MARSHALL COUNTY LAKES ASSESSMENT PROJECT

FINAL REPORT
FOR
NINE MILE LAKE
MARSHALL COUNTY, SOUTH DAKOTA

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

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SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM ASSESSMENT/PLANNING PROJECT FINAL REPORT

MARSHALL COUNTY LAKES ASSESSMENT PROJECT

FINAL REPORT FOR NINE MILE LAKE

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Sponsor

Marshall Conservation District

3/1/07

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Marshall Conservation District

South Dakota Department of Environment and Natural Resources

South Dakota Department of Game, Fish & Parks

USDA Natural Resource Conservation Service

Prairie Agricultural Research, Inc.

Sol Brich created the lake and sediment depth maps.

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EXECUTIVE SUMMARY

PROJECT TITLE: Marshall County Lakes Assessment Project

PROJECT START DATE: 4/1/02	PROJECT COMPLETION DATE: 3/1/07
FUNDING:	TOTAL BUDGET: $192,000.00
TOTAL EPA GRANT:	$165,000.00 amended to $120,000.00
TOTAL EXPENDITURE OF EPA FUNDS:	$79,981.22
NONFEDERAL MATCH	
State Natural Resources Fee Funds	$25,000.00
Marshall Con. District	1,003.50
BUDGET REVISIONS:	Decrease $165,000 EPA funds to $120,000
TOTAL EXPENDITURES:	$105,984.72

SUMMARY ACCOMPLISHMENTS

The Marshall County Lakes Assessment Project was conducted because a number of lakes in the County were placed on the 1996-2006 303(d) lists for an increasing TSI trend, siltation, nutrients and aquatic nuisances (algae). The primary goal for the project was to determine sources of impairment to Nine Mile Lake, South Red Iron Lake, and North and South Buffalo Lakes, and provide sufficient background data to drive a Section 319 Implementation Project. This report is about Nine Mile Lake.

An EPA section 319 grant provided a majority of the funding for this project. The State of South Dakota provided non-federal matching funds/in-kind services for the project.

Water quality monitoring indicated a trophic state relatively similar to other lakes in the region. The lake did not exhibit thermal stratification and dissolved oxygen concentrations were usually less than the water quality standard. The standards criteria for nitrate, unionized ammonia, conductivity, total suspended solids, and fecal coliform bacteria were not exceeded. Seasonality was indicated by typical temperature changes throughout the year and by seasonal changes in some parameter concentrations. Aquatic macrophyte and sediment surveys were completed for the lake. Aquatic macrophytes were deemed a major problem in the lake. Sediment depths in the lake were considered somewhat greater than was indicated by most other lake sediment surveys but the local financial base is likely not sufficient to support dredging. However, removing those sediments could increase the lake volume by 43%, extend the life of the lake, and possibly alleviate internal nutrient loading.

Seasonality was indicated by peaks in sediment and nutrient loading that occurred during the spring runoff period. Results from the BATHTUB model were used to establish a total maximum annual load of 376.2 kg/year (1.03 kg/day) for total phosphorus, which will maintain the lake under the Secchi-chlorophyll *a* TSI target of 63.4

The Annualized Agricultural Non-point Source computer model (AnnAGNPS) was not used because the lake was already meeting its TSI target. In-lake restoration techniques such as aeration/circulation and macrophyte control were recommended to alleviate the low dissolved oxygen concentrations and the extensive macrophyte coverage. Best Management Practices were also recommended for maintaining the TMDL and for improving dissolved oxygen concentrations.

INTRODUCTION

Purpose

The purpose of this assessment is to determine the sources of impairment to Nine Mile Lake and its tributaries, determine a total maximum daily load that will maintain full support of the lake's beneficial uses, and recommend strategies to restore the lake.

General Lake Description

Nine Mile Lake is a 282-acre natural lake located in Marshall County, South Dakota (Figure 1). The lake is primarily used for fishing. The average depth of the lake is two meters (6.6 feet) and it has a maximum depth of three meters (10 feet). A number of homes are located adjacent to the lake and all use septic systems.

No large streams enter the lake but there are two small unnamed tributaries that receive drainage from primarily grazing lands and some cropland acres. The tributaries carry sediment and nutrient loads, which are thought to degrade water quality in the lake and cause eutrophication.

The lake is currently plagued with extensive beds of macrophytes, to the extent that operating a motorized boat in the lake is difficult. There are few areas of open water.

Lake Identification and Location

Lake Name: Nine Mile Lake	State: South Dakota
County: Marshall	Township: 126-127N
Range: 55W	Sections: 5, 31-32
Nearest Municipality: Lake City	Latitude: 45.673809
Longitude: -97.318471	EPA Region: VIII
Primary Tributary: Unnamed	Receiving Body of Water: Unnamed
HUC Code: 101600100	HUC Name: North Big Sioux Coteau

Trophic State Comparison

Developed by Carlson (1977), the Trophic State Index (TSI), is a numerical value from 0 to 100 that 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 the growing-season TSI for Nine Mile Lake to other lakes in the area (Table 1) shows that Nine Mile Lake is relatively similar to other lakes in the area and that a moderate to high rate of productivity is common for the region.

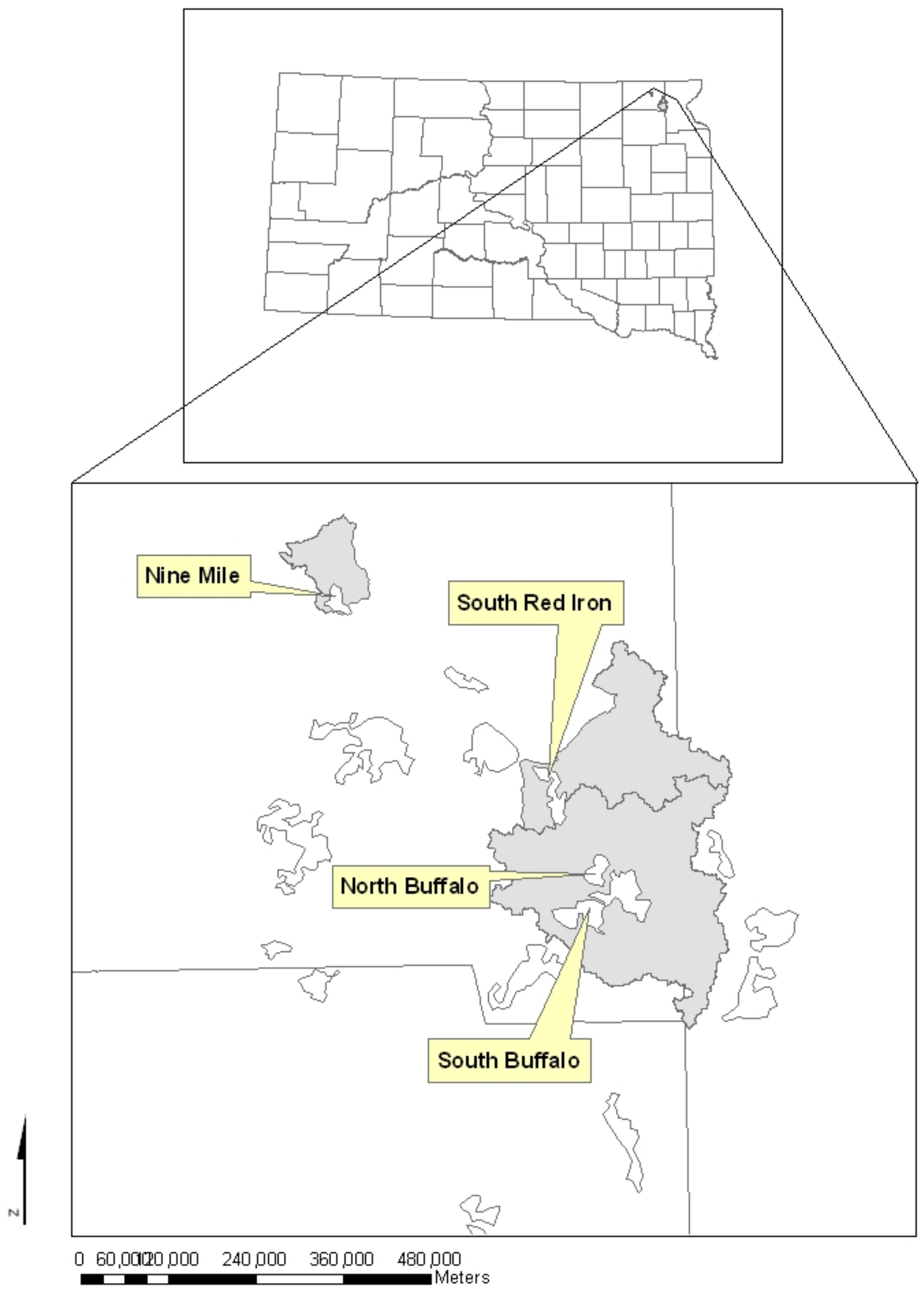

Figure 1. Lakes and their watersheds in the Marshall County Lakes Assessment Project.

Table 1. TSI comparison of Nine Mile Lake and other area lakes*.

Lake	1989 Avg. TSI	1991 Avg. TSI	1993 Avg. TSI	Mean Trophic State
White Lake	69.05	71.74	69.59	Eutrophic
Roy	62.95	65.01	60.88	Eutrophic
S. Red Iron	51.28	62.02	59.07	Eutrophic
S. Buffalo	54.17	70.09	64.24	Eutrophic
Average	**59.36**	**67.22**	**63.45**	Eutrophic
Nine Mile Lake	**60.08**	**66.11**	**63.87**	Eutrophic

* TSI values taken from Stueven and Stewart, 1996.

Beneficial Uses and Water Quality Standards

The State of South Dakota has assigned all of the water bodies that are within its borders a set of beneficial uses. With these assigned uses are sets of standards for various physical and chemical properties. These standards must be maintained for the waterbody to satisfy its assigned beneficial uses. All bodies of water in the state receive the beneficial uses of fish and wildlife propagation, recreation, and stock watering. Following is the list of beneficial uses assigned to Nine Mile Lake.

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

With each of these uses are sets of water quality standards that must not be exceeded in order to maintain these uses. The following tables list those parameters measured during this study that must be considered when maintaining the beneficial uses as well as the concentrations for each parameter. When multiple standards for a parameter exist, the most restrictive standard is used. Additional "narrative" standards that may apply can be found in the Administrative Rules of South Dakota Articles 74:51:01:05; 06; 08; and 09. These contain language that generally prohibits the presence of materials causing pollutants to form, visible pollutants, and nuisance aquatic life. Carlson's (1977) trophic state indices are used during this study as a measure of beneficial use support. The indices are based on total phosphorus, Secchi disc transparency and chlorophyll *a*. The critical values for beneficial use status were derived from a SDDENR study of South Dakota lakes and from regionality of various lake attributes (Lorenzen, 2005).

Individual parameters as well as the lake's TSI value determine the support of these beneficial uses. Nine Mile Lake is listed in the state's 2006 303(d) list and was identified as not supporting its fish life propagation use due to an elevated TSI.

Table 2. State beneficial use standards for Nine Mile Lake, Marshall County, South Dakota.

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 *(Geo.mean)*, ≤ 400 *(single sample)*	Immersion Recreation
Conductivity *(μmhos/cm @ 25 °C)*	≤ 4,000 *(mean,)* ≤ 7,000 *(single sample)*	Wildlife Propagation and Stock Watering
Nitrogen, Total ammonia as N	$(0.411/(1+10^{7.204-pH}))+(58.4/(1+10^{pH-7.204}))$ *(single sample)*	Warmwater Semi-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 Semi-permanent Fish Propagation
Solids, suspended	≤ 90 *(mean)*, ≤ 158 *(single sample)*	Warmwater Semi-permanent Fish Propagation
Temperature	≤ 32.22 C	Warmwater Semi-permanent Fish Propagation

The tributaries of Nine Mile Lake have the beneficial uses of:

(9) Fish and wildlife propagation, recreation, and stock watering, and

(10) Irrigation

In order for the tributaries to maintain these uses, there are five standards that must be maintained. These standards, along with their numeric criteria, are listed in Table 3.

Table 3. State water quality standards for the unnamed tributaries of Nine Mile Lake.

Parameters	Criterion, mg/l (except where noted)
Nitrate	≤ 50 (mean), ≤ 88 (single sample)
Alkalinity	≤ 750 (mean), ≤ 1,313 (single sample)
pH	≥ 6.5 and ≤ 9.5
Conductivity	≤ 4,000 (mean), ≤ 7,000 (single sample)

Recreational Uses

The South Dakota Department of Game, Fish, and Parks provides a list of public facilities that are maintained at area lakes (Table 4). Most of the larger and more frequently used lakes in the area have adequate facilities. This includes Nine Mile Lake.

Table 4. Comparison of recreational uses on lakes near Nine Mile Lake.

Lake	State Parks	Ramps	Boating	Campground	Fishing	Picnic Tables	Swimming	Nearest Municipality
White Lake		X	X		X		X	Britton
South Buffalo		X	X		X		X	Eden
South Red Iron		X	X		X		X	Eden
North Buffalo		X	X		X		X	Eden
Roy Lake	X	X	X	X	X	X	X	Lake City
Nine Mile Lake		**X**	**X**		**X**		**X**	**Lake City**

Watershed

Nine Mile Lake and its 2,722-acre watershed are located four miles west of Lake City, South Dakota. The watershed is characterized by rolling short-grass prairie, pastureland with a small portion in cultivation. The major soil association found in the watershed is the Forman-Aastad-Busek association (USDA, 1975). These are deep, nearly level to steep, well drained loamy soils that formed in glacial till of calcareous clay loam and located on the uplands.

Land use in the watershed is primarily agricultural grazing with some cropland. Small grains and hay are the main crops on cultivated lands. The average annual precipitation in Britton is 20.68 inches, of which most usually falls during April through September. Tornadoes and severe thunderstorms strike occasionally. These storms are local and of short duration and occasionally produce heavy rain fall events

History

Nine Mile Lake is a natural lake so named because it is nine miles from Fort Sisseton. The lake is also approximately four miles west of Lake City, the nearest municipality.

Previous water quality data and anecdotal information indicated the lake experienced algae and aquatic vegetation problems in the past. Recently, users of Nine Mile Lake reported difficulties with fishing and other recreational uses due to extensive beds of submerged macrophytes. In addition, the 2000 South Dakota Report to Congress, 305(b) water quality assessment and the 2004 and 2006 South Dakota Integrated Reports described the water quality of Nine Mile Lake as being impacted by non-point source pollution. The Marshall Conservation District was concerned enough about the quality of the lakes in the area that they agreed to sponsor a four-lake assessment in Marshall County.

