/28/2004	TWINWILWL02	242	0.8	1.40			2.84	1.46	<0.1	8.48	1.51	1.40	1307	18.11	1062	11	10
SURFACE	04/19/2004	TWINWILWL02	210	1.0	8.70	<1	<10	1.20	<0.02	<0.1	8.04	0.106	0.061	1398	13.21 C	1366	8	1
BOTTOM	08/26/2004	TWINWILWL02	223	0.6	10.79			1.15	<0.02	<0.1	9.02	0.829		1069	20.45	984	9	4
SURFACE	05/18/2004	TWINWILWL02	213	1	8.97	7.4	10	1.10	<0.02	<0.1	8.57	0.113	0.062	1417	14.50	1369	9	6
SURFACE	08/26/2004	TWINWILWL02	222	0.6	10.79	1.0	<10	2.27	<0.02	<0.1	9.02	0.793		1069	22.13	1001	25	18
BOTTOM	05/18/2004	TWINWILWL02	214	1	8.97			0.99	<0.02	<0.1	8.57	0.090	0.065	1417	14.10	1367	12	4
BOTTOM	08/11/2004	TWINWILWL02	217	0.8	7.75			1.62	0.08	<0.1		0.880	0.816	1287	21.21	981	12	4
SURFACE	06/22/2004	TWINWILWL02	188	1.1	8.29	9.7	10	1.28	0.03	<0.1	7.87	0.621	0.462	1612	19.98	949	6	6
SURFACE	08/11/2004	TWINWILWL02	216	0.8	7.81	<1	<10	1.82	0.06	<0.1		0.819	0.760	1288	21.19	967	16	6
BOTTOM	06/22/2004	TWINWILWL02	188	1.1	2.91			1.30	<0.02	0.1	8.26	0.542	0.460	1612	17.90	950	5	5
SURFACE	07/28/2004	TWINWILWL02	206	0.8	8.64	6.3	<10	1.68	<0.02	<0.1	8.30	0.630	0.565	1317	23.44	971	15	11
Surface	09/16/2004	TWINWILWL02	227	1.4	7.79	1.0	10	2.04	0.12	<0.1	8.85	0.718	0.636	1140	20.23	966	10	8
BOTTOM	09/16/2004	TWINWILWL02	222	1.4	8.82			2.10	0.12	<0.1	8.82	0.710	0.613	1131	19.82	957	9	6
SURFACE	05/16/2004	TWINWILWLT01	288		8.05			2.86	0.12	0.2	8.19	1.16	0.932	736	11.67	1799	30	10
SURFACE	03/29/2004	TWINWILWLT01	275		8.81	105	110	2.09	<0.02	0.8	7.25	0.466	0.379	1836	7.15 C	2466	7	2
SURFACE	03/28/2004	TWINWILWLT01	236		9.19			2.58	<0.02	2.0	7.23	0.508	0.401	1575	8.42 C	1960	7	2
SURFACE	05/17/2004	TWINWILWLT01	132		5.43	980	800	2.36	<0.02	1.0	7.58	1.06	0.902	925	11.49	999	43	9
SURFACE	05/18/2004	TWINWILWLT01	164		9.03	2420	1080	2.64	<0.02	0.2	8.06	1.30	1.21	1266	16.90	1201	17	3
SURFACE	03/30/2004	TWINWILWLT01	268		8.69	72.7	30	1.97	<0.02	0.9	7.02	0.474	0.398	1735	4.39 C	2578	11	9
SURFACE	06/10/2004	TWINWILWLT02	108			>2420	3000	2.68	<0.02	1.9	7.65	1.19	0.84	364	21.1	486	88	14
SURFACE	06/11/2004	TWINWILWLT02	74			>2420	39000	3.78	0.03	1.3	8.02	1.63	0.687	211		743	380	60
SURFACE	03/30/2004	TWINWILWLT03	267		7.66	435	430	1.36	<0.02	<0.1	7.66	0.334	0.258	1094	5.97 C	1299	12	8
SURFACE	05/16/2004	TWINWILWLT03	157		7.9			5.04	0.11	2.5	8.14	2.67	0.979	1703	12.62	1781	810	110
SURFACE	05/18/2004	TWINWILWLT03	172		5.27	980	1030	1.56	<0.02	1.0	8.12	0.860	0.802	1.39	16.64	1043	9	4
SURFACE	03/28/2004	TWINWILWLT03	223		11.57			2.23	<0.02	<0.1	7.98	0.406	0.291	1103	10.15 C	1175	14	8
SURFACE	05/17/2004	TWINWILWLT03	247		7.77	>2420	3000	1.20	<0.02	<0.1	7.97	0.531	0.420	1538	12.82	1593	12	2
SURFACE	05/17/2004	TWINWILWLT04	191		9.69	2420	800	1.53	<0.02	<0.1	8.78	0.228	0.189	1685	13.48	1672	22	4
