PHASE I
WATERSHED ASSESSMENT
AND TMDL
FINAL REPORT

ROSE HILL LAKE/ SAND CREEK,
HAND COUNTY, SOUTH DAKOTA

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

1889

JANUARY, 2002
SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM

ASSESSMENT/PLANNING PROJECT FINAL REPORT

ROSE HILL LAKE AND SAND CREEK WATERSHED ASSESSMENT AND TMDL
FINAL REPORT

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Sponsor

Central Plains Water Development District

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Table of Contents

Abbreviations

AFOs	Animal Feeding Operations
AGNPS	Agricultural Non-Point Source Model
BMPs	Best Management Practices
CPUE	Catch per Unit Effort
CV	Coefficient of Variance
DC	District Conservationist
DO	Dissolved Oxygen
GPS	Global Positioning System
IJC	International Joint Commission
NPS	Nonpoint Source
NRCS	Natural Resource Conservation Service
NTU	Nephelometric Turbidity Units
PSIAC	Pacific Southwest Interagency Committee
Q WTD C	Flow Weighted Concentration
SD DENR	South Dakota Department of Environment and Natural Resources
SD GF&P	South Dakota Department of Game, Fish & Parks
SU	Standard Units
TKN	Total Kjeldahl Nitrogen
TSI	Trophic State Index
µmhos/cm	micromhos/centimeter
USGS	United States Geologic Survey

Executive Summary

PROJECT TITLE: Rose Hill Lake/ Sand Creek Watershed Assessment

PROJECT START DATE: 6/1/00 PROJECT COMPLETION DATE: 6/1/01

FUNDING: TOTAL BUDGET: $124,916

TOTAL EPA GRANT: $74,370

TOTAL EXPENDITURES OF EPA FUNDS: $48,084.29

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BUDGET REVISIONS: none

TOTAL EXPENDITURES: $90,710.67

SUMMARY ACCOMPLISHMENTS

The Rose Hill Lake and Sand Creek assessment project began in June of 2000 and lasted through October of 2001 when data analysis and compilation into a final report was completed. The project met all of its milestones in a timely manner.

A EPA section 319 grant provided a majority of the funding for this project. The South Dakota State Fee Funds, Central Plains Water Development District, and Hand County Conservation District provided local matching funds for the project.

Water quality monitoring and watershed modeling resulted in the identification of several sources of impairment. These sources may be addressed through best management practices and the implementation of several nutrient management plans. Aquatic plant, algae, and sediment surveys were also completed for the lake.

Through the implementation of best management practices and animal feeding operation discharge reductions, a sufficient reduction in inlake nutrients will occur to improve the Trophic State Index (TSI) (Carlson, 1977) value of the lake and increase support of its beneficial uses.

The primary goal for the project was to determine sources of impairment to Rose Hill Lake and provide sufficient background data to drive a section 319 implementation project. Through identification of sources of impairment in the watershed, this goal was accomplished.

The water quality target established for this waterbody is a stable to decreasing trend in the trophic state of the lake. Phosphorus reductions of 20% in combination with nitrogen reductions will result in the TSI shift of 2 points required to meet the TMDL that was developed for this waterbody.

Introduction

Purpose

The purpose of this pre-implementation assessment is to determine the sources of impairment to Rose Hill Lake in Hand County, South Dakota, and the tributaries in its watershed resulting in a Total Maximum Daily Load (TMDL). The creeks and small tributaries are streams with loadings of sediment and nutrients related to snowmelt and spring rain events. The discharge from this watershed ultimately reaches the James River.

Sand Creek is the primary tributary to Rose Hill Lake and drains a mix of grazing lands with some cropland acres. Winter feeding areas for livestock are present in the watershed. The stream carries sediment and nutrient loads that degrade water quality in the lake and cause increased eutrophication.

General Lake Description

Rose Hill Lake is a 33.8 acre (13.7 ha) man-made impoundment located in south central Hand County, South Dakota (Figure 1). Damming Sand Creek 10 miles south of the town of Wessington created a lake, with an average depth of 9.3 feet (2.8 meters) and 2.1 miles (3.4 km) of shoreline. The lake has a maximum depth of 26 feet (7.9 m) and holds 470 acre-feet of water. Rose Hill Lake is subject to periods of stratification during the summer. The outlet for the lake empties into Sand Creek, which eventually reaches the James River southeast of the town of Woonsocket in Sanborn County, South Dakota. The Rose Hill Lake watershed comprises a small portion of the Middle James hydrologic unit. When the 54 hydrologic units in the state were prioritized, the Middle James was given a priority ranking of 25 in the South Dakota Unified Watershed Assessment.

Lake Identification and Location

Lake Name: Rose Hill Lake
County: Hand
Range: 66W
Nearest Municipality: Wessington
Longitude: -98.769304
Primary Tributary: Sand Creek
HUC Code: 10160006

State: South Dakota
Township: 110N
Sections: 21 and 28
Latitude: 44.312277
EPA Region: VIII
Receiving Body of Water: Sand Creek
HUC Name: Middle James

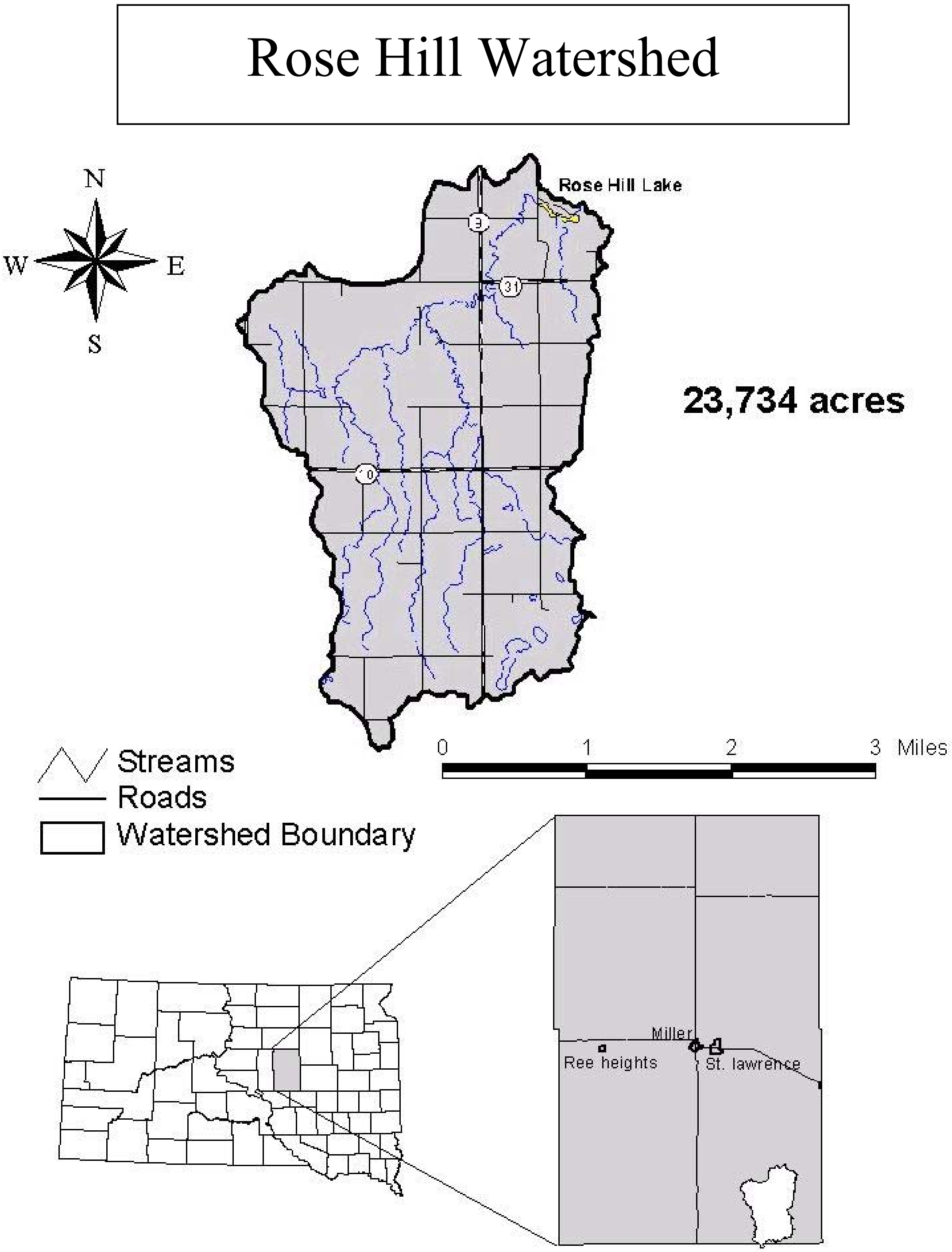

Figure 1. Sand Creek and Rose Hill Lake Watershed

Trophic Status Comparison

The trophic state of a lake is a numerical value that ranks its relative productivity. Developed by Carlson (1977), the Trophic State Index, or TSI, allows a lake's productivity to be easily quantified and compared to other lakes. Higher TSI values correlate with higher levels of primary productivity. A comparison of Rose Hill Lake to other lakes in the Northwestern Glaciated Plains Ecoregion (Table 1) shows that a high level of productivity is common for the ecoregion. With the exception of Loyalton, Rose Hill Lake has the lowest mean TSI value in the ecoregion. The values provided in Table 1 were generated from the most recent statewide lake assessment final report (Stueven and Stewart, 1996). The TSI for Rose Hill Lake will vary slightly in this report due to the use of additional new data gathered during this assessment.

Table 1. TSI Comparison for Area Lakes

Lake	County	TSI	Mean Trophic State
Andes	Charles Mix	93.98	Hyper-eutrophic
Geddes	Charles Mix	77.60	Hyper-eutrophic
Rosette	Edmunds	78.45	Hyper-eutrophic
Cottonwood	Sully	78.55	Hyper-eutrophic
Hiddenwood	Walworth	77.46	Hyper-eutrophic
Rose Hill	**Hand**	**69.39**	**Hyper-eutrophic**
Corsica	Douglas	79.93	Hyper-eutrophic
Loyalton	Edmunds	66.65	Hyper-eutrophic
Academy	Charles Mix	81.69	Hyper-eutrophic
Dante	Charles Mix	72.13	Hyper-eutrophic
Wilmarth	Aurora	72.09	Hyper-eutrophic

Beneficial Uses

The State of South Dakota has assigned all of the water bodies that lie within its borders a set of beneficial uses. Along with these assigned uses are sets of standards for the chemical properties of the lake. These standards must be maintained for the lake to satisfy its assigned beneficial uses. All bodies of water in the state are classified for the beneficial uses of fish and wildlife propagation, recreation, and stock watering. The following list of beneficial uses are assigned to Rose Hill Lake.

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

Individual parameters as well as the lake's TSI value determine the support of these beneficial uses. Rose Hill Lake is identified in *Ecoregion Targeting for Impaired Lakes in South Dakota* (Stueven et al, 2000) as partially supporting its beneficial uses.

Recreational Use

The South Dakota Department of Game, Fish, and Parks provides a list of existing public facilities that are maintained at area lakes (Table 2). Rose Hill Lake Recreation Area is located on the north side of the lake and has a number of facilities including a beach, primitive changing rooms, primitive toilet facilities, a boat ramp, and access to shore fishing. Camping is permitted in the area, and although no facilities are maintained, it is a popular area for local campers.

Table 2. Comparison of Recreational Uses and Facilities for Area Lakes

Lake	Parks	Ramps	Boating	Camping	Fishing	Picnicking	Swimming	County
Bierman Gravel Pit					X			Spink
Rosette		1	X		X			Edmunds
Cottonwood		2	X		X		X	Spink
Lake Louise	1	1	X	X	X	X	X	Hand
Rose Hill		**1**	**X**	**X**	**X**	**X**	**X**	**Hand**
Faulkton	1	1	X	X	X	X	X	Faulk
Jones Lake		1	X	X	X	X	X	Hand

Geology and Soils

Rose Hill Lake and its primary tributary, Sand Creek, are located on the edge of the Coteau du Missouri division of the Great Plains Physiographic Province. The outlet to the lake discharges into the James Basin division of the Central Lowland Physiographic Province (Fenneman, 1931). Located east of the Missouri River, the Rose Hill Lake watershed was subject to several periods of glaciation, which formed the parent material of the present day soils. The Mankato Period of glaciation was the last to affect the area and had the greatest impact on the current soils. The landscape of the watershed is level to slightly rolling. This is due in part to the past activity of the glaciers as well as ongoing water erosion.

The climate in Hand County is continental with dry winters and wet springs. The weather is subject to frequent and extreme changes with fronts dropping temperatures by as much as 40 to 50 degrees in 24 hours. Annual precipitation can be expected to yield 18 inches of which 75 percent can be expected to fall in the months of April through September.

Four primary soil associations best characterize the watershed. The dominant association is the Raber-Eakin association. It is most commonly characterized by undulating and nearly level clay loam soils from loess and clayey till. The second most common association is the Raber-Eakin-Miranda-Cavour association. It is most commonly characterized by undulating and nearly level soils from loess and clayey till; some portions may contain a claypan. The final two associations are comprised of the Zahl association and the Williams-Bonilla association. They are characterized by rolling to hilly soils from mixed materials and nearly level to gently undulating soils from loam or coarse clay loam till, respectively.

History

The area around Rose Hill Lake and Sand Creek has a diverse history. A few of the more outstanding events in the history of the area are covered here.

Hand County was founded in 1873 and named for politician George H. Hand. The boundaries were established in 1879 and it was opened for settlement in 1881. The town of Miller is the county seat and largest municipality located at the junction of highways 45 and 14.

The Rose Hill Dam and spillway were constructed in the 1930s as a result of President Roosevelt's Emergency Re-Employment Campaign during the Depression. This enabled the Civilian Conservation Corps (CCC) and Works Program Administration (WPA) operated in Hand County to undertake projects like the construction of Rose Hill Dam and spillway. The lake was named after the township in which it lies, Rose Hill Township.

During the construction of Rose Hill Dam, a large quantity of Indian artifacts were discovered. These artifacts were verified by Professor Wesley Hurt from the Department of Archaeology at the University of South Dakota as being tools and weapons of the Mandan Indians, which dated approximately 1200 AD. Later in the 1960s, more artifacts were found that suggested evidence of a group known as the Woodland People, who were early hunters that date to the year 1000 AD. Mounds found not far away from the dam served as a secondary burial site for the Woodlands. The primary burial place was located in trees. When the bones of the dead dropped to the ground along the creek, they were collected and buried again in mounds that had a square frame of earth surrounding them, serving as a cemetery fence. (Heidepriem, 1978)

Rose Hill Lake was, and still is, a popular swimming and picnicking area for the families that live nearby. Improvements to this area include a rebuilt access road, new boat ramp, and a new spillway, which were all completed in 1999.

Project Goals, Objectives, and Activities

Planned and Actual Milestones, Products, and Completion Dates

Objective 1. Lake Sampling

Sampling of Rose Hill Lake was to begin in May 2000, however, the first samples were not collected until June 2000, when a boat became available. Sampling of nutrient and solids parameters continued at the two scheduled sites through November 2000 as planned. Sufficient ice cover for foot travel lasted from late November 2000 through early February 2001, during which samples were collected through the ice. Spring samples were collected from March through May of 2000.

Objective 2. Tributary Sampling

At the onset of the project, the local coordinator and DENR staff installed Stevens Type F Stage Recorders as well as ISCO Flowmeters at pre-selected monitoring sites along the tributaries of Sand Creek. This equipment was used to obtain a detailed picture of the daily discharge of nutrients and sediments from the watershed into Rose Hill Lake. Sampling Sand Creek was limited primarily to the months of April through May of 2001. Very mild and dry conditions during the winter of 1999/2000 resulted in little or no runoff in the watershed until the spring of 2001.

Objective 3. Quality Assurance/ Quality Control (QA/QC)

Duplicate 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. QA/QC data collection began, and was completed, on schedule with the proposed timeline.

Objective 4. Watershed Modeling

Collection of the data required for completion of the Agricultural Non Point Source (AGNPS) model was finished on schedule during the project. The local coordinator utilized public records as well as personal contact with landowners and operators in the watershed to gather the required data.

Objective 5. Public Participation

All of the landowners were contacted individually to assess the condition of animal feeding operations and land management practices located within the watershed. Responses to letters, phone calls, and personal contact were excellent with all but one of the landowners cooperating to provide needed information. Further information was provided to the community and stakeholders in the project at the Hand County

Conservation District and Central Plains Water Development District Public Board Meetings.

Objective 6. Sediment Survey

The sediment survey of Rose Hill Lake was completed during January of 2001. Due to excellent ice conditions the survey was completed ahead of schedule.

Objectives 7 and 8. Restoration Alternatives and Final Report

Completion of the restoration alternatives and final report for Rose Hill Lake and Sand Creek in Hand County were completed during August through October of 2001.

Evaluation of Goal Achievements

The goal of the watershed assessment completed on Rose Hill Lake was to locate and document sources of nonpoint source pollution in the watershed and produce feasible restoration alternatives in order to provide adequate background information needed to drive a watershed implementation project to improve nutrient problems associated with the lake and creeks as well as creating a Total Maximum Daily Load Report for each of the water bodies. This was accomplished through the collection of tributary and lake data and aided by the completion of the AGNPS watershed modeling tool. Through data analysis and modeling, identification of impairment sources was possible. The identification of these impairment sources will aid the state's nonpoint source (NPS) program by allowing strategic targeting of resources to portions of the watershed that will provide the greatest benefit per expenditure.

				Milestone Table											
	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	"------>	Oct-01
Objective 1	▒	▒	▒	▒	▒	▒			▒	▒	▒	▒				
Lake Sampling		■	■	■	■	■	■	■	■	■	■		■			
Objective 2	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒				
Tributary Sampling	■	■					■	■								
Objective 3	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒				
QA/QC	■	■	■	■	■	■	■	■	■	■	■	■				
Objective 4						▒	▒	▒								
Modeling		■	■	■	■	■	■	■	■	■	■					
Objective 5	▒			▒			▒			▒			▒			
Public Participation	■	■	■	■	■	■	■	■	■	■	■	■	■			
Objective 6									▒	▒						
Sediment Survey								■								
Objective 7											▒	▒	▒			
Restoration Alternatives										■	■	■	■			
Objective 8												▒	▒	▒	▒	▒
Final Report											■	■	■	■	■	■
			■	Actual Completion Dates					▒	Proposed Completion Dates						

Table 3. Proposed and Actual Objective Completion Dates

Monitoring Results

Surface Water Chemistry (Sand Creek)

Flow Calculations

A total of five tributary and one outlet monitoring sites were selected along Sand Creek, which is the primary tributary to Rose Hill Lake. The sites were selected to determine which portions of the watershed are contributing the greatest amount of nutrient and sediment load to the lake. Two of the sites were equipped with Stevens Type F stage recorders. The remaining three sites were equipped with ISCO model 4230 Flow meters attached to a GLS auto-sampling unit. Water stages were monitored and recorded to the nearest 1/100th of a foot for each of the six sites. A Marsh-McBirney Model 210D flow meter was used to determine flows at various stages. The stages and flows were then used to create a stage/discharge table for each site. Stage-to-discharge tables may be found in Appendix A.

Load Calculations

Total nutrient and sediment loads were calculated with the use of the Army Corps of Engineers Eutrophication Model known as FLUX. FLUX uses individual sample data in correlation with daily discharges to develop six loading calculations for each parameter. As recommended in the application sequence, a stratification scheme and method of calculation was determined using the total phosphorus load. This stratification scheme is then used for each of the additional parameters. Sample data collected on Sand Creek may be found in Appendix B.

Tributary Sampling Schedule

Samples were collected at the sites during the spring of 1999 through the spring of 2000. Most samples were collected using a suspended sediment sampler. The sites that were equipped with GLS auto-sampling units sampled on their own and were usually collected within a few hours of the sample time. Water samples were then filtered, preserved, and packed in ice for shipping to the State Health Lab in Pierre, SD. The laboratory then assessed 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 stream characteristics.

Precipitation
Odor
Dead Fish
Turbidity
Water Depth
Water Color
Wind
Septic Conditions
Film
Width
Ice Cover

Parameters measured in the field by sampling personnel were:

Water Temperature
Conductivity
Field pH
Air Temperature
Dissolved Oxygen

South Dakota Water Quality Standards

The State of South Dakota assigns at least two of the eleven beneficial uses to all bodies of water in the state. Fish and wildlife propagation, recreation and stock watering as well as irrigation are assigned to all streams and rivers. All portions of Sand Creek located upstream from section 32 in Township 110 North and 66 West (Rose Hill Township), or 1 mile south (upstream) of RLT-5 must maintain the criteria that support these uses. In order for the creek to maintain these uses, there are five standards that must be maintained, these standards, as well as the water quality values that must not be exceeded, are listed in Table 4.

Table 4. State Water Quality Standards

Nitrate	≤50 (mean) ≤88 (single sample)
Alkalinity	≤750 (mean) ≤1,313 (single sample)
pH	≥ 6.5 and ≤9.5 su
Total Dissolved Solids	≤2,500 mg/L for a 30-day geometric mean ≤ 4,375 mg/L daily maximum for a grab sample
Conductivity	≤2,500 (mean) ≤4,375 (single sample

The portion of Sand Creek located downstream from Section 32, Township 110 North and 66 West (Rose Hill Township) to the James River, with the exception of Rose Hill Lake, is classified for the beneficial uses of 5 and 8 which are warmwater semipermanent fish life propagation and limited-contact recreation. These additional classifications add parameters that must be maintained to support these beneficial uses. The parameters found in table 5 must be maintained in addition to those listed in table 4. Site RLT-5 is located approximately one mile downstream from the point of classification change. This is the only watershed site above the lake that must maintain the additional standards.

Table 5. State Beneficial Use Standards for Portions of Sand Creek

Parameters	mg/L (except where noted)	Beneficial Use Requiring this Standard
Coliform, fecal *(per 100 mL)* May 1 to Sept 30	≤1000 *(mean)* ≤2000 *(single sample)*	Limited Contact Recreation
Nitrogen, un-ionized ammonia as N (mg/L)	≤.04 *(mean)* ≤1.75 times the applicable limit *(single sample)*	Warmwater Semi-permanent Fish Propagation
Oxygen, dissolved (mg/L)	≥5.0	Limited Contact Recreation
pH *(standard units)*	6.0 - 9.0	Warmwater Semi-permanent Fish Propagation
Solids, suspended (mg/L)	≤90 *(mean)* ≤158 *(single sample)*	Warmwater Semi-permanent Fish Propagation
Temperature	≤32 °C	Warmwater Semi-permanent Fish Propagation

Watershed Overview

Discharge from Sand Creek as well as rainfall are the primary sources of water entering Rose Hill Lake. There are a number of ground water seeps around the lake. Very little change was observed in the water chemistry over the course of the year 2000 sampling season. The 2000 sampling season was extremely dry with no discharges from Sand Creek and very little rainfall entering the lake, which would indicate that the amount of ground water entering the lake is having a minimal impact on the water quality.

Subwatersheds

Sand Creek was broken into six individual subwatersheds with a gauging station located at the outlet to each one. Stage and discharge data were collected from each of these as well as water chemistry samples which were combined to calculate a load from each of these subwatersheds. Significant difficulties were experienced during attempts to collect data from site RLT-4. Snowfall that blocked roads throughout most of the spring prevented access that ultimately led to insufficient data collection to calculate loadings from this site. Figure 2 indicates the locations of the sampling stations within the watershed.

Sand Creek Monitoring Stations

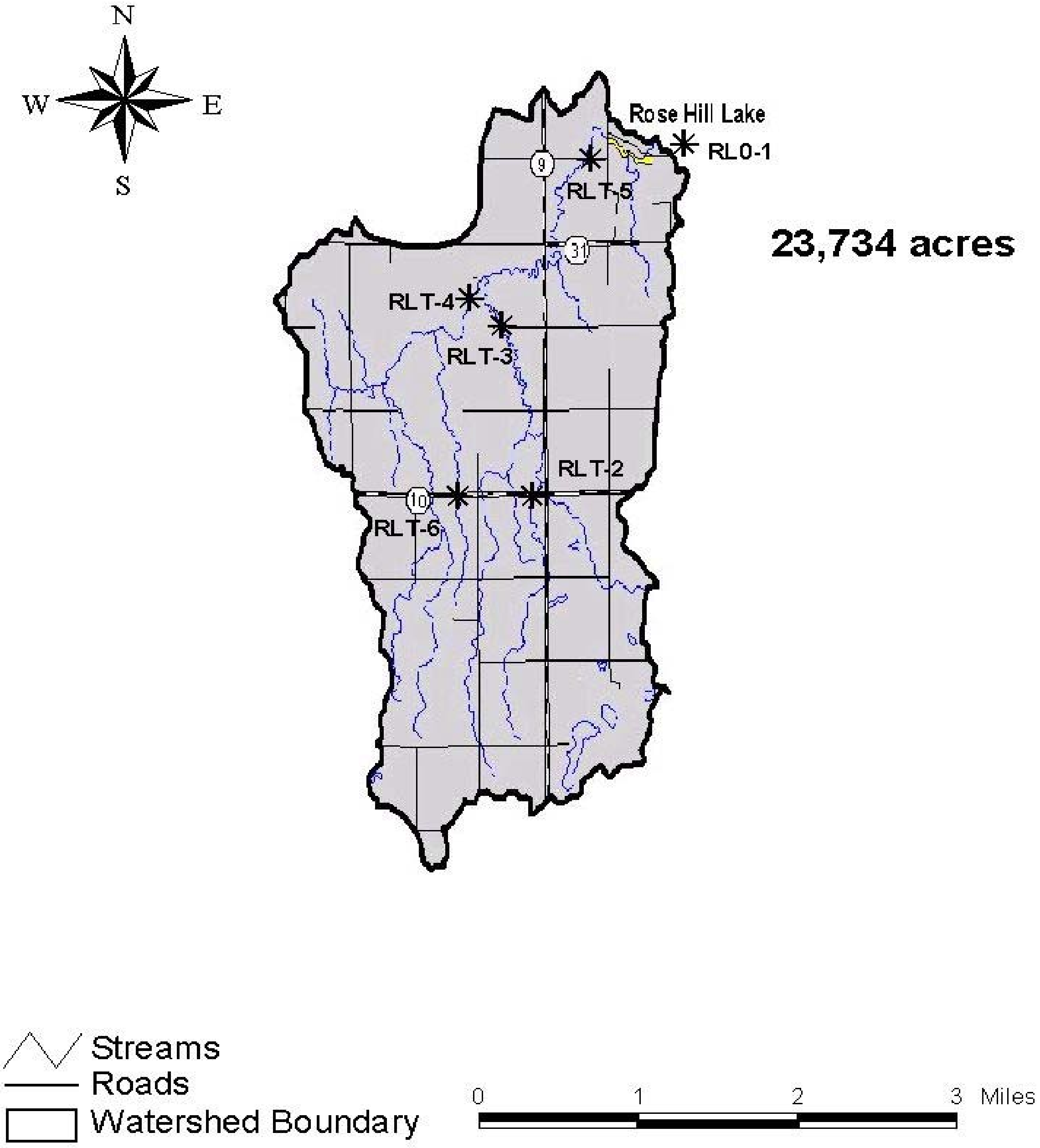

Figure 2. Sand Creek Monitoring Stations

Water and Nutrient Budgets

As creeks pass through impoundments they often lose some nutrient and sediment loads. However, this is not the case for Sand Creek and Rose Hill Lake. Table 6 indicates that Sand Creek increased its nutrient and sediment load as it passed through the lake. There are two possible reasons for this occurrence.

Table 6. Rose Hill Lake Nurtient, Sediment, and Water Budgets

	Units	Inlet	Outlet	Difference
Total Phosphorus	kg	6,936	9,319	2,383
Total Dissolved Phosphorus	kg	5,736	5,921	185
Total Alkalinity	Tons	988	1,007	19.1
Total Suspended Solids	Tons	226	1,068	842.9
Total Nitrogen	kg	20,488	27,853	7,365
Water	HM^3/yr	13.073	14.825	1.8

The first is related to the shape of the lake and the nature of the discharges that occurred. The lake is long and narrow, resembling a deep river in shape. Flows that occurred during the spring of 2001 were intense and short in duration. The large volumes of water that moved through the lake most likely did not allow enough detention time for many nutrients and sediments to settle out or be consumed through biological processes.

The second reason for the increase in nutrient and sediment loading is related to the location of the inlet site in proximity to the lake. The only feasible place to locate this gauging station is located one mile upstream from the lake. There is also a second small tributary that enters the lake from the south side. This results in approximately 2,000 acres of ungauged land discharging into Rose Hill Lake. The increase in water volume discharged would indicate that the ungauged acres in the watershed are most likely the reason for the increase in loadings around the lake.

While both theories may contribute to the increased loading, the second reason is likely the greater source. The large increase in suspended solids and phosphorus would indicate that there are some erosion problems located in the area surrounding the lake. The phosphorus discharge coefficient upstream from site RLT-5 (the inlet) is .34 kg/acre. This increases to 1.16 kg/acre downstream from site RLT-5, over 3 times the level recorded for the rest of the watershed. The sediment loss per acre increases from .01 ton/acre upstream from site RLT-5 to .41 ton/acre downstream. The most likely sources of sediment and nutrients in the area surrounding the lake are the creek banks and the shore of the lake itself.

Seasonal Loading

Seasonal loadings at Rose Hill Lake are heavily influenced by snowmelt and spring rain events. Table 7 depicts the loadings of phosphorus as well as the concentrations and water discharge volumes that occurred each month. The spring months of March, April and May in 2001 accounted for over 99% of the total discharge that occurred during the project. Loadings that occur during the remainder of the year have little impact on the condition of Rose Hill Lake.

Table 7. Seasonal Loadings to Rose Hill Lake

Date	Measured Days	Sample Count	Volume (hm3)	Mass (kg)	Phosphorus Conc. (ppb)	Percent of Discharge
May-00	8	1	0	0.1	266	0.00%
Jun-00	30	1	0.003	1.2	377.93	0.02%
Jul-00	31	0	0.014	4.1	289.4	0.11%
Aug-00	31	0	0.002	0.5	253.64	0.02%
Sep-00	30	0	0	0	253.64	0.00%
Oct-00	31	0	0	0	253.64	0.00%
Nov-00	30	0	0	0	253.64	0.00%
Dec-00	31	0	0	0	0	0.00%
01-Jan	31	0	0	0	0	0.00%
01-Feb	28	0	0	0	0	0.00%
01-Mar	31	0	0.159	57.3	359.22	1.19%
01-Apr	30	3	12.72	6358.2	499.84	95.54%
01-May	30	1	0.414	139.7	337.14	3.11%

Annual Loading

To calculate the current and future water quality in an impoundment, BATHTUB (Army Corps of Engineers Eutrophication Model) utilizes phosphorus and nitrogen loads entering the impoundment. Found in Table 8, these loads and their standard errors (CV) are calculated through the use of FLUX (Army Corps of Engineers Loading Model) for site RLT-5, the inlet to Rose Hill Lake.

Table 8. Annual Lake Loadings for Rose Hill Lake

	Concentration (mg/L)	FLUX Load (kg/yr)	CV
Total Phosphorus	0.530	6,936	0.114
Total Dissolved Phosphorus	0.438	5,736	0.099
Total Alkalinity	68.6	896,382	0.414
Total Suspended Solids	15.6	204,572	0.095
Total Nitrogen	1.567	20,488	0.111

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). Some of the samples indicated the presence of *E. coli* at levels higher than the total fecal count. This is the result of standard lab testing procedures. Fecal coliform tests are conducted with an incubation temperature of 45^{o}C while *E. coli* tests are conducted with an incubation temperature of 35^{o}C. The higher incubation temperatures for the fecal test inhibit the growth of some *E. coli,* resulting in the lower counts for total fecal coliform.

Fecal coliform standards are not a concern for the listed beneficial uses for sites RLT-2, RLT-3, RLT-4, and RLT-6 in the Sand Creek Watershed (Table 9). Generally, these sites exhibited fecal levels that fell within state standards for all recreational uses. Site RLT-2 had two samples, April 25 and May 7 of 2001 with fecal counts that were significantly higher than were found in the rest of the watershed. The source of the elevated bacterial counts is uncertain.

Site RLT-5 must maintain fecal coliform concentrations of < 2,000 colonies/100mL or a geometric mean of < 1,000 colonies/100mL. This site did not exceed its criteria for limited contact recreation during the project. Site RLT-5 had fecal coliform bacteria levels that were very similar to what was found in the rest of the watershed.

Fecal coliform samples collected at the outlet of Rose Hill Lake exceeded the geometric mean and single sample criteria for immersion and limited contact recreational uses. This was the result of a sample collected on April 25, 2001 during a large runoff event that probably included significant runoff from local pastures and feeding areas. It is unlikely that this is a frequent occurrence that warrants much concern.

Table 9. Bacterial Counts for Sand Creek

	RLO-1		RLT-2		RLT-3		RLT-4		RLT-5		RLT-6	
	Fecal	*E. coli*	Fecal	*E. coli*	Fecal	*E. coli*	Fecal	*E. coli*	Fecal	*E. coli*	Fecal	*E. coli*
31-May-00							60		240			
26-Jun-00									180			
04-Apr-01			20	65.7								
05-Apr-01									<10	5.2		
10-Apr-01	90	107	<10	34.5	10	46			60	90.9	40	135
16-Apr-01	180	345										
18-Apr-01	80	117	20	48.8	40	19.5	30	31.4	10	25.6	<10	7.4
25-Apr-01	330000	>2420	3800	>2420							150	131
30-Apr-01					10	24	40	49.6				
02-May-01	40	18.9	<10	5.2	10	24	10	29.5				
07-May-01			2400	1990							350	411
14-May-01			50	86	30	22.8						
21-May-01							820	1553				
24-May-01									470	488		
Mean	66078	602	901	664	20	27	192	416	162	152	138	171

Alkalinity

Historically, the term alkalinity referred to the buffering capacity of the carbonate system in water. Today, alkalinity is used interchangeably with acid neutralizing capacity (ANC), which refers to the capacity to neutralize strong acids such as HCL, H_2SO_4 and HNO_3. Alkalinity in water is due to any dissolved species (usually weak acid anions) with the ability to accept and neutralize protons (Wetzel, 2000). Due to the abundance of carbon dioxide (CO_2) and carbonates, most freshwater contains bicarbonates as its primary source of alkalinity. Alkalinity is commonly found in concentrations as high as 200 mg/L.

Site RLT-4 consistently produced the highest concentrations of alkalinity when compared with other sites sampled at similar times (Table 10). Similarly, the lowest concentrations were found at site RLT-6, which is upstream from site RLT-4. The area located between these two sites is characterized by steeper slopes and more grazing when compared with other portions of the watershed. The reason for the higher alkalinity concentration is probably a combination of soil types and the presence of pastured livestock.

The state standard in Sand Creek for alkalinity is ≤ 750 mg/L as a mean or ≤ 1,313 mg/L for a single sample. The highest single concentration was measured at site RLT-4 on May 21, 2001. At 282 mg/L, it is well within the state standard for alkalinity. Mean concentrations were also well within the state standard for this body of water.

Table 10. Sand Creek Alkalinity Concentrations mg/L

	Station					
Date	RLO-1	RLT-2	RLT-3	RLT-4	RLT-5	RLT-6
31-May-00					183	
26-Jun-00					172	
05-Apr-01		39			96	
10-Apr-01	38	38	39		54	28
16-Apr-01	69					
18-Apr-01	77	64	58	125	112	47
24-Apr-01		47				
25-Apr-01	75	31				19
30-Apr-01			76	143		
01-May-01	72					
02-May-01		90	90	185		
05-May-01			105			
07-May-01		74				39
14-May-01		125	131			
21-May-01				282		
24-May-01					252	
31-May-01				207		
Mean	66.2	63.5	83.17	188.4	144.8	33.25

Total Solids

Total solids are the sum of all dissolved and suspended solids including all organic and inorganic materials. Dissolved solids are typically found at higher concentrations in ground water.