Threatened and Endangered Species

The only species on the federal list of threatened and endangered species likely to occur in the Nine Mile Lake watershed is the bald eagle (*Haliaeetus leucocephalis)*, which is listed as threatened. No bald eagles were encountered during this study; however, care should be taken when conducting mitigation projects in the watershed.

Nesting bald eagles have not been documented in the project area but there could be eagles migrating through the area, especially during the fall waterfowl migration. 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.

PROJECT GOALS, OBJECTIVES, AND ACTIVITIES

Planned and Actual Milestones, Products, and Completion Dates

Objective 1. Lake Sampling

The lake water sampling commenced June 2002 and continued through May 2003. Spring samples were collected during March, April and May of 2003. Bimonthly samples were collected during June through August. The sediment survey was conducted during March 2003.

Objective 2. Tributary Sampling

Immediately after the start of the project, the local coordinator began sampling the tributaries. Detailed cross-sectional and water velocity data were collected along with daily stage readings from Stevens stage recorders. These data were used to develop stage/discharge relationships so water flows could be calculated. These flows were entered into computer models (FLUX and BATHTUB) that were used to assess the nutrient and sediment loads to the lake.

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 in June 2002 and was completed as planned.

Objective 4. AnnAGNPS Modeling

Prairie Agricultural Research, Inc. toured the watershed and made initial determinations for the AnnAGNPS model. The NRCS office located in Britton made available information concerning land use information. The AnnAGNPS modeling was not completed because the lake was already meeting its target TSI and not in need of an extensive analysis of Best Management Practices (BMPs) and their effects.

Objective 5. Public Participation

The public was kept informed of the project through monthly meetings of the Marshall Conservation District.

Objectives 6 and 7. Restoration Alternatives and Final Report

The completion of the restoration alternatives and final report for Nine Mile Lake was delayed due to DENR personnel having other commitments.

Evaluation of Goal Achievements

The goal of the watershed assessment project for Nine Mile Lake was to determine and document sources of impairment to the lake and to develop feasible restoration strategies. This was accomplished through collection of tributary and lake data. Data analysis and modeling, and identification of impairment sources were made and restoration strategies were developed. A comparison of the planned and actual objective completion dates is given in Table 5.

Table 5. Proposed and actual objective completion dates for the Marshall County Lakes Assessment Project.

	6/02	7/02	8/02	9/02	10/02	11/02	12/02	1/03	2/03	3/03	4/03	503	6/03	7/03	8/03-12/06
Objective 1															
Lake Sampling															
Objective 2															
Tributary Sampling															
Objective 3															
QA/QC															
Objective 4															
Modeling															
Objective 5															
Public Participation															
Objective 6 & 7															
Final Report															
Planned															
Actual															

Monitoring Methods and Results

OBJECTIVE 1 – Lake Sampling and Sediment Survey

In-lake Sampling Schedule, Methods, and Materials

Two sampling sites were chosen to monitor Nine Mile Lake (Figure 2). Sampling began in June 2002, and was conducted on a bimonthly basis at the two in-lake sites during June, July, and August, and monthly during other months. Water samples were collected at both sites with a Van Dorn sampler from the lake surface and near the bottom of the lake. The samples were filtered, preserved, and packed in ice for shipping to the State Health Lab in Pierre, SD according to the "Standard Operating Procedures for Field Samplers" (Stueven, et al., 2000). The Laboratory analyzed the samples for the following parameters:

Fecal coliform bacteria	Alkalinity
Total solids	Total suspended solids
Total volatile suspended solids	Ammonia
Nitrate	Total Kjeldahl Nitrogen (TKN)
Total phosphorus	Total dissolved phosphorus
E. coli	Chlorophyll *a*

Personnel conducting the sampling at each of the sites recorded the following observations.

Precipitation	Wind
Odor	Septic conditions
Dead fish	Film
Width	Water depth
Ice cover	Water color

Parameters measured in the field by sampling personnel were:

Water temperature	Air temperature
Specific conductance	Dissolved oxygen
Field pH	Secchi depth

Original data may be found in Appendix A.

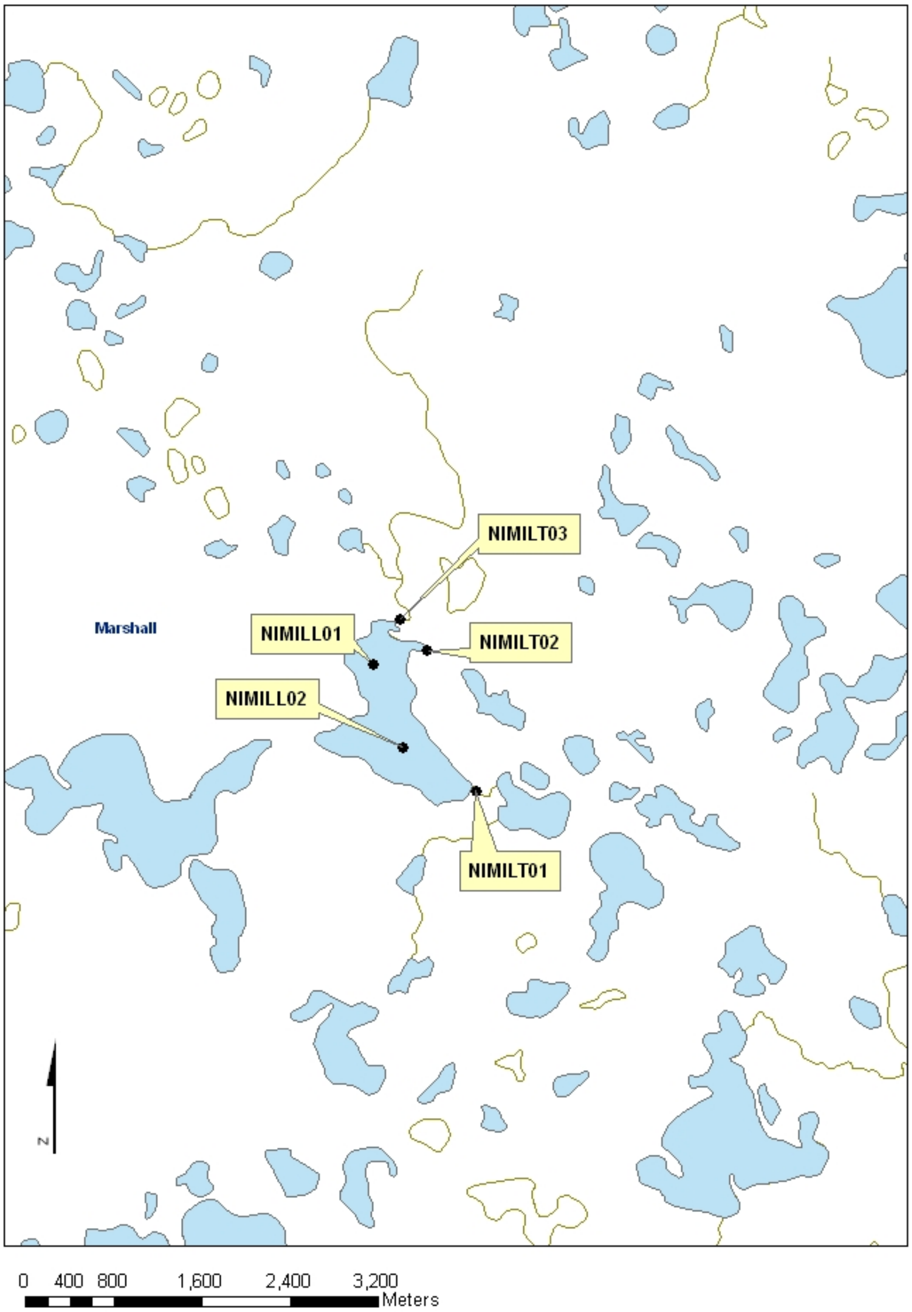

Figure 2. Sampling sites in Nine Mile Lake and its watershed.

In-lake Water Quality Results

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 do better under cooler conditions. Water temperature also plays a role in physical conditions. Oxygen dissolves in higher concentrations in cooler water. The toxicity of un-ionized ammonia is also related to warmer temperatures.

Surface water temperature in Nine Mile Lake exhibited little variation between the sites NIMILL01 and NIMILL02. Temperatures showed seasonal variations that are consistent with its geographic location, steadily increasing in the spring and summer and consistently decreasing in the fall and winter (Figure 3). It can be reasonably expected that during most years the in-lake temperatures would be within a few degrees of the project data at their respective dates.

Nine Mile Lake showed no significant thermal stratification during the study and most temperature readings at the lake surface and bottom differed by two degrees or less (Figure 3). Thermal stratification, however, has been reported in this lake (Stueven and Stewart, 1996). The water quality standard for temperature was not exceeded.

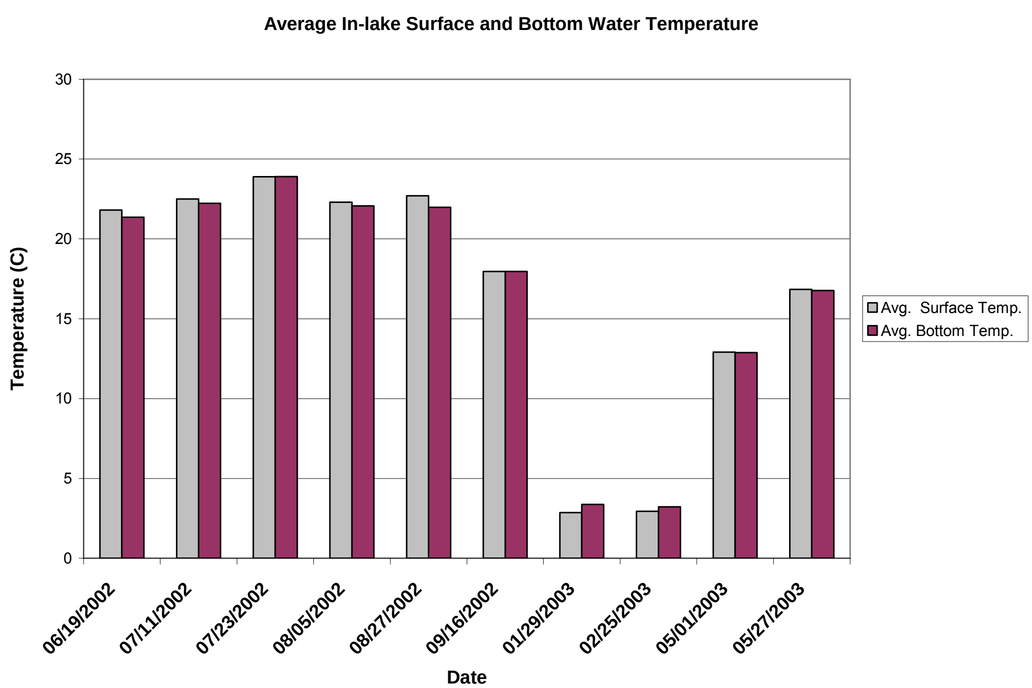

Figure 3. Average in-lake surface and bottom water temperatures for Nine Mile Lake, Marshall County, South Dakota, 2002/2003.

Dissolved Oxygen

There are many factors that influence the concentration of dissolved oxygen (DO) in a water body. 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). During winters with heavy snowfall, light penetration may be reduced to the point that the 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 (DO) levels at the surface of Nine Mile Lake were sufficient to maintain the minimum requirement for the local managed fishery but oxygen depletion did occur during August 27, 2002 (see Figure 4 and Appendix B). DO depletion was not limited to the lake bottom but occurred throughout the water column. Six out of fifty-three readings (11.3%) had DO levels below 5.0 mg/l, the DO criterion for maintaining warmwater semi-permanent fish life propagation. This was most likely due to elevated water temperatures during late summer and from bacteria using oxygen during the decomposition of organic matter in the lake. Dead fish were not noticed during the time of oxygen depletion and fish kills have not been reported to SDDENR during the past ten years.

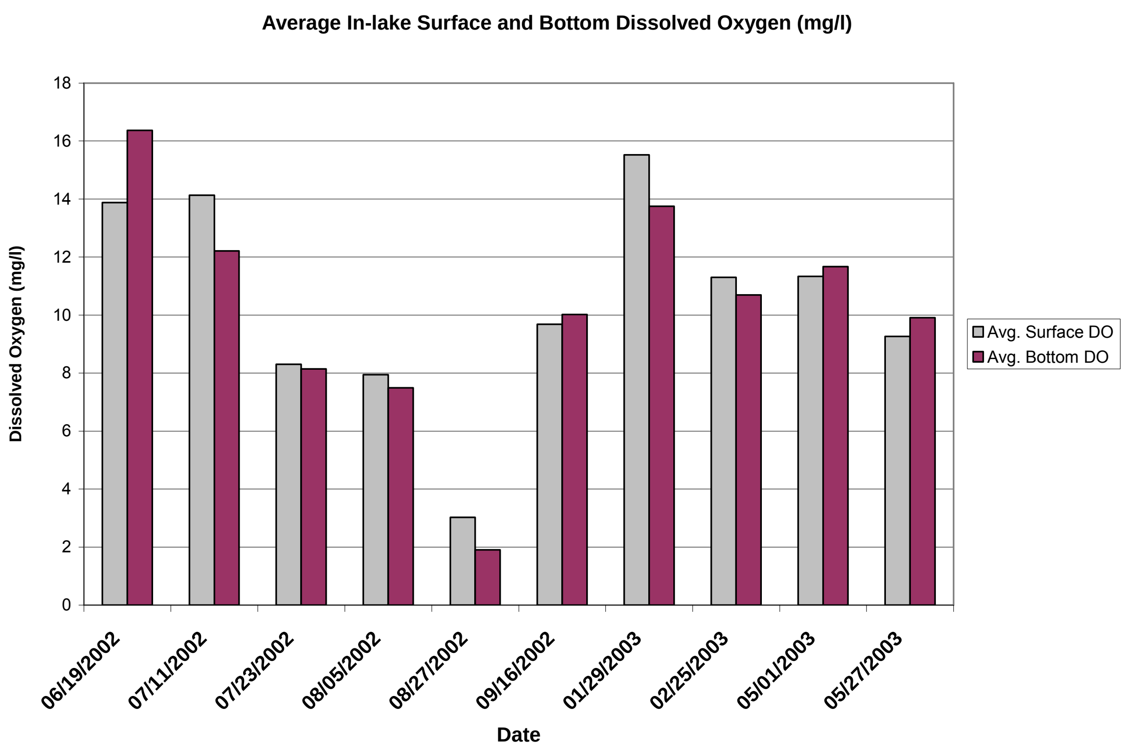

Figure 4. Average in-lake surface and bottom dissolved oxygen concentrations for Nine Mile Lake, Marshall County, South Dakota, 2002/2003.