SURFACE	03/19/2004	TWINWILWLT04	195		11.46			2.18	<0.02	<0.1	8.42	0.360	0.203	1003	7.24 C	1189	15	6
SURFACE	05/16/2004	TWINWILWLT04	172		9.70			1.53	<0.02	<0.1	9.11	0.302	0.191	1483	12.80	1538	68	13

Appendix B. Twin Lake Water Quality Data

Relative Depth	Date	StationID	Sample Type	Alkalinity mg/L	Secchi Meter	DO mg/L	Ecoli #/100mL	Fecal #/100mL	TKN mg/L	Ammonia mg/L	Nitrate mg/L	pH s.u.	Tot Phos mg/L	Dis Phos mg/L	Sp Cond umho/cm	H20 Temp °C	Tot Sol mg/L	TSS mg/L	TVSS mg/L
SURFACE	09/16/2004	TWINWLTL01	Grab	102	0.2	6.13	<1	<10	4.65	0.40	<0.1	7.74	0.125	0.016	2524	19.14	2658	37	28
SURFACE	08/11/2004	TWINWLTL01	Grab	90	0.2	8.55	<1	<10	4.31	<0.02	<0.1		0.143	0.046	2937	20.57	2731	47	35
SURFACE	06/22/2004	TWINWLTL01	Grab	112	.2	11.47	3.1	<10	3.39	0.45	<0.1	7.97	0.153	0.014	3005	19.68	2608	31	19
SURFACE	09/16/2004	TWINWLTL01	Grab	101	0.2	6.13	<1	<10	4.52	0.40	<0.1	7.74	0.121	0.015	2524	19.14	2622	35	28
SURFACE	07/13/2004	TWINWLTL01	Grab	107	.2	6.93	3.1	<10	3.19	0.04	<0.1	7.22	0.142	0.024	3071	25.53	2675	38	27
SURFACE	08/26/2004	TWINWLTL01	Grab	94	0.1	8.04	1.0	<10	3.86	<0.02	<0.1	8.02	0.131	0.020	2448	22.17	2702	41	34
SURFACE	05/18/2004	TWINWLTL01	Grab	112	.4	10.80	5.2	10	2.81	0.76	<0.1	8.71	0.073	0.015	2378	14.13	2644	20	14
SURFACE	07/28/2004	TWINWLTL01	Grab	92	0.2	7.32	1.0	<10	4.05	<0.02	<0.1	7.74	0.142	0.019	3088	23.34	2741	44	41
SURFACE	04/19/2004	TWINWLTL01	Grab	132	.4	9.19	30.1	20	4.47	1.75	<0.1	8.07	0.092	0.015	2428	13.82 C	2687	23	1
SURFACE	09/16/2004	TWINWLTL02	Grab	101	0.2	6.13	<1	<10	4.23	0.50	<0.1	7.71	0.122	0.016	2549	19.51	2658	34	28
SURFACE	08/11/2004	TWINWLTL02	Grab	90	0.2	7.85	<1	<10	3.96	<0.02	<0.1		0.131	0.017	2970	20.95	2714	40	31
SURFACE	06/22/2004	TWINWLTL02	Grab	115	.3	9.76	1.0	10	3.39	0.80	<0.1	8.11	0.102	0.013	3062	20.20	2602	21	14
SURFACE	07/13/2004	TWINWLTL02	Grab	104	0.4	7.63	7.4	10	2.70	0.20	<0.1	7.55	0.102	0.020	3079	25.20	2674	31	23
SURFACE	07/28/2004	TWINWLTL02	Grab	95	0.2	7.97	<1	<10	4.07	<0.02	<0.1	8.00	0.123	0.021	3120	23.80	2728	41	36
SURFACE	08/26/2004	TWINWLTL02	Grab	94	0.1	7.53	<1	10	4.12	<0.02	<0.1	8.16	0.124	0.018	2452	22.08	2701	39	33
SURFACE	04/19/2004	TWINWLTL02	Grab	132	.4	9.69	2.0	<10	4.48	1.79	<0.1	8.08	0.101	0.016	2441	14.13 C	2673	21	11
SURFACE	05/18/2004	TWINWLTL02	Grab	117	.4	11.09	8.6	<10	3.17	0.88	0.1	8.60	0.072	0.014	2395	14.31	2646	19	14
SURFACE	05/18/2004	TWINWLTLT01	Grab	162		6.31	866	570	2.90	<0.02	<0.1		1.58	1.22	1417	12.12	1670	132	20
SURFACE	05/17/2004	TWINWLTLT01	Grab	100		6.61	>2420	3300	2.37	0.21	<0.1	7.35	1.39	0.978	828	10.58 C	950	31	8
SURFACE	05/16/2004	TWINWLTLT01	Grab	50		7.29			1.88	0.08	0.1	8.26	0.800	0.534	400	12.43	463	82	16