The total solids concentrations in Sand Creek ranged from 127 mg/L collected from RLT-6 on April 10, 2001 to a maximum value of 2,306 mg/L collected from RLT-4 on May 31, 2001. The majority of the total solids concentration is composed of dissolved solids with suspended solids representing only a small fraction of the load. Whereas there are no state standards for total solids, the total solids concentrations for Sand Creek were less than the dissolved solids state standard of a mean less than 2,500 mg/L and a single sample value of less than 4,375 mg/L.

The suspended solids concentrations collected from Sand Creek ranged from a low of 2 mg/L collected from RLT-3 on April 30, 2001, to a high of 96 mg/L collected at the outlet to Rose Hill Lake on April 25, 2001. The volatile portion composed approximately 20% of the total suspended solids load for all sites in the watershed.

When comparing mean concentrations for solids on Sand Creek (Table 11), it becomes apparent that the majority of the dissolved solids (represented as total solids) are coming from the portion of the watershed located between sites RLT-4 and RLT-6. This is the same portion of the watershed that was identified as the largest source of alkalinity. Volatile solids concentrations are nearly identical while suspended solids appear to be coming primarily between site RLT-5 (the inlet site) and RLO-1 (the outlet site). Immediately downstream of site RLT-5 the stream became more incised and a large portion of the shoreline was failing and eroding. This type of erosion is likely the source of the suspended solids discharging from the watershed.

Table 11. Mean Solids Concentrations for Sand Creek Watershed Sites

Station	Total Suspended	Total Volatile	Total Solids
RLO-1	40.4	3.3	353.2
RLT-2	9.6	2.2	233.1
RLT-3	10.5	3.2	324.5
RLT-4	8.6	2.0	1295.6
RLT-5	25.3	4.2	835.8
RLT-6	27.5	2.9	176.8

Nitrogen

Nitrogen is assessed in four forms: nitrate/ nitrite, ammonia, and Total Kjeldahl Nitrogen (TKN). From these four 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 water.

Table 12 indicates the number of acres drained by each monitoring station, the calculated total nitrogen load, and the discharge coefficient for the portion of the watershed that is located upstream from that monitoring station. Discharge coefficients were calculated by dividing the total load by the total number of acres drained resulting in load per unit area in kg/acre.

Table 12. Subwatershed Nitrogen Loads for Sand Creek

Nitrogen			
Subwatershed	Acres Drained	Total Load (kg)	Discharge Coefficient kg/acre
RLO-1	22,080	27,853	1.261
RLT-2	2,480	2,604	1.050
RLT-3	7,600	5,093	0.670
RLT-5	20,040	20,488	1.022
RLT-6	1,720	4,073	2.368

Nitrogen loads from the Sand Creek watershed were highest from subwatersheds RLT-6 and RLO-1. The area surrounding the lake (RLO-1) produced 7,365 kg of nitrogen and is only 2,040 acres in size. This portion of the watershed actually had a discharge coefficient of 3.61 kg/acre. This may again be linked to the bank stability problems identified in the water and nutrient budget section of the report. An additional source may be livestock using this portion of the stream as a water source and loafing area.

Reducing nitrogen loading may help reduce late summer algae blooms in the lake. As is identified in the limiting nutrient section of the report, phosphorus released from lake sediments shifts the nitrogen to phosphorus ratio in the lake to a nitrogen-limited system. Reducing sources of nitrogen in the watershed may reduce the intensity and frequency of blooms that occur during the later part of summer.

Phosphorus

Phosphorus is one of the macronutrients required for primary production. In comparison to carbon, nitrogen, and oxygen, it is often the least abundant in natural systems (Wetzel, 2000). Phosphorus loading to lakes can be of an internal or external nature. External loading refers to surface runoff, dust, and precipitation. Internal loading refers to the transfer of phosphorus from the bottom sediments to the water column of the lake. 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 (the ratio of total suspended solids to total dissolved phosphorus resulted in an inverse relationship with an R^2 of .63). An increase in the amount of suspended solids increases the fraction of attached phosphorus.

Table 13 and 14 indicate the number of acres drained by each monitoring station, the calculated total phosphorus and dissolved phosphorus load, and the discharge coefficient for the portion of the watershed that is located upstream from that monitoring station. Discharge coefficients were calculated by dividing the total load by the total number of acres drained resulting in load per unit area in kg/acre.

A large portion of the total phosphorus load produced in the watershed originates from subwatershed RLO-1. As was identified earlier in the report, the primary reason for this was likely bank erosion problems along the creek and the shoreline of the lake. The remainder of the watershed had very similar discharge coefficients suggesting that Best Management Practices should be applied to areas identified in the AGNPS section of the report regardless of what subwatershed they are located in.

Table 13. Subwatershed Phosphorus Loads for Sand Creek Watershed

Phosphorus			
Subwatershed	Acres Drained	Total Load (kg)	Discharge Coefficient (kg/acre)
RLO-1	22,080	9,319	0.422
RLT-2	2,480	972	0.392
RLT-3	7,600	1,955	0.257
RLT-5	20,040	6,936	0.346
RLT-6	1,720	524	0.305

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.

Further support for the bank erosion theory in subwatershed RLO-1 may be found in Table 14. The percentage of dissolved phosphorus was significantly lower than what was found in the other subwatersheds. This would indicate that most of the phosphorus produced in that subwatershed was the result of soil erosion. The discharge coefficients for the dissolved phosphorus were very similar with the exception of RLT-2. This subwatershed had the highest discharge coefficient and the highest percentage of dissolved phosphorus.

Table 14. Subwatershed Dissolved Phosphorus Loads for Sand Creek Watershed

Dissolved Phosphorus				
Subwatershed	Acres Drained	Total Load (kg)	Discharge Coefficient (kg/acre)	% of Total P Load
RLO-1	22,080	5,921	0.268	64%
RLT-2	2,480	924	0.373	95%
RLT-3	7,600	1,678	0.221	86%
RLT-5	20,040	5,736	0.286	83%
RLT-6	1,720	407	0.237	78%

<u>Tributary Site Summary</u>

Nutrient loading to Rose Hill Lake occurs primarily during the spring snowmelt and rainstorm events. The only violation of state standards for the fecal coliform standard was recorded at the outlet to Rose Hill Lake. This was the result of the sample collected on April 25, 2001. This runoff event was close to or possibly in excess of the 25-year, 24-hour storm event. Discharges such as this are not typical and it is not expected that a fecal violation of this magnitude would be a recurring problem.

It is apparent that the area surrounding the lake (subwatershed RLO-1) was the most impaired, producing significantly larger loads of sediment and nutrients than the rest of the watershed. Approximately 25% of the phosphorus and 80% of the suspended solids originated in this subwatershed. This subwatershed should be given priority for all Best Management Practices, particularly those that will result in protection of the stream banks and lakeshore (such as grazing systems and buffer strips).

The other subwatersheds that were identified as producing moderately large amounts of nutrients were RLT-6, which was identified as a nitrogen source, and RLT-2, which was identified as a dissolved phosphorus source. The difference between these subwatersheds and the remainder of the watershed (with the exception of RLO-1) was minimal. When prioritizing areas for Best Management Practices, the recommendations of the AGNPS section of the report should be followed.

Surface Water Chemistry (Rose Hill Lake)

Inlake Sampling Schedule

Sampling began in June 2000 and was conducted on a monthly basis until the project completion in June 2001 at the two pre-selected sites (Figure 3). Water samples were filtered, preserved, and packed in ice for shipping to the State Health Lab in Pierre, SD. Sample data collected at Rose Hill Lake may be found in Appendix C. The laboratory then assessed the following parameters:

Fecal Coliform Counts
Total Solids
Total Suspended Solids
Nitrate
Total Phosphorus
Total Dissolved Phosphorus
Chlorophyll *a*
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 lake characteristics.

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

Parameters measured in the field by sampling personnel were:

Water Temperature
Conductivity
Field pH
Secchi Depth
Air Temperature
Dissolved Oxygen
Turbidity

South Dakota Water Quality Standards

All public waters within the State of South Dakota have been assigned beneficial uses. All designated waters are assigned the use of fish and wildlife propagation, recreation, and stock watering. Along with each of these uses are sets of water quality standards that must not be exceeded in order to support these uses. Rose Hill Lake has been assigned the beneficial uses of:

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

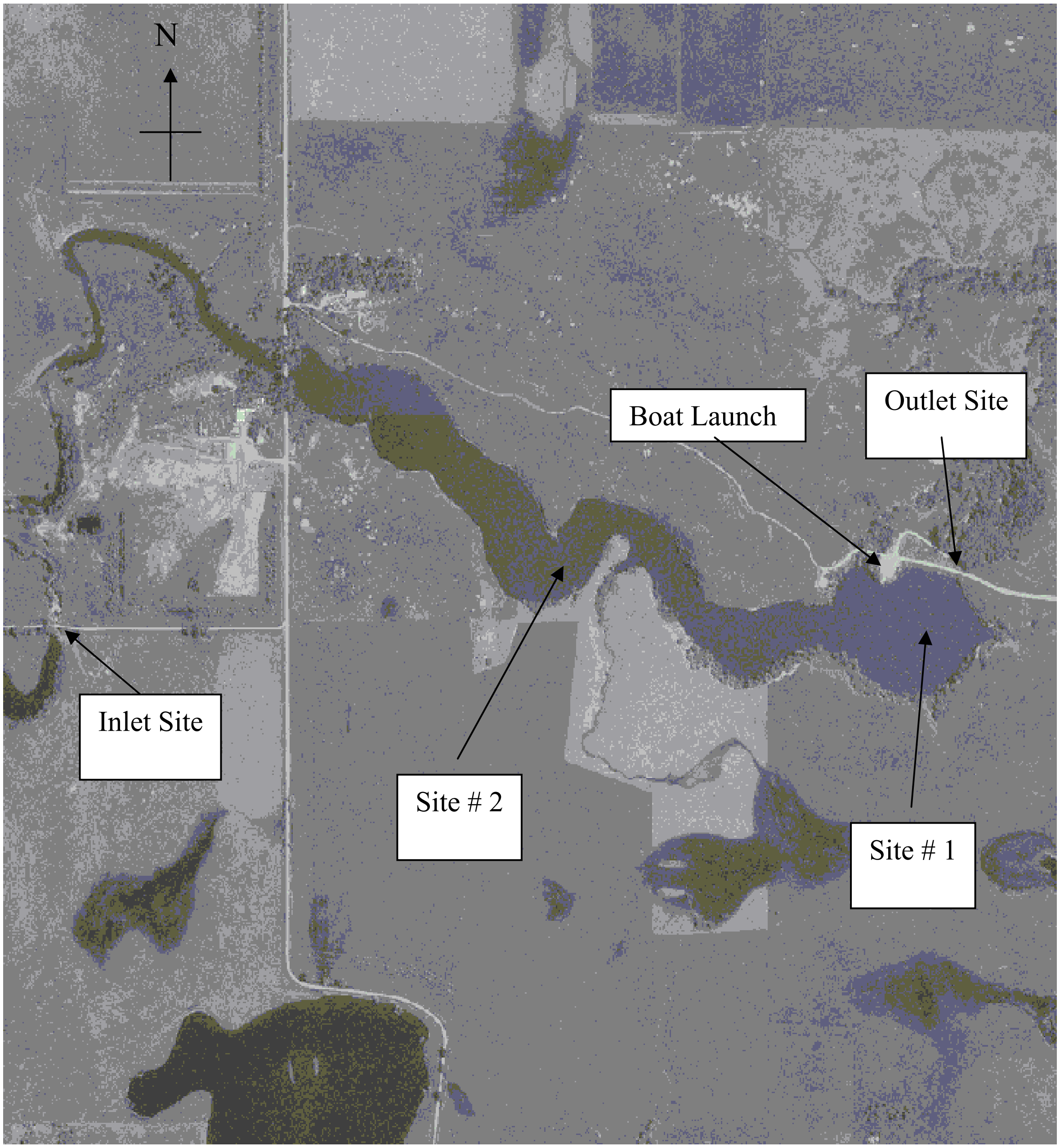

Figure 3. Lake Monitoring Sites for Rose Hill Lake

The following table lists the parameters that must be considered when maintaining beneficial uses as well as the concentrations for each. When multiple standards for a parameter exist, the most restrictive standard is used.

Table 15. State Beneficial Use Standards for Rose Hill Lake

Parameters	**mg/L (except where noted)**	**Beneficial Use Requiring this Standard**
Alkalinity *($CaCO_3$)*	≤750 *(mean)* ≤1,313 *(single sample)*	Wildlife Propagation and Stock Watering
Coliform, fecal *(per 100 mL)* May 1 to Sept 30	≤200 *(mean)* ≤400 *(single sample)*	Immersion Recreation
Conductivity (µmhos / cm @ 25^o *C)*	≤4,000 *(mean)* ≤7,000 *(single sample)*	Wildlife Propagation and Stock Watering
Nitrogen, un-ionized ammonia as N	≤.04 *(mean)* ≤1.75 times the applicable limit *(single sample)*	Warmwater Permanent Fish Propagation
Nitrogen, nitrates as N	≤50 *(mean)* ≤88 *(single sample)*	Wildlife Propagation and Stock Watering
Oxygen, dissolved	≥5.0	Immersion and Limited Contact recreation
pH *(standard units)*	6.5 - 9.0	Warmwater Permanent Fish Propagation
Solids, suspended	≤90 *(mean)* ≤158 *(single sample)*	Warmwater Permanent Fish Propagation
Solids, total dissolved	≤2,500 *(mean)* ≤4,375 *(single sample)*	Wildlife Propagation and Stock Watering
Temperature	≤26.67 C	Warmwater Permanent Fish Propagation

Inlake Water Quality Parameters

Water Temperature

Water temperature is of great importance to any aquatic ecosystem. Many organisms and biological processes are temperature sensitive. Blue-green algae tend to dominate warmer waters, while green algae and diatoms generally do better under cooler conditions. Water temperature also plays an important role in physical conditions. Oxygen dissolves in higher concentrations in cooler water. Higher toxicity of un-ionized ammonia is also related directly to warmer temperatures.

Water temperatures in Rose Hill Lake varied from 9.17°C to 27.14°C on the surface and 4.74 °C to 25.43 °C on the bottom. These temperatures all fall within the requirements for the designated beneficial uses of Rose Hill Lake.

Dissolved Oxygen

There are many factors that influence the concentration of dissolved oxygen (DO) in a waterbody. Temperature is one of the most important of these factors. As the temperature of water increases, its ability to hold DO decreases. Daily and seasonal fluctuations in DO may occur in response to algal and bacterial action (Bowler, 1998). As algae photosynthesize during the day, they produce oxygen, which raises the concentration in the epilimnion. As photosynthesis ceases at night, respiration utilizes available oxygen causing a decrease in concentration. During winters with heavy snowfall, light penetration may be reduced to the point where algae and aquatic macrophytes in the lake cannot produce enough oxygen to keep up with consumption (respiration) rates. This results in oxygen depletion and may ultimately lead to a fish kill.

Dissolved oxygen concentrations in the epilimnion of Rose Hill Lake remained well within the state standards with the exception of a single surface sample collected at site RL-1 on July 19, 2000. There is no obvious reason for the low oxygen level recorded on that day. Water temperature on that date was lower (approximately 2 degrees) at the surface than when samples were collected two weeks earlier or later. The pH values were also lower at the surface on this date. Low surface concentrations do not appear to be a persistent problem and minimally affect the beneficial use.

Table 16. Dissolved Oxygen Statistics for Rose Hill Lake

Depth	Average	Max	Min	Standard Deviation
Surface	9.22	13.01 05-Jul-00	4.07 19-Jul-00	1.86
Bottom	5.13	10.68 14-Sep-00	0.37 20-Jun-00	3.26

Dissolved Oxygen and Temperature Profiles

Dissolved oxygen and temperature profiles were recorded at intervals of approximately one foot. The first profiles were taken on June 6 of 2000 (Figure 4). By this date the lake had already begun to stratify. Dissolved oxygen concentrations below five feet steadily decreased to near zero at the bottom of the lake. These conditions persisted throughout the summer and early fall.

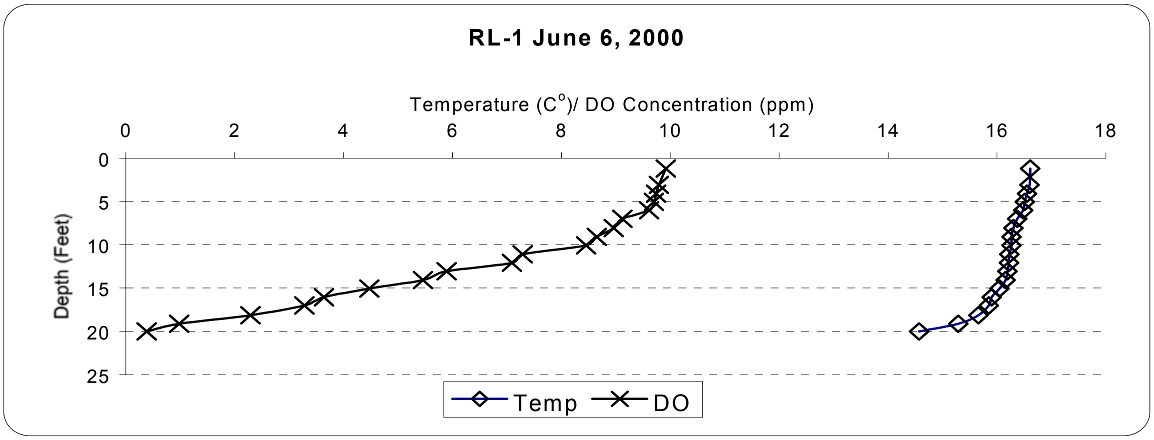

Figure 4. June 6 DO and Temperature Profile for Site RL-1

The profile in Figure 5 recorded at site RL-1 on July 19 of 2000 is very typical of the profiles recorded through the end of August. The thermocline was typically located between eight feet and twelve feet of depth with dissolved oxygen concentrations of nearly zero immediately below the thermocline and continuing to the bottom. The profile recorded on September 14 of 2000 indicated that the water column had mixed with temperatures ranging from 18.8°C to 19.6°C from the bottom to the top. Increased oxygen levels had also been restored to the lower portion of the water column.

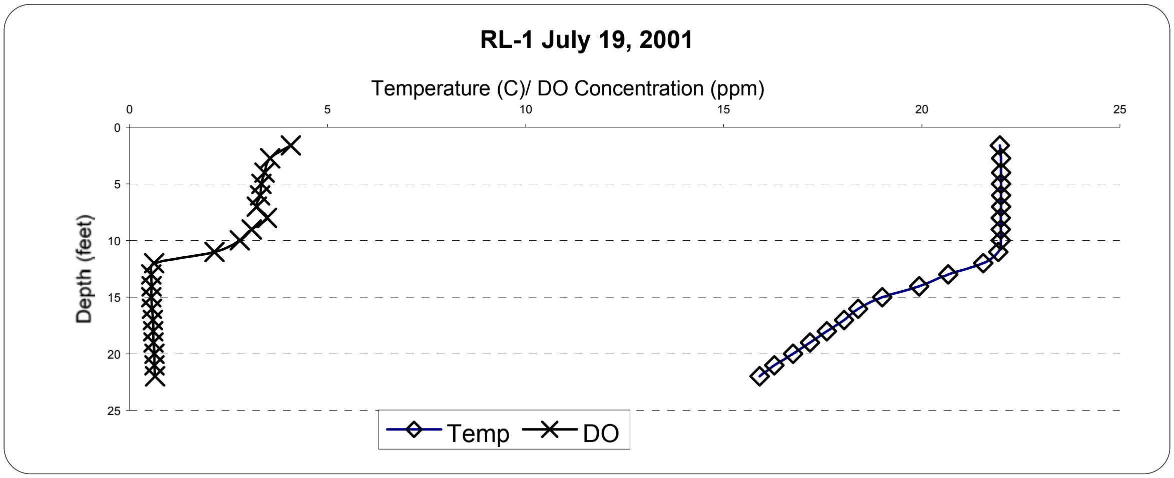

Figure 5. July 19 DO and Temperature Profile for Site RL-1

pH

pH is a measure of free hydrogen ions (H^+) or potential hydrogen. More simply it indicates the balance between acids and bases in water. It is measured on a logarithmic scale between 0 and 14 and is recorded as standard units (su). At neutral (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). Algal and macrophyte photosynthesis act to increase a lake's pH. Respiration and the decomposition of organic matter will reduce the pH. The extent to which this occurs is affected by the lake's ability to buffer against changes in pH. The presence of a high alkalinity (>200 mg/L) represents considerable buffering capacity and will reduce the effects of both photosynthesis and decay in producing large fluctuations in pH.

The beneficial uses for Rose Hill Lake require that the pH values in the lake remain between the values of 6.5 su and 9.0 su. The values recorded during the assessment remained within these limits at all times. The highest values recorded were during the month of July on the surface of the lake at 8.79 su and 8.76 su for sites RL-1 and RL-2, respectively. The lowest samples were recorded at the bottom of the lake where photosynthesis had little impact on pH level, resulting in values near neutral or 7.00 standard units.

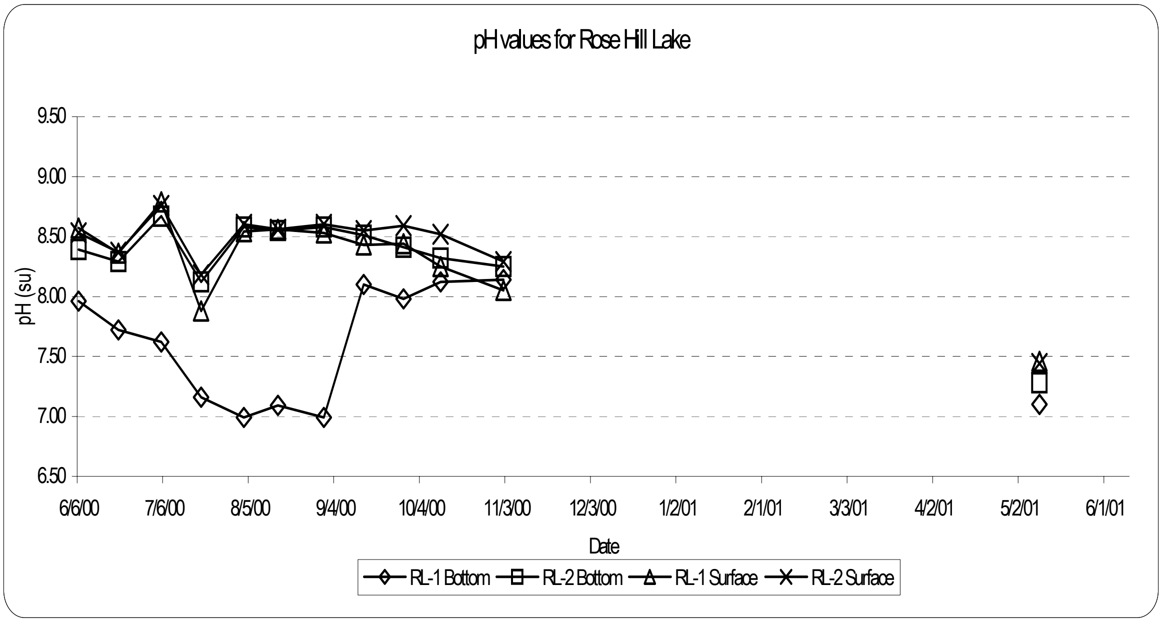

Figure 6. pH values for Rose Hill Lake

Conductivity

Conductivity is a measure of water's ability to conduct electricity, which is a function of the total number of ions present. Conductivity increases reflect an increase in the concentration of dissolved ions in the waterbody. This may also be used to indicate hardness. It is measured in μmhos/cm, and is sensitive to changes in temperature.

Conductivity values for Rose Hill Lake ranged from a low of 551 µmhos collected from site RL-2 in May of 2001, to a high of 1,900 µmhos collected from site RL-2 on July 5, 2000. State standards require mean conductivity readings of less than 4,000 µmhos and single sample values of less than 7,000 µmhos. The levels recorded during the assessment reflect full support of the state standards for Rose Hill Lakes beneficial uses.

Turbidity / Secchi Depth

Turbidity is a measure of water transparency and indicates the presence of fine suspended particulate matter. Turbidity is measured in Nephelometric Turbidity Units or NTU, which measure reflection and absorption of light when it passes through a water sample. Due to the wide variety of sizes, shapes, and densities of particles, there is often little or no direct relationship between the turbidity of a sample and the concentration and/or weight of the particulate matter present. This is addressed as total suspended solids later in the report.

There are no state standards for turbidity in waterbodies. It is important to note that high turbidity levels limit photosynthetic activity (Bowler, 1998). Aquatic plants are negatively impacted at values >30 NTU. Fish experience a reduction in feeding energy intake at values >50 NTU, in addition the structure and dynamics of fish and zooplankton populations could be affected (Claffy, 1955).

The best relationship determined for Rose Hill Lakes turbidity linked it to the total suspended solids concentration (Figure 7). No relationship existed between chlorophyll *a* and turbidity. NTU values in the lake were consistently high and may impact the macrophyte and fish communities. The presence of humic substances in the water that cause a dark stain may be a contributing factor to the turbidity.

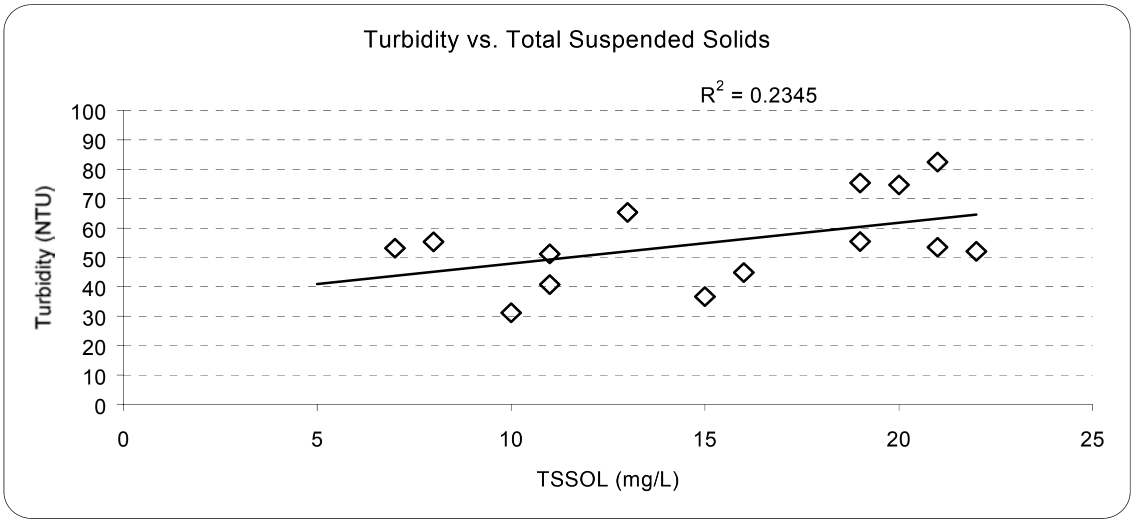

Figure 7. Turbidity vs. Total Suspended Solids for Rose Hill Lake

Secchi depth visibility is the most commonly used measurement to determine water clarity. No regulatory standards for this parameter exist, however the Secchi reading is an important tool used for determining the trophic state of a lake. The two primary causes for low Secchi readings are suspended solids and algae. Deeper Secchi readings are found in lakes that have clearer water, which is often associated with lower nutrient levels and "cleaner" water.

A strong relationship between the amount of suspended solids in the water column and the waters clarity do exist in Rose Hill Lake. There is no relationship between Secchi readings and the chlorophyll *a* concentrations. While the suspended solids concentrations appear to minimally affect turbidity, they do significantly impact Secchi visibility. Rose Hill is a very narrow lake and lies within a valley that provides significant wind protection. Large waves eroding the shoreline are not a problem for this lake, even with the steep slopes that are present along much of its shoreline.

Shoreline erosion does occur where the bank vegetation has been reduced or removed by domestic livestock. Banks that are void of vegetative cover are prone to erosion even by small waves. Livestock use of the riparian area also crushes portions of the bank into the lake. Restoring the shoreline vegetation along these sections would reduce the suspended solids in the lake and improve the water clarity.

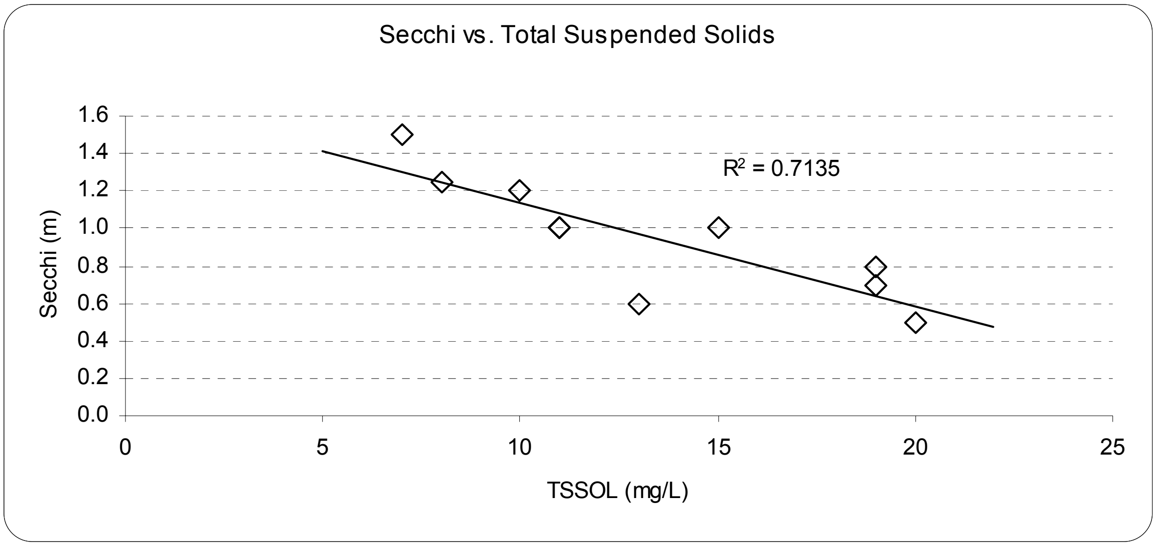

Figure 8. Secchi vs. Total Suspended Solids for Rose Hill Lake

Chlorophyll *a*

Chlorophyll *a* is the primary photosynthetic pigment found in oxygen producing organisms (Wetzel, 1982). Chlorophyll *a* is a good indicator of a lake's productivity as well as its state of eutrophication. The total concentration of chlorophyll *a* is measured in mg/m^3 (ppb) and is used in Carlson's Trophic State Index to rank a lake's state of eutrophication.

Rose Hill Lake chlorophyll *a* levels saw a significant increase in the July 19, 2000 sample. This was due to an algae bloom that occurred at this time. Other lakes in the region saw major algae blooms several weeks prior to the bloom that occurred at Rose Hill. This may be the result of two factors. Rose Hill is a small but relatively deep lake and water temperatures remained slightly cooler during the growing season possibly inhibiting the growth of algae for a few extra weeks.

The second possibility is linked to the stratification of the water column, which was followed by anoxic conditions in the hypolimnion. The anoxia is accompanied by low pH values and results in the release of nutrients, particularly phosphorus, from the bottom sediments. Stratification began in June of 2000, and a marked increase in phosphorus was observed in the bottom sample collected on July 5, 2000. The release of total nitrogen nearly doubled while the total phosphorus and total dissolved phosphorus concentration increased three and seven times respectively. This release of nutrients likely resulted in the algal blooms that persisted throughout the summer.

Little data exists on circulators, oxygenators, and other types of equipment that eliminate stratification of the water column and the affect they will have on the frequency or intensity of nuisance algal blooms. The data tends to support the hypothesis that eliminating the release of these nutrients from the bottom sediments, through oxygenation, should result in fewer and less intense algal blooms.

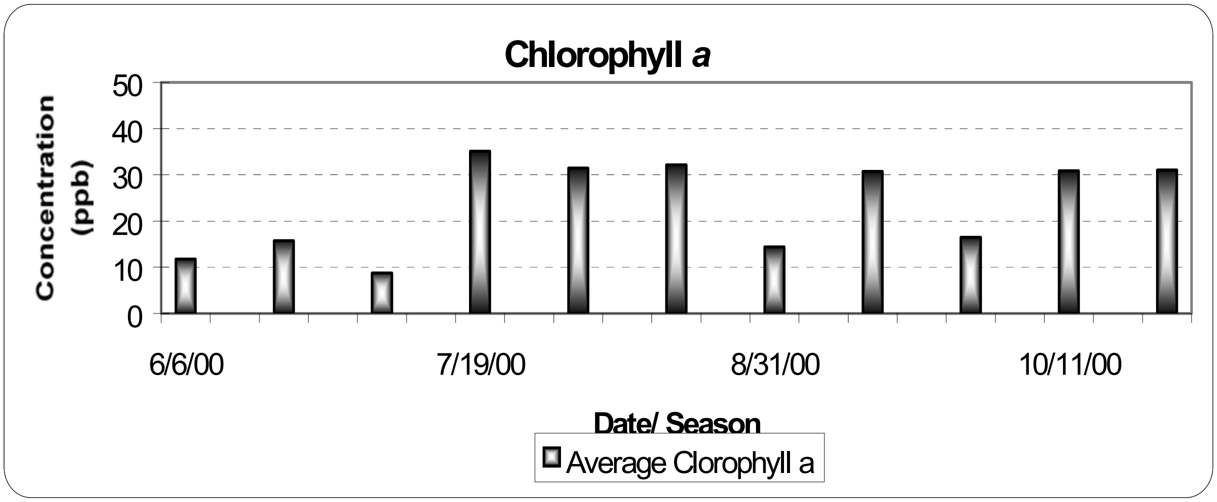

Figure 9. Chlorophyll a Samples for Rose Hill Lake

Alkalinity

A lake's total alkalinity affects its ability to buffer against changes in pH. Total alkalinity consists of all dissolved electrolytes (ions) with the ability to accept and neutralize protons (Wetzel, 2000). Due to the abundance of carbon dioxide (CO_2) and carbonates, most freshwater contains bicarbonates as their primary source of alkalinity. It is commonly found in concentrations as high as 200 mg/L or greater.

State standards for Rose Hill Lake require alkalinity concentrations to maintain a mean of less than 750 mg/L and never to exceed 1,313 mg/L in a single sample. Samples collected in Rose Hill Lake during this study varied from a minimum of 106 mg/L collected May 9, 2001 to a maximum of 239 mg/L collected on August 3, 2000 from the bottom of the lake at sites RL-2 and RL-1, respectively. Mean alkalinity concentrations were slightly higher for the bottom samples at 182 mg/L versus an average of 164 mg/L on the surface. The alkalinity in Rose Hill Lake does not impair its beneficial uses.

Solids

Solids are addressed as four separate parts in the assessment: total solids, dissolved solids, suspended solids, and volatile suspended solids. Total solids are the sum of all forms of material including suspended and dissolved as well as organic and inorganic materials that are found in a given volume of water.

Suspended solids consist of particles of soil and organic matter that may be eventually deposited in stream channels and lakes in the form of silt. Silt deposition into a stream bottom buries and destroys the complex bottom habitat. This habitat destruction reduces the diversity of aquatic insect, snail, and crustacean species. In addition to reducing stream habitat, large amounts of silt may also fill-in lake basins. As silt deposition reduces the water depth in a lake, several things occur. Wind-induced wave action increases turbidity levels by suspending solids from the bottom that had previously settled out. Shallow water increases and maintains higher temperatures. Shallow water also allows for the establishment of beds of aquatic macrophytes.