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. At neutral (pH of 7) acid ions (H+) equal the base ions (OH-). Values less than 7 are considered acidic and greater than 7 are basic. Algal and macrophyte photosynthesis act to increase a lake's pH. 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.

pH values in Nine Mile Lake ranged from 7.22 to 10.22 and averaged 8.82 (Table 6). However, during the project, the project coordinator indicated that the YSI meter used to measure pH was acting abnormally. The YSI pH probe was eventually replaced but it was felt that much of the pH data were suspect. All four lakes monitored under the Marshall County Lakes Assessment Project exhibited a number of pH values greater than 9.0 and some as high as 10. This is not considered normal for lakes in this area of South Dakota. Algae are often implicated in causing higher pH values but none of these lakes had excessively high chlorophyll *a* concentrations. In addition, historical data show pH values in these lakes averaged 8.5-8.7 with only a couple of occurrences above 9.0 (Table 29 in Appendix A). Because of this, it was decided not to use the pH data obtained during the project. Given the historical data, pH was not considered problematic in these lakes.

Table 6. In-lake pH values for Nine Mile Lake, Marshall County, South Dakota, 2002/2003.

Site	Date	pH	Site	Date	pH
NIMILL01	6/19/02	8.6	NIMILL02	6/19/02	8.29
NIMILL01	6/19/02	8.64	NIMILL02	6/19/02	8.24
NIMILL01	6/19/02	8.43	NIMILL02	6/19/02	8.29
NIMILL01	7/11/02	8.84	NIMILL02	7/11/02	8.83
NIMILL01	7/11/02	8.65	NIMILL02	7/11/02	8.78
NIMILL01	7/11/02	8.71	NIMILL02	7/11/02	8.68
NIMILL01	8/5/02	9.18	NIMILL02	8/5/02	9.65
NIMILL01	8/5/02	9.73	NIMILL02	8/5/02	9.25
NIMILL01	8/5/02	9.54	NIMILL02	8/5/02	9.67
NIMILL01	8/27/02	10.19	NIMILL02	8/27/02	10.2
NIMILL01	8/27/02	10.22	NIMILL02	8/27/02	10.06
NIMILL01	8/27/02	10.09	NIMILL02	8/27/02	9.85
NIMILL01	9/16/02	9.34	NIMILL02	9/16/02	8.57
NIMILL01	9/16/02	9.01	NIMILL02	9/16/02	8.59
NIMILL01	9/16/02	8.84	NIMILL02	9/16/02	8.55
NIMILL01	1/29/03	7.49	NIMILL02	1/29/03	6.88
NIMILL01	1/29/03	7.72	NIMILL02	1/29/03	7.22
NIMILL01	1/29/03	7.26	NIMILL02	1/29/03	7.25
NIMILL01	2/25/03	9.11	NIMILL02	2/25/03	9.05
NIMILL01	2/25/03	9.12	NIMILL02	2/25/03	9.05
NIMILL01	2/25/03	9.07	NIMILL02	5/1/03	8.56
NIMILL01	5/1/03	8.54	NIMILL02	5/1/03	8.56
NIMILL01	5/1/03	8.54	NIMILL02	5/1/03	8.56
NIMILL01	5/1/03	8.55	NIMILL02	5/27/03	8.92
NIMILL01	5/27/03	8.88	NIMILL02	5/27/03	8.93
NIMILL01	5/27/03	8.89	NIMILL02	5/27/03	8.93
NIMILL01	5/27/03	8.89			

Specific Conductance

Specific conductance is a measure of water's ability to conduct electricity, which is a function of the total number of ions present. As ions increase, increases in specific conductance reflect the total concentration of dissolved ions in the water body. This may also be used to indicate hardness.

Specific conductance ranged from 465 to 937 µS/cm. State standards for fish and wildlife propagation and stock watering require that specific conductance does not equal or exceed 7,000 µS/cm on any single day. All specific conductance readings at Nine Mile Lake were less than the state standard criterion.

Secchi Depth

Secchi depth is the most commonly used method to determine water clarity. The two primary causes for low Secchi readings are suspended solids and algae.

Secchi transparency readings in Nine Mile Lake averaged 1.80 meters with the greatest readings found during May 2003 (Figure 5). This was probably due to the algae being outcompeted for nutrients by macrophytes as the macrophytes began their growth. The mean Secchi transparency reading during the primary growing season (May 15 through September 15) was 1.68 meters, equivalent to a TSI value of 52.5. This indicates eutrophic conditions but the TSI was not considered indicative of a problem. The target growing-season median Secchi-chlorophyll *a* TSI is 63.4 (Lorenzen, 2005) and the above Secchi TSI was less than this.

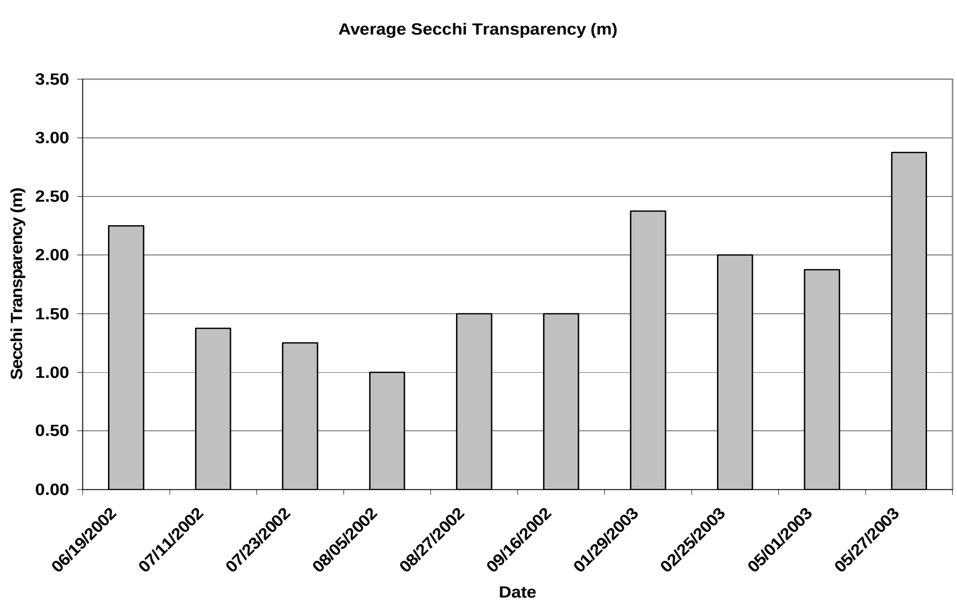

Figure 5. Average Secchi transparency depths for Nine Mile Lake, Marshall County, South Dakota, 2002/2003.

Alkalinity

A lake's total alkalinity affects the ability of its water 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. Total alkalinity is also used in the estimation procedure for calculating the amount of alum necessary for phosphorus precipitation.

The total alkalinity in Nine Mile Lake averaged 156 mg/l (Figure 6) and varied from a low of 107 mg/l during July 23, 2002 to a peak value of 217 mg/l during February 25, 2003. There was little difference in total alkalinity in samples collected from the surface or the bottom. The total alkalinity concentrations are typical for lakes in South Dakota. The alkalinity standard criterion was never exceeded.

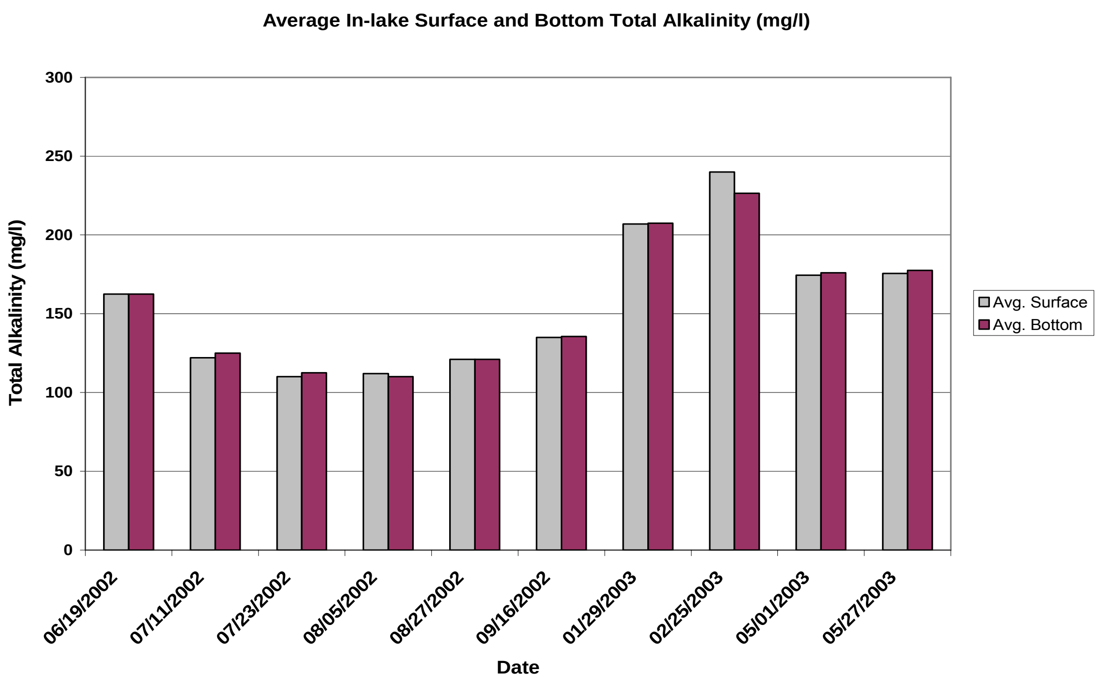

Figure 6. Average in-lake surface and bottom total alkalinity concentrations for Nine Mile Lake, Marshall County, South Dakota, 2002/2003.

Solids

Solids can be separated into four separate fractions; total solids, total dissolved solids (TDS), total suspended solids (TSS), and total volatile suspended solids (TVSS). 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 deposited in stream channels and lakes in the form of silt. Silt deposition can destroy bottom and reduce the diversity of aquatic insect, snail, and crustacean species. In addition, as silt deposition reduces the water depth in a lake, wind-induced wave action increases turbidity levels by suspending solids from the bottom that had previously settled out. Shallow water may also allow for the establishment of beds of aquatic macrophytes.

Nine Mile Lake exhibited some seasonality in total solids concentrations with slightly higher values during the fall and winter (Table 7). Higher numbers of algae during the winter may be due to macrophyte die-offs. Total solids ranged from 454 mg/l to 760 mg/l and averaged 557.4 mg/l. TSS concentrations in Nine Mile Lake exhibited similar seasonality with higher concentrations during the winter, probably a result of algae (Table 8). TSS concentrations ranged from 2 mg/l to 46 mg/l and averaged 10.8 mg/l. TVSS comprised about 54% of the total suspended solids. Algae and submerged macrophytes likely comprise the bulk of the organic matter in the lake.

Table 7. Total solids concentrations for Nine Mile Lake, Marshall County, South Dakota, 2002/2003.

	NIMILL01 Surface	NIMILL01 Bottom	NIMILL02 Surface	NIMILL02 Bottom
6/19/02	556	557	558	563
7/11/02	484	514	506	518
7/23/02	454	490	478	470
8/05/02	474	463	502	481
8/27/02	477	484	476	487
9/16/02	524	521	521	520
1/29/03	685	700	668	671
2/25/03	738	760	727	727
5/1/03	570	577	563	565
5/27/03	543	539	581	602

Table 8. Total suspended solids concentrations for Nine Mile Lake, Marshall County, South Dakota, 2002/2003.

	NIMILL01 Surface	NIMILL01 Bottom	NIMILL02 Surface	NIMILL02 Bottom
6/19/02	5	15	8	14
7/11/02	2	24	9	22
7/23/02	8	46	10	9
8/05/02	10	10	39	13
8/27/02	9	4	5	15
9/16/02	10	10	8	10
1/29/03	3	3	3	5
2/25/03	5	15	4	5
5/1/03	4	18	5	6
5/27/03	4	4	3	30

Nitrogen

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

All forty of the samples collected from Nine Mile Lake and analyzed for nitrates had concentrations at or below the 0.1 mg/l detection limit (see Appendix A). Thirty-three out of forty ammonia concentrations were at or below the 0.02 mg/l detection limit (92.5% of the samples). Ammonia concentrations averaged 0.021 mg/l and ranged from below the 0.02 mg/l detection limit to .03 mg/l (Table 9). The median concentration was 0.02 mg/l. The water quality standard criterion for total ammonia was not exceeded in any of the forty samples

Total nitrogen in Nine Mile Lake averaged 1.02 mg/l and ranged from 0.65 mg/l to 1.38 mg/l; which is relatively low for lakes in South Dakota. Organic nitrogen comprised about 97.9% of the total nitrogen. This was likely due to macrophyte debris, algae and other organic matter in the lake.

Table 9. Total ammonia concentrations (mg/l) for Nine Mile Lake, Marshall County, South Dakota during 2002/2003.

	NIMILL01 Surface	NIMILL01 Bottom	NIMILL02 Surface	NIMILL02 Bottom
6/19/02	<0.02	<0.02	<0.02	<0.02
7/11/02	<0.02	<0.02	<0.02	<0.02
7/23/02	<0.02	<0.02	<0.02	<0.02
8/05/02	<0.02	<0.02	<0.02	<0.02
8/27/02	<0.02	<0.02	<0.02	<0.02
9/16/02	<0.02	<0.02	<0.02	<0.02
1/29/03	0.03	<0.02	<0.02	<0.02
2/25/03	<0.02	<0.02	0.03	0.03
5/1/03	<0.02	<0.02	<0.02	<0.02
5/27/03	<0.02	<0.02	<0.02	<0.02

Phosphorus

Phosphorus is one of the macro-nutrients required for primary production. When compared with carbon, nitrogen, and oxygen, it is the least abundant (Wetzel, 2000). Phosphorus loading to lakes can be of an internal or external nature. External loading refers to surface runoff over land, 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 average in-lake total phosphorus concentration during the assessment was 0.037 mg/l. Total phosphorus concentrations greater than 0.02 mg/l are generally regarded as indicative of eutrophic conditions (USEPA, 1974) and so Nine Mile Lake could be considered eutrophic. Total phosphorus concentrations were generally highest during the latter half of the growing season (Table 10).

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 total phosphorus.

Table 10. Total phosphorus concentrations (mg/l) for Nine Mile Lake, Marshall County, South Dakota during 2002/2003.