The total and dissolved solids concentrations in Rose Hill Lake are nearly identical and will be addressed as one parameter. Peak values for total solids were recorded during the December 27, 2000 sampling. These samples contained total and dissolved solids concentrations in excess of 1,300 mg/L. The lowest values recorded were in the May 9, 2001 samples, which had values that ranged from 400 to 900 mg/L.

Samples collected in December of 2000 had little influence from surface runoff. Due to less than normal rainfall, there had been little or no discharge from the lake for the previous 18 months. This time period allowed for the ground water entering the lake (typically higher in dissolved solids) to have greater than normal impact on the lake water quality. The samples collected in May of 2001 were collected after large amounts of snowmelt and spring rain runoff (typically lower in dissolved solids) had resulted in an extended period of spring discharge.

The suspended solids found in Rose Hill Lake play a significant role through their effects on other parameters such as Secchi readings and turbidity. Suspended solids concentrations were found to contain anywhere from 9% to 70% volatile organic matter. The mean organic concentration was approximately 37%. Total suspended solids concentrations varied from 4 mg/L to 40 mg/L collected at the bottom at site RL-2 on December 27, 2000 and June 6, 2000, respectively. The ice cover that was present during the December sampling protected the lake from wind, runoff, and livestock-induced turbidity, resulting in the low December concentration.

Figure 10 depicts the average inlake concentration of total suspended solids and volatile suspended solids collected at each site. The line graph represents the volatile percentage of the total suspended solids found in each sample.

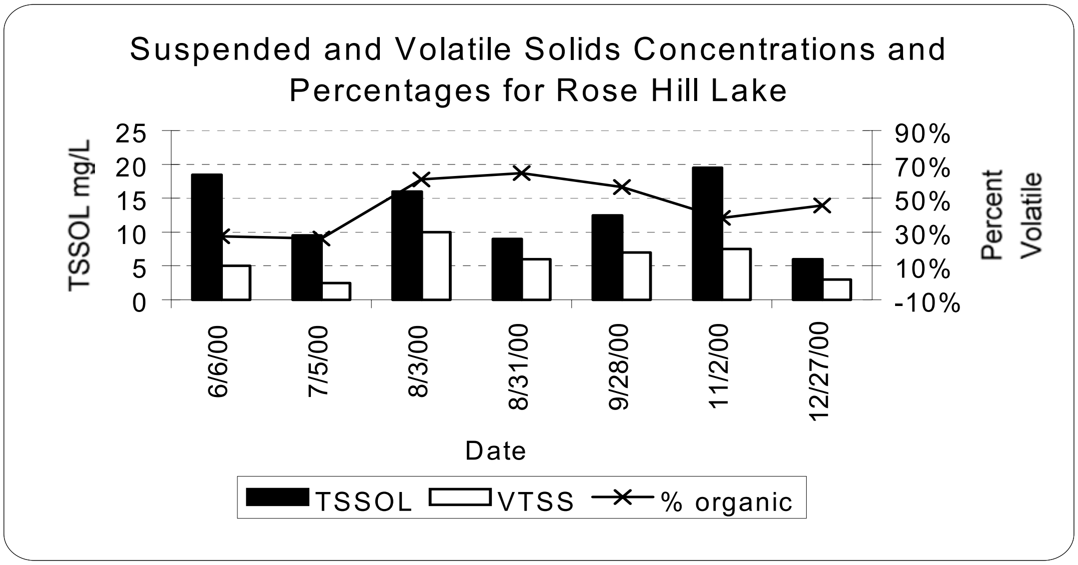

Figure 10. Suspended and Volatile Suspended Solids Concentrations and Percentages in Rose Hill Lake

Nitrogen

Nitrogen is analyzed in four forms: nitrate/nitrite, ammonia, and Total Kjeldahl Nitrogen (TKN). From these four 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.

Inorganic nitrogen is the most plant available form, consisting of the sum of nitrate/nitrite and ammonia. Rose Hill Lake inorganic nitrogen concentrations were below the detection limit on the surface for the entire growing season (Figure 11). July and August samples from the bottom of the lake indicate that the anoxic conditions were releasing large amounts of inorganic nitrogen into the water column. The concentrations at the surface remained below detection limits due to the fact that the excess amount of phosphorus in the water allowed for plant growth in the lake to use all the inorganic nitrogen as it became available.

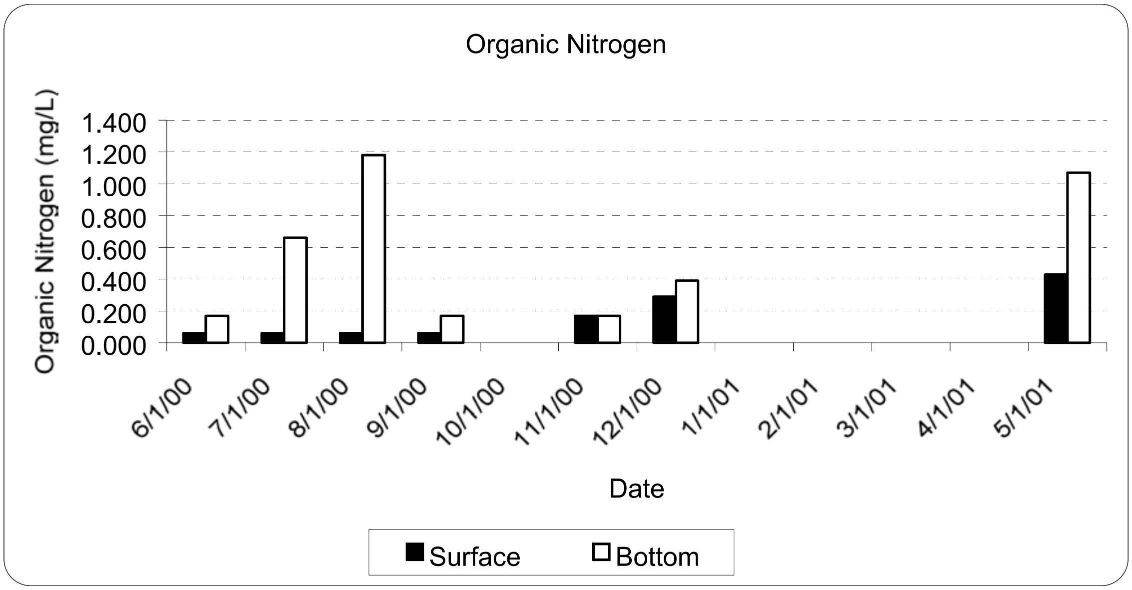

Figure 11. Organic Nitrogen in Rose Hill Lake

Ammonia may be found in two forms, ionized and un-ionized. The latter form can be extremely toxic to fish. The un-ionized fraction of ammonia is dependent on pH and temperature. As these two parameters increase, so does the un-ionized fraction of ammonia. Ammonia tends to remain in its ionic form (NH^{4+}) except under higher alkaline conditions (pH>9.0) (Wetzel 2000). Un-ionized levels in excess of 5% are lethal to fish and other aquatic life. Samples collected from Rose Hill Lake all remained below 1% un-ionized, resulting in no impairment of beneficial uses.

Total Phosphorus

Phosphorus is one of the macronutrients required for primary production. When compared with carbon, nitrogen, and oxygen, it is often the least abundant (Wetzel, 2000). Phosphorus loading to lakes can be of an internal or external nature. External loading refers to surface runoff, dust, and precipitation. Internal loading refers to the release of phosphorus from the bottom sediments to the water column of the lake. 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.

Total phosphorus concentrations were significantly different during the July and August samples (Figure 12). Nutrients released from the lake sediment impacted the bottom samples first. As the summer progressed into September, surface and bottom samples were nearly identical in value and remained this way throughout the remainder of the project. Winter samples indicated that a portion of the phosphorus had been adsorbed back into the sediments. This process likely continued until spring runoff events added large concentrations of phosphorus to the lake. This cycle of winter adsorption under aerobic conditions and summer release under anoxic conditions probably occurs on an annual basis.

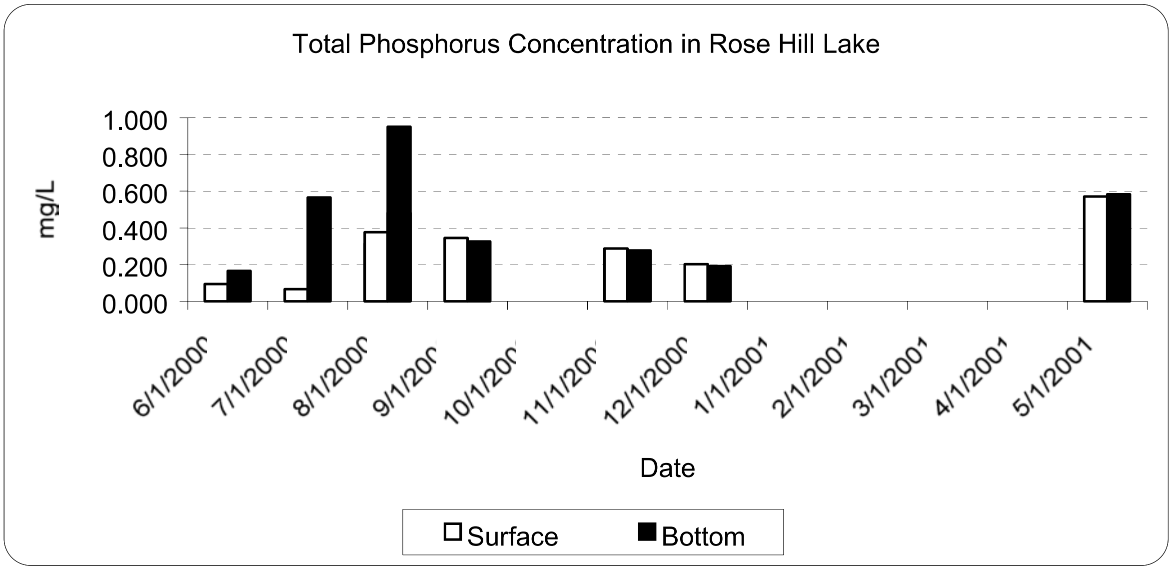

Figure 12. Total Phosphorus Concentrations in Rose Hill Lake

Complete elimination of the internal load would result in summertime phosphorus concentrations of less than .2mg/L. This is similar to what would be obtained through a 50% reduction in phosphorus loadings from the stream. This may be possible through the addition of an aeration system preventing stratification of the lake and maintaining an aerobic sediment to water interface.

Other inlake treatments would include an alum treatment. Alum treatments use an aluminum sulfate slurry that, when applied to water, creates an aluminum hydroxide precipitate (floc). The aluminum hydroxide (Al3O2) floc removes phosphorus and suspended solids, both organic and inorganic, from the water column by reacting with the assimilated phosphorus to create aluminum phosphate that settles to the bottom. By collecting and settling out suspended particles including algae, alum leaves the lake noticeably clearer.

Treatments may last up to ten years and are dependent upon the amount of alum applied, total suspended solids sedimentation rate and external phosphorus loading.

Welch and Cooke (1995) studied lakes treated with alum and found that phosphorus concentrations were reduced from 30 percent to 90 percent after application. If long-term disturbance and tributary loadings are significantly reduced, a significant reduction in in-lake phosphorus is estimated based upon in-lake concentrations prior to application. A conservative estimate for in-lake phosphorus reductions may be 30%.

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 than attached phosphorus.

The dissolved fraction of phosphorus found in bottom water samples at Rose Hill Lake exhibited a strong inverse correlation between the amount of total suspended solids and the percent of dissolved phosphorus. As suspended solids levels increased, the percentage of dissolved phosphorus decreased (Figure 13).

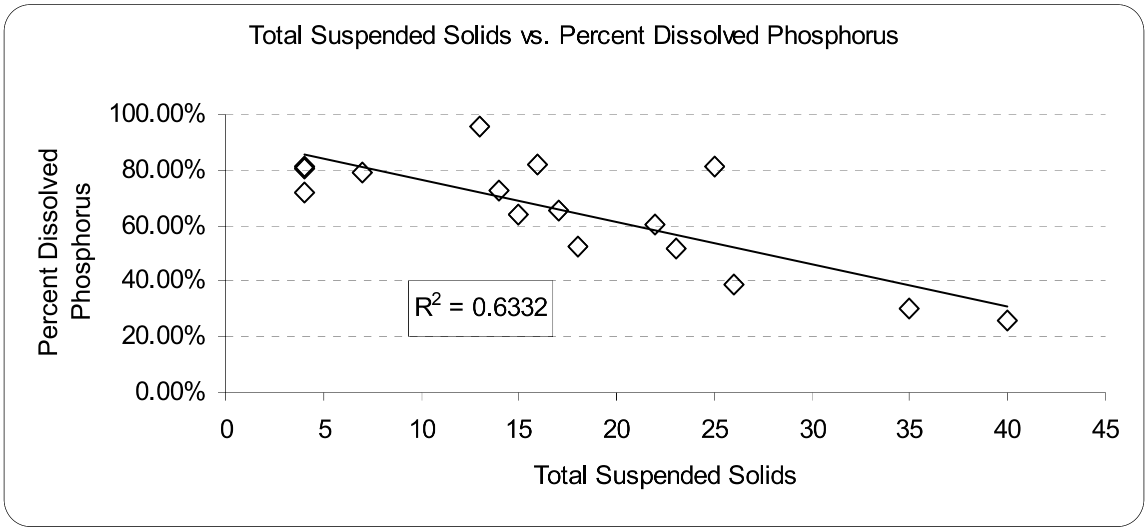

Figure 13. Total Suspended Solids vs. Total Dissolved Phosphorus

Samples collected from the surface of Rose Hill Lake showed no correlation between the percentage of dissolved phosphorus and organic suspended solids, inorganic suspended solids, or chlorophyll *a*. The strongest relationship observed compared the date of the sample with the portion of dissolved phosphorus. As the summer months progressed, anoxia at the bottom of the lake continued to release nutrients into the water column. The phosphorus was released slowly and dissolved throughout the water column increasing the percentage at the surface. As this process occurs, a visible algal bloom would be expected. While moderately large summer algae populations developed, based on phosphorus levels, higher algae densities would have been likely if nitrogen supplies had been comparable to the high phosphorus concentrations present in Rose Hill lake during the summer months. This was not the case due to the limited amount of nitrogen available for plant consumption. This large increase in dissolved phosphorus shifted the lake from a phosphorus-limited system to a nitrogen-limited system.

Fecal Coliform Bacteria

Fecal coliform are bacteria that 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).

Water samples collected from Rose Hill Lake exhibited a consistent pattern of fecal coliform concentrations that were below detection limits for Site RL-1 and concentrations that were at or slightly above detection limits (10 colonies/100mL) for site RL-2. The exceptions to this were the samples collected during May of 2001. These samples were collected during periods of peak runoff. The sample collected from site RL-2 on November 2, 2000 had concentrations that approached but did not exceed the state standards.

The most likely cause for the existence of consistent fecal coliform at site RL-2 may be attributed to the shoreline topography and domestic livestock use along the shoreline. The shoreline around site RL-1 is primarily public access with no domestic livestock use. The south shore along this portion of the lake is used for livestock grazing and watering, however the shoreline slopes are very steep and the livestock spends very little time accessing the water along this portion of the lake. Site RL-2 is located in the upper end of the lake with grazing on the shores surrounding it. It was regularly observed by the coordinator and technician that the favorite spot for watering and loafing for stock located in the pasture on the south side of the lake happened to be located within 100 meters of the sampling location. Access for stock to the lake is better along this section of the lake because of the gentle slopes and shallow water along the shoreline. Restricting livestock use of the shoreline would likely eliminate this fecal contamination.

Table 17. Fecal Coliform Counts in Rose Hill Lake

SITE	DATE	SAMPLE DEPTH	Fecal Coliforms (Colonies/ 100 mL)
RL-1	06-Jun-00	Surface	-
RL-2	06-Jun-00	Surface	10
RL-1	05-Jul-00	Surface	-
RL-2	05-Jul-00	Surface	20
RL-1	03-Aug-00	Surface	-
RL-2	03-Aug-00	Surface	10
RL-1	31-Aug-00	Surface	-
RL-2	31-Aug-00	Surface	30
RL-1	28-Sep-00	Surface	-
RL-2	28-Sep-00	Surface	10
RL-1	02-Nov-00	Surface	-
RL-2	02-Nov-00	Surface	280
RL-1	09-May-01	Surface	1,100
RL-2	09-May-01	Surface	570

Limiting Nutrients

Two primary nutrients are required for cellular growth in organisms, 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, 1990). Ratios higher than 10 indicate a phosphorus-limited system. Those that are less than 10:1 represent nitrogen-limited systems.

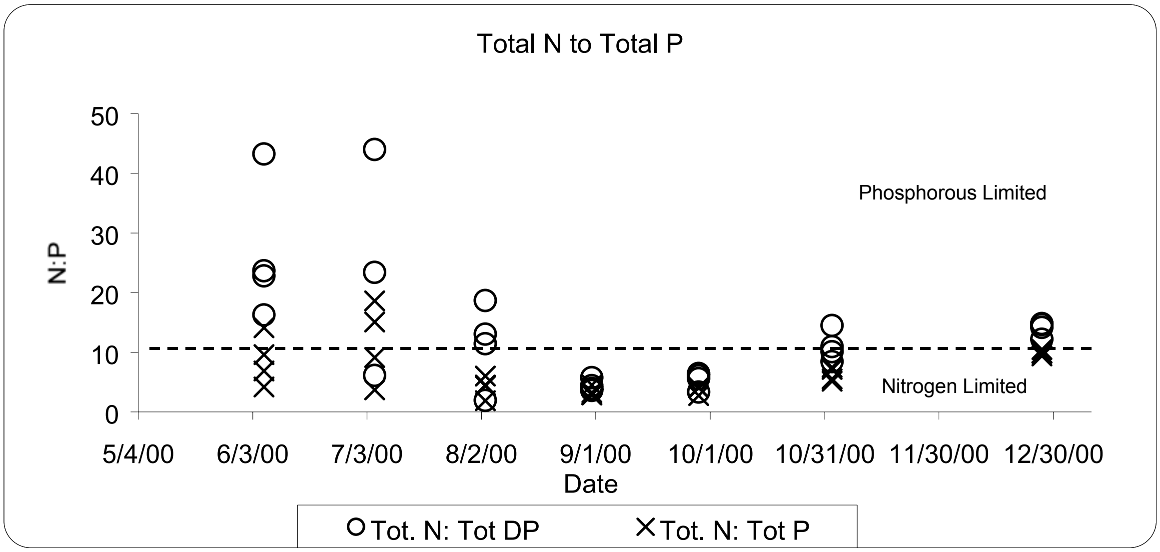

Figure 14. Limiting Nutrients

The average nitrogen to phosphorus ratio for Rose Hill Lake was 15.5:1. Samples collected after stratification had nearly identical N:P values for surface and bottom samples. Samples collected shortly after spring turnover and during the first few weeks of stratification showed a significant difference between surface and bottom ratios.

Samples collected on July 5, 2000 exhibited the greatest difference between surface and bottom N:P ratios. Surface ratios were phosphorus limited at 51:1 and 44:1 for RL-1 and RL-2, respectively. The bottom ratios were 6:1 and 23:1 at the same sites. This large shift is due to the thermal stratification of the lake and the lack of oxygen present at the sediment water interface. A large amount of phosphorus is released under these conditions resulting in the nitrogen-limitation. This release of nutrients eventually affects the entire lake as nutrients are mixed throughout the water column resulting in an average phosphorus concentration that is conducive to nuisance algal blooms.

Trophic State

Trophic state relates to the degree of nutrient enrichment of a lake and its ability to produce aquatic macrophytes and algae. The most widely used and commonly accepted method for determining the trophic state of a lake is the Trophic State Index (TSI) (Carlson, 1977). It is based on Secchi depth, total phosphorus, and chlorophyll *a* in surface waters. The values in a combined TSI number of the aforementioned parameters are averaged to give the lake's trophic state.

Lakes with TSI values less than 35 are generally considered to be oligotrophic and contain very small amounts of nutrients, little plant life, and are generally very clear. Lakes that obtain a score of 35 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 are subject to algal blooms and have large amounts of primary production. Hyper-eutrophic lakes receive scores greater than 65 and are subject to frequent and massive blooms of algae that severely impair their beneficial uses and aesthetic beauty.

TROPHIC STATE	COMBINED TSI NUMERIC RANGE
OLIGOTROPHIC	0-35
MESOTROPHIC	36-50
EUTROPHIC	51-64
HYPER-EUTROPHIC	65-100

Rose Hill Lake is located in the Northern Glaciated Plains (a level III ecoregion). As determined in "Ecoregion Targeting for Impaired Lakes in South Dakota" (Stueven et al. 2000) reservoirs in this region should have a mean TSI value of 65.0 or less to fully support their beneficial uses. Partial support of these uses is reached at TSI values between 65.0 and 75.0. Lakes that do not support these uses have TSI values greater than 75.0. Rose Hill lake is rated as partially supporting its beneficial uses with a mean TSI value of slightly greater than 65.

The average TSI for Rose Hill Lake was calculated using only sample sets with Secchi, phosphorus, and chlorophyll *a* samples. The average TSI[1] during the study for Rose Hill Lake was 66.89. This varied from a 58.39 recorded on July 5, 2000 to a 71.57 recorded on August 3, 2000. These values place Rose Hill Lake within the hyper-eutrophic category on Carlson's scale.

Mean values were calculated only for sample dates that had TSI values for chlorophyll *a*, Secchi, and phosphorus (Figure 15). These dates represent months during the growing season. Mean Trophic State Index (TSI) values for Rose Hill Lake during the assessment were 82.73 (hyper-eutrophic) for total phosphorus, 61.31 (eutrophic) for Secchi reading, and 59.3 (eutrophic) for chlorophyll *a*.

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[1] The TSI calculated here is a true representation of the actual conditions in Rose Hill Lake and may be slightly different than numbers generated in BATHTUB

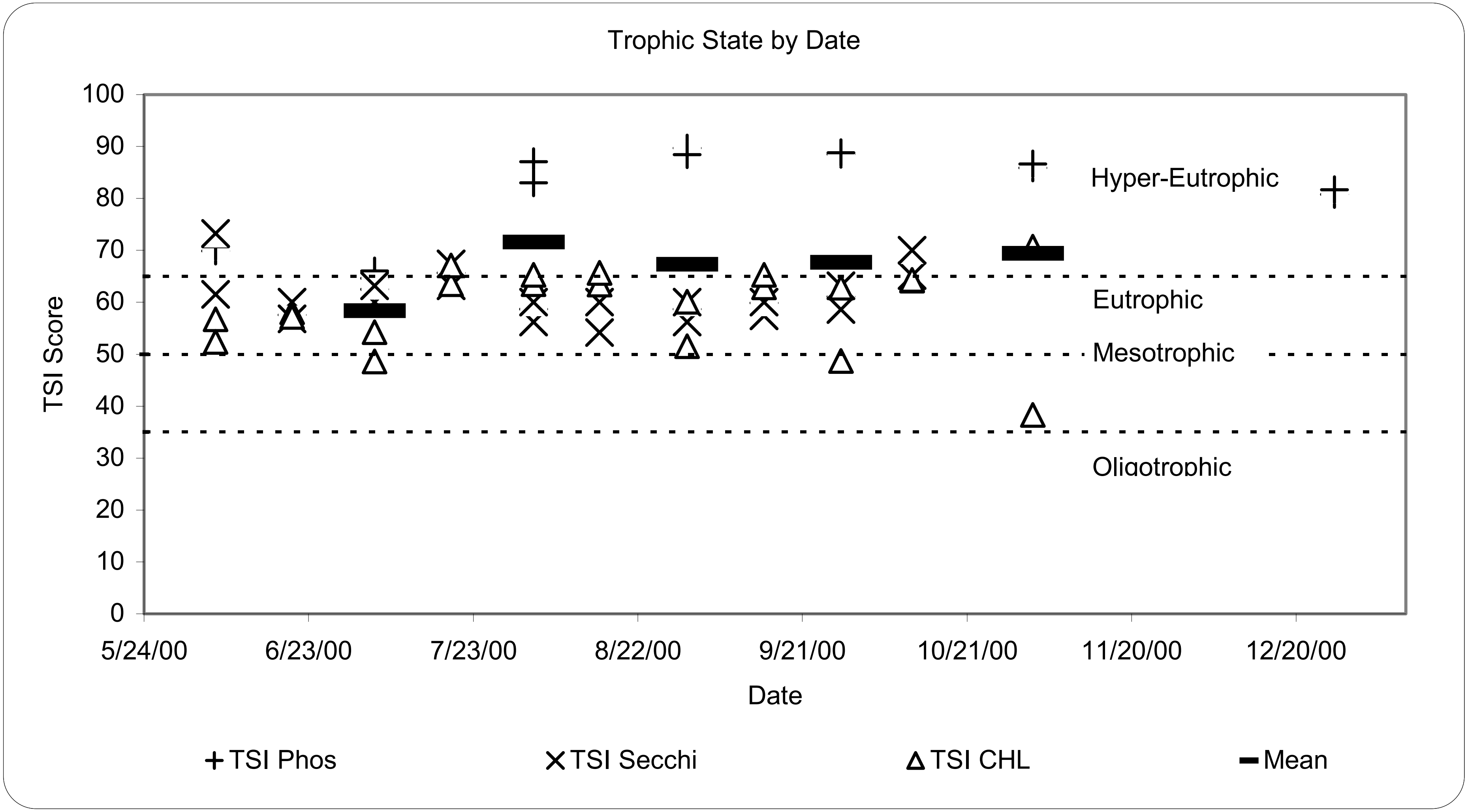

Figure 15. Trophic State by Date for Rose Hill Lake

Reduction Response Modeling

Inlake reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers Eutrophication Response Model (Walker, 1999). System responses were calculated using reductions in the loading of phosphorus to the lake from Sand Creek. Loading data for Sand Creek was taken directly from the results obtained from the FLUX modeling data calculated for the inlet to the lake.

BATHTUB provides numerous models for the calculation of inlake concentrations of phosphorus, nitrogen, chlorophyll *a*, and Secchi depth. Models are selected that most closely predict current inlake conditions from the loading data provided. As reductions in the phosphorus load are predicted in the loading data, the selected models will closely mimic the response of the lake to these reductions.

BATHTUB not only predicts the inlake concentrations of nutrients; it also produces a number of diagnostic variables that help to explain the lake responses. Table 15 shows the response to reductions in the phosphorus load. The observed and predicted water quality is listed in the first two columns. The observed[2] and predicted trophic states are 69.7 and 69.3 respectively, less than 1% difference between them.

The variables (N-150)/P and INORGANIC N/P are both indicators of phosphorus and nitrogen limitation. The first, (N-150)/P, is a ratio of total nitrogen to total phosphorus. Values less than 10 are indicators of a nitrogen-limited system. The second variable, INORGANIC N/P, is an inorganic nitrogen to ortho-phosphorus ratio. Values less than 7 are nitrogen-limited. The current state of Rose Hill Lake is nitrogen-limited. Phosphorus limitation would only be possible through 70% or greater reductions in the total phosphorus load from the watershed, or elimination of nutrient release by lake sediments.

The variable FREQ (CHL-a)% represents the predicted algal nuisance frequencies or bloom frequencies. Blooms are often associated with concentrations of 30 to 40 ppb of total phosphorus. These frequencies are the percentage of days during the growing season that algal concentrations may be expected to exceed the respective values. Reductions in phosphorus loads from external sources of 60% to 70% predict less frequent algal blooms. Bloom frequency would also be expected to be significantly less with the elimination of the internal nutrient loading.

TSI responses to the reductions in phosphorus load to the lake exhibited substantial variation. The TSI phosphorus value showed consistent positive responses to the reductions. The chlorophyll *a* and Secchi responses were much less significant. Each showed very little response to the external reductions until they reached 70% or greater. The limited responses are a result of the limited nitrogen supply and excessive phosphorus concentrations. The model predicted a mean TSI value reduction to less than 65 with a reduction in phosphorus loading of 65% or greater from the watershed, as this is very unlikely, the only way to reach a TSI of less than 65 would be to significantly reduce or eliminate internal nutrient loading in the lake.

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[2] The method used to calculate the observed TSI in BATHTUB results in a weighted average that may be slightly different from the actual calculated value.

Table 18. BATHTUB Calculations for Rose Hill Lake

		Phosphorus Reduction in the Sand Creek Watershed										
	Present	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
VARIABLE	Condition	ESTIMATED	ESTIMATED	ESTIMATED	ESTIMATED	ESTIMATED	ESTIMATED	ESTIMATED	ESTIMATED	ESTIMATED	ESTIMATED	ESTIMATED
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TOTAL P MG/M3	310	295.83	274.98	253.13	230.11	205.73	179.71	151.66	121.01	86.88	47.71	5.27
TOTAL N MG/M3	1480	1558.54	1558.54	1558.54	1558.54	1558.54	1558.54	1558.54	1558.54	1558.54	1558.54	1558.54
CHL-A MG/M3	23.51	23.06	22.93	22.78	22.56	22.27	21.84	20.88	19.01	15.78	9.98	0.84
SECCHI M	0.96	0.97	0.97	0.98	0.98	0.99	1	1.02	1.08	1.18	1.42	2.11
ORGANIC N MG/M3	210	716.85	714.08	710.48	705.66	698.94	689.08	667.14	624.62	550.9	418.63	210.34
ANTILOG PC-1	600.58	942.51	931.36	917.09	898.29	872.71	836.41	771.03	660.21	488.64	240.71	11.46
ANTILOG PC-2	7.86	9.44	9.44	9.44	9.44	9.43	9.42	9.34	9.14	8.7	7.57	2.48
(N - 150) / P	4.29	4.76	5.12	5.56	6.12	6.85	7.84	9.29	11.64	16.21	29.52	267.39
INORGANIC N / P	4.23	3.39	3.71	4.12	4.65	5.39	6.48	8.27	11.6	19.33	48.93	1348.2
FREQ(CHL-a>20) %	48.03	46.78	46.44	46	45.4	44.56	43.31	40.47	34.75	24.43	7.61	0
FREQ(CHL-a>30) %	24.09	23.12	22.87	22.53	22.08	21.46	20.55	18.54	14.78	8.9	1.85	0
FREQ(CHL-a>40) %	12.15	11.53	11.37	11.15	10.87	10.48	9.92	8.71	6.55	3.51	0.54	0
FREQ(CHL-a>50) %	6.34	5.95	5.85	5.72	5.55	5.32	4.99	4.28	3.08	1.5	0.18	0
FREQ(CHL-a>60) %	3.43	3.2	3.14	3.06	2.96	2.82	2.62	2.21	1.52	0.69	0.07	0
CARLSON TSI-P	86.87	86.2	85.14	83.95	82.57	80.96	79.01	76.56	73.31	68.53	59.89	28.11
CARLSON TSI-CHLA	61.57	61.38	61.33	61.26	61.17	61.04	60.85	60.41	59.49	57.66	53.16	28.89
CARLSON TSI-SEC	60.59	60.43	60.39	60.33	60.26	60.15	60	59.65	58.94	57.63	54.93	49.27
Mean TSI	69.68	69.34	68.95	68.51	68.00	67.38	66.62	65.54	63.91	61.27	55.99	35.42

Table 19. BATHTUB Calculations Legend

TOTAL P MG/M3	Pool Mean Phosphorus Concentration
TOTAL N MG/M3	Pool Mean Nitrogen Concentration
CHL-A MG/M3	Pool Mean Chlorophyll *a* Concentration
SECCHI M	Pool Mean Secchi depth
ORGANIC N MG/M3	Pool Mean Organic Nitrogen Concentration
ANTILOG PC-1	First principal component of reservoir response. Measure of nutrient supply. < 50 = Low Nutrient Supply and Low Eutrophication potential // >500 = High nutrient supply and high Eutrophication potential
ANTILOG PC-2	Second principal component of reservoir response variables. Nutrient association with organic vs. inorganic forms; related to light-limited areal productivity. Low: PC-2 < 4 = turbidity-dominated, light-limited, low nutrient response. High: PC-2 >10 = algae-dominated, light unimportant, high nutrient response.
(N - 150) / P	(Total N - 150)/ Total P ratio. Indicator of limiting nutrient. Low: (n-150)/P < 10-12 + nitrogen-limited High: (n-150)/P > 12-15 phosphorus-limited
INORGANIC N / P	Inorganic Nitrogen/ ortho-phosphorus ratio. Indicator of limiting nutrient Low: N/P < 7-10 Nitrogen- limited High: N/P > 7-10 phosphorus limited
FREQ(CHL-a>10) %	Algal nuisance frequencies or bloom frequencies. Estimated from mean chlorophyll *a*. Percent of time during growing season that Chl *a* exceeds 10, 20, 30, 40, 50, 60 ppb. Related to risk or frequency of use impairment.
TSI	Trophic State Indices (Carlson 1977)

Long Term Trends

Rose Hill Lake is listed on the state's 303(d) list as an impaired waterbody with a declining trend in water quality as a result of nutrients, sediment, and algal growth. This is also supported in the 1995 South Dakota Lakes Assessment Final Report. Data from this report is included in Figure 16 together with TSI values collected during the 2000-growing season. The year 2000 TSI value for Rose Hill Lake is only slightly higher than for samples collected in 1979. If present conditions remain unchanged, this slowly increasing trend will eventually peak at a higher TSI value.

Reductions in nutrient and sediment loadings to Rose Hill Lake should help to reverse this trend, and eventually return the lake to a state equal to or better than the condition it was in during the 1979 assessment. To fully support its beneficial uses, a TSI reduction of 2 points is required to establish a stable to decreasing trophic state for the lake. Achieving a stable TSI is a practical goal for a watershed restoration project.

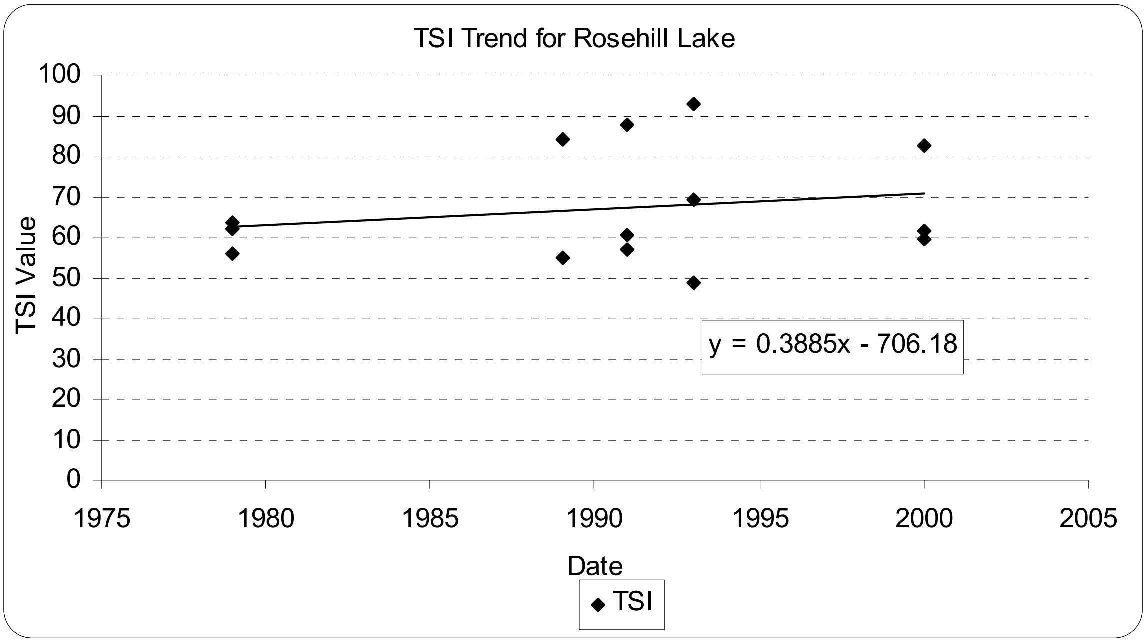

Figure 16. Long Term TSI Trend for Rose Hill Lake

Biological Monitoring

Fishery

The most recently published fisheries survey was completed during the summer of 1998. Previous surveys were completed during 1997 as well as 1994. A copy of the South Dakota Game, Fish and Parks Fisheries Survey for Rose Hill Lake can be found in Appendix D.