Date	NIMILL01 Surface	NIMILL01 Bottom	NIMILL02 Surface	NIMILL02 Bottom
6/19/02	0.025	0.025	0.026	0.032
7/11/02	0.037	0.045	0.047	0.051
7/23/02	0.033	0.054	0.043	0.048
8/05/02	0.040	0.039	0.063	0.044
8/27/02	0.040	0.033	0.044	0.049
9/16/02	0.050	0.051	0.053	0.052
1/29/03	0.032	0.030	0.031	0.031
2/25/03	0.034	0.036	0.023	0.028
5/1/03	0.034	0.040	0.032	0.032
5/27/03	0.021	0.021	0.020	0.029

Table 11. Total dissolved phosphorus concentrations (mg/l) for Nine Mile Lake, Marshall County, South Dakota during 2002/2003.

Date	NIMILL01 Surface	NIMILL01 Bottom	NIMILL02 Surface	NIMILL02 Bottom
6/19/02	0.012	0.012	0.013	0.014
7/11/02	0.013	0.012	0.016	0.020
7/23/02	0.013	0.012	0.013	0.014
8/05/02	0.010	0.010	0.011	0.010
8/27/02	0.013	0.012	0.020	0.021
9/16/02	0.016	0.015	.0011	0.012
1/29/03	0.014	0.010	0.012	0.014
2/25/03	0.012	0.012	0.015	0.014
5/1/03	0.011	0.012	0.011	0.011
5/27/03	0.011	0.011	0.011	0.011

Total dissolved phosphorus (TDP) in Nine Mile Lake averaged .013 mg/l and ranged from .010 to .021 mg/l (Table 11). TDP comprised about 37% of the total phosphorus and did not exhibit much seasonality.

Fecal Coliform Bacteria

Nine Mile Lake is listed for the beneficial use of immersion recreation which requires that no single sample exceed 400 colonies/100ml or the 30-day geometric mean (consisting of at least 5 samples) not exceed 200 colonies/100ml. No exceedences of the state standard criterion were observed during the project. Samples collected and analyzed by the State Health Lab for fecal coliform were consistently at or below the detection limit of 10 colonies per 100 ml (see Appendix A). The only sample collected that indicated a clear presence of fecal coliform was collected on August 27, 2002 and had a concentration of 30 colonies per 100 ml. Fecal coliform bacteria concentrations did not indicate any human or animal waste source.

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 and algal uptake of nitrogen from the atmosphere. Phosphorus is easier to control, making it the primary nutrient targeted for reduction when attempting to control eutrophication. The ideal ratio of nitrogen to phosphorus for aquatic plant growth is 10:1 (EPA, 1990). Ratios higher than 10:1 indicate a phosphorus-limited system. Those that are less than 10:1 represent nitrogen-limited systems.

The average total nitrogen (TN) to total phosphorus (TP) ratio for the water samples collected from Nine Mile Lake was 29.66 with a range of 13.27 to 48.8 (Appendix A). All of the TN:TP ratios calculated for the lake were greater than 10 and indicated phosphorus limitation. There was little seasonality to the TN:TP ratios.

Chlorophyll *a*

The data indicated relatively low concentrations throughout the project. (Table 12). This was probably due to the large amount of macrophtyes in the lake, which presumably out compete the algae for nutrients. Chlorophyll *a* concentrations in South Dakota lakes are often as high as 100 µg/l, but in Nine Mile Lake the growing-season chlorophyll *a* concentration only averaged 5.62 µg/l. This level indicated mesotrophic conditions. The growing season chlorophyll *a* concentrations coincided well with in-lake total phosphorus concentrations (Figure 7). The phosphorus limiting conditions probably helped create conditions favorable for a good phosphorus-chlorophyll *a* relationship. Light limitation was probably not a factor because the lake was usually clear and the bottom of the lake was visible.

Table 12. Chlorophyll *a* concentrations (µg/l) for Nine Mile Lake, Marshall County, South Dakota during 2002/2003.

Date	NIMILL01 (µg/l)	NIMILL02 (µg/l)
6/19/02	2.1	0.5
7/11/02	3.6	4.31
7/23/02	3.7	3.6
8/05/02	7.01	12.52
8/27/02	16.12	7.91
9/16/02	7.91	8.01
1/29/03		
2/25/03	2.10	7.01
5/1/03	1.90	1.2
5/27/03	0.60	0.80

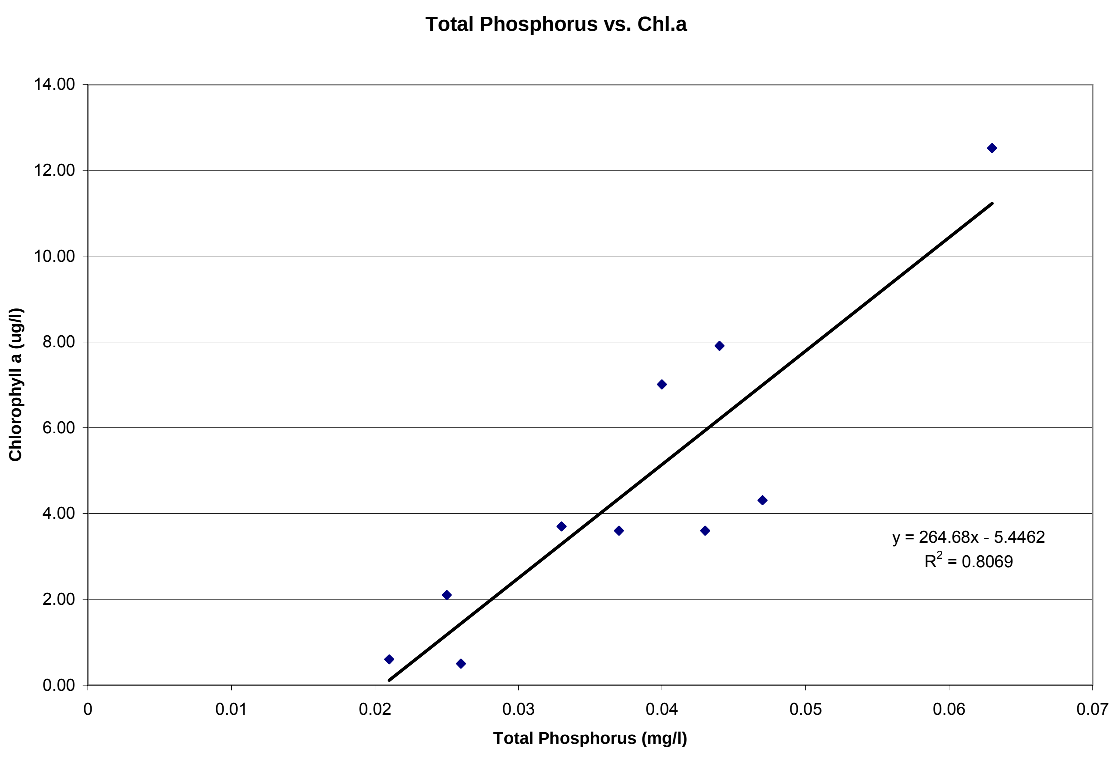

Figure 7. Regression between growing-season total phosphorus and chlorophyll *a* in Nine Mile Lake, 2002/2003 (with one outlier point eliminated from the regression analysis).

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 Carlson's (1977) Trophic State Index (TSI). It is based on Secchi depth, total phosphorus, and chlorophyll *a* in surface waters. The values for each 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 have a score of 35 to 50 are considered mesotrophic and have more nutrients and primary production than oligotrophic lakes (Table 13). 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 use and aesthetic beauty.

During the study the average growing season trophic state for Nine Mile Lake was 51, placing it at the lowest end of the eutrophic category. This TSI was based on total phosphorus, Secchi transparency, and chlorophyll *a*.

Table 13. Trophic state and TSI values.

TROPHIC STATE	TSI NUMERIC RANGE
OLIGOTROPHIC	0-35
MESOTROPHIC	36-50
EUTROPHIC	51-65
HYPER-EUTROPHIC	66-100

Lorenzen (2005) recognized the problems with using total phosphorus in TSIs and developed narrative standard targets based on the fish life classification of a lake. For a lake with a semi-permanent fish life propagation use, full support of the use is obtained at a median growing-season Secchi-Chlorophyll *a* TSI of $\leq$63.4. The median growing-season Secchi-Chlorophyll *a* TSI for Nine Mile Lake was 50.86 and indicated the lake was meeting its target TSI value.

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 the 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 species. The end result may be a reduction in the diversity of aquatic insect, snail, and crustacean species.

A sediment survey was conducted on Nine Mile Lake during March 2003. A total of 117 holes were drilled through the ice. At each hole, the water depth was recorded and a piece of rebar was pushed into the sediment as far as possible and the length of rebar from the end back to the surface ice was noted. The difference between that measurement and the water depth equals the sediment depth.

Figures 8 and 9 provide contour maps of water depth and sediment depth. Water depth ranged from 0 to 11.5 feet (3.51 meters) with an average depth of eight feet (2.44 meters). The sediment depths ranged from 0 to 13.5 feet (4.11 meters) with an average of six feet (1.83 meters). Most other lakes surveyed by SDDENR usually had average sediment depths of a few feet so the sediment depth in Nine Mile Lake might be considered somewhat unusual. Because there are presently no significant disruptive forces in the watershed that might accelerate sedimentation of the lake, it is assumed that the sedimentation of the lake is a natural process which has occurred since the creation of the lake. The lake is considered a “pothole” lake and as such will eventually fill in and become a marsh.

Lake depth could be increased, possibly by 43%, if this sediment was removed. This might remove sediment that could otherwise release nutrients into the water column, remove the macrophytes, and extend the life of the lake.

<u>Elutriate Testing</u>

Elutriate tests were run on composite sediment and water samples collected from the two in-lake sites during 5/18/2004. Sediment was collected with a Petite Ponar sampler and water was collected with a Van Dorn sampler. The samples were shipped to the State Health Lab for analysis. The sediment was mixed with lake water and the resultant elutriate was analyzed for the same parameters as the receiving water.

The elutriate and receiving water tests indicated many of the parameters were below their respective detection limits and none of the results indicated problematic conditions concerning these parameters (Table 14). If the lake is ever dredged, these results provide evidence that the dredged sediment would not contain dangerous levels of the measured parameters.

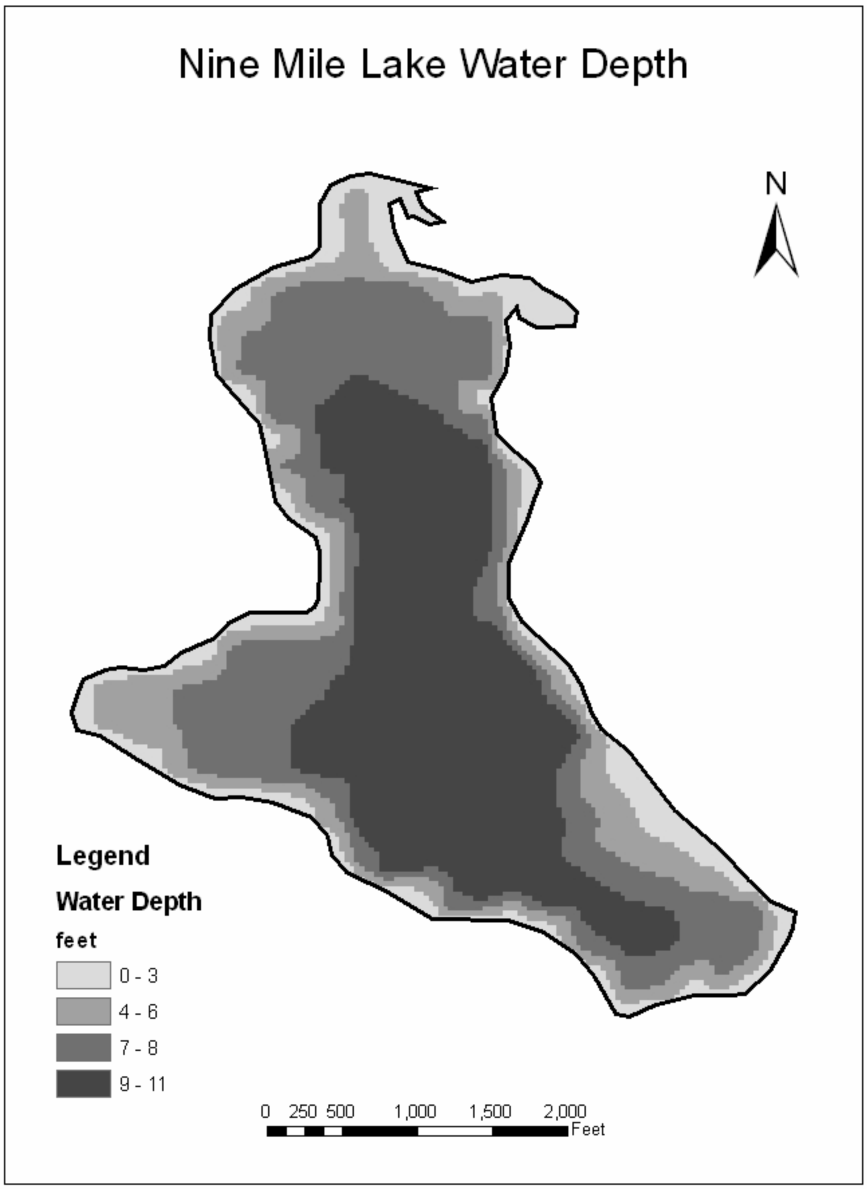

Figure 8. Water depths for Nine Mile Lake, Marshall County, South Dakota, 2004.