The survey discusses in detail five of the six fish species found in the lake. The sixth species, green sunfish, consisted of a single fish caught in a trap net and was not identified as a significant member of the local fish community. The remaining species identified during the survey were black bullhead, black crappie, yellow perch, largemouth bass, and northern pike.

The lake has primarily been managed for quality size largemouth bass. However, there have been some problems with population recruitment. The 1998 survey indicated a reduction in density from the 1997 sample. The 1995, 1996, and 1997 year classes appeared to be weak or even nonexistent.

Black crappies were introduced to Rose Hill Lake in 1995. The stocking appears to have been a success as there were excellent condition fish from four year classes sampled in 1998. The catch per unit effort (CPUE) for black crappie was 15.41, which was only surpassed by black bullhead at 28.46.

Black bullhead were the most common species collected during the 1998 survey. The mean CPUE for black bullheads was not significantly different between 1997 and 1998 indicating little change in the population. Some concern over the lack of largemouth bass recruitment was expressed citing that this may lead to an expansion of the black bullhead community.

Yellow perch and northern pike were also collected during the survey with CPUE at 1.26 and .64 respectively. The yellow perch population appeared to be stable, changing very little from the 1997 to the 1998 survey.

Northern pike were significantly more abundant in the 1998 survey (19 individuals) when compared with the surveys conducted in 1994 (4 individuals) and 1997 (0 individuals). The expansion in the northern pike population is attributed to high water levels in the preceding years which allowed for successful reproduction. Continued expansion in the community is not expected due to the low biomass supported by small impoundments such as Rose Hill Lake.

The 1998 angler survey estimated approximately 796 angler days on the lake, most of which were contributed or spent by local anglers. The local economic benefit translates into $59,700 based on the average South Dakota angler spending $75 per fishing day. (U.S. Department of Interior, Fish and Wildlife Service, and U.S. Department of Commerce, Bureau of Census 1997).

Phytoplankton

Composited surface samples were collected twice a month from two inlake sites in Rose Hill Lake from June through September 2000 and monthly in October and November 2000. A total of 48 algal taxa were identified by Aquatic Analysts, Wilsonville, Oregon, for the period of the survey (Table 18 – species list). Diatoms (Bacillariophyceae) represented the most diverse algal group with 17 taxa collected, followed by green algae (Chlorophyta) with 13 taxa including one motile taxon – *Chlamydomonas* sp. Blue- green algae (Cyanophyta) was the most frequently collected but least diverse group during this study with only 4 species identified (Table 18). Fifteen taxa of motile (flagellated) algae made up 31% of the total algal taxa identified. Euglenoids (Euglenophyta) and dinoflagellates (Pyrrhophyta) were the most diverse of the motile algae with 4 taxa each, whereas the green algae were represented by only 1 taxon. Cryptomonads (Cryptophyta) and yellow-brown flagellates (Chrysophyta) were present in the lake as 3 and 2 taxa, respectively. Algae species richness in Rose Hill Lake during this study (48) was rated as only average compared with other monitored state lakes.

Table 20. Algae Species List for Rose Hill Lake

Algae Species	Avg % Density	Algae Type	Algae Species	Avg % Density	Algae Type
Aphanizomenon flos-aquae	43.6	Blue-Green Algae (filament)	Nephrocytium sp.	0.2	Green Algae (colonial)
Cyclotella meneghiniana	15.9	Diatom (centric)	Anabaena flos-aquae	0.1	Blue-Green Algae (filament)
Peridinium cinctum	7.1	Flagellated Algae (Dinoflagellate)	Stephanodiscus hantzschii	0.1	Diatom (centric)
Rhodomonas minuta	5.8	Flagellated Algae (Cryptophyte)	Stephanodiscus astraea minutula	0.1	Diatom (centric)
Aphanothece sp.	4.9	Blue-Green Algae (colonial)	Oocystis lacustris	0.1	Green Algae (colonial)
Oocystis pusilla	3.1	Green Algae (colonial)	Staurastrum gracile	0.1	Green Algae (colonial)
Cyclotella stelligera	3.0	Diatom (centric)	Pediastrum boryanum	0.1	Green Algae (colonial)
Cryptomonas erosa	2.2	Flagellated Algae (Cryptophyte)	Mallomonas sp.	0.1	Flagellated Algae (Yellow-Brown Algae)
Microcystis aeruginosa	2.0	Blue-Green Algae (colonial)	Euglena sp.	0.1	Flagellated Algae (Euglenoid)
Selenastrum minutum	1.5	Green Algae	Navicula gregaria	0.0	Diatom (pennate)
Trachelomonas volvocina	1.2	Flagellated Algae (Euglenoid)	Nitzschia paleacea	0.0	Diatom (pennate)
Melosira granulata	1.1	Diatom (centric, filament)	Cyclotella atomus	0.0	Diatom (centric)
Ankistrodesmus falcatus	1.0	Green Algae	Scenedesmus quadricauda	0.0	Green Algae (colonial)
Crucigenia quadrata	1.0	Green Algae (colonial)	Cryptomonas ovata	0.0	Flagellated Algae (Cryptophyte)
Sphaerocystis schroeteri	0.9	Green Algae (colonial)	Chromulina sp.	0.0	Flagellated Algae (Yellow-Brown Algae)
Chlamydomonas sp.	0.7	Flagellated Algae (Green Algae)	Melosira ambigua	0.0	Diatom (centric, filament)
Unidentified microflagellate	0.7	Flagellated Algae	Ceratium hirundinella	0.0	Flagellated Algae (Dinoflagellate)
Cocconeis placentula	0.7	Diatom (pennate)	Stephanodiscus astraea	0.0	Diatom (centric)
Melosira granulata angustissima	0.6	Diatom (centric, filament)	Navicula cryptocephala veneta	0.0	Diatom (pennate)
Glenodinium sp.	0.6	Flagellated Algae (Dinoflagellate)	Gymnodinium sp.	0.0	Flagellated Algae (Dinoflagellate)
Trachelomonas hispida	0.6	Flagellated Algae (Euglenoid)	Navicula cryptocephala	0.0	Diatom (pennate)
Closteriopsis longissima	0.4	Green Algae	Staurastrum sp.	0.0	Green Algae
Trachelomonas pulchella	0.3	Flagellated Algae (Euglenoid)	Amphora coffeiformes	0.0	Diatom (pennate)
Synedra rumpens	0.3	Diatom (pennate)	Navicula sp.	0.0	Diatom (pennate)

The seasonal distribution of algae numbers (population density) in the lake consisted of a small peak on June 20, 2000 and a much larger maximum in mid-October. The autumn peak was followed by a steep decline in algae numbers as a natural part of the seasonal downturn (Figure 17). The seasonal fluctuation in the size of the algae population was similar to that in Lake Alvin, another small eutrophic reservoir in southeastern South Dakota. However, diatoms were responsible for the spring and fall peaks in Lake Alvin whereas the peaks in Rose Hill Lake were caused by blooms of blue-green algae, primarily *Aphanizomenon*.

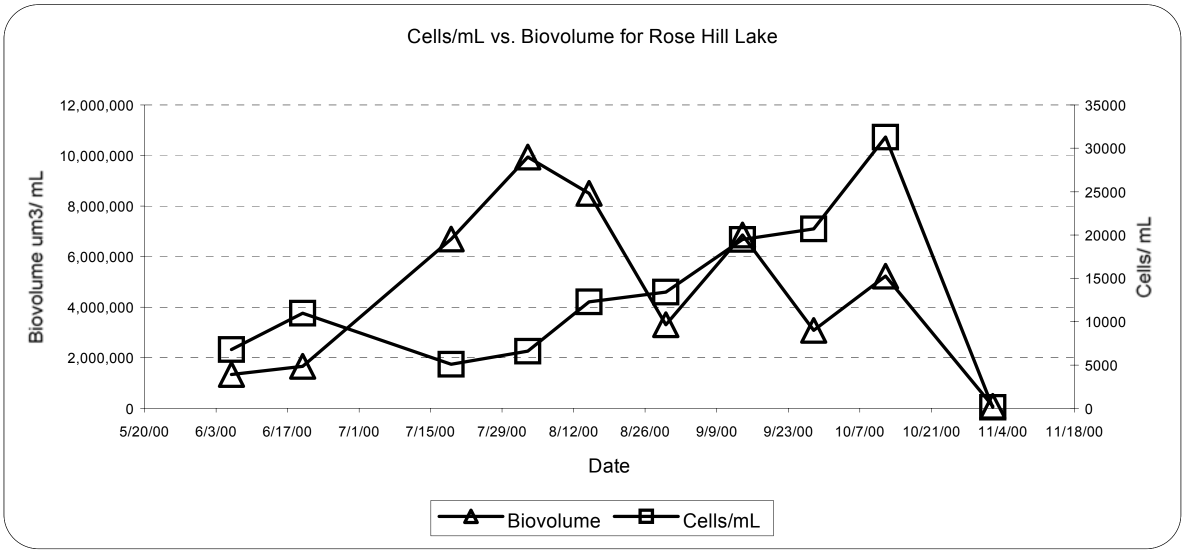

Figure 17. Algae Cells/ mL vs. Biovolume by Date for Rose Hill Lake

The seasonal pattern of algal biovolume (approx. algal biomass) in Rose Hill Lake can be characterized by what was essentially a single annual maximum during the first half of August followed by two small peaks on a declining trend for the remainder of the survey (Figure 17). The August peak was produced almost entirely by relatively moderate numbers of a large-sized dinoflagellate, *Peridinium* (Figures 18 and 19). *Peridinium* comprised the bulk of total algal biovolume from late July to mid-September (Table 21). Similar results were obtained in summer for Lake Alvin and some other highly eutrophic state lakes, notably Lake Faulkton and Lake Campbell (Brookings Co.). It is believed that this prominence of dinoflagellates may be caused by the abundance of organic compounds in those lakes, possibly from feedlot runoff as one source (Wetzel, 2000).

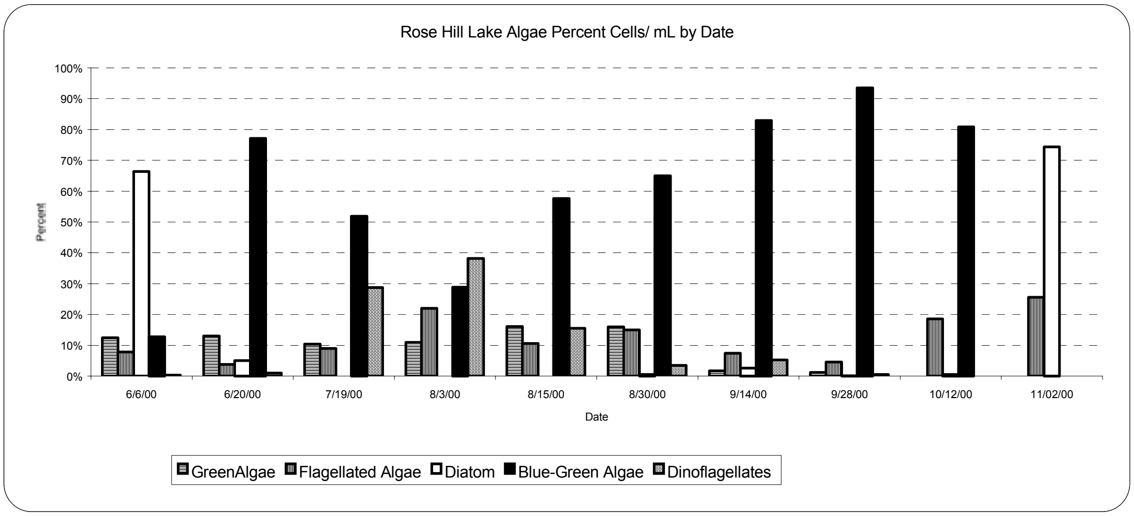

Figure 18. Rose Hill Lake Algae Cells/ mL by Date

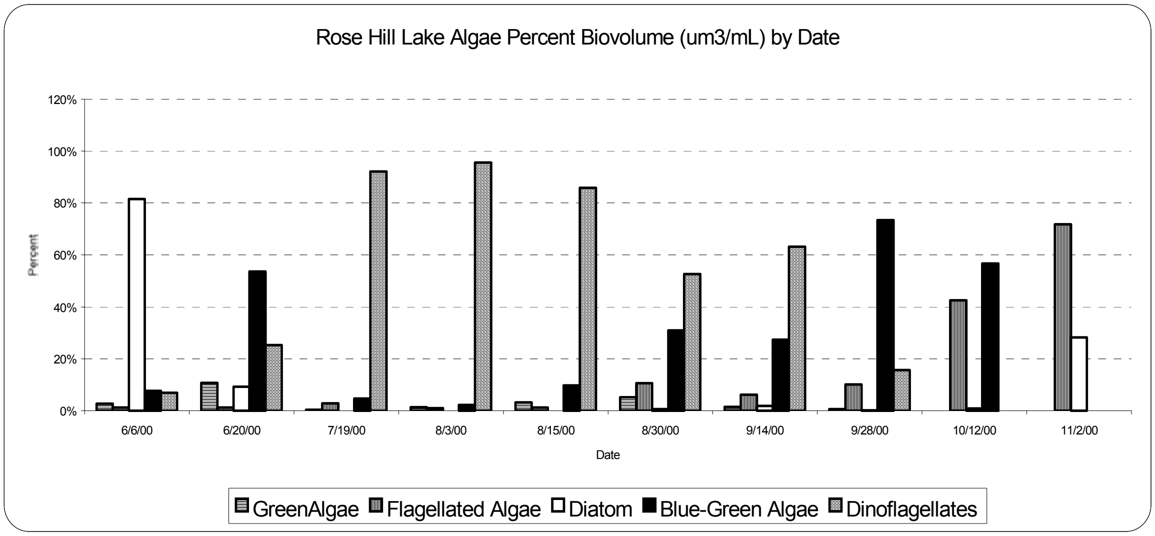

Figure 19. Rose Hill Lake Algae Percent Biovolume (μm^3/mL) by Date

In terms of annual algal biomass produced, Rose Hill Lake ranks somewhere in mid-range of recently monitored eutrophic state lakes. Examples of lakes with considerably higher algal production are Geddes and Andes. Algae (phytoplankton) biovolume ranged from 0.082 ul/L (= 82,000 um^3/mL x 10^{-6}) in November to 9.935 μl/L in August 2000 (Table 19). Average biovolume and density for the study period amounted to 4.666 μl/L and 12,679 cells/mL, respectively.

Table 21. Rose Hill Lake Algae Biovolume (μm^3/mL) and Abundance (cells/mL)

Date	Algal Group	Bio Volume	Percent	Cells/mL	Percent
06-Jun-00	UnIdentified Algae	660	0.0%	22	0.3%
	Blue-Green Algae	101,556	7.6%	868	12.8%
	Diatom	1,086,516	81.4%	4,496	66.2%
	Dinoflagellates	92,400	6.9%	22	0.3%
	Flagellated Algae	16,880	1.3%	532	7.8%
	Non-Motile GreenAlgae	36,370	2.7%	847	12.5%
06-Jun-00	**Total**	**1,334,382**		**6,787**	
20-Jun-00	Blue-Green Algae	887,133	53.6%	8,469	77.2%
	Diatom	153,345	9.3%	548	5.0%
	Flagellated Algae	19,496	1.2%	424	3.9%
	Dinoflagellates	418,200	25.3%	106	1.0%
	Non-Motile GreenAlgae	176,951	10.7%	1,430	13.0%
20-Jun-00	**Total**	**1,655,125**		**10,977**	
19-Jul-00	Blue-Green Algae	309,348	4.6%	2,644	51.9%
	Flagellated Algae	192,696	2.9%	456	9.0%
	Dinoflagellates	6,157,200	92.1%	1,466	28.8%
	Non-Motile GreenAlgae	27,744	0.4%	528	10.4%
19-Jul-00	**Total**	**6,686,988**		**5,094**	
03-Aug-00	Blue-Green Algae	222,885	2.2%	1,905	28.9%
	Flagellated Algae	92,172	0.9%	1,447	22.0%
	Dinoflagellates	9,491,300	95.5%	2,514	38.2%
	Non-Motile GreenAlgae	128,746	1.3%	723	11.0%
03-Aug-00	**Total**	**9,935,103**		**6,589**	
15-Aug-00	Blue-Green Algae	829,647	9.8%	7,091	57.6%
	Flagellated Algae	101,462	1.2%	1,311	10.7%
	Dinoflagellates	7,297,500	85.9%	1,915	15.6%
	Non-Motile GreenAlgae	268,057	3.2%	1,984	16.1%
15-Aug-00	**Total**	**8,496,666**		**12,301**	
30-Aug-00	Blue-Green Algae	1,020,825	30.9%	8,725	65.0%
	Diatom	20,400	0.6%	68	0.5%
	Flagellated Algae	348,530	10.6%	2,014	15.0%
	Dinoflagellates	1,739,500	52.7%	470	3.5%
	Non-Motile GreenAlgae	170,249	5.2%	2,148	16.0%
30-Aug-00	**Total**	**3,299,504**		**13,425**	
14-Sep-00	Blue-Green Algae	1,877,641	27.4%	16,157	82.9%
	Diatom	130,620	1.9%	515	2.6%
	Dinoflagellates	4,330,200	63.1%	1,031	5.3%
	Flagellated Algae	423,532	6.2%	1,444	7.4%
	Non-Motile GreenAlgae	99,625	1.5%	344	1.8%
14-Sep-00	**Total**	**6,861,618**		**19,491**	
28-Sep-00	Blue-Green Algae	2,265,822	73.4%	19,366	93.5%
	Diatom	5,520	0.2%	32	0.2%
	Flagellated Algae	313,960	10.2%	952	4.6%
	Dinoflagellates	483,000	15.6%	115	0.6%
	Non-Motile GreenAlgae	19,288	0.6%	246	1.2%
28-Sep-00	**Total**	**3,087,590**		**20,711**	
12-Oct-00	Blue-Green Algae	2,961,387	56.7%	25,311	80.9%
	Diatom	43,250	0.8%	173	0.6%
	Flagellated Algae	2,220,249	42.5%	5,811	18.6%
12-Oct-00	**Total**	**5,224,886**		**31,295**	
02-Nov-00	Diatom	23,200	28.2%	87	74.4%
	Flagellated Algae	58,945	71.8%	30	25.6%
02-Nov-00	**Total**	**82,145**		**117**	

Motile (flagella-bearing) algae, including dinoflagellates, were more abundant and diverse in Rose Hill Lake than was observed in many other monitored state lakes. Possible reasons for their prominence here may be the small size of the lake (< 100 ac), superabundant available phosphorus, and a sufficient supply of dissolved organic compounds and vitamins (ibid.).

The largest populations of diatoms and flagellates were encountered during the cooler months of the year in spring and fall, respectively (Figures 18 and 19). Diatoms were abundant only in early June whereas motile algae were also common in August when diatoms were virtually absent in samples (Table 21). Diatoms were not detected in samplings from July to mid-August and appeared in rather low densities for the remainder of the survey.

Blue-green algae, almost all *Aphanizomenon*, were numerically dominant (cells/mL) in the lake plankton from 20 June to November 2000 but only on three sampling dates in terms of biovolume (Figures 18, 19 and Table 21). *Aphanizomenon* densities ranged from 868 cells/mL on 6 June to 25,311 cells/mL on 12 October 2000. These are considered to be relatively moderate densities when compared to other monitored eutrophic state lakes.

Green algae were the least important algal group in Rose Hill Lake during this study and were most common in spring and summer. They were almost never significant in terms of biovolume contributed to the lake algal biomass. The most common green algae species collected during this assessment were *Oocystis pusilla, Crucigenia quadrata,* and *Sphaerocystis schroeteri*. The relatively small populations of green algae (Chlorophyta) observed in the plankton of many monitored state lakes appears to be a common phenomenon in the eutrophic hardwater lakes of the Midwest (Prescott 1962).

Aquatic Macrophyte Survey

The project coordinator and technician conducted an aquatic plant survey on August 9 of 2000. Submerged and emergent aquatic vegetation was located, sampled, identified, and recorded at fifteen predetermined sampling transects. In addition to vegetation sampling at each transect, the presence or absence of livestock was also recorded. Transects were located every 225 meters proceeding in a clockwise fashion around the lake beginning at the boat access. Prior to sampling, flags were placed at 225 meter intervals along the waters edge. GPS coordinates were not recorded during the survey, however, Figure 20 represents the approximate locations of the transects around Rose Hill Lake.

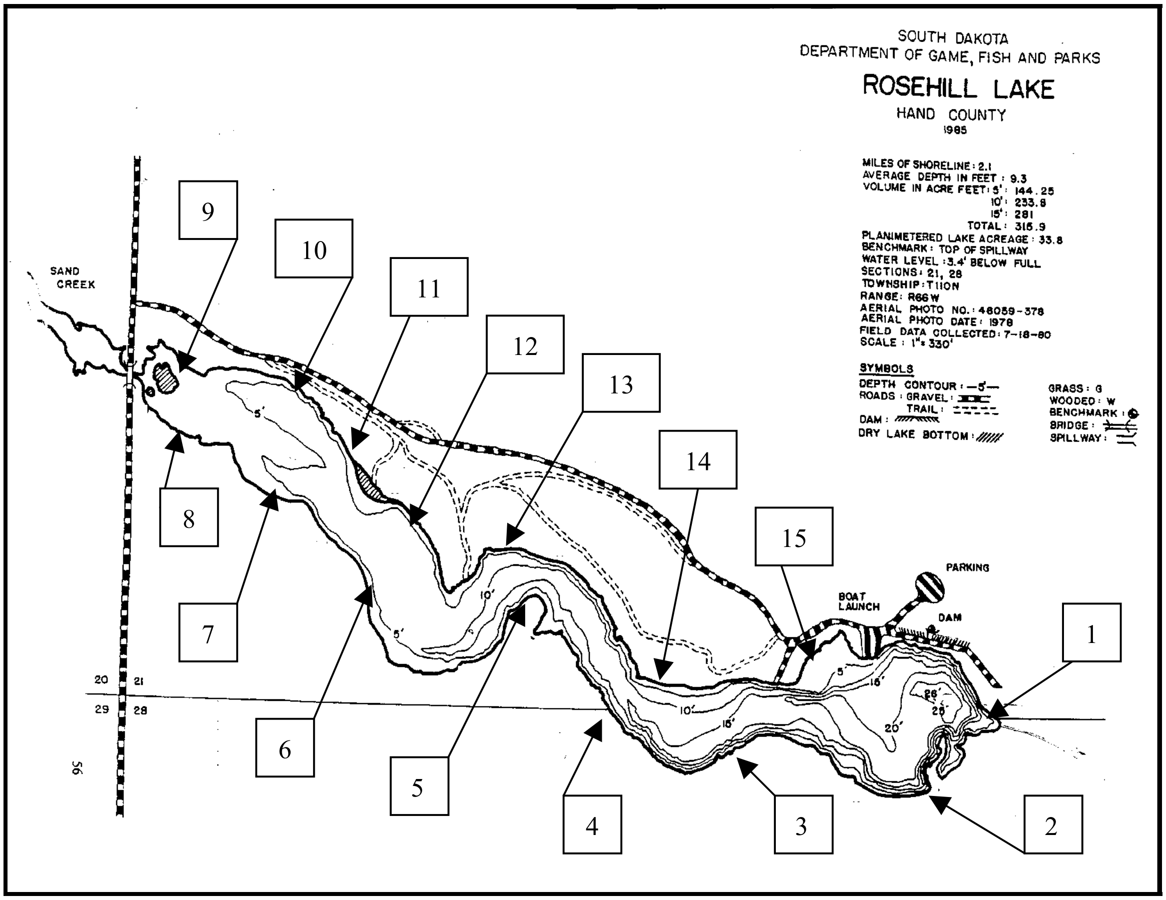

Figure 20. Aquatic Macrophyte Survey Transects

Submergent vegetation in the lake was predominantly located within 2 meters of the shoreline. For this reason, sampling with the plant grapple was restricted to two pulls conducted parallel to the shoreline within the aquatic macrophyte zone. The density rating found in the SOP was modified to accommodate the reduced number of pulls taken at each transect. A single plant in either pull received a rating of "1"; a single plant in each pull received a "2"; multiple plants in either pull received a "3"; multiple plants in each pull received a "4"; and if both pulls resulted in a species filling the teeth of the rake, it was rated with a "5".

Emergent species in the riparian zone were identified and recorded as present or absent within 5 meters of the transect flag. Species recorded were limited to those identified as aquatic or wetland species in "Aquatic and Wetlands Plants of South Dakota", written by Gary E. Larson. The plant species identified in this survey and their habitat can be found in the following table.

Table 22. Aquatic Plant Species

Common Name	Genus	Species	Habitat
Arrowhead	*Sagittaria*	*latifolia*	Emergent
Bushy Pondweed	*Najas*	sp.	Submergent
Clasping leaf Pondweed	*Potamogeton*	*richardsonii*	Submergent
Common Smartweed	*Polygonum*	*pennsylvanicum*	Emergent
Dull-leaf Indigo	*Amorpha*	*fruiticosa*	Emergent
Mexican Dock	*Rumex*	*mexicanas*	Emergent
Plantain	*Alisma*	sp.	Emergent
Pondweed Family	*Potamogeton*	*filiformis*	Submergent
Reed Canarygrass	*Phalaris*	*arundinacea*	Emergent
Sago Pondweed	*Potamogeton*	*pectinatus*	Submergent
Sedge	*Carex*	spp.	Emergent
Sour Dock	*Rumex*	*crispus*	Emergent
Strawcolored Nutsedge	*Cyperus*	*strigosus*	Emergent
Swamp Smartweed	*Polygonum*	*coccineum*	Emergent
Water Hemp	*Amaranthus*	*rudis*	Emergent
Waterweed	*Anacharis*	*canadensis*	Submergent
Willows	*Salix*	sp.	Emergent

The submergent and emergent species were sampled using different methods which restricts the comparisons that may be made between them. Table 20 lists both submergent and emergent species and their densities at each transect as well as the presence or absence of livestock at the time of the survey. Livestock have access to a majority of the shoreline at various times during the year. The only transect located in an area that livestock are strictly excluded from the entire year is transect 15 located west of the boat launch. The remainder of the transects that are identified as not having livestock present showed little or no signs of their presence at the time of the survey.

While no differences in submergent species were expected between sites with and without livestock, some were observed. Site 15, which is free from the impacts of livestock the entire year, had two species that were almost entirely absent in the rest of the lake with the exception of one site. *Najas* sp. was found only at transect 15 and received a heavy rating of 4. *Potamogeton richardsonii* received a dense rating (5) at transect 15 and was identified at one additional transect (2), which produced a single plant (sparse rating of 1).

Table 23. Submergent Aquatic Species

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Livestock	Livestock
Livestock Present		No	No	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	No
Potamogeton	*filiformis*	4	4	3	2		2	3	5	5			3				13	18
Potamogeton	*pectinatus*	1	1	3	4	4	2	4	5	5	5	3	5	2	2	3	27	22
Anacharis	*canadensis*		5		5	5	5	5	2		5	5	5	5	5	2	37	17
Potamogeton	*richardsonii*		1													4		5
Najas	*sp.*															5		5
															Total		77	67

The results of the submergent aquatic macrophyte survey suggest that livestock are having a negative effect on the species diversity of the submergent macrophyte community.

A total of twelve emergent species were identified along the shore of Rose Hill Lake. All twelve of these species were identified at transects without livestock present while only eight of the twelve species were located at transects with livestock present. This reduction in diversity may be a result of selective grazing or stress. The livestock present (in this case cattle) may favor consumption of the species that were absent from grazed areas.

Table 24. Emergent Aquatic Species

																Total	
Transect #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Livestock	Livestock
Livestock Present	No	No	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	No
Rumex crispus	1		1	1		1	1			1	1	1	1	1	1	6	5
Cyperus strigosus	1			1	1	1	1	1		1		1	1	1	1	7	4
Amaranthus rudis		1														0	1
Phalaris arundinacea			1			1				1					1	1	2
Amorpha fruiticosa			1	1	1					1					1	1	3
Salex sp.			1													0	1
Polygonum coccineum				1			1	1			1					3	1
Polygonum pennsylvanicum				1		1		1	1	1		1		1		4	3
Alisma sp.				1												0	1
Rumex mexicanus						1				1				1	1	2	2
Sagittaria latifolia									1							0	1
Carrex sp.									1				1	1		2	1
																26	25

Whether eliminated by stress or consumption, it is evident that the presence of livestock likely reduced the species diversity in the riparian area around Rose Hill Lake. With both the emergent and submergent vegetation suggesting negative impacts from livestock, exclusion of domestic livestock from the riparian area should increase the macrophyte diversity around Rose Hill Lake.

Threatened and Endangered Species

There are no threatened or endangered species documented in the Sand Creek watershed. The US Fish and Wildlife Service lists the whooping crane, bald eagle, and western prairie fringed orchid as species that could potentially be found in the area. None of these species were encountered during this study; however, care should be taken when conducting mitigation projects in the Sand Creek Watershed.

Bald eagles typically prefer large trees for perching and roosting. As there are no confirmed documentation of bald eagles within the Sand Creek watershed, little impact to the species should occur. Any mitigation processes that take place should avoid the destruction of large trees that may be used as eagle perches, particularly if an eagle is observed using the tree as a perch or roost.

Whooping cranes have never been documented in the Sand Creek watershed. Sightings in this area are likely only during fall and spring migration. When roosting, cranes prefer wide, shallow, open water areas such as flooded fields, marshes, artificial ponds, reservoirs, and rivers. Their preference for isolation and avoidance of areas that are surrounded by tall trees or other visual obstructions makes it highly unlikely that they will be present to be negatively impacted as a result of the implementation of BMPs.

Although there have never been any confirmed documentations of the western prairie fringed orchid in this watershed, habitat suitable for its survival does exist. Western prairie fringed orchid grows in tall grass prairies and meadows. Wetland draining and the conversion of rich soil prairies to agricultural cropland have reduced the orchids numbers. Overgrazing, improper use of pesticides, and collecting also threatens its survival. (Missouri, 2001) Proposed BMPs for the Sand Creek watershed should reduce the occurrence of overgrazing, ultimately enhancing the condition of wetlands and increasing the survivability of this species if it were ever to grow here.

Other Monitoring

Agricultural Nonpoint Source Model (AGNPS)

AGNPS is a data intensive watershed model that routes sediment and nutrients through a watershed by utilizing land uses and topography. The watershed is divided up into equally sized portions, or cells of 40 acres. Each of these cells requires 26 parameters to be collected and entered into the program. Best Management Practices (BMPs) are then simulated by altering the land use in the individual cells.

The targeted or "critical" cells are identified by the amount of nutrients that they produce and ultimately reach the outlet of the watershed. The cells in the Sand Creek watershed were broken into four levels of priority. Cell priority was assigned based on average nutrient loads produced by cells within the watershed. Cells that produced nitrogen **and** phosphorus loads greater than two standard deviations over the mean for the watershed were given a priority ranking of 1. Cells that produced nitrogen **or** phosphorus loads greater than two standard deviations over the mean were given a priority ranking of 2. Cells that produced nitrogen **and** phosphorus loads greater than one standard deviation over the mean were given a priority ranking of 3. Cells that produced nitrogen **or** phosphorus loads greater than one standard deviation over the mean were given a priority ranking of 4. The locations of the priority cells may be found in Figures 21 through 24.

The effects of the treated cells on the nitrogen and phosphorus delivered at the end of the watershed may be found in table 23. The average pounds per acre delivered by the watershed is compared before and after implementation of proposed BMPs.