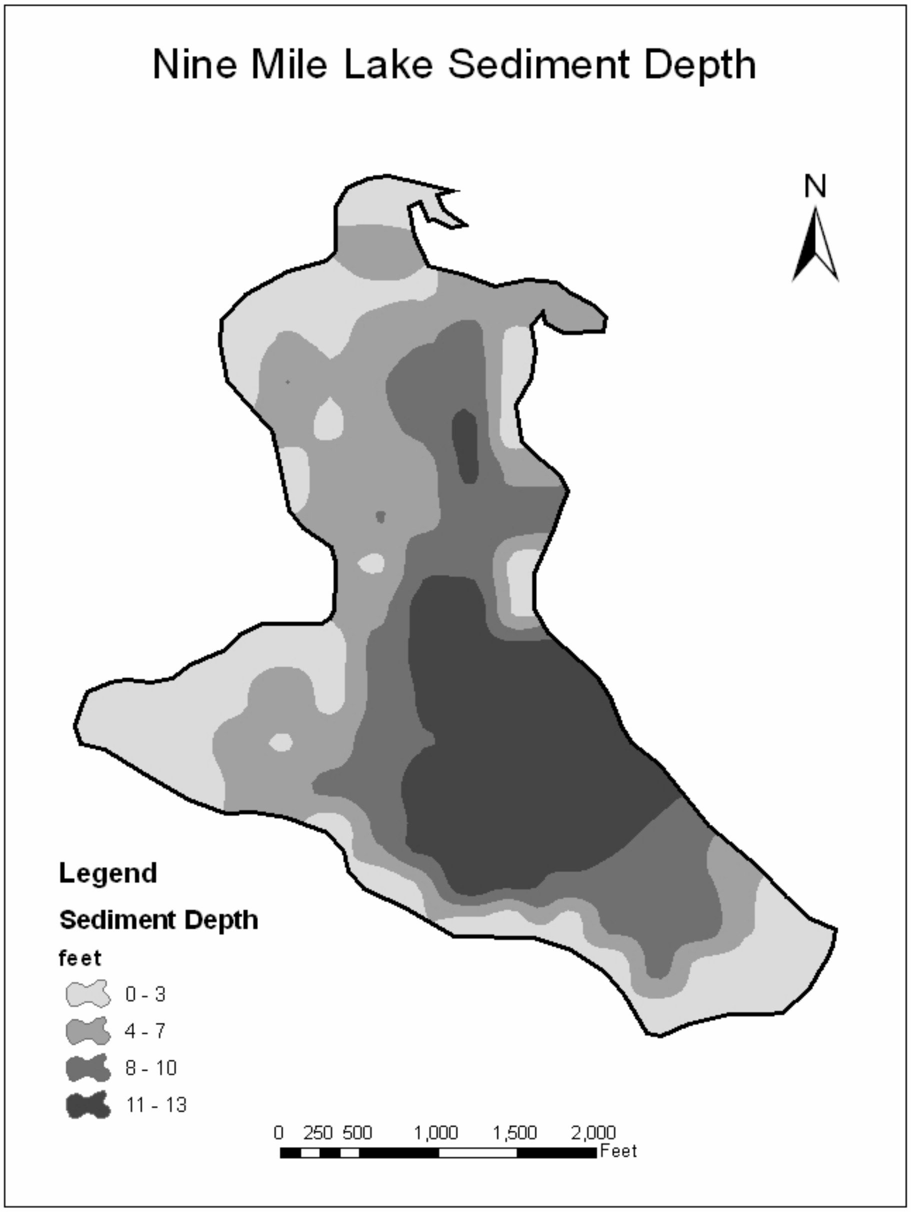

Figure 9. Sediment depths for Nine Mile Lake, Marshall County, South Dakota, 2004.

Table 14. Elutriate test results for Nine Mile Lake, Marshall County, South Dakota, during 5/18/2004.

Parameter	Receiving Water Nine Mile Lake	Elutriate Sample Nine Mile Lake	Unit
COD	22.1	26.2	mg/l
Phosphorus, total	0.011	0.025	mg/l
TKN	0.75	2.01	mg/l
Hardness	730	750	mg/l
Nitrate	<0.1	0.1	mg/l
Nitrite	<0.02	<0.02	mg/l
Ammonia	<0.02	0.51	mg/l
Aluminum	0.8	7.3	µg/l
Zinc	<3.0	<3.0	µg/l
Silver	<0.2	<0.2	µg/l
Selenium	1.2	1.3	µg/l
Nickel	2.8	2.5	µg/l
Mercury, total	<0.1	<0.1	µg/l
Lead	<0.1	<0.1	µg/l
Copper	9.5	1.9	µg/l
Cadmium	<0.2	<0.2	µg/l
Arsenic	0.002	0.003	µg/l
Alachlor	< 0.100	< 0.100	µg/l
Chlordane	< 0.500	< 0.500	µg/l
Endosulfan II	< 0.500	< 0.500	µg/l
Atrazine	< 0.100	< 0.100	µg/l
Endrin	< 0.500	< 0.500	µg/l
Heptachlor	< 0.400	< 0.400	µg/l
Heptachlor Epoxide	< 0.500	< 0.500	µg/l
Methoxychlor	< 0.500	< 0.500	µg/l
Toxaphene	< 0.100	< 0.100	µg/l
Aldrin	< 0.500	< 0.500	µg/l
Dieldrin	< 0.500	< 0.500	µg/l
Aroclor 1016	< 0.100	< 0.100	µg/l
Aroclor 1221	< 0.100	< 0.100	µg/l
Aroclor 1232	< 0.100	< 0.100	µg/l
Aroclor 1242	< 0.100	< 0.100	µg/l
Aroclor 1248	< 0.100	< 0.100	µg/l
Aroclor 1254	< 0.100	< 0.100	µg/l
Aroclor 1260	< 0.100	< 0.100	µg/l
Diazinon	< 0.500	< 0.500	µg/l
DDD	< 0.500	< 0.500	µg/l
DDT	< 0.500	< 0.500	µg/l
DDE	< 0.800	< 0.800	µg/l
BETA BHC	< 0.500	< 0.500	µg/l
GAMMA BHC	< 0.500	< 0.500	µg/l
ALPHA BHC	< 0.500	< 0.500	µg/l

Macrophyte Survey

A macrophyte/shoreline condition survey was conducted during August 2003. Thirteen locations were established approximately equidistant from each other around the perimeter of the lake. At each location, the bank stability, vegetative cover, and vegetative zone width were rated from 0 to 10 (10 being the optimal condition). Three macrophyte survey points were also established at each location with the nearest point being approximately ten feet from the shoreline and the farthest point 30-40 feet away from the shoreline. At each point, a weighted garden rake (tined portion with one foot of handle) was thrown in four directions. The relative percent recovery of plant species on the rake was noted and the relative plant density at each point was judged from the four rake pulls.

The shoreline of Nine Mile Lake was rated as being in good but suboptimal condition. The rating scores for bank stability, vegetative cover, and vegetative zone width averaged scores of 8.56, 8.00, and 6.43 respectively (with scores of 9-10 being optimal, 6-8 as suboptimal, 3-5 as marginal, and 0-2 as poor). Some natural cut banks contributed to the lower score for vegetative zone width.

The macrophyte survey indicated light density of emergent vegetation, cattails (*Typha* spp.) and bulrush (*Scirpus* spp.) along the lake's shoreline. The emergent vegetation was not considered a problem for the lake users. Submergent vegetation consisted of a mix of coontail (*Ceratophyllum demersum*) and sago pondweed (*Potamogeton pectinatus* L.), and *Chara* spp., and was so extensive as to almost completely cover the lake bottom. *Chara* is classified as an algae but is typically treated as a macrophyte.

The submergent vegetation extended to the water surface and was dense enough to severely impact boating and fishing. Fishermen reported the only decent location to fish was near the boat ramp where the vegetation was more sparse. Decay of this vegetation may contribute to low oxygen concentrations periodically occurring in the lake.

<u>Long-Term Trends</u>

Data from this report are included in Figure 10 as well as TSI values calculated during previous sampling efforts. The trend of the TSI values is towards a decrease in TSI value and hence an improvement in lake quality. Nine Mile Lake is listed on the state's 2006 303(d) list as an impaired water body due to TSI. Figure 10 shows a decreasing trend in TSI. The median growing season Secchi-chlorophyll *a* TSI values showed an improvement in water quality.

Lorenzen's (2005) TSI target for full support was a median growing season Secchi-chlorophyll *a* TSI of $\leq$ 63.4. It is clear that the recent data show a median growing-season Secchi-chlorophyll *a* TSI that meets the 63.4 target value and will improve even more if the trend continues. But the TSI trends do not account for the influence of the extensive macrophyte beds on the TSI parameters and if these macrophytes are thinned out enough to allow algae to proliferate, the TSI trend may change.

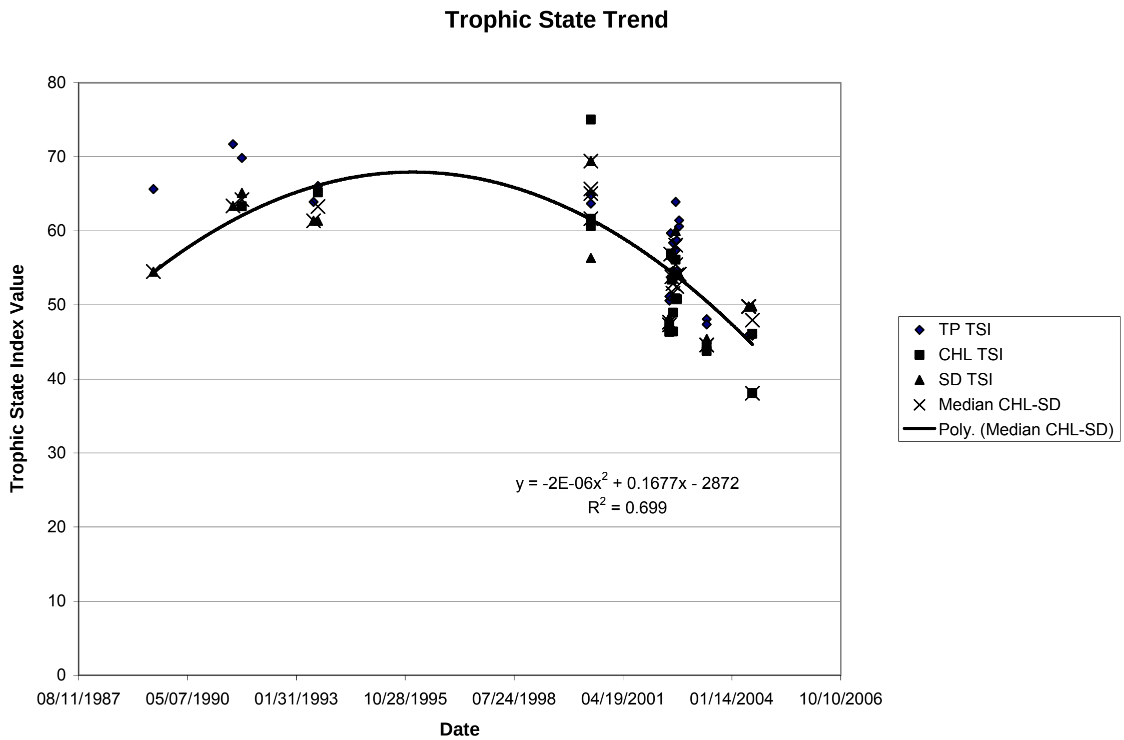

Figure 10. Growing-season total phosphorus, Secchi transparency and chlorophyll *a* trophic state indices in Nine Mile Lake, South Dakota; with trend line for median Secchi-chlorophyll TSI.

OBJECTIVE 2 – Tributary Water Chemistry and Loadings to Nine Mile Lake

Tributary Sampling Schedule, Methods, and Materials

Three tributary monitoring sites were selected for Nine Mile Lake (Figure 2). The outlet site, NIMILT01, was located on tribal land and away from easy access and was never monitored. The other two sites were equipped with OTT Thalimedes type stage recorders. Water stages were monitored and recorded for each of the sites. A Marsh-McBirney Model 210D flow meter was used to determine flows at various stages during spring run-off. The stages and flows were then used to create a stage/discharge relationship for each site.

Sampling at the tributary sites began June 17, 2002 and continued until flows stopped. Most samples were collected with the "grab" method by holding the sample bottle under the water until filled. The water samples were then filtered, preserved, and packed in ice for shipping to the State Health Lab in Pierre, SD according to the "Standard Operating Procedures for Field Samplers" (Stueven, et al., 2000).

The laboratory analyzed the samples for the following parameters: Fecal coliform bacteria; alkalinity; total solids; total volatile suspended solids; total suspended solids; ammonia; nitrate; Total Kjeldahl Nitrogen (TKN); total phosphorus; total dissolved phosphorus; and *E. coli*.

Personnel conducting the sampling at each of the sites recorded precipitation, odor, presence of dead fish, wind speed, septic conditions, surface film, ice cover, and water color and depth. Parameters measured in the field by sampling personnel included water temperature, air temperature, conductivity, dissolved oxygen, and field pH.

Tributary Sampling Results

Fecal Coliform Bacteria

Approximately 70% of the samples had fecal coliform bacteria concentrations at or below 10 colonies/100 ml (Table 15). Although no fecal coliform standard exists for the tributaries, one of the twenty samples had a concentration above the 400 colonies/100 ml criterion for immersion recreation and greater than the 2000 colonies/100 ml criterion for limited contact recreation. This high count (5600/100ml) was thought to be due to livestock.

Table 15. Fecal coliform concentrations in Nine Mile Lake tributaries, Marshall County, South Dakota during 2002/2003.

Date	NIMILT02 #/100 ml	NIMILT03 #/100 ml
6/17/02		330
7/15/02	5600	<10
8/13/02		340
4/03/03	<10	2
4/16/03	240	<10
4/24/03	<10	<10
4/30/03	30	<10
5/06/03	<10	10
5/13/03	<10	<10
5/21/03	<10	<10
5/29/03	10	80

Alkalinity

Alkalinity concentrations in Nine Mile Lake's tributaries ranged from 396 mg/l to 133 mg/l (Table 16). These concentrations are generally typical of water bodies in South Dakota. The state standard criterion for alkalinity is a maximum of 750 mg/l as a geometric mean or 1,313 mg/l in a single sample, which the tributary sites did not exceed in any of their samples.

Table 16. Total alkalinity concentrations (mg/l) for Nine Mile Lake tributaries, Marshall County, South Dakota during 2002/2003.

Date	NIMILT02 mg/l	NIMILT03 mg/l
6/17/02		396
7/15/02	322	327
8/13/02		291
4/03/03	169	252
4/16/03	202	133
4/24/03	249	202
4/30/03	255	248
5/06/03	245	243
5/13/03	238	254
5/21/03	232	256
5/29/03	238	298
Mean	239	264

Solids

The mean total solids (TS) concentrations for the tributaries were 594 and 818 mg/l with site NIMILT03 having the greatest mean (Table 17). Total suspended solids (TSS) concentrations ranged from <1 to 220 mg/l and usually comprised only about 4% or less of the total solids. There are no state standards for TS or TSS that applies to the tributaries. The data obtained are not unusual for streams in South Dakota.

Table 17. Total solids and suspended solids concentrations (mg/l) for Nine Mile Lake tributaries, Marshall County, South Dakota during 2002/2003.

	Total Solids (mg/l)		Total suspended solids (mg/l)	
Date	**NIMILT02**	**NIMILT03**	**NIMILT02**	**NIMILT03**
6/17/02		1058		21
7/15/02	591	1171	124	24
8/13/02		608		12
4/03/03	621	419	220	10
4/16/03	493	1015	9	48
4/24/03	603	627	6	2
4/30/03	633	785	2	5
5/06/03	613	814	8	10
5/13/03	599	839	8	13
5/21/03	590	795	5	<1
5/29/03	599	871	5	5
Mean	594	818	43	14

Nitrogen

Inorganic nitrogen is the form of nitrogen most readily available for plant growth. The total inorganic nitrogen concentrations were highest during the April-March spring run-off period and decreased to levels generally at or below 0.12 mg/l throughout the summer (Table 18). The 0.12 mg/l concentration is equal to the 0.1 mg/l detection limit for nitrate plus the .02 mg/l detection limit for ammonia. These low values are probably a reflection of diminished runoff during the summer months and uptake by the algae and macrophytes.

Total organic nitrogen concentrations averaged 97% of the total nitrogen concentration. This is likely comprised of dissolved organics, algae, and perhaps fragments of the macrophytes.

Table 18. Total inorganic and organic nitrogen concentrations (mg/l) for Nine Mile Lake tributaries, Marshall County, South Dakota during 2002/2003.

	Total Inorganic Nitrogen		**Total Organic Nitrogen**	
Date	**NIMILT02**	**NIMILT03**	**NIMILT02**	**NIMILT03**
6/17/02		0.12		1.79
7/15/02	0.31	0.12	1.36	1.3
8/13/02		0.12		0.92
4/03/03	0.72	0.12	4.96	1.2
4/16/03	0.53	0.32	2.02	1.71
4/24/03	0.12	0.12	1.66	1.12
4/30/03	0.12	0.12	1.9	1.54
5/06/03	0.12	0.12	1.79	1.23
5/13/03	0.12	0.12	1.78	1.3
5/21/03	0.12	0.12	1.46	0.82
5/29/03	0.12	0.12	1.82	1.08
Mean	0.25	0.14	2.08	1.27

Phosphorus

The total phosphorus concentrations in the tributaries ranged from 0.027 to 0.36 mg/l and averaged .235 and 0.091 mg/l at sites NIMLT02 and NIMILT03 respectively (Table 19). These data were used in the BATHTUB phosphorus loading model (see next section). Total dissolved phosphorus (Appendix A) averaged 56% of the total phosphorus in the incoming tributaries.

Table 19. Total phosphorus concentrations (mg/l) for Nine Mile Lake tributaries, Marshall County, South Dakota during 2002/2003.

Date	NIMILT02	NIMILT03
6/17/02		0.148
7/15/02	0.36	0.19
8/13/02		0.068
4/03/03	1.2	0.069
4/16/03	0.246	0.221
4/24/03	0.065	0.086
4/30/03	0.058	0.036
5/06/03	0.06	0.063
5/13/03	0.054	0.049
5/21/03	0.028	0.027
5/29/03	0.044	0.039
Mean	0.235	0.091

Tributary flows and phosphorus loading using the BATHTUB model

Tributary flows were calculated from regression equations established between the stage and the measured flows at each tributary. The r^2 value of the regression equation for Site NIMILT02 was .86 but the r^2 value of the regression for Site NIMILT03 was only .46. Rather than use the regression to calculate the flows for Site NIMILT03, the calculated flows (based on velocity readings and cross-sectional measurements) were used to represent the daily flows for each time interval during the study and an annual flow was estimated (Scheider, et al., 1979).

Table 20 exhibits the total inflows and outflow calculated for Nine Mile Lake during 2002/2003. Atmospheric data came from a South Dakota State University database (http://climate.sdstate.edu/climate_site/climate.htn) where the precipitation data were collected from Britton, South Dakota. The precipitation total for the study period compared favorably with the long term average precipitation (20.13" vs. 20.68") so these data are considered representative of annual precipitation. Evaporation data for Britton were not available so evaporation was based on the evaporation:precipitation ratio from Brookings, South Dakota. Because the outflow site was not monitored, the total outflow from Nine Mile Lake was based on the difference between the total inflows (tributaries plus precipitation) minus the evaporation.

The spring months of April through June comprised all of the total measured inflow. This is typical of South Dakota where water inflows (and nutrient and sediment loadings) peak during the spring and early summer.

The Army Corps of Engineers BATHTUB program (Walker, 1999) was used to predict Secchi depth, and concentrations of phosphorus, nitrogen, and chlorophyll *a* in Nine Mile Lake. A model was selected that most closely predicted current in-lake conditions and TSIs. These estimates are used in determining a TMDL for the lake.

Table 20. Monthly total water inflows/outflows (acre-feet) for Nine Mile Lake, Marshall County, South Dakota, 2002/2003.

Month/Year	NIMILT02 inflow	NIMILT03 inflow	Avg. Ann. Ppt.	NIMILT01 outflow	Avg. Ann. Evap.
½June, 2002	0	0	5.758		
July 2002	0	0	82.485		
August 2002	0	0	72.615		
September 2002	0	0	13.865		
October 2002	0	0	41.830		
November 2002	0	0	1.645		
December 2002	0	0	8.225		
January 2003	0	0	3.995		
February 2003	0	0	3.760		
March 2003	0	0	4.230		
April 2003	12.345	50.824	71.440		
May 2003	31.751	52.034	91.650		
½June , 2003	28.019	0.445	71.558		
Total (Ac-ft)	**72.115**	**103.303**	**473.056**	**Est. 215.438**	**433.036**

Because the annual flow from Site NIMILT03 was generated from only a handful of field measurements rather than from a good stage/discharge relationship, it was felt that the annual flow would not reflect significant rain events and ultimately underestimate the actual annual flow. Therefore, the United States Geological Survey EDNA (Elevation Derivatives for National Application) Program (http://edna.usgs.gov) was used to generate an annual inflow for Nine Mile Lake. The annual inflow generated by EDNA was then used in the BATHTUB model.

The BATHTUB model produced good agreement between the observed and predicted total phosphorus concentration and TP TSI (Table 21). The predicted chlorophyll *a* and Secchi TSIs were not as close to the observed TSIs but this was not unexpected. The macrophytes in the lake are likely keeping the algae populations down and also impacting Secchi transparency.

Because the model slightly overestimates TSIs, this provides a margin of safety when using the model. No progressive decreases in total phosphorus loads in the tributaries were modeled because the predicted TSI already met the target TSI of 63.4.

The total phosphorus mass balance for Nine Mile Lake was as follows:

Precipitation	34.2 kg/yr	Advective outflow	1.9 kg/yr
Tributary inflows	147.8 kg/yr	Outflow	36.4 kg/yr
Total inflow	182.0 kg/yr	Total outflow	38.3 kg/yr

Table 21. **Predicted & Observed Values Ranked Against CE Model Development Dataset.**

	Predicted Values			Observed Values		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	38.3	0.39	40.2%	38.7	0.33	40.6%
TOTAL N MG/M3	1001.4	0.18	50.0%	1001.4	0.18	50.0%
C.NUTRIENT MG/M3	33.7	0.30	47.2%	34.0	0.28	47.5%
CHL-A MG/M3	17.2	0.61	78.4%	5.6	0.79	25.3%
SECCHI M	1.3	0.40	57.7%	1.7	0.40	72.0%
ORGANIC N MG/M3	595.4	0.42	67.3%	881.4	0.20	88.8%
TP-ORTHO-P MG/M3	41.0	0.52	62.9%	25.6	0.48	43.3%
ANTILOG PC-1	335.4	0.82	59.5%	181.4	0.50	40.9%
ANTILOG PC-2	11.3	0.25	85.9%	6.8	0.61	54.2%
(N - 150) / P	22.2	0.45	65.3%	22.0	0.38	64.7%
INORGANIC N / P	406.0	0.76	99.6%	9.2	2.49	11.9%
TURBIDITY 1/M	0.6	0.51	50.1%	0.5	0.51	50.1%
ZMIX * TURBIDITY	1.2	0.51	11.1%	1.2	0.51	11.1%
ZMIX / SECCHI	1.6	0.40	3.0%	1.2	0.39	0.9%
CHL-A * SECCHI	21.5	0.33	85.5%	9.4	0.89	45.7%
CHL-A / TOTAL P	0.4	0.31	90.4%	0.1	0.85	31.9%
FREQ(CHL-a>10) %	71.4	0.48	78.4%	10.8	2.22	25.3%
FREQ(CHL-a>20) %	29.1	1.17	78.4%	0.9	3.57	25.3%
FREQ(CHL-a>30) %	11.4	1.66	78.4%	0.1	4.44	25.3%
FREQ(CHL-a>40) %	4.7	2.04	78.4%	0.0	5.08	25.3%
FREQ(CHL-a>50) %	2.1	2.34	78.4%	0.0	5.59	25.3%
FREQ(CHL-a>60) %	1.0	2.59	78.4%	0.0	6.02	25.3%
CARLSON TSI-P	56.7	0.10	40.2%	56.9	0.08	40.6%
CARLSON TSI-CHLA	58.5	0.10	78.4%	47.5	0.16	25.3%
CARLSON TSI-SEC	56.8	0.10	42.3%	52.5	0.11	28.0%

Based on the BATHTUB model results, the total maximum daily load can be set at 376.2 kg/yr (1.03 kg/day). This will ensure meeting the target TSI of 63.4

OBJECTIVE 3 - Quality Assurance Reporting

Quality Assurance/ Quality Control (QA/QC) samples were collected for at least 10% of the total number of samples taken. Sixty samples were taken from Nine Mile Lake and its tributaries. Six sets of blanks and duplicates samples were collected during the project for QA/QC purposes (Table 22). The industrial statistic "%I" was used to assess the data precision; where precision (%I) = difference between duplicate analytical values divided by the sum of the values, multiplied by 100. Values greater than 10% were considered problematic and further investigation may be needed to correct the problem.

The field blanks were consistently at or below the detection limits of the parameters tested except for total and dissolved phosphorus during 8/27/02. This may be due to laboratory error, contamination of the water used for the blank samples, or perhaps not rinsing the sample bottle well enough with distilled water. Because most of the blank samples were satisfactory, it is felt that no further action needs to be taken to investigate reasons for the errant data.

The duplicate samples were generally satisfactory except for *E. coli* bacteria, total suspended solids, total dissolved phosphorus, and total volatile suspended solids; all of which had average %I values greater than 10% There are no obvious reasons beyond natural variability for these results so further investigation may be needed to resolve this issue. These data should not be used or at least used with caution.

Table 22. Field blanks and duplicates for the Nine Mile Lake assessment.

StationID	SampleDate	Relative Depth	Type	Alka, mg/l	Fecal Col., #/100ml	E. Coli, #/100ml	NH3, mg/l	TKN, mg/l	NO3, mg/l	Diss P, mg/l	Total P, mg/l	TS, mg/l	TSS, mg/l	VSS, mg/l
NIMILL01	01/29/2003	Bottom	Blank				<0.02	<0.1	<0.1	0.002	0.002	<7	<1	<1
NIMILL01	01/29/2003	Bottom	Sample	210			<0.02	1.19	<0.1	0.01	0.03	700	3	<1
NIMILL01	01/29/2003	Bottom	Replicate	210			<0.02	1.01	<0.1	0.012	0.03	702	6	2
%I				0.00			0.00	8.18	0.00	9.09	0.00	0.14	33.33	33.33
NIMILL01	01/29/2003	Surface	Blank		<2	<1	<0.02	<0.1	<0.1	<0.002	<0.002	<7	<1	<1
NIMILL01	01/29/2003	Surface	Sample	209	<2	<1	<0.02	1.14	<0.1	0.014	0.032	685	3	<1
NIMILL01	01/29/2003	Surface	Replicate	207	<2	<1	<0.02	1.1	<0.1	0.013	0.027	686	4	3
%I				0.48	0.00	0.00	0.00	1.79	0.00	3.70	8.47	0.07	14.29	50.00
NIMILL02	08/27/2002	Bottom	Blank	<6			<0.02	<.32	<0.1	0.01	0.011	<7	<1	<1
NIMILL02	08/27/2002	Bottom	Sample	123			<0.02	0.55	<0.1	0.021	0.049	487	15	5
NIMILL02	08/27/2002	Bottom	Replicate	125			<0.02	0.75	<0.1	0.012	0.041	514	31	13
%I				0.81			0.00	15.38	0.00	27.27	8.89	2.70	34.78	44.44
NIMILL02	08/27/2002	Surface	Blank	<6	<10	<1	<0.02	<.32	0.1	0.01	0.01	<7	<1	<1
NIMILL02	08/27/2002	Surface	Sample	119	<10	<1	<0.02	0.64	0.1	0.02	0.044	476	5	3
NIMILL02	08/27/2002	Surface	Replicate	112	<10	<1	<0.02	0.68	<0.1	0.011	0.035	473	5	4
%I				3.03	0.00	0.00	0.00	3.03	0.00	29.03	11.39	0.32	0.00	14.29
NIMILT02	04/24/2003		Blank	<6	<10	<1	<0.02	<0.11	<0.1	<0.002	<0.002	<7	<1	<1
NIMILT02	04/24/2003		Sample	249	<10	3	<0.02	1.58	<0.1	0.016	0.065	603	6	3
NIMILT02	04/24/2003		Replicate	246	<10	4.1	<0.02	1.47	<0.1	0.016	0.078	603	6	4
%I				0.61	0.00	15.49	0.00	3.61	0.00	0.00	9.09	0.00	0.00	14.29
NIMILT03	04/30/2003		Blank	<6	<10	<1	<0.02	<0.11	<0.1	<0.002	<0.002	<7	<1	<1
NIMILT03	04/30/2003		Sample	248	<10	<1	<0.02	1.46	<0.1	0.034	0.036	785	5	<1
NIMILT03	04/30/2003		Replicate	246	<10	4.1	<0.02	1.83	<0.1	0.029	0.047	783	12	2
%I				0.44	0.00	60.78	0.00	11.25	0.00	7.94	13.25	0.13	41.18	33.33
Average %I				0.90	0.00	19.07	0.00	7.21	0.00	12.84	8.52	0.56	20.60	31.61

OBJECTIVE 4- Annualized Agricultural Non-Point Source Model (AnnAGNPS)

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

The AnnAGNPS model was not used because the lake is already meeting its target TSI of 63.4. However, to maintain the condition of the lake the current effort to implement Best

Management Practices (BMPs) through existing cost-share programs should continue. Potential nutrient and sediment reductions in this watershed will be largely dependent on the willingness of the small number of landowners to participate in these programs

OBJECTIVE 5 - Public Participation

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 project. The South Dakota Department of Game, Fish and Parks provided information about threatened and endangered species and a copy of the latest Fishery Report on Nine Mile Lake.

Federal Agencies

The Environmental Protection Agency (EPA) provided the primary source of funds for the completion of the assessment on Nine Mile Lake. The Natural Resource Conservation Service (NRCS) provided technical assistance. The Farm Service Agency allowed access to historical records to obtain data for this project report.

Local Governments; Industry, Environmental, and other Groups; and General Public

The Marshall Conservation District (CD) sponsored the project, provided project accounting, and hired a consulting firm, Prairie Agricultural Research, to do the field work. Public involvement primarily consisted of monthly meetings of the Marshall Conservation District.

Table 23 shows the funding sources, the budgeted amounts from each of these sources, total expenditures, and the percentage that was utilized. In-kind match came primarily from the Marshall Conservation District for utilizing their time to manage and direct the project. The project was completed using only about 72% of the proposed budget. This was probably due to fewer samples being collected than what was proposed.