Table 25. Expected Nutrient Reductions in the Sand Creek Watershed after BMP Implementation

Expected Nutrient Reductions in the Sand Creek Watershed after BMP implementation				
	Lbs/ acre at outlet	Total N	Lbs/ acre at outlet	Total P
Current	1.66	36603	0.43	9481.5
Priority 1 (1.6% of the Watershed)	1.58	34839	0.41	9040.5
% Reduction		4.8%		4.7%
	Lbs/ acre at outlet	Total N	Lbs/ acre at outlet	Total P
Current	1.66	36603	0.43	9481.5
Priority 2 (2.5% of the Watershed)	1.57	34618.5	0.41	9040.5
% Reduction		5.4%		4.7%
	Lbs/ acre at outlet	Total N	Lbs/ acre at outlet	Total P
Current	1.66	36603	0.43	9481.5
Priority 3 (8% of the Watershed)	1.51	33295.5	0.39	8599.5
% Reduction		9.0%		9.3%
	Lbs/ acre at outlet	Total N	Lbs/ acre at outlet	Total P
Current	1.66	36603	0.43	9481.5
Priority 4 (13.7% of the Watershed)	1.51	33295.5	0.38	8379
% Reduction		9.0%		11.6%

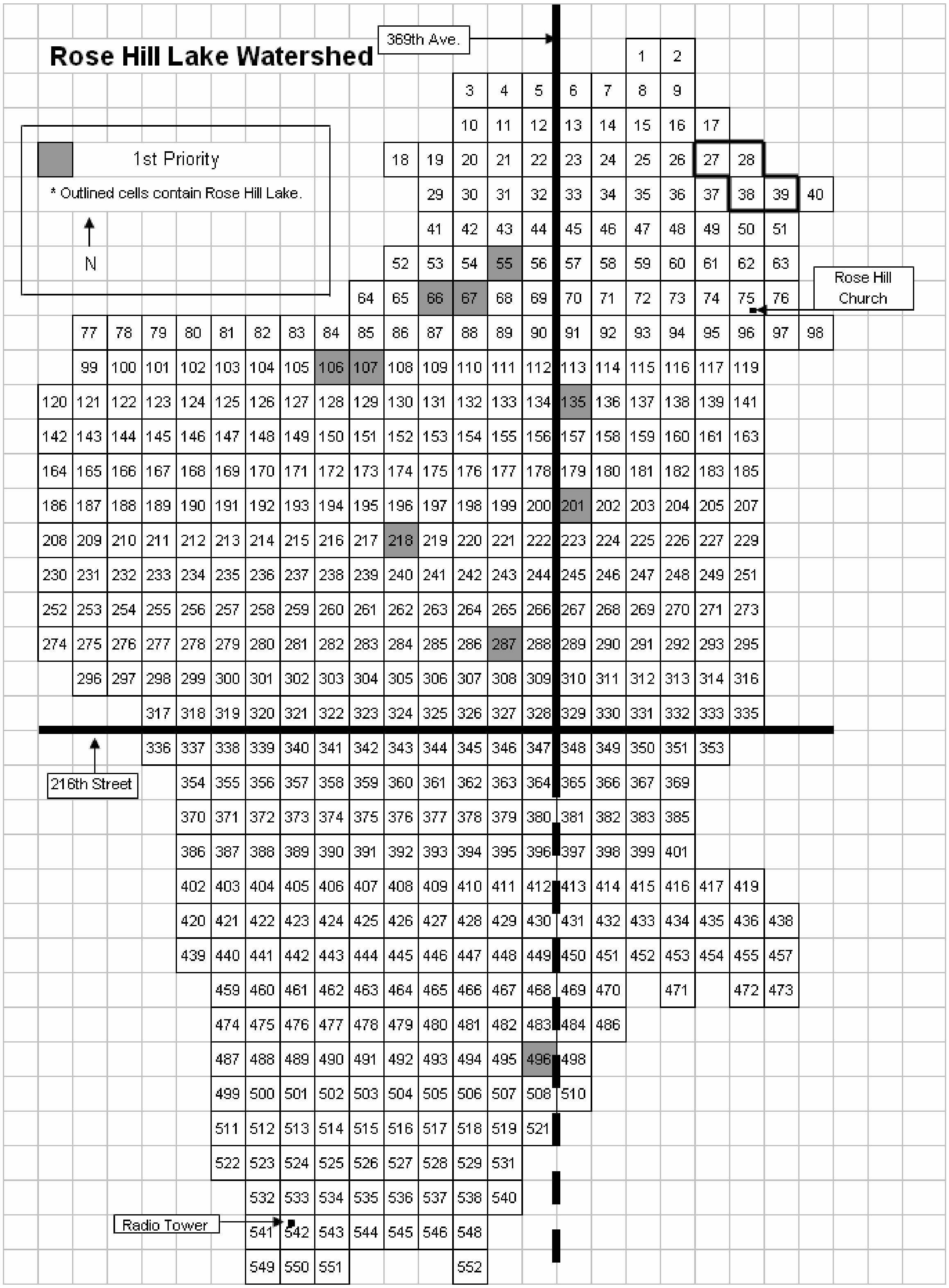

Figure 21. Rose Hill Lake Priority 1 Cells

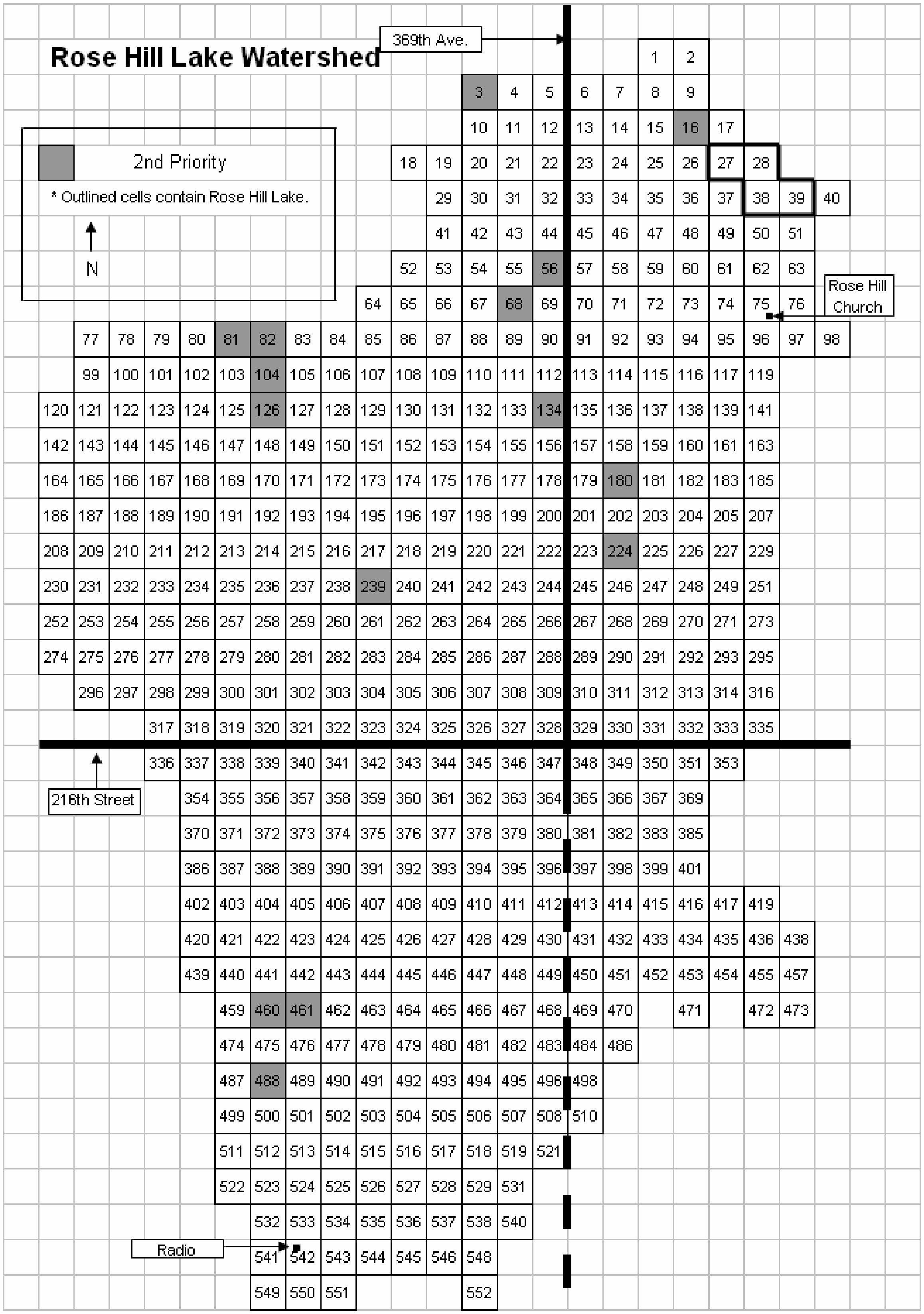

Figure 22. Rose Hill Lake Priority 2 Cells

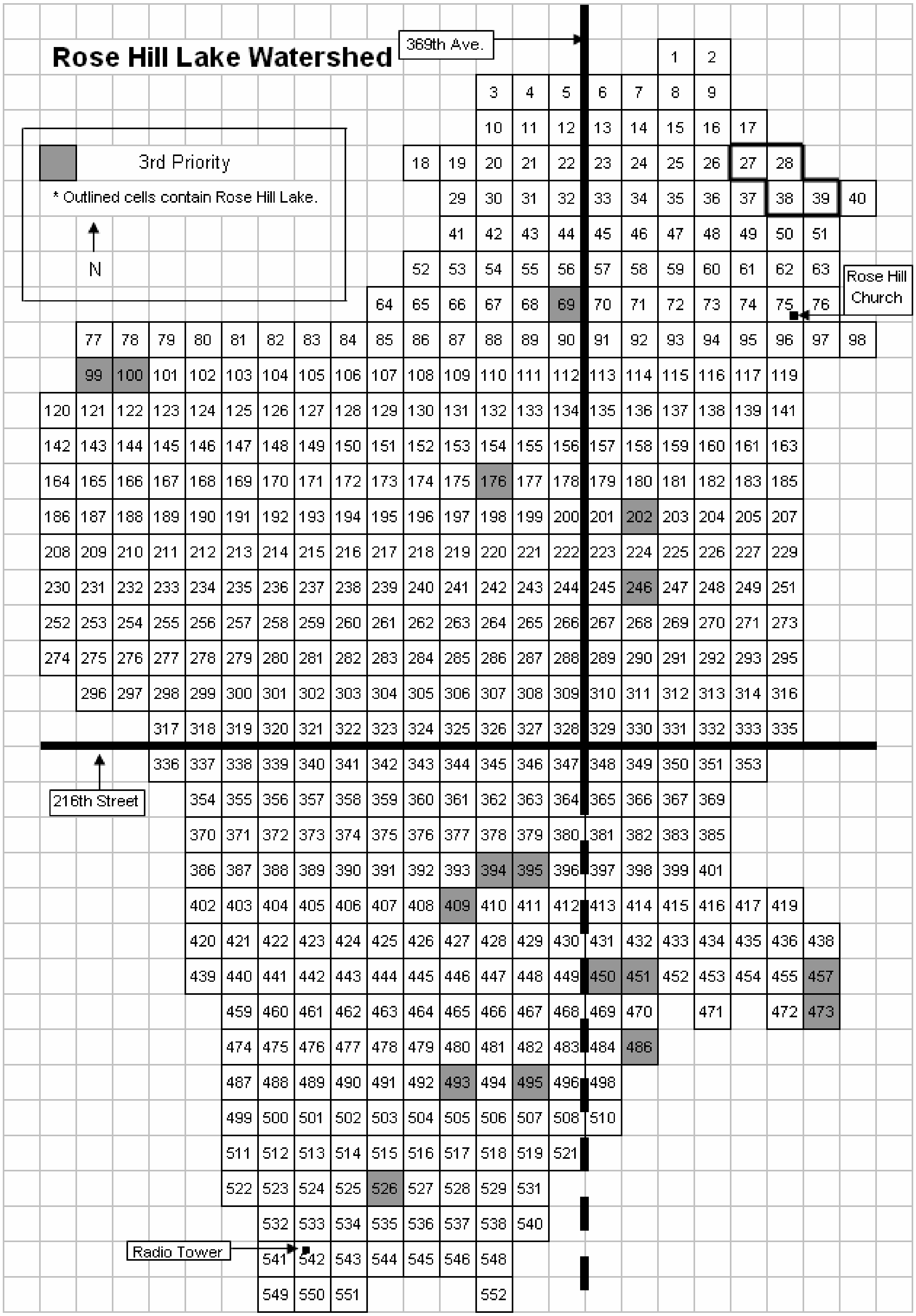

Figure 23. Rose Hill Lake Priority 3 Cells

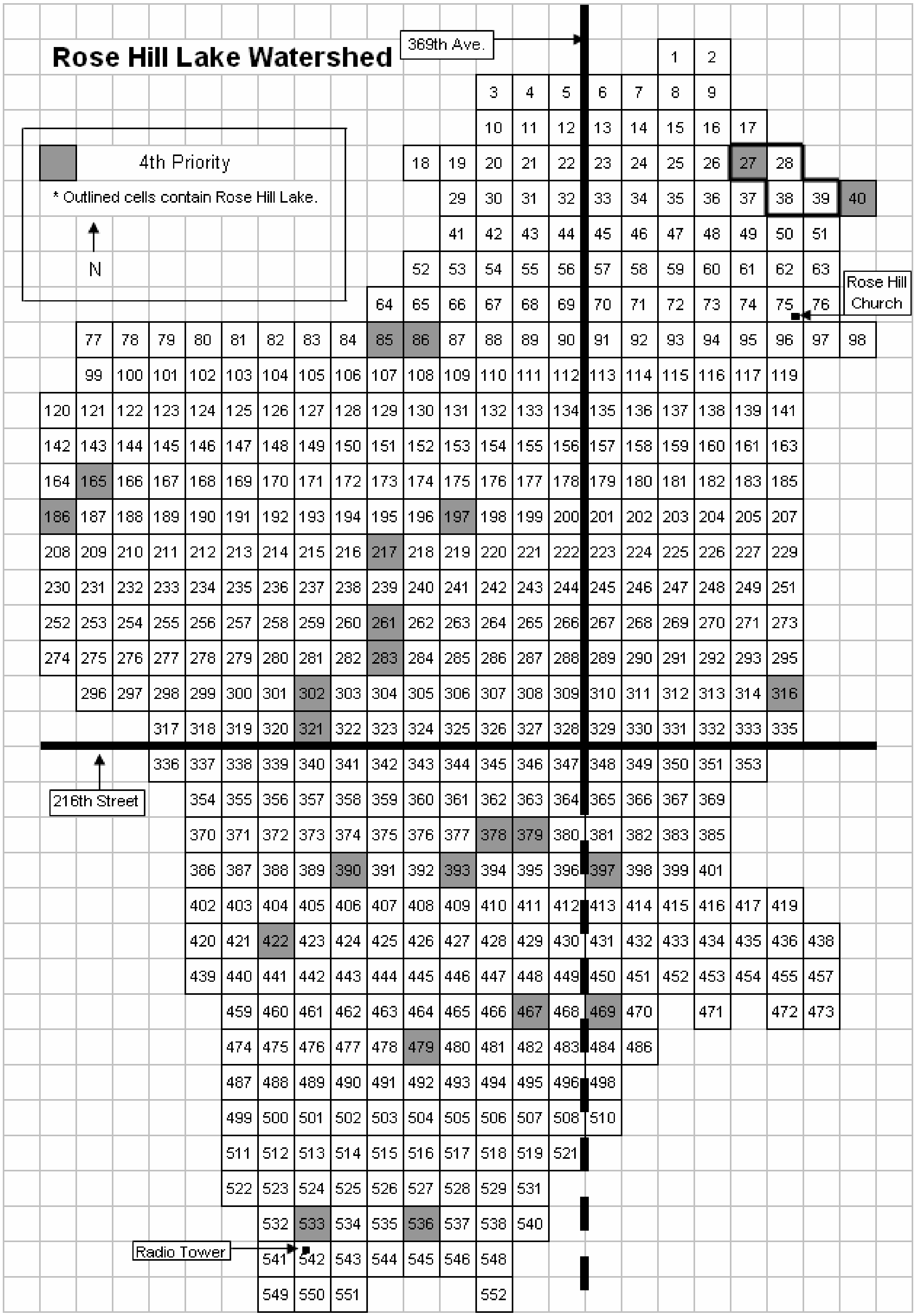

Figure 24. Rose Hill Lake Priority 4 Cells

The Sand Creek watershed is composed of 552 cells resulting in a total acreage of 22,080. Of this, 360 acres or 1.6% of the watershed falls within the priority 1 category. Expected nutrient reductions from the treatment of these cells include a 4.8% reduction in total nitrogen and 4.7% reduction in total phosphorus delivered to the outlet of the watershed. Best Management Practices for priority 1 cells include 200 acres of reduced tillage practices, 1 animal feeding operation, a buffer strip or grass waterway and adding a cover crop to 80 acres of wheat fallow ground.

An additional 200 acres fall within the priority 2 category, bringing the total treated acreage to 560 acres or 2.5% of the entire watershed. Treatment of these acres includes a 5.4% reduction in total nitrogen and 4.7% reduction in total phosphorus delivered to the outlet of the watershed. Best Management Practices include 160 acres of reduced tillage practices and one additional buffer strip.

Table 26. Targeted Cells for BMP Implementation

Priority	Tillage Practices	Animal Feeding Operation	Buffer Strips	Grazing
1	66, 67, 218, 496, 539	135	400	
2	106, 107, 273, 540		16	
3	3, 81, 82, 99, 100, 104, 126, 180, 202, 246, 239, 217, 460, 461	134, 201, 486	287, 409	
4	85, 86, 295, 316, 435		27, 40, 176, 283, 261, 302, 321, 378, 390, 393, 394, 395, 397, 417, 418, 450	186, 467

A total of 31 cells (1,240 acres) fell within the priority 3 ranking bringing the total treated acreage to 1,800 acres or 8% of the watershed. Best Management Practices for priority 3 cells include 600 acres of reduced tillage practices and a total of 3 animal feeding operations. Cells 287 and 409 were most effectively improved through the use of either buffer strips or grassed waterways, and adding a cover crop to 80 acres of wheat fallow ground.

An additional 320 acres or 8 cells were identified by the model as priority 3 cells and were significantly contributing nutrient loads. All of these acres were cropland acres that had existing conservation tillage practices and were not located within close proximity to an identified channel. The use of grass waterways or buffer strips may reduce nutrient loadings from these cells, however each one should be examined individually in the field before implementation of BMP practices.

Priority 4 cells totaled 28 (1,120 acres) and bring the treated portion of the watershed to 2,920 acres or 13.7%. As with the priority 3 cells, 200 acres or 5 cells were identified as nutrient sources to the lake that already have conservation tillage practices in place. As with the earlier cells, these should be examined in the field to determine if grass waterways, buffer strips, or some other type of BMP would result in reduced nutrient runoff. The remainder of the cells include 200 acres of reduced tillage, 120 acres with steep slopes and grazing pressure, and 15 cells were identified in which buffer strips or grass waterways would be the most effective treatment.

The treatment of additional cropland acres in the watershed will likely result in very little additional reductions in nutrient loading to the lake. Figure 25 represents the AGNPS predicted diminishing nutrient load reductions as additional cropland acres are treated with BMPs. Loading reductions begin to significantly decrease when 10% to 20% of the cropland acres in the watershed are implemented with BMPs. By treating the priority 1 through 4 cells, 13.7% of the watershed cropland acres would receive some type of BMP. This falls within the range of treated cropland acres that is optimum for this watershed.

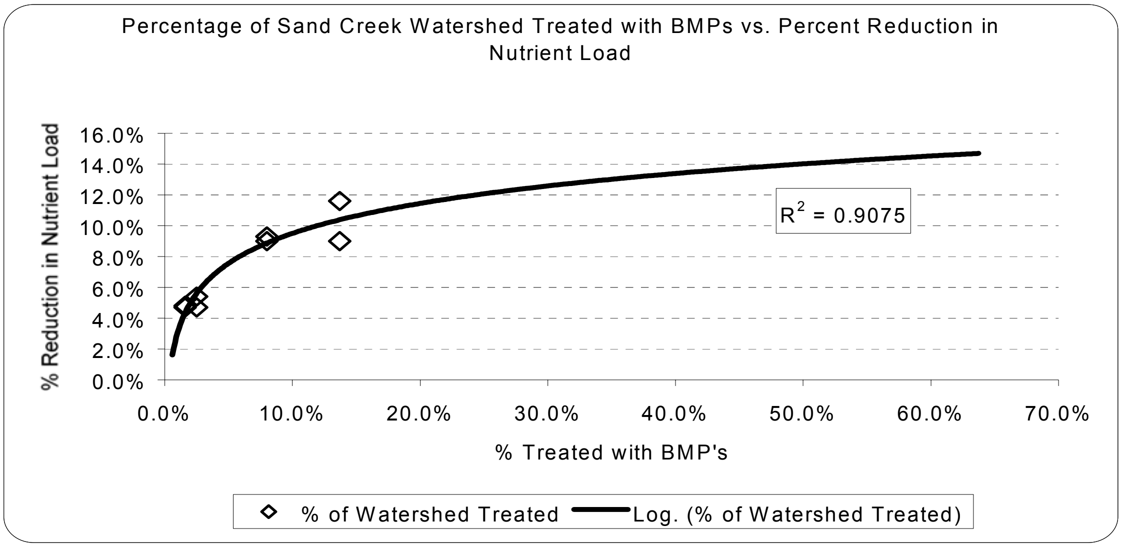

Figure 25. Percent of Sand Creek Watershed Treated with BMPs vs. Percent of Nutrient Load Reduced

The AGNPS program is not designed to adequately assess range conditions. The Sand Creek watershed is composed of 48% rangeland and 40% cropland. The three cells that were indicated as priority 4 cells for grazing management (27,186, and 467) only represent a small portion of the cells that may benefit from improved grazing management practices. Rotational grazing and exclusion of livestock from critical areas (steep slopes adjacent to the lake and stream) will provide benefits that are difficult to simulate in this model. Estimates of 20% to 40% of the rangeland in Hand County were identified in the Lake Louise/ Wolf Creek watershed assessment as needing some type of improved grazing management practices. Using these estimates for all of Hand County would indicate that approximately 4,500 to 9,000 acres would benefit from grazing management practices.

When using a model to simulate actual events that occur in the natural environment, a certain amount of error is expected. This error is dependent on the quality of the model, the quality of the data collected, and the quality of the actual measurements that are used to compare with the model data. Table 25 represents a comparison between the AGNPS data collected for the Sand Creek watershed and those measurements that were made in the field. The differences range from as small as 1% for nitrogen measurements at site RLT-5 (inlet to Rose Hill Lake) to as great as 68% for phosphorus measurements at RLO-1 (outlet to Rose Hill Lake). The mean difference for phosphorus loads was 30% while nitrogen was 18% resulting in an overall average of 24%.

The greatest differences were observed for site RLO-1. This is likely the result of shoreline and bank stabilization problems identified in the tributaries section of the report. This type of erosion was not accounted for in the model, likely resulting in the underestimation by the model. Considering that there was a definite underestimation that occurred at site RLO-1, the remaining percent differences between modeled and actual loads reduce to 20% and 15% for phosphorus and nitrogen respectively. It is likely that the watershed will respond to Best Management Practices in much the same way the model has predicted.

If the bank stabilization problems are the primary source of phosphorus between RLT-5 and the outlet to the lake, then it is likely that the model may be accurately predicting the discharge that will occur if the banks are stabilized. This would indicate reductions in phosphorus of 20% to 40%. These percentages seem high suggesting there are additional sources of phosphorus located in this area. To make a conservative estimate, bank stabilization practices could be expected to reduce loads by at least 10%.

Table 27. AGNPS Predicted Loads and Flux Calculated Loads for Sand Creek

Site	Parameter	Calculated (AGNPS in kg)	Measured (Flux in kg)	Difference	% Difference
RLT-6	Phosphorus	585	524	61	11%
	Nitrogen	2,496	4,073	1,577	48%
RLT-2	Phosphorus	708	972	264	31%
	Nitrogen	2,677	2,604	73	3%
RLT-3	Phosphorus	2,240	1,955	285	14%
	Nitrogen	5,688	5,093	595	11%
RLT-5	Phosphorus	5,363	6,936	1,573	26%
	Nitrogen	20,725	20,488	237	1%
RLO-1	Phosphorus	4,607	9,319	4,712	68%
	Nitrogen	20,631	27,853	7,222	30%

Total watershed reductions calculated for the proposed AGNPS Best Management Practices include a 9.0% reduction in nitrogen and an 11.6% reduction in phosphorus loading to the lake. With the data available, it would not be possible to accurately estimate the reductions that are possible from grazing management practices. It is recognized that they do ultimately improve water quality and should be a part of any restoration efforts conducted in this watershed. The bank stability problems identified in the lower reaches of the watershed should also be addressed. This increases the reduction in phosphorus loading to 21.6% for the BMPs discussed.

Sediment Survey

The amount of soft sediment in the bottom of a lake may be used as an indicator of the volume of erosion occurring in its watershed and along its shoreline. The soft sediment on the bottom of lakes is often rich in phosphorus. When lakes turn over in the spring and fall, sediment and attached nutrients are suspended in the water column making them available for plant growth. The accumulation of sediments in the bottom of lakes may also have a negative impact on fish and aquatic invertebrates. Sediment accumulation may often cover bottom habitat used by these invertebrate species. The end result may be a reduction in the diversity of aquatic insect, snail and crustacean species.

The sediment survey conducted on January 4, 2001 revealed an average sediment depth of .88 meter covered by an average water depth of 2.8 meters. Rose Hill Lake is approximately 33.8 acres in size resulting in a total sediment accumulation of 120,905 m^3 of sediment. Sediment depths are indicated in Figure 26. It is interesting to note that the two areas with the greatest amount of accumulated sediment are located in the center of the lake. These sites are immediately adjacent to the areas that livestock regularly access the lake for drinking and loafing. Removal of the sediment would increase the mean depth to 3.7 meters resulting in a TSI shift of approximately 2-3 points.

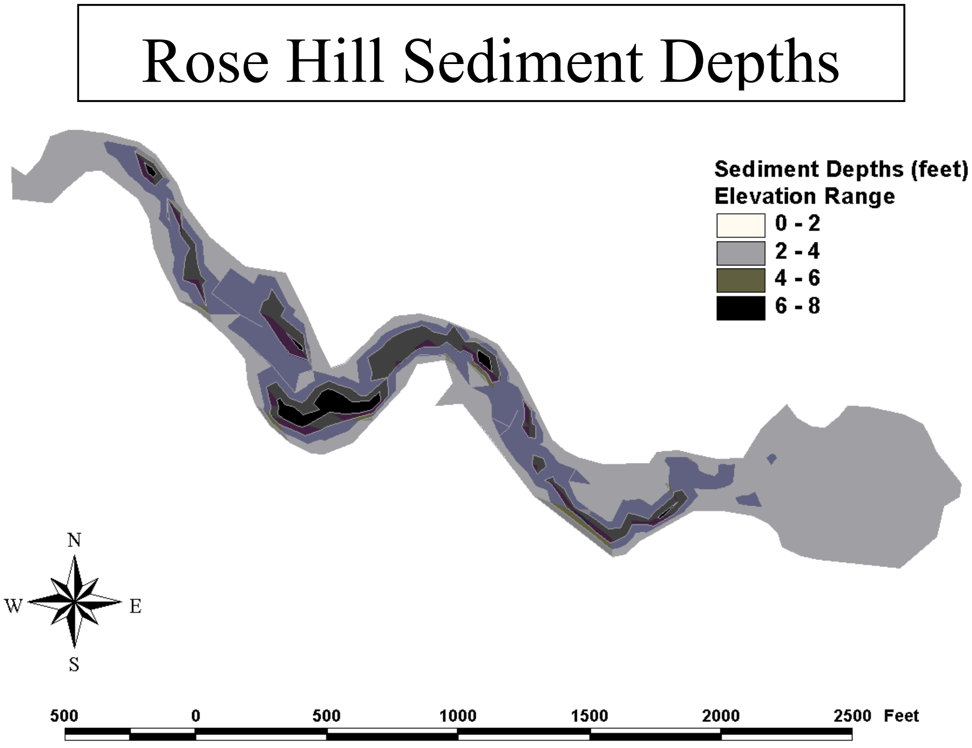

Figure 26. Sediment Depths in Rose Hill Lake

Elutriate test results indicated low to undetectable levels of all contaminants tested for with the exception of Atrazine. Atrazine is a broad-leaf, pre-emergence herbicide. Eighty million pounds are applied to soils annually in the United States, more than any other herbicide. Atrazine is the leading member of a class of triazine ring-containing herbicides that includes simazine and terbuthylazine. Atrazine has been found to be less biodegradable than other less substituted s-triazine ring compounds with a half-life ranging from 1 week to 1 year in different soils. The Triazine Metapathway Map contains additional information on triazine metabolism. Information about the transport, movement, leaching and mobility of atrazine (162k) is also available. A number of different bacteria have been identified that are capable of metabolizing atrazine to ammonia and carbon dioxide. (Minnesota, 2001) Results of the elutriate tests may be found in table 26.

Table 28. Elutriate Test Toxins for Rose Hill Lake

Parameter	Water	Elutriate	units
COD	40.9	47.9	mg/L
Phosphorus	0.793	0.295	mg/L
TKN	1.56	5.03	mg/L
Hardness	270	280	mg/L
Nitrate	0.1	0.1	mg/L
Aluminum	8	57	ug/L
Zinc	<3	<3	ug/L
Silver	<.2	<.2	ug/L
Selenium	1.2	0.7	ug/L
Nickel	6.4	6.4	ug/L
Mercury	<.2	<.2	ug/L
Lead	<.1	<.1	ug/L
Copper	2.2	1.3	ug/L
Cadmium	<.2	<.2	ug/L
Arsenic	5	6.4	ug/L
Nitrite	<.02	<.02	mg/L
Atrazine	3.11	2.07	ug/L
Ammonia	0.43	3.07	mg/L

The atrazine level for the water sample was slightly above EPA's maximum contaminant level of 3 ppb. There are no aquatic life standards established in the United States, however Canadian water quality guidelines lists a maximum level of 1.8 ppb. Maximum limits for agricultural uses are 10 ppb for irrigation waters and 5 ppb for livestock water. Secondary samples collected on October 3, 2001 were analyzed for a number of pesticides commonly used in South Dakota as well as atrazine. Again, the only pesticide detected was atrazine. As was expected prior to sampling, the levels had decreased as a result of the natural breakdown of the compound. Two water samples and two elutriate samples were collected, all of which had detectable levels of atrazine. As in the earlier samples, the water had higher levels at 1.55 ppb in each sample while the mud had concentrations of 1.02 and 1.19 ppb.

It is difficult to determine whether this was a one-time contamination or a recurring problem in this watershed. Remediation steps should include information and educational materials dealing with safe pesticide use and disposal. Additional testing (preferrably on a monthly bases for a two year period of time) for this compound is also advisable.

Quality Assurance Reporting (QA/QC)

Quality assurance and quality control or QA/QC samples were collected for 10% of the inlake and tributary samples taken. A total of 34 tributary samples and 32 lake samples were collected along with seven sets of replicates and blanks. All QA/QC samples may be found in Table 27, with blank samples that were above the detection limit highlighted.

Blank samples were very clean with the exception of nitrate concentrations. Even when the sample and the replicate were below the detection limit, the blank was recorded at the detection limit. It is unclear why there was a consistent hit of the same value for all of the nitrate tests. It is likely that the distilled water supply was contaminated. It is unlikely that the bottles or lab techniques were inadequate, as undetectable levels were measured in four of the replicates and four of the samples. Due to the large number of samples in which nitrates were not detected, the fact that the distilled water supply had nitrate contamination will have little or no impact on the results of the assessment.

Two detectable hits that were recorded for total solids and one for total phosphorus was also recorded in the blank samples. The levels at which they were detected were slightly above the detection limits for each of these parameters. The phosphorus detection was .004 mg/L, which is twice the detection limit of .002 mg/L. This level of contamination would represent approximately a 1% shift in the typical sample collected from Sand Creek or Rose Hill Lake. The total solids detections of 9 and 12 mg/L are less than twice the detection limit of 7 mg/L. This level of contamination would represent less than a 1% change in the average sample collected.

Replicate samples for alkalinity, total solids, nitrates, and dissolved phosphorus were all within 10% of the actual samples. Total phosphorus and *E. coli* were 14% and 18% respectively. They would have fallen within the 10% range, however, each had two samples with differences of approximately 30%. Samples that posed the greatest differences were chlorophyll *a*, suspended solids, Total Kjeldahl Nitrogen (TKN), and volatile suspended solids.

Volatile solids may be considered the least reliable of the data with an average percent difference of 70%. The other parameters mentioned had 20% to 30% difference between the replicate and the sample with the exception of TKN.

TKN had a 38% difference as a result of the sample collected on May 14, 2001 that had a difference of 182%. There is no evident explanation for this large difference other than an anomaly of nature or sampling. Removing this sample as an outlier reduces the percent difference for TKN to less than 10% placing it among the most accurate of the parameters tested.

Table 29. Quality Assurance and Quality Control Samples For Sand Creek Monitoring Stations

SITE	DATE	TYPE	Chl-A	Talka	TSOL	TSSOL	AMMO	NIT	TKN	TPO4	TDPO4	VTSS	Fecal	E COLI
RLT-2	5/14/01	Grab		125	400	5	<0.02	0.1	0.1	1.89	1.34	<1	50	86
RLT-12	5/14/01	Replicate		126	399	8	<0.02	0.1	2.15	1.28	1.36	2	60	88.4
RLT-92	5/14/01	Blank		<6	<7	<1	<0.02	**0.1**	<0.36	<0.002	<0.002	<1	<10	<1
				1%	0%	46%	No Det	0%	182%	38%	1%	No Det	18%	3%
RLT-3	5/14/01	Grab		131	472	7	<0.02	0.1	1.6	0.907	0.804	4	30	22.8
RLT-13	5/14/01	Replicate		132	477	6	<0.02	0.1	1.45	0.873	0.776	1	60	21.6
RLT-93	5/14/01	Blank		<6	<7	<1	<0.02	**0.1**	<0.36	<0.002	<0.002	<1	<10	<1
				1%	1%	15%	No Det	0%	10%	4%	4%	120%	67%	5%
RLT-4	5/21/01	Grab		282	1506	6	<0.02	<0.1	1.31	0.345	0.322	<1	820	1553
RLT-14	5/21/01	Replicate		281	1505	5	<0.02	<0.1	1.51	0.349	0.317	<1	660	1120
RLT-94	5/21/01	Blank		<6	**9**	<1	<0.02	**0.1**	<0.36	<0.002	**0.004**	<1	<10	<1
				0%	0%	18%	No Det	No Det	14%	1%	2%	No Det	22%	32%
RLT-5	5/24/01	Grab		252	1142	82	<0.02	<0.1	0.61	0.241	0.096	8	470	488
RLT-15	5/24/01	Replicate		257	1180	114	<0.02	<0.1	0.51	0.185	0.093	10	550	687
RLT-95	5/24/01	Blank		<6	<7	<1	<0.02	**0.1**	<0.36	<0.002	<0.002	<1	<10	<1
				2%	3%	33%	No Det	No Det	18%	26%	3%	22%	16%	34%
RL-1	6/6/00	Grab	14.42	213	1178	16	<.02	<.1	1.29	0.095	0.031	5.0	<10	
RL-11	6/6/00	Replicate	18.02	211	1178	16	<.02	0.10	1.35	0.083	0.036	1.0	10	
RL-9	6/6/00	Blank		<6	<7	<1	<.02	<.1	<.21	<.002	<.002	<1	<10	
			22%	1%	0%	0%	No Det	No Det	5%	13%	15%	133%	No Det	
RL-2	11/2/00	Grab	59.97	184	1175	20	<.02	<.1	1.52	0.304	0.156	8.0	280	
RL-12	11/2/00	Replicate	NA	183	1170	21	<.02	<.1	1.41	0.291	0.154	5.0	220	
RL-9	11/2/00	Blank		<6	**12**	<1	<.02	**0.1**	<.21	<.002	<.002	<1	<10	
				1%	0%	5%	No Det	No Det	8%	4%	1%	46%	24%	
RL-1	9/28/00	Grab	26.68	174	1125	10	<.02	<.1	1.36	0.346	0.252	6.0	<10	
RL-11	9/28/00	Replicate	37.54	173	1135	16	<.02	<.1	1.37	0.374	0.245	8.0	<10	
RL-9	9/28/00	Blank		<6	<7	<1	<.02	**0.1**	<.21	<.002	<.002	<1	<10	
			34%	1%	1%	46%	No Det	No Det	1%	8%	3%	29%	No Det	
Average Percent Difference			28%	1%	1%	23%		0%	34%	14%	4%	70%	29%	18%

Public involvement and coordination

State Agencies

The South Dakota Department of Environment and Natural Resources (SDDENR) was the primary state agency involved in the completion of this assessment. SDDENR provided equipment as well as technical assistance throughout the course of the project.

The South Dakota Department of Game, Fish and Parks also aided in the completion of the assessment by providing use historical information on the recreation area and a complete report on the condition of the fishery in Rose Hill Lake.

Federal Agencies

The Environmental Protection Agency (EPA) provided the primary source of funds for the completion of the assessment on Rose Hill Lake.

The Natural Resource Conservation Service (NRCS) provided technical assistance, particularly in the collection of soils data for the AGNPS portion of the report.

The Farm Service Agency provided a great deal of information that was utilized in the completion of the AGNPS modeling portion of the assessment.

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

The Central Plains Water Development District (CPWDD) provided the local sponsorship that made this project possible. In addition to providing administrative sponsorship, CPWDD also provided local matching funds and personnel to complete the assessment.

The Hand County Conservation District provided work space, financial assistance, and aided in the completion of the AGNPS report.

Public involvement consisted of some individual meetings with landowners that provided a great deal of historic perspective on the watershed. Additionally, landowners were contacted through mailings to which most responded with information needed to complete the AGNPS model.

Aspects of the Project That Did Not Work Well

All of the objectives proposed for the project were met in an acceptable fashion and in a reasonable time frame. The number of tributary samples collected during the project was less than proposed, but adequate for the completion of the report. The exception to this was the collection of data from site RLT-4, which was the result of weather related access problems.

Quality Assurance and Quality Control samples were not significantly impacted by the quality of distilled water used, however future projects in this area should attempt to locate a source of distilled water with no detectable nitrate concentration.

Future Activities Recommendations

There are a number of concerns that need to be addressed in the Sand Creek and Rose Hill Lake watershed. Best Management Practices in the watershed are expected to reduce phosphorus loads to the lake in excess of 20%.

The mean phosphorus concentration during the growing season was approximately .3 mg/L. An alum treatment with an effective reduction of 30% would result in a mean phosphorus concentration of .21 mg/L. This is similar to what would be achieved from a 40% reduction in watershed loadings. Similar reductions in phosphorus concentrations may also be expected through intensive aeration of the water column to the sediment interface.

The reductions from the alum treatment and the watershed reductions can not be effectively modeled together. It is expected that the combination of these treatments will result in conditions similar to what would be expected from just a 50% reduction in the watershed loading with a resulting TSI shift of 4 points, giving the lake a trophic state of less than 65 which fully supports its beneficial uses.

Mitigation procedures should include all of those listed in the AGNPS section of the report. These include reduced tillage practices, grass waterways or buffer strips where applicable, four animal waste treatment systems, and between 4,500 and 9,000 acres of grazing management practices. Bank stabilization may be achieved through the use of buffer strips and livestock exclusion in the most critical areas.

In addition to “on the ground” management practices, the use of informational meetings and materials will also aid in local understanding and involvement in a project. Continued monitoring as well as a post-implementation assessment should be completed if any or all of the discussed mitigation procedures are completed.