Table 23. Funding sources and funds utilization for the Marshall County Lakes Assessment Project.

Organization	Amount in the Budget	Spent	In-Kind	% utilized
USEPA 319	165,000.00 amended to 120,000.00	79,981.22	0	67%
SDDENR	25,000.00	25,000.000	0	100%
Marshall CD	2,000.00	0	1,003.50	50%

RECOMMENDATIONS

There are a limited number of lake restoration techniques available to lake managers and the bulk of these are summarized by Cooke, et al. (1986). Thirteen general categories were reviewed for their applicability to the Nine Mile Lake situation and each one is discussed below. Table 24 at the end of this section summarizes those techniques recommended for consideration for use in Nine Mile Lake.

Lake Restoration Techniques Rejected for Nine Mile Lake

<u>Dilution/flushing</u>

Dilution/flushing is a technique to reduce algal biomass by introducing water of lower nutrient concentration while concurrently increasing water exchange (flushing) in the lake. This category was not considered a viable option for Nine Mile Lake because there is no source of dilution water nearby and because algae are currently not the problem.

<u>Lake Drawdown</u>

Lake drawdown is sometimes used to control aquatic macrophytes. Because Nine Mile Lake is a natural lake with no controllable outlet, this technique is not recommended at this time.

<u>Biological Controls</u>

Use of biological controls to control algae or aquatic macrophytes is considered experimental and is in need of additional studies to refine the technique. As such, biological controls are not recommended.

<u>Hypolimnetic Withdrawal</u>

Withdrawal of water from the hypolimnion is done to remove nutrient laden water that might otherwise be available for algal growth. Withdrawals may also be used to improve dissolved oxygen conditions in the lake by replenishing the hypolimnion with well-oxygenated epilimnetic water. This would improve conditions for aquatic life at the bottom of the lake.

Hypolimnetic withdrawal for Nine Mile Lake is not recommended at this time because there is no dam or structure where hypolimnetic water can be released

<u>Phosphorus Inactivation and Bottom Sealing with Aluminum Sulfate</u>

This technique is not recommended because the lake is currently meeting its TSI target. This technique is not normally used for macrophyte control, probably because macrophytes, through their root systems, can acquire nutrients from the lake bottom.

Sediment Removal for Nutrient Control

Sediment removal is sometimes used to remove nutrient-rich sediments that might release nutrients during anaerobic conditions. The idea is to remove enough sediment until a "new" layer of sediment is exposed that contains lower concentrations of nutrients than what was removed or that has a lower nutrient release rate. In addition, organic matter in the overlying sediment might be removed, resulting in less bacterial decomposition of organic matter and less oxygen depletion in the hypolimnion.

The lake is currently meeting its TSI target and is not in need of extensive nutrient control. Lake dredging is a relatively expensive endeavor and there does not appear to be a local financial base to support dredging.

Sediment Removal for Organics Control

With all of the macrophytes in Nine Mile Lake it is not unrealistic to expect a significant amount of organic matter at the bottom of the lake. This organic matter is likely decomposing at the bottom of the lake and could create oxygen deficits from time to time. Only once during the study did the dissolved oxygen concentrations from both the surface and bottom samples drop below 5.0 mg/l, so it is still unclear whether macrophyte decomposition is a problem. The financial considerations also prohibit using this technique.

Sediment Removal for Lake Longevity

One process of lake aging is the gradual sedimentation and filling of a lake. This could eventually lead to shallower depths, increased fish kills due to oxygen depletion, and other negative impacts to the lake's beneficial uses. Because approximately 43% of the lake is silted in, it is clear that removing sediment from the lake is an option to extend the life of the lake and maintain lake conditions related to lake depth and volume. Secondary benefits of sediment removal might be the removal of phosphorus-rich sediment that may release nutrients to the lake, and improved dissolved oxygen through the removal of organics that decompose and create oxygen deficits.
.
The lack of a local financial base to support dredging would likely prohibit its use. However, this option should be reconsidered if a financial package can be created to support dredging.

Techniques Recommended for Consideration

Watershed conservation practices/animal waste management

The lake is currently meeting its target TSI of 63.4 and does not need extensive watershed conservation practices or animal waste management facilities (AWMs). However, in order to maintain the beneficial use support status, it is recommended that the current effort to promote and implement existing and new BMPs and AWMs through the USDA programs or other cost-share programs continue.

In addition, nutrients, especially phosphorus, have been shown to increase eutrophication in lakes and reservoirs throughout the country increasing oxygen depletion caused by decomposition of algae and aquatic plants (Carpenter et al., 1998). Carpenter et al. (1998) and Bertram (1993) also indicate that reductions in nutrients will eventually lead to the reversal of eutrophication and attainment designated beneficial uses. Nurnberg (1995, 1995a, 1996, 1997), developed a model that quantified duration (days) and extent of lake oxygen depletion, referred to as an anoxic factor (AF). This model showed that AF is positively correlated with average annual local phosphorous (TP) concentrations. The AF may also be used to quantify response to watershed restoration measures which makes it very useful for TMDL development. Nurnberg also developed several regression models that show nutrients (P and N) control all trophic state indicators related to oxygen and phytoplankton in lakes/reservoirs. Nine Mile Lake's morphological characteristics are well within those Nurnberg used to develop regression models Nurnberg's dataset ranges were: $\bar{z}$ mean depth (m), 1.8 – 200; A_o lake surface area (hectares), 1.0 – $8.2*10^6$ and $\bar{z} / A_o^{0.5}$ (m/km^2), 0.14 – 48.1. The dataset for Nine Mile Lake were: $\bar{z}$ (m), 2.0; A_o (hectares), 114.12; and $\bar{z} / A_o^{0.5}$ (m/km^2), 0.19. This supports SDDENR conclusions that nutrients can affect dissolved oxygen concentrations in Nine Mile Lake. Thus reduction in nutrient (phosphorus) loads to the lake will improve dissolved oxygen concentrations and overall water quality in the lake. South Dakota's approach to treat the sources of nutrients and reduce/eliminate nutrient loads to impaired waters is consistent with accepted watershed strategies to treat sources rather than symptoms (low dissolved oxygen).

However, controlling nutrient loads to Nine Mile Lake will be difficult and in-lake treatments, such as aeration, should also be considered to alleviate low DO conditions. Adding oxygen (air) to the lake will break up stratification and increase conversion of organic matter improving dissolved oxygen concentrations throughout the lake profile. Two lakes in South Dakota, Stockade Lake in Custer County and Lake Waggoner in Haakon County, have or have had aeration systems installed to break up stratification to improve water quality. Stockade Lake aeration system was put into service in 1999 and operates only during the summer months during thermal stratification. SD GF&P monitoring results indicate aeration during the summer did not allow the lake to stratify, improving the dissolved oxygen profile and increasing fish habitat during the summer. Improved water quality, especially dissolved oxygen concentrations, has been observed in Stockade Lake in recent years based on SD GF&P monitoring data and current SD DENR statewide lake assessment data (SD GF&P, 2004, SD GF&P, 2005, SD GF&P, 2005a and Stueven and Stewart, 1996).

Waggoner Lake installed a mechanical aeration system in the mid 1990s to break up thermal stratification and improve drinking water taste. This system successfully operated during the summer months through 2002 when the City of Philip switched its drinking water source from Waggoner Lake to West River/Lyman Jones rural water.

Surface/Sediment Covers

Various materials have been used for rooted aquatic plant control. Sediment covers are a viable option for macrophyte control in small localized areas such as in front of lakeside homes or at the boat ramp area. These covers do not address the cause of the macrophyte problem but should at least provide small open areas devoid of macrophytes. They are easy to install over small areas but sometimes gases will be trapped under the covers and cause lifting or floating of the covers. Maintenance of the covers may be critical for their continued effectiveness.

Aeration/Circulation

Aeration and circulation are well known techniques for preventing oxygen depletion in a lake. Numerous aeration/circulation units are available and the proper sizing and use of the unit(s) must be done by someone who is knowledgeable about the particular unit. Frequent monitoring (including the winter months) for dissolved oxygen must occur in order to know when to aerate and when to cease operation. Otherwise, an aeration system should be set up to continuously operate. The target dissolved oxygen concentration is 5.0 mg/l.

Macrophyte Control by Application of Herbicides

Use of herbicides has been shown to be an effective means to control nuisance aquatic macrophytes. However, it is well known that these controls are short lived and there is often a need for repeated treatment.

The use of herbicides in Nine Mile Lake for macrophyte control is recommended for consideration on an "as needed" basis only and not as a long-term solution. Applicators should consult SDDENR, the SD Department of Game, Fish & Parks, and the SD Department of Agriculture to obtain the proper authorizations. These products should only be applied according the manufacturer's specifications and recommendations. Typically, the product is applied and the results are usually evident within a few days.

It is recommended that the percent macrophyte coverage be decreased by 30% and that macrophyte control is limited to the deeper areas of the lake, the boat ramp area, and possibly near the lakeshore adjacent to lakeside homes. This relatively conservative target was chosen because of the possibility that extensive macrophyte control may very well result in proliferation of algae, which simply replaces one problem with another. Scheffer (1998) discusses algae/macrophyte dynamics in detail and predicting the shift from one dominating over the other is not easy to do nor is it well understood. It is perhaps best to proceed with macrophyte control cautiously and hope the lake stabilizes such that there are enough macrophytes to still provide the positive attributes (refuge for animals, decreased wind mixing, etc.) but also enough open water to allow boating, swimming, and fishing.

Macrophyte Control by Mechanical Harvesting

Harvesting nuisance aquatic plants has been a common lake restoration technique. This technique may be useful in Nine Mile Lake if a local entity is able to purchase or rent a weed harvester. The technique is relatively easy (similar to cutting one's lawn) but there will likely be a need for repeated cutting. In addition, the cut plants should be removed from the lake and not be allowed to settle to the bottom to decompose.

Table 24. Summary of recommended lake restoration techniques for Nine Mile Lake.

Restoration Technique	Action	Targets	Comments
Macrophyte control by mechanical means (weed harvester).	Remove macrophytes in center areas of the lake or other small localized areas.	Decrease percent macrophyte coverage by 30%.	Not recommended as a long term solution. As needed only.
Macrophyte control by chemical means.	Remove macrophytes in center areas of the lake or other small localized areas.	Decrease percent macrophyte coverage by 30%.	Not recommended as a long term solution. As needed only.
Macrophyte control with sediment covers.	Cover lake bottom in localized areas.	Decrease macrophytes by 100% in small areas near boat ramp or lakeside homes.	As needed only.
Aeration/circulation.	Aerate until DO concentration is at least 5.0 mg/l.	DO concentration of 5.0 mg/l.	Frequent monitoring of DO recommended for initiation and continuation of aeration.
Best Management Practices and Animal Waste Management.	Promote use of BMPs and AWMs in the watershed.	TSI target of 63.4 DO of 5.0 mg/l	Used to maintain TSI target. May help alleviate low DO concentrations.

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 except for the preparation of the final report. This was due to DENR personnel having other commitments.

The decision not to use the pH data would have been easier if all of the calibration information was documented. Emails and/or written notes about telephone conversations between the project officer and the project coordinator that clearly describe the calibration information and any problems with the pH probe would provide documentation and help trace when the problems arose. Project coordinators may not know what readings might be considered abnormal so it is imperative that the project officer have access to the data (and calibration information) as soon as possible so corrective measures can be initiated.

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APPENDIX A

Water Quality Data for the Nine Mile Lake Assessment Project

Table 25. Water quality data for Nine Mile Lake, Marshall County, South Dakota.