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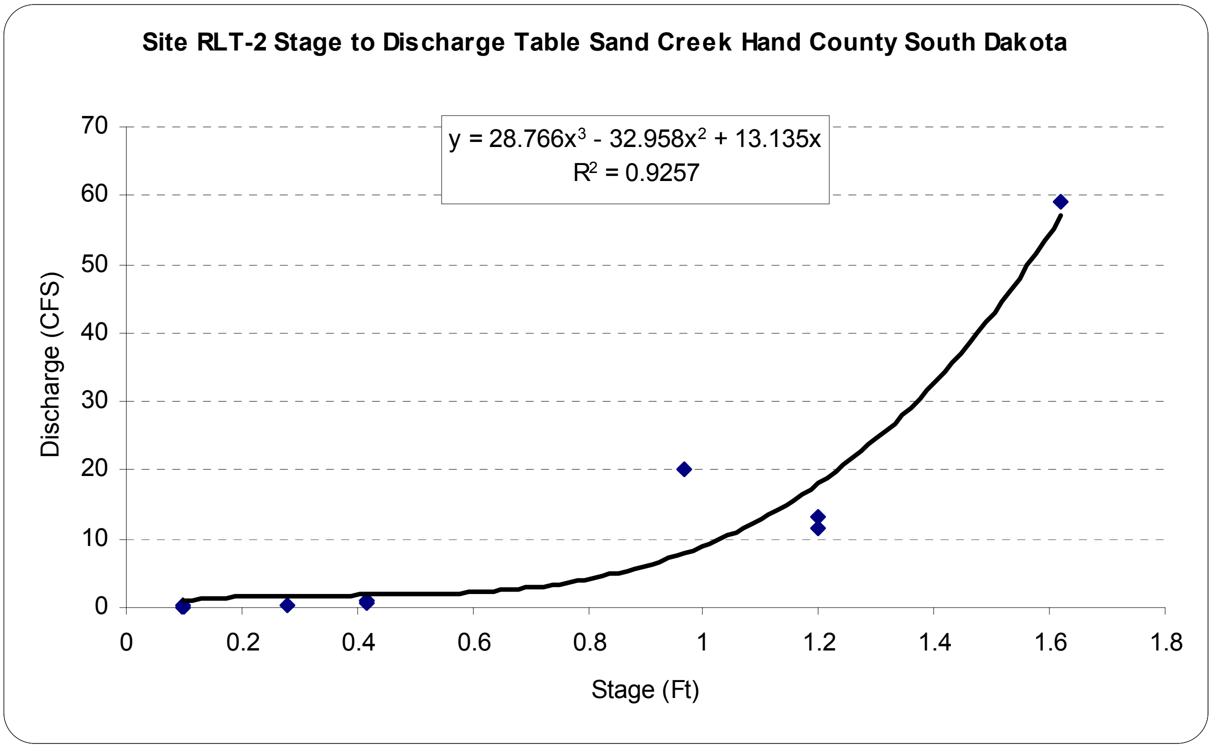
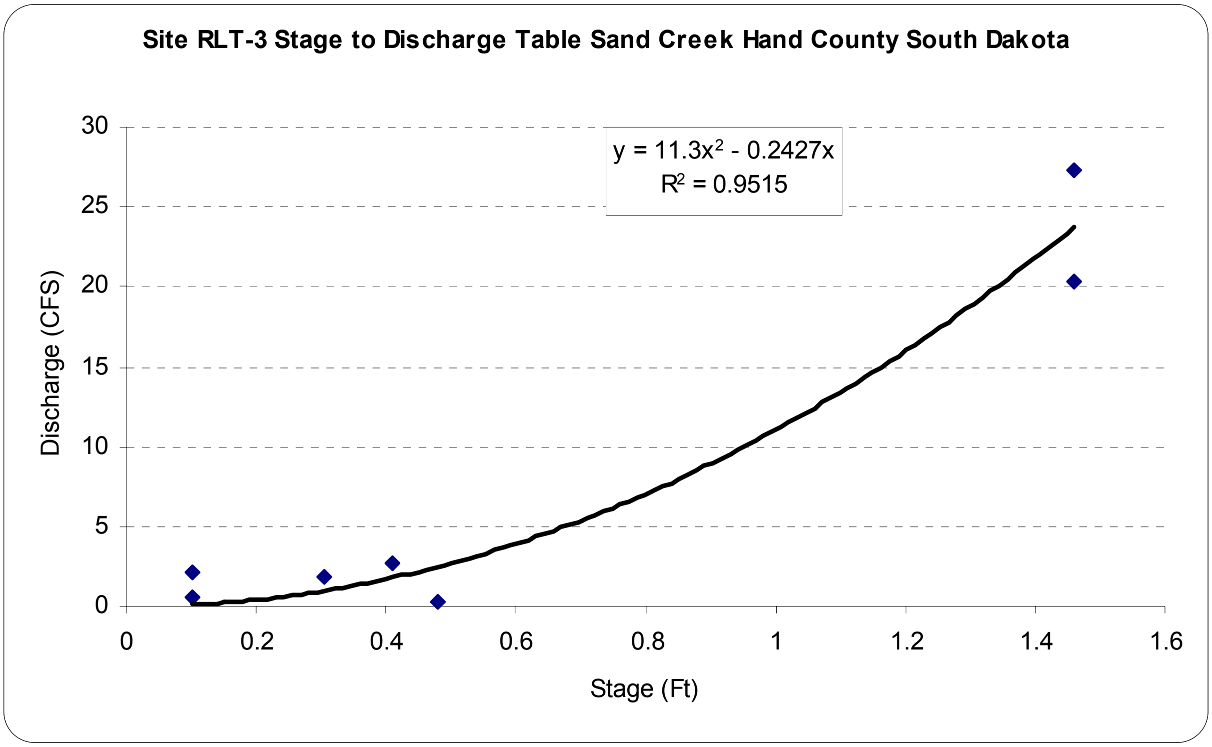
List of Tables

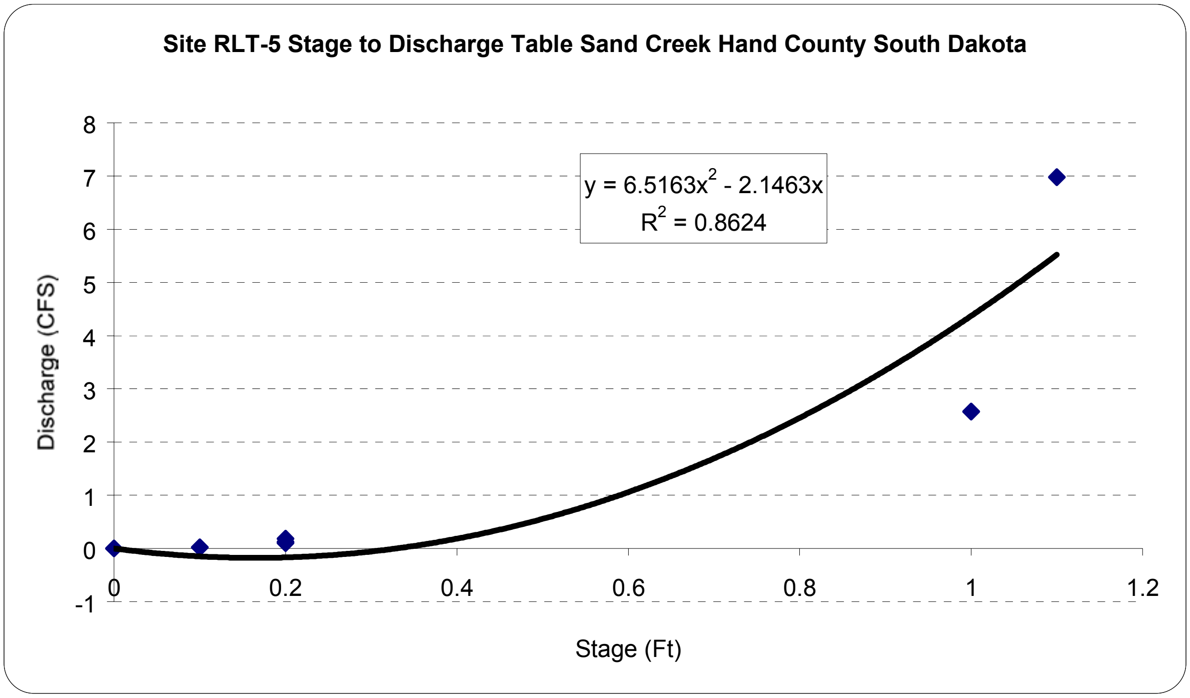
List of Figures

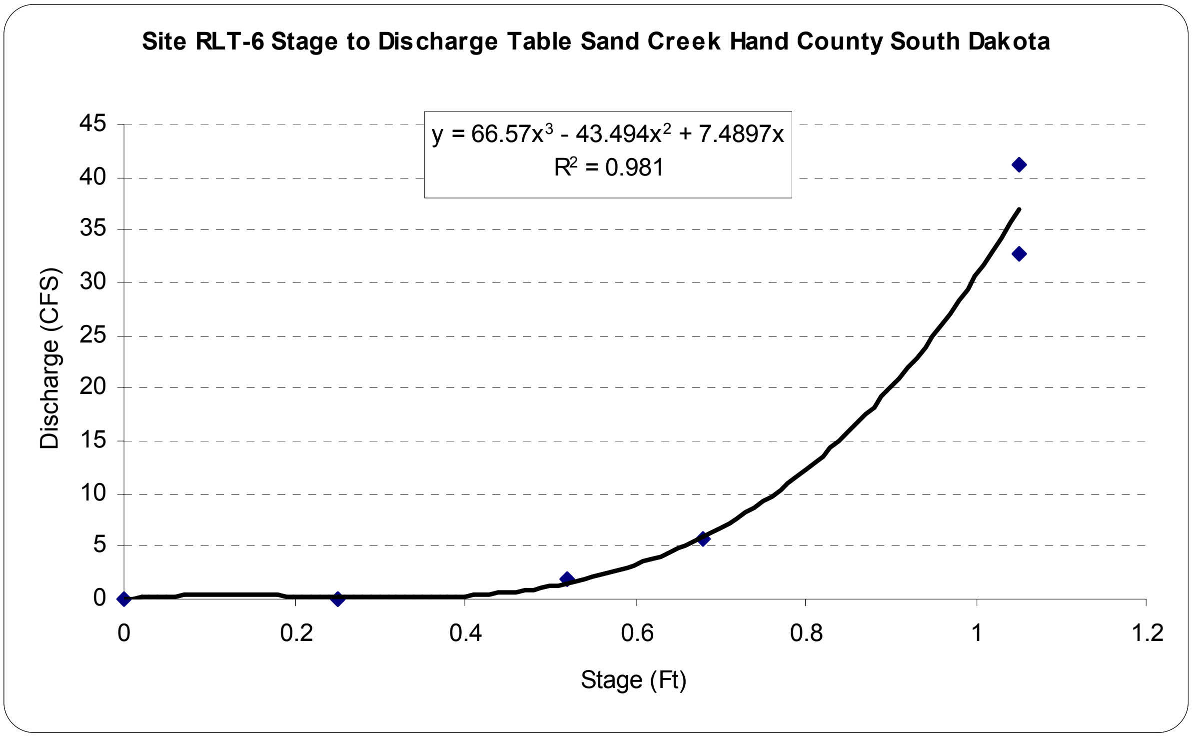
List of Appendices

Appendix A. Stage to Discharge Tables






Site RLT-5 Stage to Discharge Table Sand Creek Hand County South Dakota
y = 6.5163x2 - 2.1463x
R2 = 0.8624
Discharge (CFS)
8
7
6
5
4
3
2
1
0
-1
0
0.2
0.4
0.6
0.8
1
1.2
Stage (Ft)


Site RLT-6 Stage to Discharge Table Sand Creek Hand County South Dakota
y = 66.57x3 - 43.494x2 + 7.4897x
R2 = 0.981
Discharge (CFS)
45
40
35
30
25
20
15
10
5
0
0
0.2
0.4
0.6
0.8
1
1.2
Stage (Ft)

Appendix B. Tributary Sample Data

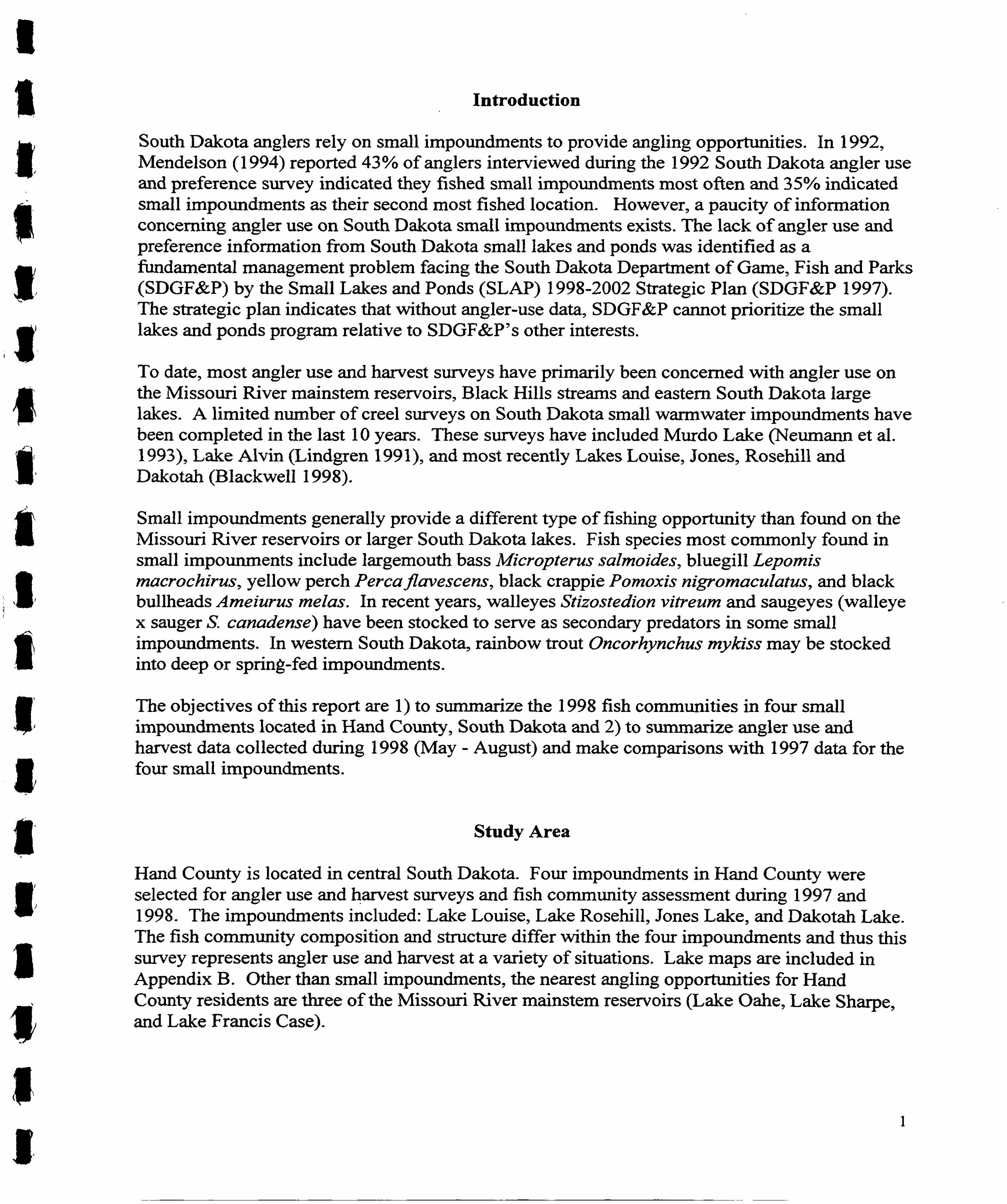
station	date	cfs	talka	tsol	tssol	tvsol	ammo	nit	tkn	tp	tdp	tnit	onit	inonit
RLO-1	04/10/01		38	194	33	7	0.24	0.7	0.77	0.559	0.366	1.47	0.53	0.94
RLO-1	04/16/01		69	375	28	2	0.23	0.6	1.39	0.566	0.435	1.99	1.16	0.83
RLO-1	04/18/01		77	411	30	5	0.26	0.6	1.38	0.546	0.442	1.98	1.12	0.86
RLO-1	04/25/01		75	479	96	0.5	0.2	0.5	1.68	0.7	0.418	2.18	1.48	0.7
RLO-1	05/01/01		72	307	15	2	0.08	0.4	1.17	0.476	0.392	1.57	1.09	0.48
RLT-5	04/05/01		96	409	8	4	0.33	0.4	0.81	0.435	0.366	1.21	0.48	0.73
RLT-5	04/10/01		54	244	14	4	0.16	0.7	0.95	0.559	0.463	1.65	0.79	0.86
RLT-5	04/18/01		112	523	21	2	0.09	0.4	1.14	0.48	0.418	1.54	1.05	0.49
RLT-5	05/31/00		183	1261	10	3	0.1	0.1	0.79	0.266	0.154	0.89	0.69	0.2
RLT-5	06/26/00		172	1436	17	4	0.04	0.05	1.02	0.38	0.299	1.07	0.98	0.09
RLT-5	05/24/01		252	1142	82	8	0.01	0.05	0.61	0.241	0.096	0.66	0.6	0.06
RLT-2	04/05/01		39	145	4	0.5	0.04	0.4	0.53	0.636	0.588	0.93	0.49	0.44
RLT-2	04/10/01		38	142	7	3	0.46	0.6	1.62	0.898	0.877	2.22	1.16	1.06
RLT-2	04/18/01		64	233	8	3	0.01	0.2	1.64	0.923	0.86	1.84	1.63	0.21
RLT-2	04/24/01		47	205	22	3								
RLT-2	04/25/01		31	151	12	0.5	0.01	0.5	1.52	0.534	0.481	2.02	1.51	0.51
RLT-2	05/02/01		90	291	5	1	0.01	0.05	1.82	0.982	0.988	1.87	1.81	0.06
RLT-2	05/07/01		74	298	14	6	0.01	0.1	1.97	0.906	0.803	2.07	1.96	0.11
RLT-2	05/14/01		125	400	5	0.5	0.01	0.1	1.89	1.34	1.34	1.99	1.88	0.11
RLT-6	04/10/01		28	127	15	4	0.05	0.9	0.93	0.464	0.401	1.83	0.88	0.95
RLT-6	04/18/01		47	177	21	5	0.01	0.3	0.98	0.39	0.346	1.28	0.97	0.31
RLT-6	04/25/01		19	174	50	2	0.08	1.4	1.72	0.389	0.314	3.12	1.64	1.48
RLT-6	05/07/01		39	229	24	0.5	0.03	0.9	2.11	0.403	0.225	3.01	2.08	0.93
RLT-4	05/31/01		207	2306	20	5	0.01	0.05	1.89	0.307	0.172	1.94	1.88	0.06
RLT-4	04/18/01		125	807	10	2	0.01	0.05	1.49	0.491	0.446	1.54	1.48	0.06
RLT-4	04/30/01		143	769	3	0.5	0.01	0.05	1.31	0.452	0.426	1.36	1.3	0.06
RLT-4	05/02/01		185	1090	4	2	0.01	0.05	1.29	0.461	0.414	1.34	1.28	0.06
RLT-4	05/21/01		282	1506	6	0.5	0.01	0.05	1.31	0.345	0.322	1.36	1.3	0.06
RLT-3	04/10/01		39	160	12	1	0.3	0.7	1.49	0.798	0.677	2.19	1.19	1
RLT-3	04/18/01		58	249	9	2	0.01	0.5	1.16	0.694	0.622	1.66	1.15	0.51
RLT-3	04/30/01		76	277	2	1	0.03	0.05	1.15	0.734	0.673	1.2	1.12	0.08
RLT-3	05/02/01		90	324	6	2	0.01	0.05	1.37	0.73	0.666	1.42	1.36	0.06
RLT-3	05/05/01		105	465	27	9								
RLT-3	05/14/01		131	472	7	4	0.01	0.1	1.6	0.907	0.804	1.7	1.59	0.11

Appendix C. Lake Sample Data

SAMPLER	TYPE	SITE	DATE	SAMPLE DEPTH	Chl-A	Water Temp	SECCHI	DO	Cond	Turb	pH	TALK	Tot Sol	TDS	TSS	Amm	Nit	TKN	TP	TDP	Fecal	VTSS	Total N	Inorg	Org	Att P
Kruger/Nielsen	Grab	RL-1	6-Jun-00	Surface	14.42	16.61		9.92	1496	44.9	8.57	213	1178	1083	16	0.01	0.05	1.29	0.095	0.031	5	5.0	1.34	0.060	1.28	0.064
Kruger/Nielsen	Grab	RL-2	6-Jun-00	Surface	9.21	17.93		9.73	1570	82.5	8.53	211	1190	1104	21	0.01	0.05	0.92	0.101	0.041	10	5.0	0.97	0.060	0.91	0.060
Kruger/Nielsen	Grab	RL-1	6-Jun-00	Bottom		14.57		0.38	1433	301.1	7.96	217	1196	1085	35	0.12	0.05	1.09	0.166	0.050		7.0	1.14	0.170	0.97	0.116
Kruger/Nielsen	Grab	RL-2	6-Jun-00	Bottom		16.80		5.81	1529	344.7	8.39	210	1208	1091	40	0.01	0.05	0.78	0.199	0.051		8.0	0.83	0.060	0.77	0.148
Kruger/Nielsen	Grab	RL-1	20-Jun-00	Surface	16.52	20.67	0.9	9.50	1706	36.4	8.36															
Kruger/Nielsen	Grab	RL-2	20-Jun-00	Surface	15.02	20.59	0.4	7.46	1728	142.2	8.37															
Kruger/Nielsen	Grab	RL-1	20-Jun-00	Bottom		13.29		0.37	1446	179.3	7.72															
Kruger/Nielsen	Grab	RL-2	20-Jun-00	Bottom		19.92		6.30	1697	195.6	8.29															
Kruger/Nielsen	Grab	RL-1	5-Jul-00	Surface	6.31	26.85	1.0	10.26	1839	40.8	8.79	141	1151	1123	11	0.01	0.05	1.18	0.066	0.024	5	3.0	1.23	0.060	1.17	0.042
Kruger/Nielsen	Grab	RL-2	5-Jul-00	Surface	11.21	27.14	1.3	13.01	1900	55.3	8.76	148	1155	1136	8	0.01	0.05	1.05	0.073	0.025	20	2.0	1.10	0.060	1.04	0.048
Kruger/Nielsen	Grab	RL-1	5-Jul-00	Bottom		16.32		0.84	1553	85.9	7.62	227	1194	1148	22	0.61	0.05	2.04	0.565	0.342		2.0	2.09	0.660	1.43	0.223
Kruger/Nielsen	Grab	RL-2	5-Jul-00	Bottom		25.43		6.75	1828	75.3	8.67	158	1172	1125	26	0.01	0.05	0.98	0.113	0.044		6.0	1.03	0.060	0.97	0.069
Kruger/Nielsen	Grab	RL-1	19-Jul-00	Surface	28.74	21.97	1.0	4.07	1688	43.0	7.88															
Kruger/Nielsen	Grab	RL-2	19-Jul-00	Surface	41.44	21.91	0.8	7.51	1665	57.7	8.18															
Kruger/Nielsen	Grab	RL-1	19-Jul-00	Bottom		15.91		0.65	1568	58.4	7.16															
Kruger/Nielsen	Grab	RL-2	19-Jul-00	Bottom		21.05		5.69	1631	66.8	8.12															
Kruger/Nielsen	Grab	RL-1	3-Aug-00	Surface	28.55	24.88	0.8	7.93	1788	55.4	8.54	134	1150	1075	19	0.01	0.05	1.37	0.314	0.076	5	13.0	1.42	0.060	1.36	0.238
Kruger/Nielsen	Grab	RL-2	3-Aug-00	Surface	34.33	25.41	0.6	8.89	1806	65.3	8.60	132	1156	1076	13	0.01	0.05	0.98	0.237	0.079	10	7.0	1.03	0.060	0.97	0.158
Kruger/Nielsen	Grab	RL-1	3-Aug-00	Bottom		15.28		3.90	1561	47.8	6.99	239	1171	1102	13	1.01	0.05	1.73	0.951	0.912		3.0	1.78	1.060	0.72	0.039
Kruger/Nielsen	Grab	RL-2	3-Aug-00	Bottom		24.91		7.15	1795	67.8	8.58	134	1166	1092	18	0.01	0.05	1.00	0.174	0.092		4.0	1.05	0.060	0.99	0.082
Kruger/Nielsen	Grab	RL-1	15-Aug-00	Surface	28.50	25.90	1.3	7.62	1786	29.6	8.56															
Kruger/Nielsen	Grab	RL-2	15-Aug-00	Surface	35.85	25.57	1.0	7.32	1782	35.8	8.56															
Kruger/Nielsen	Grab	RL-1	15-Aug-00	Bottom		16.54		1.23	1576	42.1	7.09															
Kruger/Nielsen	Grab	RL-2	15-Aug-00	Bottom		25.05		6.34	1768	99.8	8.55															
Kruger/Nielsen	Grab	RL-1	31-Aug-00	Surface	8.51	24.87	1.5	8.28	1788	53.2	8.53	152	1084	986	7	0.01	0.05	1.04	0.377	0.302	5	4.0	1.09	0.060	1.03	0.075
Kruger/Nielsen	Grab	RL-2	31-Aug-00	Surface	20.33	25.16	1.0	8.12	1800	51.2	8.60	153	1086	991	11	0.04	0.05	1.06	0.344	0.251	30	8.0	1.11	0.090	1.02	0.093
Kruger/Nielsen	Grab	RL-1	31-Aug-00	Bottom		15.28		3.90	1561	47.8	6.99	158	1073	985	7	0.09	1.09	1.09	0.481	0.380		5.0	2.18	1.180	1.00	0.101
Kruger/Nielsen	Grab	RL-2	31-Aug-00	Bottom		24.91		7.15	1795	67.8	8.58	154	1115	1106	14	0.01	0.05	0.98	0.363	0.264		8.0	1.03	0.060	0.97	0.099
Kruger/Nielsen	Grab	RL-1	14-Sep-00	Surface	26.98	19.65	1.3	10.34	1627	27.1	8.43															
Kruger/Nielsen	Grab	RL-2	14-Sep-00	Surface	34.43	19.70	1.0	12.10	1616	37.5	8.55															
Kruger/Nielsen	Grab	RL-1	14-Sep-00	Bottom		18.82		3.09	1608	27.7	8.10															
Kruger/Nielsen	Grab	RL-2	14-Sep-00	Bottom		19.55		10.68	1618	37.7	8.51															
Kruger/Nielsen	Grab	RL-1	28-Sep-00	Surface	26.68	13.84	1.2	10.78	1435	31.2	8.44	174	1125	1069	10	0.01	0.05	1.36	0.346	0.252	5	6.0	1.41	0.060	1.35	0.094
Kruger/Nielsen	Grab	RL-2	28-Sep-00	Surface	6.36	13.83	1.0	10.84	1439	36.7	8.59	174	1136	1073	15	0.01	0.05	1.38	0.353	0.236	10	8.0	1.43	0.060	1.37	0.117
Kruger/Nielsen	Grab	RL-1	28-Sep-00	Bottom		12.32		2.49	1387	22.9	7.98	175	1120	1057	4	0.12	0.05	0.84	0.326	0.266		0.5	0.89	0.170	0.72	0.060
Kruger/Nielsen	Grab	RL-2	28-Sep-00	Bottom		13.31		9.09	1418	25.7	8.41	175	1135	1062	15	0.06	0.05	1.37	0.347	0.221		11.0	1.42	0.110	1.31	0.126
Kruger/Nielsen	Grab	RL-1	11-Oct-00	Surface	30.66	9.52	1.1	9.44	1284	28.3	8.25															
Kruger/Nielsen	Grab	RL-2	11-Oct-00	Surface	31.09	9.67	0.8	11.01	1304	41.1	8.52															
Kruger/Nielsen	Grab	RL-1	11-Oct-00	Bottom		9.06		6.71	1269	35.0	8.12															

SAMPLER	TYPE	SITE	DATE	SAMPLE DEPTH	Chl-A	Water Temp	SECCHI	DO	Cond	Turb	pH	TALK	Tot Sol	TDS	TSS	Amm	Nit	TKN	TP	TDP	Fecal	VTSS	Total N	Inorg	Org	Att P
Kruger/Nielsen	Grab	RL-2	11-Oct-00	Bottom		9.64		8.96	1309	64.3	8.32															
Kruger/Nielsen	Grab	RL-1	2-Nov-00	Surface	2.20	10.80	0.7	9.85	1343	75.3	8.05	185	1149	1130	19	0.07	0.10	1.96	0.288	0.188	5	7.0	2.06	0.170	1.89	0.100
Kruger/Nielsen	Grab	RL-2	2-Nov-00	Surface	59.97	9.17	0.5	10.23	1252	74.7	8.29	184	1175	1155	20	0.01	0.05	1.52	0.304	0.156	280	8.0	1.57	0.060	1.51	0.148
Kruger/Nielsen	Grab	RL-1	2-Nov-00	Bottom		10.84		7.71	1316	71.1	8.14	185	1165	1148	17	0.07	0.10	1.43	0.278	0.182		4.0	1.53	0.170	1.36	0.096
Kruger/Nielsen	Grab	RL-2	2-Nov-00	Bottom		9.16		10.13	1252	91.2	8.25	185	1170	1147	23	0.01	0.50	1.77	0.305	0.157		8.0	2.27	0.510	1.76	0.148
Kruger/Nielsen	Grab	RL-1	27-Dec-00	Surface								204	1307	1300	7	0.19	0.10	1.80	0.202	0.134		5.0	1.90	0.290	1.61	0.068
Kruger/Nielsen	Grab	RL-2	27-Dec-00	Surface								210	1312	1307	5	0.13	0.10	2.03	0.216	0.144		1.0	2.13	0.230	1.90	0.072
Kruger/Nielsen	Grab	RL-1	27-Dec-00	Bottom								212	1346	1342	4	0.29	0.10	1.79	0.192	0.155		1.0	1.89	0.390	1.50	0.037
Kruger/Nielsen	Grab	RL-2	27-Dec-00	Bottom								210	1330	1326	4	0.07	0.10	1.86	0.187	0.134		1.0	1.96	0.170	1.79	0.053
Kruger/Nielsen	Grab	RL-1	9-May-01	Surface		14.35		8.46	586	52.1	7.46	109	501		22	0.03	0.40	1.14	0.570	0.436	1100	7.0				
Kruger/Nielsen	Grab	RL-2	9-May-01	Surface		14.48		8.50	551	53.5	7.44	106	467		21	0.03	0.30	1.25	0.593	0.459	570	4.0				
Kruger/Nielsen	Grab	RL-1	9-May-01	Bottom		4.74		0.83	1112	13.1	7.10	173	810		16	0.87	0.20	1.82	0.583	0.478		5.0				
Kruger/Nielsen	Grab	RL-2	9-May-01	Bottom		12.15		7.07	590	60.7	7.28	111	520		25	0.09	0.40	1.31	0.586	0.475		5.0				
				Surface Avg	23.51	19.19	0.96	9.22	1532.46	52.12	8.37	164.38	1082.63	1114.86	14.06	0.04	0.10	1.33	0.28	0.18	147.14	5.81	1.41	0.10	1.32	0.10
				Surface Max	59.97	27.14	1.50	13.01	1900.00	142.20	8.79	213.00	1312.00	1307.00	22.00	0.19	0.40	2.03	0.59	0.46	1100.00	13.00	2.13	0.29	1.90	0.24
				Surface Min	2.20	9.17	0.40	4.07	551.00	27.10	7.44	106.00	467.00	986.00	5.00	0.01	0.05	0.92	0.07	0.02	5.00	1.00	0.97	0.06	0.91	0.04
				Surface Std Dev	13.95	6.02	0.28	1.86	353.07	24.50	0.35	35.33	241.98	93.47	5.79	0.05	0.10	0.34	0.16	0.14	317.68	2.88	0.38	0.08	0.32	0.05
				Surface Coef. Of Var	0.59	0.31	0.29	0.20	0.23	0.47	0.04	0.21	0.22	0.08	0.41	1.41	1.06	0.26	0.56	0.78	2.16	0.50	0.27	0.77	0.25	0.54
				Average	23.51	17.61	0.96	7.17	1508.31	70.43	8.16	173.53	1100.41	1122.29	15.88	0.13	0.14	1.35	0.32	0.22	147.14	5.36	1.46	0.22	1.24	0.10
				Max	59.97	27.14	1.50	13.01	1900.00	344.70	8.79	239.00	1346.00	1342.00	40.00	1.01	1.09	2.04	0.95	0.91	1100.00	13.00	2.27	1.18	1.90	0.24
				Min	2.20	4.74	0.40	0.37	551.00	13.10	6.99	106.00	467.00	985.00	4.00	0.01	0.05	0.78	0.07	0.02	5.00	0.50	0.83	0.06	0.72	0.04
				Std Deviation	13.95	5.98	0.28	3.34	310.67	64.11	0.51	35.85	217.98	93.65	8.61	0.24	0.21	0.37	0.19	0.19	317.68	2.93	0.45	0.29	0.35	0.05
				Coef of Var	0.59	0.34	0.29	0.47	0.21	0.91	0.06	0.21	0.20	0.08	0.54	1.93	1.50	0.28	0.60	0.85	2.16	0.55	0.31	1.33	0.28	0.51
				Bottom Avg		16.04		5.13	1484.17	88.73	7.96	182.69	1118.19	1129.71	17.69	0.22	0.18	1.37	0.36	0.26		4.91	1.51	0.35	1.16	0.10
				Bottom Max		25.43		10.68	1828.00	344.70	8.67	239.00	1346.00	1342.00	40.00	1.01	1.09	2.04	0.95	0.91		11.00	2.27	1.18	1.79	0.22
				Bottom Min		4.74		0.37	590.00	13.10	6.99	111.00	520.00	985.00	4.00	0.01	0.05	0.78	0.11	0.04		0.50	0.83	0.06	0.72	0.04
				Bottom Std Dev		5.62		3.26	267.13	84.26	0.57	35.06	197.42	96.73	10.61	0.32	0.28	0.42	0.22	0.22		3.00	0.51	0.38	0.36	0.05
				Bottom Coef. Of Var		0.35		0.64	0.18	0.95	0.07	0.19	0.18	0.09	0.60	1.49	1.51	0.30	0.61	0.85		0.61	0.34	1.09	0.31	0.51

Appendix D. Fisheries Report



Introduction

South Dakota anglers rely on small impoundments to provide angling opportunities. In 1992, Mendelson (1994) reported 43% of anglers interviewed during the 1992 South Dakota angler use and preference survey indicated they fished small impoundments most often and 35% indicated small impoundments as their second most fished location. However, a paucity of information concerning angler use on South Dakota small impoundments exists. The lack of angler use and preference information from South Dakota small lakes and ponds was identified as a fundamental management problem facing the South Dakota Department of Game, Fish and Parks (SDGF&P) by the Small Lakes and Ponds (SLAP) 1998-2002 Strategic Plan (SDGF&P 1997). The strategic plan indicates that without angler-use data, SDGF&P cannot prioritize the small lakes and ponds program relative to SDGF&P's other interests.

To date, most angler use and harvest surveys have primarily been concerned with angler use on the Missouri River mainstem reservoirs, Black Hills streams and eastern South Dakota large lakes. A limited number of creel surveys on South Dakota small warmwater impoundments have been completed in the last 10 years. These surveys have included Murdo Lake (Neumann et al. 1993), Lake Alvin (Lindgren 1991), and most recently Lakes Louise, Jones, Rosehill and Dakotah (Blackwell 1998).

Small impoundments generally provide a different type of fishing opportunity than found on the Missouri River reservoirs or larger South Dakota lakes. Fish species most commonly found in small impounments include largemouth bass *Micropterus salmoides*, bluegill *Lepomis macrochirus*, yellow perch *Perca flavescens*, black crappie *Pomoxis nigromaculatus*, and black bullheads *Ameiurus melas*. In recent years, walleyes *Stizostedion vitreum* and saugeyes (walleye x sauger *S. canadense*) have been stocked to serve as secondary predators in some small impoundments. In western South Dakota, rainbow trout *Oncorhynchus mykiss* may be stocked into deep or spring-fed impoundments.

The objectives of this report are 1) to summarize the 1998 fish communities in four small impoundments located in Hand County, South Dakota and 2) to summarize angler use and harvest data collected during 1998 (May - August) and make comparisons with 1997 data for the four small impoundments.

Study Area

Hand County is located in central South Dakota. Four impoundments in Hand County were selected for angler use and harvest surveys and fish community assessment during 1997 and 1998. The impoundments included: Lake Louise, Lake Rosehill, Jones Lake, and Dakotah Lake. The fish community composition and structure differ within the four impoundments and thus this survey represents angler use and harvest at a variety of situations. Lake maps are included in Appendix B. Other than small impoundments, the nearest angling opportunities for Hand County residents are three of the Missouri River mainstem reservoirs (Lake Oahe, Lake Sharpe, and Lake Francis Case).

Lake Louise is approximately 66.8 ha (165 acres) and is located 9.6 km (6 mi) north and 11.3 km (7 mi) west of Miller, South Dakota. The mean depth is 2.4 m (8 ft) and the maximum depth is 6.1 m (20 ft). Submerged vegetation can be found throughout Lake Louise and emergent vegetation surrounds the lake. Recreational facilities can be considered excellent with a maintained state campground, shore and pier fishing opportunities, and a boat-launching ramp.

Lake Rosehill has a maximum depth of 9.2 m (30 ft), an average depth of 4.0 m (13 ft), and a surface area of 14.2 ha (35 acres). Lake Rosehill is located 16.1 km (10 mi) south and 5.6 km (3.5 mi) west of Wessington, South Dakota. Submerged vegetation is abundant in near-shore areas and the upper end of the reservoir. A concrete boat ramp is present, a small picnic area is available for use, and shoreline-fishing access exists. A largemouth bass 381-mm (15-inch) minimum length limit became law on 1 January 1999.

Jones Lake is located 4.8 km (3 mi) south and 2.4 km (1.5 mi) east of Miller, South Dakota. The lake surface encompasses approximately 40.5 ha (100 acres), has a maximum depth of 5.5 m (18 ft), and an average depth of 2.6 m (8.6 ft). A public boat ramp exists for boat access to the lake and shoreline-fishing opportunities are available. Jones Lake is currently part of experimental research being conducted through South Dakota State University (SDSU) to determine the utility of walleyes and saugeyes as secondary predators for restructuring overabundant panfish populations. Two new length regulations went into effect 1 January 1999. These regulations include a largemouth bass 381-mm minimum length limit and a 432-mm (17-inch) walleye/saugeye minimum length limit.

Dakotah Lake is located 8.1 km (5 mi) south and 8.1 km (5 mi) west of Miller, South Dakota. The maximum depth at Dakotah Lake is 6.1 m (20 ft), the mean depth is 2.4 m (8 ft), and the surface area is 3.6 ha (9 acres). A boat ramp is present and a limited amount of shoreline access exists. Dakotah Lake was chemically renovated during 1992 to remove undesirable fish species. Largemouth bass have gained access to Dakotah Lake and currently provide a limited fishery. Spring and autumn rainbow trout stockings have been completed annually since chemical renovation.

Methods

Fish Community Survey

The Lake Louise largemouth bass and bluegill populations were sampled 22 June 1998 by electrofishing with pulsed-DC (150 volts, 7.0 amps). At Lake Rosehill, pulsed-DC electrofishing (150 volts, 7 amps) was conducted on 16 June 1998 to sample the largemouth bass population. Jones Lake was electrofished 29 May 1998 as part of research being completed by SDSU (personal communication, Kris Koski, SDSU research assistant). Collected fish were measured for total length (TL; mm) and weighed (g). Scale samples for age and growth analysis were removed from largemouth bass and bluegill at Lake Louise, largemouth bass at Lake Rosehill and walleye, saugeye and largemouth bass at Jones Lake. Dakotah Lake was electrofished in September 1998 (personal communication, Bill Miller, SDGF&P).

Passive sampling at Lake Louise (7 and 8 July 1998) included two 45.7-m experimental gill nets (six 7.6 m panels; bar mesh sizes: 13 mm, 19 mm, 25 mm, 32 mm, 38 mm, and 51 mm) and eight 1.2-m X 1.5-m double framed trap nets (19-mm bar mesh). At Lake Rosehill (7 and 8 June 1997), eight 1.2-m X 1.5-m double framed trap nets (19-mm bar mesh) were set; however only seven trap nets were used in subsequent analysis. Jones Lake was netted 31 June and 1 July 1998 using a total of eight 1.2-m X 1.5-m double framed trap nets (19-mm bar mesh). All nets were allowed to fish overnight and total fishing time was approximately 24 h. Collected fish were measured TL, weighed, and scale samples removed for age and growth analysis from bluegill, walleye and yellow perch at Lake Louise, yellow perch and black crappie at Lake Rosehill and walleye and largemouth bass at Jones Lake.

Scale samples were pressed onto acetate slides and viewed with a microfiche projector (42X). Scale annulus locations were recorded on paper strips and digitized using a Summa Graphics digitizing pad and the software DISBCAL (Missouri DOC 1989). Fish population parameters were computed using the Nebraska standard fish analysis program (Nebraska G&PC) combined with SAS software (SAS 1994). Parameters calculated included Proportional Stock Density (PSD) and Relative Stock Density (RSD) (Willis et. al 1993) of various length groups. Minimum total lengths for the Gabelhouse (1984) length categorization system are provided in Table 1. Confidence intervals (90%) were calculated for PSD and RSD values. Catch per unit effort (CPUE) for electrofishing is the number of a given fish species caught per hour of electrofishing and CPUE for gill nets and trap nets is the mean number per overnight net set. Standard errors of mean CPUE values were calculated. Relative weight (Wr) values were calculated using the standard weight (Ws) equations given in Blackwell et al. (in press, 1999). Mean Wr values were calculated per Gabelhouse (1984) length categories. Previous lengths at age were estimated using Lee's equation to back calculate length to specific ages. Intercept values used were as follows: largemouth bass 20 mm; bluegill 20 mm; black crappie 35 mm; saugeye 55 mm, walleye 55 mm and yellow perch 30 mm. Mortality estimates, when sample sizes were adequate, were derived both by catch curve (Ricker 1975) analysis and with the Chapman-Robson method (Robson and Chapman 1961).

Statistical analyses were completed using Systat 8.0 (Wilkinson 1998) and statistical significance was set at $P \leq 0.05$. Relative weight values were statistically tested across length categories using analysis of variance (Steel and Torrie 1980). When a significance difference was identified across length categories, Fishers Least Significant Difference (LSD; Steel and Torrie 1980) was used to detect separate means. Chi-square analysis was used to examine difference in PSD values and the Kolmogorov-Smirnov test was used to examine for differences in length-frequency distribution locations and dispersions (Daniel 1990).

Table 1. Minimum total lengths (mm) for Gabelhouse (1984) length categories for selected fish species.

Species	Stock (S)	Quality (Q)	Preferred (P)	Memorable (M)	Trophy (T)
Bluegill	80	150	200	250	300
Largemouth Bass	200	300	380	510	630
Yellow Perch	130	200	250	300	380
Black Crappie	130	200	250	300	380
Black Bullhead	150	230	300	380	460
Walleye	250	380	510	630	760
Northern Pike	350	530	710	860	1120

Angler Use and Sport Fish Harvest

An angler use and harvest survey was conducted during the last 3 weeks of May 1998 through August 1998. The survey technique used utilizes instantaneous angler counts and angler interviews. Instantaneous angler counts are used to provide fishing pressure estimates and angler interviews provide information necessary for estimating fish species catch rates, mean angler trip length, and mean party size. Additional questions asked during interviews were used to obtain angler primary residence and fish species targeted. In addition, a sample of caught fish could be measured during the interview process. Two questions with a series of potential responses were also asked to anglers. The questions asked and potential responses were as follows:

1. How often do you fish South Dakota small lakes and ponds?
    1. 0-5 times per year
    2. 5-10 times per year
    3. 10-15 times per year
    4. >15 times per year

2. Walleyes and saugeyes (walleye x sauger hybrid) have recently been introduced into many South Dakota small lakes and ponds as secondary predators to assist in controlling overabundant panfish. Would you be willing to release walleyes and saugeyes less than 17 inches to help restructure panfish populations in these waters?

    1. Yes
    2. No
    3. No opinion

The angler use and harvest survey followed a stratified random design (Malvestuto 1996). Two strata (1-weekdays and 2-weekend days and holidays) were used for data collection intervals. All weekend and holidays were included in data collection while the weekdays used were randomly selected. Data collection days were divided into four time frames in which a clerk was present at a lake. The four time frames were 1) 800 to 1200 hours, 2) 1200 to 1600 hours, 3) 1400 to 1800 hours, and 4) 1800 to 2200 hours. Within each month, days and times were randomly assigned as to when the clerk would be present at each specific lake. Dakotah Lake, because of its close proximity to Jones Lake, was visited concurrently with Jones Lake. Attempts were made to interview all anglers present at a lake during the assigned time interval. Two instantaneous counts of the total number of boats fishing and all shoreline anglers present were made during each time interval. Angler use and harvest estimates were computed using the software designed by Jacobson (1988) and modified by Dave Lucchesi (personal communication, SDGF&P).

Results and Discussion

Lake Louise

Fish Community Survey

Largemouth Bass

The PSD of the electrofishing largemouth bass sample was 45 (Table 3). The 1998 PSD represents a significant increase in the proportion of quality-length largemouth bass over that obtained in 1997 (20; Blackwell 1998). No change in RSD-P was observed with both 1998 and 1997 values equal to 15. The increase in PSD appears to be related to the 1996 year class growing slower than the 1995 year class. In 1997, many age-2 largemouth bass exceeded 200 mm TL (minimum stock length), but in 1998 most age-2 bass were sub-stock. Electrofishing length frequency histograms were similar between 1998 and 1997 (Figure 1) and these distributions did not differ significantly. Largemouth bass sample PSD and RSD-P values in 1998 exceeded the objective ranges for bass when managing under the panfish option (Table 2; Willis et al. 1993). However, confidence limits extend into the panfish objective ranges (Table 3). Under a panfish option a PSD near 40 may be risky because of the potential for largemouth bass recruitment failure allowing panfish species to overpopulate (Guy and Willis 1990). I do not believe the 1998 PSD of 48 should be of concern because it appears there are two relatively strong sub-stock year classes and it is likely the PSD will decrease as the 1996 year class exceeds 200 mm TL. Largemouth bass PSD values in 1997 and 1998 were higher than PSD values reported in 1993 (Meester 1994) and 1994 (Meester 1995) (Figure 2).

Stock-length largemouth bass electrofishing CPUE was 42.9 (Table 3) and for all size classes was 78.8. Catch per hour values do not differ significantly between 1997 and 1998 and it is likely they do not differ from those obtained in 1994 and 1995. Largemouth bass density appears to be high and likely has not significantly changed in recent years. The population is primarily composed of age-4 and younger largemouth bass (Table 4). The 1998 largemouth bass mean lengths at age were below the South Dakota mean back-calculated lengths at age (Willis et al. 1990) but are similar to those recorded in 1997 (Blackwell 1998). Reduced growth may be indicative of the high density largemouth bass population.

Lake Rosehill

Fish Community Survey

Largemouth Bass
Largemouth bass electrofishing CPUE significantly decreased in 1998 (10.5; Table 16) when compared to 1997 (49.8; Blackwell 1998). In 1997, the largemouth bass density was considered moderate to high; however, based on the 1998 sample the population would be considered a low density. It appears that largemouth bass recruitment continues to be a problem. In 1998, a single small largemouth bass (116 mm TL; age 1) was collected. Thus, it appears the 1995, 1996 and 1997 year classes are relatively weak or nonexistent. Also, additional electrofishing was completed in September (1998) and very few age-0 largemouth bass were observed. It is probable four year classes are weak or missing. Three or four consecutive missing year classes could dramatically change the fish community structure at Lake Rosehill.

The largemouth bass sample was primarily composed of individuals greater than 300 mm (Figure 6). Proportional stock density for the sample was 100 and the RSD-P was 56 (Table 16). Stock density values should be interpreted with caution because of small sample size. However, PSD and RSD-P values were similar to 1997 values. The current values exceed the ranges provided for the big bass objective range (Willis et al. 1993; Table 2). The high PSD and RSD-P values are the result of the missing 1995 and 1996 year classes. Willis et al. (1993) suggested that largemouth bass recruitment might cease in impoundments managed for the big bass option. It was believed that a high biomass of panfish could prevent largemouth bass recruitment. Reasons behind the apparent three and potentially four years of recruitment failure are unknown, but efforts should be made to stock largemouth bass in 1999.

Largemouth bass condition was excellent in 1998 with all Wr values exceeding 110 (Table 17). No length-related trends in Wr values were observed making an overall stock-length mean appropriate. Growth rates continue to be fast (Table 18). Back-calculated lengths at each age were similar to 1997 (Blackwell 1998) and the South Dakota average (Willis et al. 1990). The high condition and good growth rates indicate ample prey availability. A mortality rate was not calculated because of the low sample size.

Yellow Perch
Yellow perch trap net CPUE increased slightly over 1997 but remains relatively low at 2.9 (Table 16). The 1998 value is similar to the 1994 lake survey CPUE of 2.88 (Meester 1995). In 1997, the entire yellow perch sample was from the 1994 year class; however, the 1998 sample contained 1995-97 year classes but none from 1994. The absence of the 1994 year class from the trap net sample is conspicuous. It is probable that older and larger yellow perch may remain offshore and were not vulnerable to trap nets. Trap nets may not be the best method for sampling yellow perch populations during summer periods. However, the consistency of yellow perch trap net CPUE indicates little change in yellow perch density. In 1998, yellow perch composed 3.9% of the trap net sample (Table 19).

Yellow perch condition was good during the 1998 trap net sample. An overall stock-length mean Wr of 92 was obtained in 1998 (Table 17), the same mean was recorded in 1997

(Blackwell 1998) and 1994 (Meester 1995). Growth (Table 20) remains good with little change in back-calculated lengths at age from 1997 (Blackwell 1998) or 1994 (Meester 1995). In 1998, mean lengths at age were slightly greater than the South Dakota average (Willis et al. 1992). Low sample size precluded the calculation of mortality rates.

Black Crappie

Adult black crappies were introduced into Lake Rosehill in 1995 (Appendix A). The 1995 adult black crappie stocking was successful. In 1998, black crappies representing four year classes were collected in trap nets (Table 21). The collected black crappies ranged in size from 12 cm to 28 cm (Figure 5). The 1998 trap net CPUE (38.4; Table 16) increased significantly over 1997 (3; Blackwell 1998). Along with the increase in CPUE a significant increase in the proportion of quality-length black crappies occurred in 1998. A mortality rate was not calculated because of the continued black crappie population expansion. In 1998, black crappie accounted for 28% of the trap net catch (Table 19).

Black crappies were in excellent condition with Wr values exceeding 100 for all length categories. A significant length related trend was identified for black crappie condition making an overall stock-length mean inappropriate. Stock- to quality-length black crappies were in significantly better condition than quality- to preferred-length individuals, albeit the condition of both length groups was excellent. Growth remained similar to 1997 (Blackwell 1998). Mean back-calculated lengths at age were slightly lower than the South Dakota average (Guy and Willis 1993).

Table 16. Catch per unit effort (standard error is given in parentheses), proportional stock density (PSD), relative stock density of preferred- (RSD-P) and memorable-length (RSD-M) estimates (90% confidence intervals are given in parentheses) for largemouth bass, black crappie, yellow perch, northern pike and black bullheads collected from Lake Rosehill during 1998.

Species	Stock CPUE	PSD	RSD-P	RSD-M
Largemouth Bass $_{\text{Electrofish}}$	10.5 (1.61)	100[a]	56 (34, 79)	0
Black Crappie $_{\text{Trap Net}}$	38.4 (15.41)	43 (38, 48)	0 (0, 1)	0
Yellow Perch $_{\text{Trap Net}}$	2.9 (1.26)	15 (3, 20)	0	0
Northern Pike $_{\text{Trap Net}}$	2.7 (0.64)	47 (27, 68)	21 (4, 38)	0
Black Bullhead $_{\text{Trap Net}}$	90.7 (28.46)	8 (6, 9)	1 (0, 2)	0

[a] PSD estimate of 100 does not allow for confidence interval calculation

Table 17. Mean relative weight values by Gabelhouse (1984) length categories (standard error values are given in parentheses) for largemouth bass, black crappie yellow perch and northern pike collected at Lake Rosehill during 1998. Means followed by different letters within a row are significantly different (S-Q = stock to quality length, Q-P = quality to preferred length, P-M = preferred to memorable length, and M-T = memorable to trophy length).

Species	Sub-stock	S-Q	Q-P	P-M	Stock
Largemouth bass $_{\text{Electrofish}}$	--	--	114 (1.23)	113 (2.05)	114 (1.23)
Black crappie $_{\text{Trap Net}}$	119	111(0.82)z	107(0.70)y	103zy	109 (0.55)
Yellow perch $_{\text{Trap Net}}$	99 (1.43)	92 (0.54)	88 (2.72)	--	92 (0.46)
Northern pike $_{\text{Trap Net}}$	--	88 (0.23)	91 (1.88)	--	89 (0.15)

Table 18. Lake Rosehill largemouth bass year class, age in 1998, sample size (N), mean back calculated total length at age for each year class, the weighted mean back calculated length at age, weighted mean standard error, 1997 weighted mean length at age and the South Dakota largemouth bass mean length at age (Willis et al. 1990).

			Back-calculated length-at-age (mm)									
Year Class	Age	N	1	2	3	4	5	6	7	8	9	10
1997	1	0	---									
1996	2	0	---	---								
1995	3	0	---	---	---							
1994	4	3	90	175	223	297						
1993	5	5	88	171	236	293	357					
1992	6	2	91	146	201	307	373	402				
1991	7	0	---	---	---	---	---	---	---			
1990	8	3	110	173	231	285	330	388	413	435		
Weighted Mean			94	168	226	295	352	394	413	435		
Standard Error			6.38	6.33	8.30	9.81	10.67	12.78	24.24	19.30		
1997			110	198	274	343	389	423	452	477	501	508
South Dakota			91	184	251	305	345	400	435			

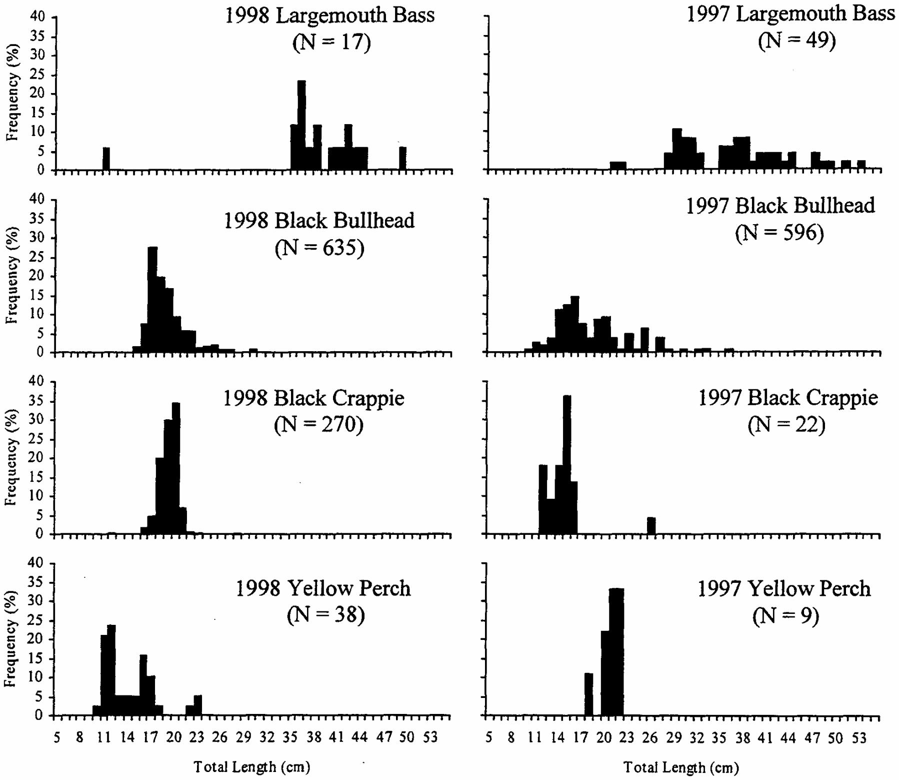


Figure 5. Length frequency distributions of largemouth bass (electrofishing), black bullheads (trap net), black crappies (trap net) and yellow perch (trap net) collected at Lake Rosehill in 1998 and 1997 (N is the total number captured for each species).

Black Bullhead

Black bullheads continue to be the most abundant species caught in trap nets (Table 19). Collected black bullheads ranged in size from 15 cm to 30 cm TL (Figure 5). Mean black bullhead CPUE was 90.7 (Table 16) and was not significantly different from the 1997 value (79; Blackwell 1998). Both the 1997 and 1998 mean CPUE values were considerably higher than reported in 1990 (15.5; Meester 1991) and 1994 (3.0; Meester 1995). The proportion of quality-length black bullheads in the trap net sample was significantly lower than the 1997 sample and likely is lower than reported in 1994 (Meester 1995). In 1998, the PSD was 8 and the RSD-P was 1 (Table 16). A disturbing trend of increased bullhead CPUE values and reduced PSD values has occurred. The recent missing largemouth bass year classes will likely exacerbate this trend.

Northern Pike

Northern pike were common in trap nets during 1998 (CPUE = 2.7; Table 16), none were collected during trap netting in 1997 (Blackwell 1998) and four were caught in trap nets during 1994 (Meester 1995). Several northern pike were observed during electrofishing. The northern pike population would not be expected to become abundant because of the low biomass typically supported in small impoundments. It is conceivable recent high water levels have allowed for successful northern pike reproduction and recruitment. Nineteen northern pike were collected and ranged in length from 35 cm to 85 cm TL (Figure 7).

The northern pike population is capable of providing angling opportunities. A PSD of 47 and RSD-P of 21 was obtained for the 1998 sample (Table 16). Northern pike condition was good (Table 17). No preferred-length individuals were weighed because their weight exceeded the scale maximum weight.

Other Species

A single green sunfish (TL = 15 cm) was collected in 1998. No other species were collected during 1998 sampling.

Table 19. Number collected and percent (%) composition of species collected in trap nets at Lake Rosehill during 1998.

	Trap Net Catch	
Species	Number	% Composition
Black Bullhead	635	65.9
Yellow Perch	38	3.9
Black Crappie	270	28.0
Northern Pike	19	2.0
Green Sunfish	1	0.1

Table 20. Lake Rosehill yellow perch year class, age in 1998, sample size (N), back calculated total length at age, the weighted mean back calculated length at age, weighted mean standard error, 1997 weighted mean length at age and the South Dakota yellow perch mean length at age (Willis et al. 1992).

Year			Age		
Class	Age	N	1	2	3
1997	1	12	94		
1996	2	11	77	140	
1995	3	3	103	159	202
Weighted Mean			88	144	202
Standard Error			2.21	3.50	3.64
1997			94	152	197
South Dakota			80	139	181

Table 21. Lake Rosehill black crappie year class, age in 1998, sample size (N), back calculated total length at age, the weighted mean back calculated length at age, weighted mean standard error, 1997 weight mean length at age and the South Dakota black crappie mean length at age (Guy and Willis 1993).

Year			Age				
Class	Age	N	1	2	3	4	5
1997	1	1	93				
1996	2	12	67	143			
1995	3	20	80	126	188		
1994	4	0	----	----	----	----	
1993	5	1	92	125	176	241	267
Weighted Mean			76	132	187	241	267
Standard Error			2.00	3.08	3.41		
1997			81	129	186	235	
South Dakota			77	151	198	227	

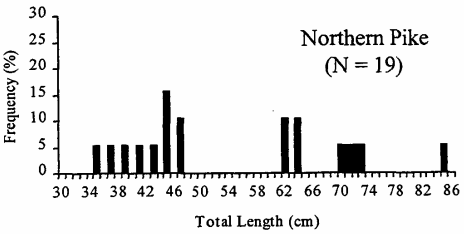


Figure 7. Length frequency distributions of northern pike collected at Lake Rosehill in 1998 (N is the total number captured).

Angler Use and Harvest

Angler Demographics

In 1998, the estimated monthly angler mean trip length ranged from 2.44 (July) to 3.17 hours (August; Table 22). The greatest fishing activity occurred during June. The June estimate may be inflated because of a small tournament held during a June Saturday. The percentage of boat anglers increased as the summer proceeded (Table 22). The increase in the percentage of boats may be related to increased submerged vegetation in near-shore areas during July and August. All interviewed anglers indicated South Dakota as their residence (Table 22).

Similar to 1997, most anglers fishing Lake Rosehill traveled less than 81 km (50 mi), one way (Table 23). Wessington, Miller and Huron, South Dakota were the most frequently indicated angler home residences. Contrary to 1997, when only 35.7% (Blackwell 1998) of anglers were local (travel less than 40 km), in 1998, local anglers made up 68.7% of the Lake Rosehill anglers. Residences of anglers traveling the greatest distance were Brookings, Volga and Pierre, South Dakota.

Anglers indicated a variety of target species during 1999 (Table 24). Any fish species was the most common response followed by largemouth bass. In 1998, a small percentage of anglers indicated they were fishing for northern pike and black crappie. Anglers sought neither of these species in 1997 (Blackwell 1998). A limited number of anglers continued to target black bullheads.

Table 22. Lake Rosehill 1998, monthly number of interviews, estimated angler pressure hours and days, percent of anglers fishing by boat, percent of total anglers fishing weekends and holidays, percent of anglers that are South Dakota residents, and the mean trip length and 1997 totals.

	May	June	July	August	Σ1998	Σ1997
Interviews	10	37	15	5	67	28
Angler hours	367 (202)	927 (626)	676 (309)	390 (337)	2,360	1,168
Angler days	120 (81)	323 (224)	230 (119)	123 (123)	796	409
Percent (%) boat anglers	23.5	27.7	84.1	63.3	-	-
Percent (%) weekend/holiday	67.1	79.9	57.0	24.1	-	-
Percent (%) resident	100	100	100	100	100	89.3
Mean trip length (hours)	3.07	2.87	2.44	3.17	2.83	3.11

Table 23. Distance (km) traveled by anglers, one way, to fish Lake Rosehill during May through August, 1998 and all months combined for 1998 and 1997.

Distance (km)	May %	June %	July %	August %	All 1998	All 1997
<40	60.0	75.7	66.7	40.0	68.7	35.7
40-81	40.0	18.9	26.7	20.0	23.9	46.1
82-161	--	5.4	6.7	40.0	7.5	3.7
162-322	--	--	--	--	--	--
322+	--	--	--	--	--	14.3

Fishing Pressure
The number of angler hours at Lake Rosehill in 1998 increased by greater than 1,000 hours over that measured in 1997 (Table 22). An estimated 796 angler days occurred during the survey period at Lake Rosehill. Economically Lake Rosehill during the survey period would be valued at $59,700. The economic value is based on a South Dakota angler spending $75 per fishing day (U.S. Department of Interior, Fish and Wildlife Service, and U.S. Department of Commerce, Bureau of Census 1997). However, because of the local nature of this fishery the economic value may be inflated.

Estimated catch rates for all fish species combined were generally higher than 1997 with the exception of August (Table 25). Anglers fishing Lake Rosehill in 1998 had a general expectation of catching more than one fish for every hour fished. Harvest rates were less than one fish per hour except during June (Table 26).

Black Bullhead
Black bullheads were the most abundant species caught and harvested by anglers in 1998 (Table 27). An estimated 2,640 black bullheads were caught during the survey period and 1,213 were harvested. Again, these numbers may be somewhat inflated because of the tournament held in June primarily targeted black bullheads. Catch rates exceeded one black bullhead per hour during May and June (Table 25).

Yellow Perch
The catch and harvest of yellow perch in 1998 was similar to 1997. Yellow perch catch rates remained at approximately the same level each month (Table 25). The percentage of anglers targeting yellow perch was lower in 1998 with only 7.5% indicating yellow perch either alone or in combination as their target species.

Largemouth bass
An estimated 17 (4% of 431 caught) largemouth bass were harvested from Lake Rosehill during the 1998 survey (Table 27). The 1998 harvest was similar to 1997 when an estimated 12 largemouth bass were harvested (Blackwell 1998). Largemouth bass catch rates ranged from 0.08 (August) to 0.33 (July; Table 25). It appears the largemouth bass fishery is primarily a catch and release fishery. With the recent enactment of the 380-mm length limit newly recruited year classes will be protected through age 4.

Northern Pike
Northern pike were common in the angler's catch during 1998, but were only harvested during May and June. Catch rates ranged from 0.12 (August) to 0.32 (June; Table 25). An estimated 637 northern pike were caught in 1998 while none were reportedly caught from Lake Rosehill during 1997. A small percentage of anglers were targeting northern pike in 1998 (Table 24).

Black Crappie
Black crappies were caught each month, but like northern pike were only harvested during May and June. With the exception of August, catch rates exceed 0.2 fish per hour (Table 25). As the black crappie population matures catch and harvest of this species will undoubtedly increase. Anglers harvested 35% of the black crappies caught in 1998 (Table 27).

Table 24. Percent (%) of anglers targeting selected fish species at Lake Rosehill during May through August 1998, overall 1998 and 1997.

	Percent %					
Target Species	May[a]	June	July	August	1998	1997
Any	20.0	67.6	53.3	20.0	53.7	32.1
Bluegill	0.0	0.0	0.0	0.0	0.0	3.6
Black Bullhead	20.0	2.7	0.0	0.0	4.5	7.1
Largemouth Bass	20.0	16.2	46.7	40.0	25.4	25.0
Largemouth Bass/Black Crappie	0.0	2.7	0.0	0.0	1.5	0.0
Northern Pike	10.0	8.1	0.0	0.0	6.0	0.0
Northern Pike/Black Bullhead	0.0	2.7	0.0	0.0	1.5	0.0
Yellow Perch	0.0	0.0	0.0	20.0	1.5	25.0
Yellow Perch/ Black Bullhead	0.0	0.0	0.0	20.0	1.5	0.0
Yellow Perch/Largemouth Bass	30.0	0.0	0.0	0.0	4.5	7.1

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[a] only last three weeks in May

Table 25. Estimated 1998 and 1997 angler catch rates for Lake Rosehill during the last three weeks in May through August for largemouth bass, yellow perch, black bullhead, walleye, northern pike, black crappie and all species combined (two standard errors are given in parentheses).

	May[a] Catch/hour		June Catch/hour		July Catch/hour		August Catch/hour	
Species	1998	1997	1998	1997	1998	1997	1998	1997
Largemouth Bass	0.09	--	0.16	0.01	0.33	0.03	0.08	0.52
	(0.14)	--	(0.13)	(0.03)	(0.31)	(0.04)	(0.16)	(0.67)
Yellow Perch	0.36	--	0.39	0.41	0.28	0.51	0.39	0.51
	(0.54)	--	(0.24)	(0.53)	(0.15)	(0.59)	(0.48)	(0.52)
Black Bullhead	1.64	--	1.60	0.78	0.57	0.54	0.44	0.40
	(1.30)	--	(0.58)	(0.78)	(0.32)	(0.33)	(0.26)	(0.57)
Walleye	0.00	--	0.0	0.0	0.0	0.08	0.0	0.0
	(0.01)	--	(0.0)	(0.0)	(0.0)	(0.16)	(0.0)	(0.0)
Northern Pike	0.25	--	0.32	0.0	0.29	0.0	0.12	0.0
	(0.21)	--	(0.17)	(0.0)	(0.38)	(0.0)	(0.24)	(0.0)
Black Crappie	0.29	--	0.24	0.0	0.31	0.0	0.05	0.0
	(0.39)	--	(0.15)	(0.0)	(0.26)	(0.0)	(0.11)	(0.0)
All Species	2.63	--	2.71	1.21	1.78	1.17	1.08	2.24
	(1.48)	--	(0.68)	(0.95)	(0.66)	(0.69)	(0.63)	(2.78)

[a] only last three weeks in May

Table 26. Estimated 1998 and 1997 angler harvest rates for Lake Rosehill during the last three weeks in May through August for largemouth bass, yellow perch, black bullhead, walleye, northern pike, black crappie and all species combined (two standard errors are given in parentheses).

	May^a Catch/hour		June Catch/hour		July Catch/hour		August Catch/hour	
Species	1998	1997	1998	1997	1998	1997	1998	1997
Largemouth Bass	0.0	--	0.0	0.01	0.02	0.01	0.0	0.0
	(0.0)	--	(0.01)	(0.03)	(0.04)	(0.02)	(0.0)	(0.0)
Yellow Perch	0.0	--	0.13	0.22	0.03	0.14	0.22	0.10
	(0.0)	--	(0.13)	(0.44)	(0.06)	(0.17)	(0.44)	(0.20)
Black Bullhead	0.55	--	1.01	0.17	0.0	0.02	0.18	0.30
	(0.81)	--	(0.60)	(0.24)	(0.0)	(0.04)	(0.36)	(0.60)
Walleye	0.00	--	0.0	0.0	0.0	0.08	0.0	0.0
	(0.01)	--	(0.0)	(0.0)	(0.0)	(0.16)	(0.0)	(0.0)
Northern Pike	0.05	--	0.04	0.0	0.0	0.0	0.0	0.0
	(0.09)	--	(0.05)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Black Crappie	0.24	--	0.12	0.0	0.0	0.0	0.0	0.0
	(0.40)	--	(0.11)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
All Species	0.84	--	1.31	0.41	0.05	0.16	0.40	0.40
	(0.81)	--	(0.62)	(0.50)	(0.08)	(0.17)	(0.57)	(0.63)

[a] only last three weeks in May

Table 27. Estimated number of largemouth bass (LMB), bluegill (BLG), yellow perch (YEP), black bullhead (BLB), and northern pike (NOP) caught by anglers, harvested by anglers and the percent of the those caught that were harvested during the last three weeks in May through August 1998 and 1997 at Lake Rosehill.

Parameter	LMB		YEP		BLB		BLC		NOP	
	1998	1997	1998	1997	1998	1997	1998	1997	1998	1997
Catch	431	245	835	552	2,640	718	563	0	637	0
Harvest	17	12	231	193	1,213	137	196	0	56	0
% Harvest	4%	5%	28%	35%	46%	19%	35%	0%	9%	0%

Summary

Largemouth bass density as represented by electrofishing CPUE is significantly lower in 1998 than 1997. The last year class to recruit substantially into the fishery was the 1994 year class. It appears that three and possibly four year classes are weak to missing. The missing year classes could have detrimental effects on the panfish size structure. Without adequate predation panfish species may recruit out of control leading to high-density populations dominated by small individuals.

Black bullheads continue to be abundant in Lake Rosehill and size structure is relatively small. Black bullhead densities appear to be greater than reported in 1994 and the size structure has decreased in recent years. The yellow perch population was relatively unchanged. Black crappie numbers continue to increase with four year classes currently present. Sufficient predation will be needed to keep this population from overpopulating.

Northern pike were probably always a component of the fish community but now show a higher abundance. Northern pike are not typically considered for management purposes in small impoundments. Gurtin et al. (1996) believed northern pike could be beneficial for structuring panfish populations. Thus, the surge in northern pike abundance may be beneficial in helping control panfish densities.

An increase in fishing pressure was observed in 1998 over 1997. Local anglers (traveling less than 40 km on way) constituted greater than 65% of the anglers fishing Lake Rosehill. A high percentage of anglers were generalists in 1998 with 53.7% indicating any fish as their target species. Largemouth bass were targeted by 25% of interviewed anglers in both 1998 and 1997. Black bullheads were the most caught and harvested species by anglers in 1998. Black crappies and northern pike were caught and harvested in 1998.

Recommendations

Largemouth bass should be stocked in 1999 to hopefully prevent another missing year class. Supplemental largemouth bass fingerling stocking has had limited success and in general survival has been poor. Thus, stocking juvenile largemouth bass should also be considered. Juvenile largemouth bass can likely be moved from Dakotah Lake, Hand County (personal communication, D. Jost, SDGF&P) to supplement the aging Lake Rosehill largemouth bass population.

The largemouth bass population should be monitored on an annual basis to determine recruitment success or failure and to evaluate potential changes following enactment of the 380-mm length limit. Electrofishing should be completed in a manner (i.e., shocking intervals or stations) that allows for statistical comparisons across years. The remaining fish community can likely be evaluated on an every other year basis using trap nets.

The angler use and harvest survey should be repeated beginning in the year 2003 to continue to gain information from South Dakota small lakes and ponds. This information fulfills Objective 4, Strategy 4.1 of the Small Lakes and Ponds Strategic Plan (SDGF&P 1997).

Angler Responses to Questions

Small Impoundment Angler-Use Frequency

In 1998 and 1997, the following question was asked to determine the frequency at which anglers fish South Dakota small impoundments. How often do you fish South Dakota small lakes and ponds? Four potential responses included 0 to 5 times, 6 to 10 times, 11 to 15 times and greater than 15 times in a year.

An increase in the percentage of anglers fishing small impoundments for 6 to 10 and 11 to 15 times was observed in 1998 when compared to 1997 (Table 36; Blackwell 1998). The increase in these categories may be related to reduced fishing quality on Lake Oahe during 1998. Many anglers may have fished small impoundments instead of traveling to Lake Oahe. Anglers fishing small impoundments greater than 15 times in a year accounted for 36% of the question responses in 1998 and 64% in 1997 (Blackwell 1998). The importance of small impoundments to South Dakota anglers is apparent when viewing how often anglers indicate they fish small lakes and ponds in a year.

Table 36. The number of responses by anglers (the percentage is in parentheses) to the question, "How often do you fish South Dakota small lakes and ponds?" asked during the 1998 angler-use and harvest survey for Lakes Louise, Rosehill, Jones, Dakotah, the four lakes combined in 1998 and 1997.

					Combined	
Times	Louise	Rosehill	Jones	Dakotah	1998	1997
0-5	13 (8%)	18 (22%)	8 (20%)	0	39 (13%)	28 (17%)
6-10	41 (26)	20 (25%)	11 (26%)	3 (21%)	75 (25%)	10 (6%)
11-15	37 (24%)	27 (33%)	6 (14%)	4 (29%)	74 (25%)	23 (14%)
>15	66 (42%)	16 (20%)	18 (42%)	7 (50%)	107 (36%)	108 (64%)

Largemouth Bass 380-mm Minimum Length Limit

Sufficient panfish predation must occur for consistent production of quality-size panfish. To produce quality panfish fisheries top-level predators must remain at high enough densities to provide adequate predation. A common problem in many unregulated waters is overharvest of largemouth bass and other predators. Thus, as part of the Hand County angler use and harvest survey, anglers were asked questions concerning their willingness to release predatory fishes.

In 1997, Hand County anglers were asked if they would be in favor of a 380-mm (15-inch) largemouth bass minimum length limit on some waters in an attempt to produce quality panfish opportunities. A majority (73%) indicated they would be in favor of such a regulation.

In 1998, anglers were asked a similar question but it concerned the use of walleyes and saugeyes to restructure panfish populations. The 1998 question asked if anglers would be willing to release walleyes and saugeyes less than 432 mm (17 inch) to restructure panfish populations. Again, a strong majority (76%) indicated they would be in favor of a regulation requiring the release of walleyes and saugeyes less than 432 mm.

Responses to the questions during the past two survey periods reveal South Dakota anglers are interested in catching quality-size panfish. Providing anglers with panfish fishing opportunities will require harvest regulations designed to keep predators from being overharvested and potentially panfish harvest regulations designed to protect panfish population size structure. The recent enactment of 380-mm largemouth bass length limits and 432-mm walleye/saugeye length limits on several South Dakota small impoundments were moves in the right direction.

Table 37. The number of responses by anglers (the percentage is in parentheses) to the question, "Would you be willing to released walleyes and saugeyes less than 17 inches to help restructure panfish populations?" asked during the 1997 angler-use and harvest survey for Lakes Louise, Rosehill, Jones, Dakotah, and the four lakes combined.

Response	Louise	Rosehill	Jones	Dakotah	Combined
Yes	118 (76%)	57 (85%)	33 (77%)	9 (64%)	302 (76%)
No	35 (22%)	9 (13%)	8 (19%)	5 (36%)	90 (22%)
No opinion	3 (2%)	1 (1%)	2 (5%)	0	8 (2%)

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Appendix A

Lake Louise fish stocking history.

Year	Number	Species	Size
1984	13,500	walleye	fingerling
1986	6,750	walleye	fingerling
1988	6,750	walleye	fingerling
1989	5,000	walleye	fingerling
1991	13,500	walleye	fingerling
1993	3,400	walleye	fingerling
1995	1,650	walleye	fingerling
1997	4,125	walleye	fingerling

Lake Rosehill fish stocking history.

Year	Number	Species	Size
1984	2,000	walleye	fingerling
1985	2,850	yellow perch	fingerling
1988	2,850	walleye	fingerling
1989	2,850	walleye	fingerling
1990	6,000	largemouth bass	fingerling
	4,000	yellow perch	fingerling
1991	13,800	walleye	fingerling
1992	2,000	yellow perch	fingerling
1993	2,000	largemouth bass	fingerling
1995	234	black crappie	adults

Jones Lake fish stocking history.

Year	Number	Species	Size
1988	5,000	walleye	fingerling
1989	5,000	walleye	fingerling
1991	464	black crappie	adult
1992	5,000	largemouth bass	fingerling
1993	5,000	largemouth bass	fingerling
1994	2,100	walleye	fingerling
1995	850	walleye	fingerling
1996	1,760	walleye	fingerling
1997	2,100	saugeye	fingerling
	2,100	walleye	fingerling
1998	864	saugeye	fingerling
	1,335	walleye	fingerling

Appendix E. Total Maximum Daily Load Summary (TMDL)

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

ROSE HILL LAKE

SAND CREEK WATERSHED

(HUC 10160006)

HAND COUNTY, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

JANUARY, 2002

Rose Hill Lake Total Maximum Daily Load

Waterbody Type: Lake (Impounded)
303(d) Listing Parameter: TSI Trend,
Designated Uses: Recreation, Warmwater permanent aquatic life
Size of Waterbody: 33.8 acres
Size of Watershed : 23,734 acres
Water Quality Standards: Narrative and Numeric
Indicators: Trophic State Index (TSI)
Analytical Approach: **AGNPS, BATHTUB, FLUX**
Location: HUC Code: 10160006
Goal: 20 % reduction in phosphorus from the watershed and 30% reduction in sediment released phosphorus
Target: TSI less than 65

Objective:

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

Introduction

Rose Hill Lake is a 33.8-acre man-made impoundment located in southern Hand County, South Dakota. The 1998 South Dakota 303(d) Waterbody List (page 22) identified Rose Hill Lake for TMDL development for trophic state index (TSI) and increasing eutrophication trend.

Figure 27. Watershed Location in South Dakota

The damming of Sand Creek 10 miles south of Wessington created the lake, which has an average depth of 9 feet (3 meters) and over 2.1 miles (3.4 km) of shoreline. The lake has a maximum depth of 25 feet (7.6 m), holds 315 acre-feet of water, and is subject to periods of stratification during the summer. The outlet for the lake empties into Sand Creek, which eventually reaches the James River south of Wolsey.

Problem Identification

Sand Creek is the primary tributary to Rose Hill Lake and drains a mixture of grazing lands with some cropland acres. Winter feeding areas for livestock are present in the watershed. The stream carries nutrient loads, which degrade water quality in the lake and cause increased eutrophication. Additional impairments are a result of internal nutrient loading.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

Rose Hill Lake has been assigned beneficial uses by the state of South Dakota Surface Water Quality Standards regulations. Along with these assigned uses are narrative and numeric criteria that define the desired water quality of the lake. These criteria must be maintained for the lake to satisfy its assigned beneficial uses, which are listed below:

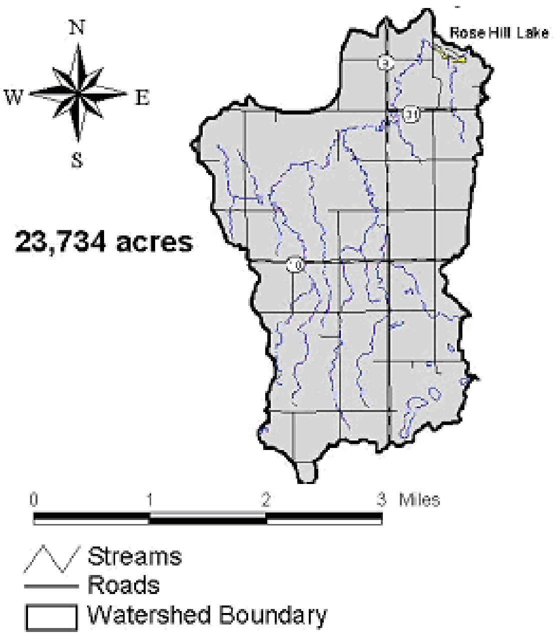

Figure 28. Rose Hill Lake and Sand Creek Watershed

Warmwater permanent fish life propagation; Immersion recreation; Limited contact recreation; and Fish and wildlife propagation, recreation and stock watering.

Individual parameters, including the lake's Trophic State Index (TSI) (Carlson, 1977) value, determine the support of beneficial uses and compliance with standards. A gradual increase in fertility of the water due to nutrients washing into the lake from external sources is a sign of the eutrophication process.

Rose Hill Lake is identified in both the 1998 South Dakota Waterbody List and "Ecoregion Targeting for Impaired Lakes in South Dakota" as partially supporting its aquatic life beneficial use. This support was determined through comparison of its trophic state to other lakes in its ecoregion.

South Dakota has several applicable narrative standards that may be applied to the undesired eutrophication of lakes and streams. Administrative Rules of South Dakota Article 74:51 contains language that prohibits the existence of materials causing pollutants to form, visible pollutants, taste and odor producing materials, and nuisance aquatic life.

If adequate numeric criteria are not available, the South Dakota Department of Environment and Natural Resources (SD DENR) uses surrogate measures. To assess the trophic status of a lake, SD DENR uses the mean TSI which incorporates secchi depth, chlorophyll *a* concentrations and phosphorus concentrations. SD DENR has developed a protocol that establishes desired TSI levels for lakes based on an ecoregion approach. This protocol was used to assess impairment and determine a numeric target for Rose Hill Lake.

Rose Hill Lake currently has a mean TSI of 66.89, which is indicative of high levels of primary productivity. Assessment monitoring indicates that the primary cause of the high productivity is phosphorus loads from the watershed and the bottom sediments in the lake. Growing season releases of phosphorus from bottom sediments in Rose Hill Lake resulted in an increase in the phosphorus concentration during the growing season from .1 mg/L to .4 mg/L (page 33).

The numeric target, established to improve the trophic state of Rose Hill Lake, is a growing season average TSI of 65 or less. This target may be achieved in part through a 20% reduction in phosphorus loads from Sand Creek. Reducing the release of phosphorus from the bottom sediments by 30% in addition to the 20% watershed load reduction will result in a TSI of less than 65.

Pollutant Assessment

Point Sources

There are no point sources of pollutants of concern in this watershed.

Nonpoint Sources/ Background Sources

Of the 6,936 kg. of phosphorus that enter the lake on an average annual basis, approximately 4,092 kg or 59% originate from the cropland acres in the watershed. The remaining 2,158 kg or 31% originate from other areas of the watershed, primarily hay and pasture lands. Additional nutrient loadings were attributed to bank and channel problems between the inlet site and the lake itself. Phosphorus loads from this source totaled 694 kg or 10% of the total load. Pages 16-20, 54. Of the total external load, treatment of 13.7% of the most critical acres in addition to the 10% from the bank stability problems will result in phosphorus reductions of 1,531 kg or 22%.

Linkage Analysis

Water quality data was collected from five monitoring sites within the Rose Hill Lake and Sand Creek watershed. Samples collected at each site were taken according to South Dakota's EPA approved Standard Operating Procedures for Field Samplers. Water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected on 10% of the samples according to South Dakota's EPA approved Clean Lakes Quality Assurance/Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed on pages 9-49 of the assessment final report.

In addition to water quality monitoring, data was collected to complete a watershed landuse model. The Agriculture Nonpoint Pollution Source (AGNPS) model was used to provide comparative values for each of the land uses and animal feeding operations located in the watershed. See the AGNPS section of the final report, pages 52-59.

The impacts of phosphorus reductions on the condition of Rose Hill Lake were calculated using BATHTUB, an Army Corps of Engineers model. The model predicted that to achieve a 2 point reduction in the TSI, a 40% reduction in the phosphorus load from the watershed is required. Social and economic interests in this watershed make a 40% reduction an unrealistic goal. Local interests will result in a 20% reduction in the phosphorus load to Rose Hill Lake.

Additional improvements in the lakes TSI are only possible through inlake inactivation of nutrients. Rose Hill Lake releases large amounts of nutrients during the growing season that account for a large part of the impairment. Modeling efforts indicated that with inactivation of 30 % of sediment-released phosphorus, a TSI of less than 65 is possible. (pages 33-34, 67)

TMDL and Allocations

TMDL for Phosphorus

	0 kg/yr	(WLA)
+	3,260 kg/yr	(LA) Crop
+	2,158 kg/yr	(LA) Range
+	,0 kg/yr	(Background)
	Implicit (MOS)	
	5,418 kg/yr	(TMDL)

Wasteload Allocations (WLAs)

There are no point sources of pollutants of concern in this watershed. Therefore, the "wasteload allocation" component of these TMDLs is considered a zero value. The TMDLs are considered wholly included within the "load allocation" component.

Load Allocations (LAs)

A 22% reduction in the phosphorus and 9% reduction in the nitrogen load to Rose Hill Lake may be obtained through the improvement of the critical cells identified in the AGNPS section of the final report reducing the annual load from 6,963 kg/yr to 5,418 kg/yr of phosphorus and 20,488 kg/yr to 18,645 kg/yr of nitrogen. This meets or exceeds the reductions needed to meet the lakes water quality goal.

Rangeland BMPs targeting 4,500 to 9,000 acres of rangeland will result in additional reductions in phosphorus loads to the lake. This is addressed on page 53 of the final report.

In lake reductions in total phosphorus were also estimated for Rose Hill Lake. A 30% reduction in phosphorus concentrations resulting in a 7% reduction in the phosphorus TSI values.

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in precipitation and agricultural practices. To determine seasonal differences, Rose Hill Lake samples were separated into spring (March-May), summer (June-August), fall (September-November), and winter (December-February) collection periods. Seasonalized data may be found on page 14.

Margin of Safety

Implementation of best management practices on the rangeland acres in the Rose Hill watershed will result in an implicit margin of safety for the loading reductions as a result of the modeling that was used in addition to reductions as a result of improved rangeland conditions.

Critical Conditions

The impairments to Rose Hill Lake are most severe during the late summer. This is the result of warm water temperatures and peak algal growth as well as peak recreational use of the lake.

Follow-Up Monitoring

As part of the implementation, monitoring and evaluation efforts will target the effectiveness of implemented BMP's. Sample sites will be based on BMP site selection and parameters will be based on a product specific basis.

Monitoring will also take place prior to the construction at least two of the proposed BMP's and three times at the lake during each growing season. Samples will be collected both upstream and downstream of the proposed project area to measure impact of the specific site. Following construction, these sites will again be tested to measure the effectiveness of the BMP.

Once the implementation project is completed, post-implementation monitoring will be necessary to assure that the TMDL has been reached and improvement to the beneficial uses occurs.

Public Participation

Efforts taken to gain public education, review, and comment during development of the TMDL involved:

1. Central Plains Water Development District Board Meetings
2. Hand County Conservation District Board Meetings
3. Articles in the local newspapers
4. Individual contact with over 95% of the residents in the watershed.

The findings from these public meetings and comments have been taken into consideration in development of the Rose Hill Lake TMDL.

Implementation Plan

The South Dakota DENR is working with the Hand County Conservation District and the Central Plains Water Development District to initiate an implementation project beginning in the spring of 2002. It is expected that a local sponsor will request project assistance during the spring 2002 EPA Section 319 funding round.

Forty copies of this document were printed by the Department of Environment and Natural Resources at a cost of $3.51 per copy.

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APR 2003
Dept. of Environment
and Natural Resources,
Environmental Services

APR - 2 2003

Ref: 8EPR-EP

Steven M. Pirner, Secretary
Department of Environment & Natural Resources
Joe Foss Building
523 East Capitol
Pierre, SD 57501-3181

Re: TMDL Approvals
Jones Lake
Loyalton Dam
Mina Lake
Rose Hill Lake

Dear Mr. Pirner:

We have completed our review, and have received ESA Section 7 concurrence from the US Fish and Wildlife Service, on the total maximum daily loads (TMDLs) as submitted by your office for the waterbodies listed in the enclosure to this letter. In accordance with the Clean Water Act (33 U.S.C. 1251 *et. seq.*), we approve all aspects of the TMDLs as developed for the water quality limited waterbodies as described in Section 303(d)(1).

Based on our review, we feel the separate TMDL elements listed in the enclosed review table adequately address the pollutants of concern, taking into consideration seasonal variation and a margin of safety. Please find enclosed a detailed review of these TMDLs.

For years, the State has sponsored an extensive clean lakes program. Through the lakes assessment and monitoring efforts associated with this program, priority waterbodies have been identified for cleanup. It is reasonable that these same priority waters have been a focus of the Section 319 nonpoint source projects as well as one of the priorities under the State's Section 303(d) TMDL efforts.

In the course of developing TMDLs for impaired waters, EPA has recognized that not all impairments are linked to water chemistry alone. Rather, EPA recognizes that *"Section 303(d) requires the States to identify all impaired waters regardless of whether the impairment is due to toxic pollutants, other chemical, heat, habitat, or other problems."* (see 57 Fed. Reg. 33040 for July 24, 1992). Further, EPA states that "*...in some situations water quality standards – particulary designated uses and biocriteria – can only be attained if nonchemical factors such as hydrology, channel morphology, and habitat are also addressed. EPA recognizes that it is* *chemical parameters that are preventing the attainment of water quality standards.*" (see Guidance for Water Quality-based Decisions: The TMDL Process; USEPA; EPA 440/4-91-001, April 1991; pg. 4). We feel the State has developed TMDLs that are consistent with this guidance, taking a comprehensive view of the sources and causes of water quality impairment within each of the watersheds. For example, in several of the TMDLs, the State considered nonchemical factors such as trophic state index (TSI) and its relationship to the impaired uses. Further, we feel it is reasonable to use factors such as TSI as surrogates to express the final endpoint of the TMDL.

Thank you for your submittal. If you have any questions concerning this approval, feel free to contact Vernon Berry of my staff at 303-312-6234.

Sincerely,

Max H. Dodson
Assistant Regional Administrator
Office of Ecosystems Protection and
Remediation

Enclosure

Enclosure

APPROVED TMDLS

Waterbody Name*	TMDL Parameter/ Pollutant	Water Quality Goal/Endpoint	TMDL	Section 303(d)1 or 303(d)3 TMDL	Supporting Documentation (not an exhaustive list of supporting documents)
Jones Lake*	phosphorus	TSI mean ≤ 70.0	10% reduction in tributary phosphorus loads and 35% reduction of inlake phosphorous	Section 303(d)(1)	■ Phase I Watershed Assessment and TMDL Final Report, Jones Lake/Turtle Creek, Hand County, South Dakota (SD DENR, May 2002)
Loyalton Dam*	phosphorus	TSI mean ≤ 65	10% reduction in tributary phosphorus loads and 50% reduction of inlake phosphorous	Section 303(d)(1)	■ Phase I Watershed Assessment Final Report and TMDL, Loyalton Dam Watershed, Edmunds County, South Dakota (SD DENR, October 2002)
Mina Lake*	phosphorus	TSI mean < 79.18	38.8% reduction of total phosphorus load	Section 303(d)(1)	■ Phase I Watershed Assessment Final Report and TMDL, Mina Lake/Snake Creek, Brown, Edmunds and McPherson Counties, South Dakota (SD DENR, March 2002)
Rose Hill Lake*	phosphorus	TSI mean < 65	20% reduction in tributary phosphorus loads and 30% reduction of inlake phosphorous	Section 303(d)(1)	■ Phase I Watershed Assessment and TMDL Final Report, Rose Hill Lake/Sand Creek, Hand County, South Dakota (SD DENR, January 2002)

* An asterisk indicates the waterbody has been included on the State's Section 303(d) list of waterbodies in need of TMDLs.

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Loyalton Dam, Edmunds County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: December 24, 2002 Date Review completed: January 24, 2003 VEB

Review Criteria (All criteria must be met for approval)	**Approved** (check if yes)	**Comments**
■ **TMDLs result in maintaining and attaining water quality standards**	X	The waterbody classification uses which are addressed by this TMDL are warmwater semipermanent fish life propagation, immersion recreation, limited contact recreation, and criteria for fish and wildlife propagation, recreation and stock watering.
■ **Water Quality Standards Target**	X	Water quality targets were established based on trophic status. This is a reasonable approach because the trophic status of the waterbody relates to the uses of concern.
■ **TMDL**	X	The TMDL is expressed in terms of annual phosphorus load reduction. This is a reasonable way to express the TMDL for this lake because it provides an effective surrogate that reflects both aquatic life and recreational needs, and reflects the long response time of lakes of this type to pollutant controls within the watershed.
■ **Significant Sources Identified**	X	Significant sources were adequately identified in a categorical and/or individual source-by-source basis. All sources that need to be addressed through controls were identified.
■ **Technical Analysis**	X	Monitoring, empirical relationships, AGNPS and BATHTUB modeling, and best professional judgement were used in identifying pollutant sources, and in identifying acceptable levels of pollutant control. This level of technical analysis is reasonable and appropriate because of the character of the pollutants, the type of land use practices, and the waterbody type.
■ **Margin of Safety and Seasonality**	X	An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing that BMPs be tailored to seasonal needs.
■ **Allocation**	X	The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. Allocation was attributed to range and cropland management practices, and internal loading.
■ **Public Review**	X	Public review and participation was conducted through meetings, electronic media, and mailings. The extent of public review is acceptable. Further, the review process sponsored by the State was adequate for purposes of developing a TMDL that will be implemented because of public acceptance.
■ **EPA approved Water Quality Standards**	X	Standards upon which this TMDL was based have been formally approved by the EPA. No tribal waters were involved in this TMDL.

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Rose Hill Lake, Hand County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: December 24, 2002 Date Review completed: January 24, 2003 VEB

Review Criteria (All criteria must be met for approval)	**Approved** (check if yes)	**Comments**
■ **TMDLs result in maintaining and attaining water quality standards**	X	The waterbody classification uses which are addressed by this TMDL are warmwater permanent fish life propagation, immersion recreation, limited contact recreation and fish and wildlife propagation, recreation and stock watering.
■ **Water Quality Standards Target**	X	Water quality targets were established based on trophic status. This is a reasonable approach because the trophic status of the waterbody relates to the uses of concern.
■ **TMDL**	X	The TMDL is expressed in terms of inlake phosphorus load reduction. This is a reasonable way to express the TMDL for this lake because it provides an effective surrogate that reflects both aquatic life and recreational needs.
■ **Significant Sources Identified**	X	Significant sources were adequately identified in a categorical and/or individual source-by-source basis. All sources that need to be addressed through controls were identified.
■ **Technical Analysis**	X	Monitoring, empirical relationships, AGNPS and BATHTUB modeling , and best professional judgement were used in identifying pollutant sources, and in identifying acceptable levels of pollutant control. This level of technical analysis is reasonable and appropriate because of the character of the pollutants, the type of land use practices, and the waterbody type.
■ **Margin of Safety and Seasonality**	X	An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing that BMPs be tailored to seasonal needs.
■ **Allocation**	X	The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. Allocation was attributed to range and cropland management practices, and internal loading.
■ **Public Review**	X	Public review and participation was conducted through meetings, electronic media, and mailings. The extent of public review is acceptable. Further, the review process sponsored by the State was adequate for purposes of developing a TMDL that will be implemented because of public acceptance.
■ **EPA approved Water Quality Standards**	X	Standards upon which this TMDL was based have been formally approved by the EPA. No tribal waters were involved in this TMDL.

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Jones Lake, Hand County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: December 24, 2002 Date Review completed: January 24, 2003 VEB

A. Water Quality Standards - **Approved**	The State's submittal provides a good description of the geographic scope of the TMDL as well as information on the watershed and land use characteristics of Jones Lake. The South Dakota Department of Environment and Natural Resources (SD DENR) has identified Jones Lake as a water that is intended to support a range of designated uses including: warmwater semipermanent fish life propagation, immersion recreation, limited contact recreation, fish and wildlife propagation, recreation and stock watering. The narrative standards being implemented in this TMDL are: "*Materials which produce nuisance aquatic life may not be discharged or caused to be discharged into surface waters of the state in concentrations that impair a beneficial use or create a human health problem.*" (See ARSD §74:51:01:09) "*All waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities.*" (See ARSD §74:51:01:12)
B. Water Quality Standards Targets - **Approved**	Water quality targets for this TMDL are based on interpretation of narrative provisions found in State water quality standards. In May 2000, SD DENR published *Ecoregion Targeting for Impaired Lakes in South Dakota*. This document proposed ecoregion-specific targeted Trophic State Index (TSI) values based on beneficial uses. EPA approved the use of these ecoregion-specific targets to evaluate lakes using beneficial use categories. In South Dakota algal blooms can limit contact and immersion recreation beneficial uses. Also algal blooms can deplete oxygen levels which can affect aquatic life uses. SD DENR considers several algal species to be nuisance aquatic species. TSI measurements can be used to estimate how much algal production may occur in lakes. Therefore, TSI is used as a measure of the narrative standard in order to determine whether beneficial uses are being met. The overall mean TSI for Jones Lake during the period of the assessment (June 2000 through spring 2001) was 71.1. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that 70% or more reduction in the total phosphorous loading from the watershed would be necessary to meet the ecoregion-based beneficial use TSI target of 65 or less. However, Jones Lake does not appear to fit the ecoregion-based beneficial use criteria due to legacy phosphorous loading to the lake and the technical and financial inability to fully treat new loading to the lake. Therefore, a higher TSI target has been established for Jones Lake. The target used in this TMDL is: ▪ TSI mean less than 70 (growing season average)

State/Tribe: South Dakota
Waterbody Name: Jones Lake, Hand County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: December 24, 2002 Date Review completed: January 24, 2003 VEB

C. Significant Sources - **Approved**	The TMDL identifies the major sources of phosphorous as coming from nonpoint source agricultural landuses within the watershed and internal loading from bottom sediments within the lake. In particular, a loading analysis was done for nutrients and sediment considering various agricultural land use and land management factors.
D. Technical Analysis - **Approved**	The technical analysis addresses the needed phosphorous reduction to achieve the desired water quality. The TMDL recommends a 10% reduction in phosphorous loading from the watershed to Jones Lake, and a 35% reduction in sediment released phosphorous to achieve the desired results. This reduction is based in large part on the BATHTUB mathematical modeling of the Lake and its predicted response to nutrient load reductions. The Agricultural Non-Point Source Model (AGNPS) model was used to simulate alterations in land use practices and the resulting nutrient reduction response. The analysis of which nutrient loading sources were in need of control was based on a identification of targeted or "critical" cells. Cell priority was assigned based on average nutrient loads produced that ultimately reach the outlet of the watershed. Cells that produce nitrogen *and* phosphorous loads greater than two standard deviations over the mean for the watershed were given a priority ranking of 1. Cells that produce nitrogen *or* phosphorous loads greater than two standard deviations over the mean were given a priority ranking of 2. The initial load reductions under this TMDL will be achieved through controls on the priority 1 and 2 cells within the watershed combined with modification of grazing practices. The reduction in sediment released phosphorous will be possible through inlake treatments such as the application of alum.
E. Margin of Safety & Seasonality - **Approved**	An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing that BMPs be tailored to seasonal needs.
F. TMDL - **Approved**	The TMDL established for Jones Lake is a 10% reduction in annual tributary loading phosphorus and a 35% reduction in sediment released phosphorous. Since the annual loading varies from year-to-year, this TMDL is considered a long term average reduction in phosphorous loading.
G. Allocation - **Approved**	This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in Jones Lake. The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. The allocation for phosphorous was attributed to such sources as animal feeding areas, internal loading and cropland tillage. There is a desire to move forward with controls in the areas of the basin where there is confidence that phosphorous reductions can be achieved through modifications to priority 1 and 2 cells within the watershed combined with modification of grazing practices and modest reductions in sediment released phosphorous. Additional phosphorous load reductions are possible if all of the cropping and grazing uses were converted to conservation reserve program (CRP) use (i.e., 68% reduction in phosphorus), or through extensive inlake restoration activities. However, much of the cropland within the watershed is already following conservation tillage practices and complete conversion to CRP is unrealistic. The size and location of this lake would make it difficult to obtain local support and funding for extensive inlake restoration activities necessary to achieve significantly higher phosphorous load reductions.

State/Tribe: South Dakota
Waterbody Name: Jones Lake, Hand County
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: December 24, 2002 Date Review completed: January 24, 2003 VEB

H. Public Participation - **Approved**	The State's submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through public meetings in the watershed, articles in local newspapers, individual contact with over 95% of the residents in the watershed, and widespread solicitation of comments on the draft TMDL. The State also employed the Internet to post the draft TMDL and to solicit comments. The level of public participation is found to be adequate.

■ TMDL Checklist ■

EPA Region VIII

State/Tribe: South Dakota
Waterbody Name: Mina Lake, Brown, Edmunds and McPherson Counties
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: December 24, 2002 Date Review completed: January 24, 2003 VEB

A. Water Quality Standards - **Approved**

The State's submittal provides a good description of the geographic scope of the TMDL as well as information on the watershed and land use characteristics of Mina Lake.

The South Dakota Department of Environment and Natural Resources (SD DENR) has identified Mina Lake as a water that is intended to support a range of designated uses including: domestic water supply, warmwater permanent fish life propagation, immersion recreation, limited contact recreation, fish and wildlife propagation, recreation and stock watering. The narrative standards being implemented in this TMDL are:

> "*Materials which produce nuisance aquatic life may not be discharged or caused to be discharged into surface waters of the state in concentrations that impair a beneficial use or create a human health problem.*" (See ARSD §74:51:01:09)
>
> "*All waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities.*" (See ARSD §74:51:01:12)

B. Water Quality Standards Targets - **Approved**

Water quality targets for this TMDL are based on interpretation of narrative provisions found in State water quality standards. In May 2000, SD DENR published *Ecoregion Targeting for Impaired Lakes in South Dakota*. This document proposed ecoregion-specific targeted Trophic State Index (TSI) values based on beneficial uses. EPA approved the use of these ecoregion-specific targets to evaluate lakes using beneficial use categories. In South Dakota algal blooms can limit contact and immersion recreation beneficial uses. Also algal blooms can deplete oxygen levels which can affect aquatic life uses. SD DENR considers several algal species to be nuisance aquatic species. TSI measurements can be used to estimate how much algal production may occur in lakes. Therefore, TSI is used as a measure of the narrative standard in order to determine whether beneficial uses are being met.

The overall mean TSI for Mina Lake during the period of the assessment (June 1999 through spring 2000) was 79.4. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that 94% or more reduction in the total phosphorous loading from the watershed would be necessary to meet the ecoregion-based beneficial use TSI target of 65 or less. However, Mina Lake does not appear to fit the ecoregion-based beneficial use criteria due to legacy phosphorous loading to the lake and the technical and financial inability to fully treat new loading to the lake. Therefore, a higher TSI target has been established for Mina Lake.

The target used in this TMDL is:

- TSI mean less than 79.2 (growing season average)
- Phosphorous TSI less than 98.4

State/Tribe: South Dakota
Waterbody Name: Mina Lake, Brown, Edmunds and McPherson Counties
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: December 24, 2002 Date Review completed: January 24, 2003 VEB

C. Significant Sources - **Approved**	The TMDL identifies the major sources of phosphorous as coming from nonpoint source agricultural landuses within the watershed and internal loading from bottom sediments within the lake. In particular, a loading analysis was done by sub-watershed for nutrients and sediment considering various agricultural land use and land management factors.
D. Technical Analysis - **Approved**	The technical analysis addresses the needed phosphorous reduction to achieve the desired water quality. The TMDL recommends a 38.8% reduction in total phosphorous loading from watershed and sediment released phosphorous sources to Mina Lake. This reduction is based in large part on the BATHTUB mathematical modeling of the Lake and its predicted response to nutrient load reductions. The Agricultural Non-Point Source Model (AGNPS) model was used to simulate alterations in land use practices and the resulting nutrient reduction response. The analysis of which nutrient loading sources were in need of control was based on a identification of targeted or "critical" cells. Cell priority was assigned based on average nutrient loads produced that ultimately reach the outlet of the watershed. Cells that produce phosphorous loads greater than 1, 2, and 3 standard deviations over the mean for each sub-watershed were given a priority ranking of 1, 2 and 3 respectively. The initial load reductions under this TMDL will be achieved through controls on the priority 1 and 2 cropland cells within the watershed such as reducing fertilizer application rates and conversion to conservation tillage (i.e., minimum or no-till) practices. Controls at critical livestock feeding area combined with modification of grazing practices will also be necessary to achieve the desired results. The reduction in sediment released phosphorous will be possible through inlake treatments such as the application of alum.
E. Margin of Safety & Seasonality - **Approved**	An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing that BMPs be tailored to seasonal needs.
F. TMDL - **Approved**	The TMDL established for Mina Lake is a 38.8% reduction in total annual phosphorus loading from the watershed and sediment released sources. Since the annual loading varies from year-to-year, this TMDL is considered a long term average reduction in total phosphorous loading.
G. Allocation - **Approved**	This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in Mina Lake. The allocation for the TMDL was a "load allocation" attributed to nonpoint sources. The allocation for phosphorous was attributed to such sources as cropland tillage, fertilizer application, animal feeding areas, and internal loading. There is a desire to move forward with controls in the areas of the basin where there is confidence that phosphorous reductions can be achieved through modifications to priority 1 and 2 cropland cells within the watershed combined with animal feeding area controls, modification of grazing practices and modest reductions in sediment released phosphorous. Additional phosphorous load reductions are possible if all of the cropping and grazing uses were converted to conservation reserve program (CRP) use and other drastic changes in land use and management. However, historic data indicate that Mina Lake has been hyper-eutrophic for the entire period of data collection (beginning in 1979). Therefore, the goal is to reverse the TSI trend. It would be technically and economically very difficult to implement enough BMPs within the watershed to achieve long term TSI values in eutrophic range.

State/Tribe: South Dakota
Waterbody Name: Mina Lake, Brown, Edmunds and McPherson Counties
Point Source-control TMDL: Nonpoint Source-control TMDL: X (check one or both)
Date Received: December 24, 2002 Date Review completed: January 24, 2003 VEB

H. Public Participation - **Approved**	The State's submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through public meetings in the watershed, articles in local newspapers, individual contact with landowners in the watershed, and widespread solicitation of comments on the draft TMDL. The State also employed the Internet to post the draft TMDL and to solicit comments. The level of public participation is found to be adequate.