StationID	Date	Relative Depth	Air Temp. °C	Water Temp. °C	DO, mg/l	pH	Secchi, m	Spec. Cond.	Chl.*a* ug/l	Alka, mg/l	Fecal Col., #/100ml	E. Coli, #/100ml	NH3, mg/l	TKN, mg/l	NO3, mg/l	TN, mg/l	Diss P, mg/l	Total P, mg/l	TS, mg/l	TSS, mg/l	VSS, mg/l	TN:TP	CHL TSI	SEC TSI	TP TSI
NIMILL01	6/19/02	Surface	28.88	21.81	13.88	8.81	2.25	557	2.10	162	<10	<1	<0.02	1.12	<0.1	1.22	0.012	0.025	556	5	5	48.80	37.85	48.30	50.59
NIMILL01	6/19/02	Bottom	28.88	21.26	18.1	8.21		552		162			<0.02	1.01	<0.1	1.11	0.012	0.025	557	15	9	44.40			50.59
NIMILL01	7/11/02	Surface	19.44	22.41	15.23	8.84	1.50	511	3.60	120	<10	1	<0.02	0.78	<0.1	0.88	0.013	0.037	484	2	<1	23.78	43.13	54.15	56.24
NIMILL01	7/11/02	Bottom	19.44	22.15	13.71	8.71		512		123			<0.02	1.02	<0.1	1.12	0.012	0.045	514	24	4	24.89			59.07
NIMILL01	7/23/02	Surface	18.33	23.92	8.66	9.62	1.25		3.70	107	<10	<1	<0.02	1.06	<0.1	1.16	0.013	0.033	454	8	5	35.15	43.40	56.78	54.59
NIMILL01	7/23/02	Bottom	18.33	23.94	8.54	9.67				113			<0.02	0.88	<0.1	0.98	0.012	0.054	490	46	14	18.15			61.70
NIMILL01	8/5/02	Surface	23.33	22.24	7.72	9.68	1.00	467	7.01	110	<10	<1	<0.02	0.94	<0.1	1.04	0.01	0.04	474	10	8	26.00	49.67	60.00	57.37
NIMILL01	8/5/02	Bottom	23.33	22	7.01	9.58		466		110			<0.02	0.64	<0.1	0.74	0.01	0.039	463	10	8	18.97			57.00
NIMILL01	8/27/02	Surface	26.66	22.13	2.96	10.1	1.50	481	16.12	123			<0.02	0.94	<0.1	1.04	0.013	0.04	477	9	5	26.00	57.84	54.15	57.37
NIMILL01	8/27/02	Bottom	26.66	23.82	2.3	10.18		484		119	30	9.7	<0.02	0.84	<0.1	0.94	0.012	0.033	484	4	2	28.48			54.59
NIMILL01	9/16/02	Surface	17.77	17.8	9.11	9.43	1.50	527	7.91	136	<10	1	0.02	1.08	<0.1	1.18	0.016	0.05	524	10	5	23.60	50.86	54.15	60.59
NIMILL01	9/16/02	Bottom	17.77	17.79	9.8	8.82		529		137			0.03	1.21	<0.1	1.31	0.015	0.051	521	10	3	25.69			60.87
NIMILL01	1/29/03	Surface	-15.55	3.03	14.85	7.35	2.25	870		209	<2	<1	<0.02	1.14	<0.1	1.24	0.014	0.032	685	3	<1	4.13		48.30	54.15
NIMILL01	1/29/03	Bottom	-15.55	3	14	7.02		884		210			<0.02	1.19	<0.1	1.29	0.01	0.03	700	3	<1	43.00			53.22
NIMILL01	2/25/03	Surface	-15	2.95	12.08	9.08	1.75	933	2.10	256	<10	<1	<0.02	1.2	<0.1	1.3	0.012	0.034	738	5	2	38.75	37.85	51.93	55.02
NIMILL01	2/25/03	Bottom	-15	3.22	10.69	9.07		937		228			<0.02	1.38	<0.1	1.48	0.012	0.036	760	15	4	41.11			55.85
NIMILL01	5/1/03	Surface	13.33	12.94	10.96	8.54	2.00	848	1.90	174	<10	<1	<0.02	0.77	<0.1	0.87	0.011	0.034	570	4	3	25.59	36.86	50.00	55.02
NIMILL01	5/1/03	Bottom	13.33	12.91	11.8	8.54		849		177			<0.02	0.82	<0.1	0.92	0.012	0.04	577	18	6	23.00			57.37
NIMILL01	5/27/03	Surface	13.33	16.88	8.77	8.86	2.75	853	0.60	175	<10	<1	<0.02	0.85	<0.1	0.95	0.011	0.021	543	4	3	45.24	25.56	45.40	48.07
NIMILL01	5/27/03	Bottom	13.33	16.87	9.33	8.98		853		176			<0.02	0.7	<0.1	0.8	0.011	0.021	539	4	4	38.10			48.07
NIMILL02	6/19/02	Surface	30	21.81	13.88	8.81	2.25	561	0.50	163	<10	<1	<0.02	1.03	<0.1	1.13	0.013	0.026	558	8	8	43.46	23.77	48.30	51.15
NIMILL02	6/19/02	Bottom	30	21.45	14.64	8.26		559		163			<0.02	0.93	<0.1	1.03	0.014	0.032	563	14	9	32.19			54.15
NIMILL02	7/11/02	Surface	19.44	22.6	13.04	8.83	1.25	516	4.31	124	<10	<1	<0.02	0.65	<0.1	0.75	0.016	0.047	506	9	5	15.96	44.90	56.78	59.70
NIMILL02	7/11/02	Bottom	19.44	22.33	10.71	8.68		518		127			<0.02	0.68	<0.1	0.78	0.02	0.051	518	22	7	15.29			60.87
NIMILL02	7/23/02	Surface	18.33	23.86	7.95	9.51	1.25		3.60	113	<10	<1	<0.02	0.72	<0.1	0.82	0.013	0.043	478	10	6	19.07	43.13	56.78	58.41
NIMILL02	7/23/02	Bottom	18.33	23.88	7.74	9.47				112			<0.02	0.68	<0.1	0.78	0.014	0.048	470	9	5	16.25			60.00
NIMILL02	8/5/02	Surface	23.33	22.38	8.17	9.65	1.00	465	12.52	114	<10	<1	<0.02	1.02	<0.1	1.12	0.011	0.063	502	39	23	17.78	55.36	60.00	63.92
NIMILL02	8/5/02	Bottom	23.33	22.15	7.97	9.59		465		110			<0.02	1.11	<0.1	1.21	0.01	0.044	481	13	9	27.50			58.74
NIMILL02	8/27/02	Surface	28.33	23.27	3.1	10.2	1.50	483	7.91	119	<10	<1	<0.02	0.64	0.1	0.74	0.02	0.044	476	5	3	16.82	50.86	54.15	58.74
NIMILL02	8/27/02	Bottom	28.33	20.14	1.51	9.93		495		123			<0.02	0.55	<0.1	0.65	0.021	0.049	487	15	5	13.27			60.30
NIMILL02	9/16/02	Surface	17.77	18.12	10.25	8.59	1.50	526	8.01	134	<10	1	<0.02	1.1	<0.1	1.2	0.011	0.053	521	8	4	22.64	50.98	54.15	61.43
NIMILL02	9/16/02	Bottom	17.77	18.12	10.24	8.57		527		134			<0.02	1.24	<0.1	1.34	0.012	0.052	520	10	5	25.77			61.15
NIMILL02	1/29/03	Surface	-16.11	2.7	16.21	7.35	2.50	846		205	<10	<1	<0.02	0.94	<0.1	1.04	0.012	0.031	668	3	2	33.55		46.78	53.69
NIMILL02	1/29/03	Bottom	-16.11	3.76	13.51	7.29		863		205			<0.02	0.97	<0.1	1.07	0.014	0.031	671	5	3	34.52			53.69
NIMILL02	2/25/03	Surface	-17.22	2.94	10.53	9.11	2.25	925	7.01	224	<10	<1	0.03	0.93	<0.1	1.03	0.015	0.023	727	4	<1	44.78	49.67	48.30	49.39
NIMILL02	2/25/03	Bottom	-17.22	3.22	10.69	9.07		928		225			0.03	1.04	<0.1	1.14	0.014	0.028	727	5	1	40.71			52.22
NIMILL02	5/1/03	Surface	13.33	12.88	11.72	8.56	1.75	851	1.20	175	10	<1	<0.02	0.83	<0.1	0.93	0.011	0.032	563	5	3	29.06	32.36	51.93	54.15
NIMILL02	5/1/03	Bottom	13.33	12.84	11.54	8.56		851		175			<0.02	0.84	<0.1	0.94	0.011	0.032	565	6	4	29.38			54.15
NIMILL02	5/27/03	Surface	13.33	16.79	9.76	8.92	3.00	850	0.80	176	<10	<1	<0.02	0.69	<0.1	0.79	0.011	0.02	581	3	2	39.50	28.38	44.15	47.37
NIMILL02	5/27/03	Bottom	13.33	16.67	10.48	8.93		849		179			<0.02	0.83	<0.1	0.93	0.011	0.029	602	30	11	32.07			52.73

Table 26. Water quality data for Nine Mile Lake's tributaries, Marshall County, South Dakota.

StationID	SampleDate	Air Temp. ºC	Water Temp. ºC	DO, mg/l	pH	Spec. Cond.	Alka, mg/l	Fecal Col., #/100ml	E. Coli, #/100ml	NH3, mg/l	TKN, mg/l	NO3, mg/l	TN, mg/l	Diss P, mg/l	Total P, mg/l	TS, mg/l	TSS, mg/l	VSS, mg/l
NIMILT02	07/15/2002	32.77	22.31	2.3	7.55	559	322	5600	>2420	0.21	1.47	<0.1	1.57	0.173	0.36	591	124	42
NIMILT02	04/03/2003	-2.22	0.35	17	8.11	470	169	<10	5.2	0.62	5.48	<0.1	5.58	0.055	1.2	621	220	104
NIMILT02	04/16/2003	1.11	4.13	13.29	7.98	690	202	240	228	0.13	1.75	0.4	2.15	0.137	0.246	493	9	7
NIMILT02	04/24/2003	9.99	11.05	9.06	8.28	740	249	<10	3	<0.02	1.58	<0.1	1.68	0.016	0.065	603	6	3
NIMILT02	04/30/2003	8.88	10.38	9.05	7.93	960	255	30	23.1	<0.02	1.82	<0.1	1.92	0.016	0.058	633	2	1
NIMILT02	05/06/2003	8.88	9.16	9.46	8.02	930	245	<10	14.5	<0.02	1.71	<0.1	1.81	0.024	0.06	613	8	3
NIMILT02	05/13/2003	13.88	10.8	11.48		910	238	<10	17.5	<0.02	1.7	<0.1	1.8	0.018	0.054	599	8	5
NIMILT02	05/21/2003	12.22	13.31	8.99	8.4	890	232	<10	3.1	<0.02	1.38	<0.1	1.48	0.016	0.028	590	5	2
NIMILT02	05/29/2003	23.88	18.65	5.51	7.84	880	238	10	5.2	<0.02	1.74	<0.1	1.84	0.02	0.044	599	5	2
NIMILT03	06/17/2002	21.66	17.28	8.79	8.02	985	396	330	387	<0.02	1.71	<0.1	1.81	0.028	0.148	1058	21	12
NIMILT03	07/15/2002	31.66	22.31	6.18	7.55	1064	327	<10	22.8	<0.02	1.22	<0.1	1.32	0.085	0.19	1171	24	10
NIMILT03	08/13/2002	13.88	13.57	7.52	9.14	561	291	340	457	<0.02	0.84	<0.1	0.94	0.058	0.068	608	12	5
NIMILT03	04/03/2003	-3.33	0.78	22.63		860	252	2	2	<0.02	1.12	<0.1	1.22	0.043	0.069	419	10	5
NIMILT03	04/16/2003	1.11	3.18	12.39	8.02	1030	133	<10	52	0.02	1.43	0.3	1.73	0.179	0.221	1015	48	15
NIMILT03	04/24/2003	7.99	7.37	10.57	8.06	710	202	<10	2	<0.02	1.04	<0.1	1.14	0.069	0.086	627	2	<1
NIMILT03	04/30/2003	8.88	7.27	11.77	7.97	1090	248	<10	<1	<0.02	1.46	<0.1	1.56	0.034	0.036	785	5	<1
NIMILT03	05/06/2003	8.33	7.11	10.55	7.65	1110	243	10	18.7	<0.02	1.15	<0.1	1.25	0.047	0.063	814	10	3
NIMILT03	05/13/2003	13.88	7.97	11.19		1140	254	<10	3.1	<0.02	1.22	<0.1	1.32	0.033	0.049	839	13	4
NIMILT03	05/21/2003	12.22	9.51	8.99	6.67	1110	256	<10	1	<0.02	0.74	<0.1	0.84	0.024	0.027	795	<1	<1
NIMILT03	05/29/2003	13.44	14.53	8.78	7.56	1170	298	80	80.1	<0.02	1	<0.1	1.1	0.036	0.039	871	5	2

Table 27. Profile data for site NIMILL01 in Nine Mile Lake, Marshall County, South Dakota.

Site	Date	Temp	SpCond	DO%	DO Conc	Depth	pH
NIMILL01	6/19/02 1:17 PM	21.79	0.557	159.3	13.96	0.958	8.6
NIMILL01	6/19/02 1:18 PM	21.32	0.554	189.2	16.74	1.944	8.64
NIMILL01	6/19/02 1:19 PM	21.27	0.552	204.3	18.1	2.123	8.43
NIMILL01	7/11/02 12:34 PM	22.41	0.511	152.3	13.19	1.103	8.84
NIMILL01	7/11/02 12:35 PM	22.21	0.511	151.2	13.15	2.118	8.65
NIMILL01	7/11/02 12:36 PM	22.15	0.512	137.1	11.94	2.554	8.71
NIMILL01	8/5/02 12:00 AM	22.25	0.467	88.8	7.72	0.986	9.18
NIMILL01	8/5/02 12:00 AM	22.04	0.466	86.6	7.56	1.970	9.73
NIMILL01	8/5/02 12:00 AM	21.95	0.466	79.6	6.96	2.538	9.54
NIMILL01	8/27/02 1:37 PM	23.87	0.481	35.2	2.96	1.007	10.19
NIMILL01	8/27/02 1:38 PM	23.65	0.481	34	2.88	2.004	10.22
NIMILL01	8/27/02 1:40 PM	22.14	0.484	26.4	2.3	2.257	10.09
NIMILL01	9/16/02 8:55 AM	17.81	0.527	98.5	9.35	0.982	9.34
NIMILL01	9/16/02 8:57 AM	17.79	0.529	102.5	9.73	1.976	9.01
NIMILL01	9/16/02 8:58 AM	17.79	0.529	104	9.88	2.192	8.84
NIMILL01	1/29/03 10:01 AM	3.11	0.87	106.4	14.25	1.012	7.49
NIMILL01	1/29/03 10:02 AM	2.92	0.877	103.2	13.89	2.011	7.72
NIMILL01	1/29/03 10:04 AM	2.97	0.884	104.5	14.03	2.19	7.26
NIMILL01	2/25/03 10:15 AM	2.99	0.933	89.1	11.97	0.868	9.11
NIMILL01	2/25/03 10:15 AM	3	0.935	88.4	11.87	1.847	9.12
NIMILL01	2/25/03 10:17 AM	3.27	0.937	82.3	10.97	2.364	9.07
NIMILL01	5/1/03 10:35 AM	12.94	0.848	104.2	10.96	1.007	8.54
NIMILL01	5/1/03 10:36 AM	12.92	0.848	105.3	11.08	1.948	8.54
NIMILL01	5/1/03 10:37 AM	12.91	0.849	105.2	11.08	2.525	8.55
NIMILL01	5/27/03 8:47 AM	16.88	0.853	91	8.8	1.124	8.88
NIMILL01	5/27/03 8:48 AM	16.87	0.853	94	9.08	2.074	8.89
NIMILL01	5/27/03 8:49 AM	16.87	0.853	96.5	9.33	2.481	8.89

Table 28. Profile data for site NIMILL02 in Nine Mile Lake, Marshall County, South Dakota.

Site	Date	Temp	SpCond	DO%	DO Conc	Depth	pH
NIMILL02	06/19/2002 13:40	21.64	0.561	154.1	13.55	0.937	8.29
NIMILL02	06/19/2002 13:41	21.53	0.56	157	13.83	1.923	8.24
NIMILL02	06/19/2002 13:43	21.38	0.559	166.7	14.74	2.571	8.29
NIMILL02	07/11/2002 12:52	22.6	0.516	151.1	13.04	1.096	8.83
NIMILL02	07/11/2002 12:53	22.35	0.517	138.5	12.01	2.113	8.78
NIMILL02	07/11/2002 12:54	22.33	0.518	123.4	10.71	2.637	8.68
NIMILL02	08/05/2002	22.37	0.465	94.2	8.17	0.999	9.65
NIMILL02	08/05/2002	22.28	0.465	94.6	8.22	1.992	9.25
NIMILL02	08/05/2002	22.16	0.465	91.5	7.97	2.393	9.67
NIMILL02	08/27/2002 14:06	23.2	0.483	36.3	3.1	1.008	10.2
NIMILL02	08/27/2002 14:07	21.09	0.487	28.1	2.5	1.992	10.06
NIMILL02	08/27/2002 14:08	20.12	0.495	16.7	1.51	2.62	9.85
NIMILL02	09/16/2002 9:13	18.12	0.526	110.8	10.45	1.022	8.57
NIMILL02	09/16/2002 9:15	18.11	0.527	109.5	10.33	1.981	8.59
NIMILL02	09/16/2002 9:17	18.12	0.527	108.3	10.22	2.545	8.55
NIMILL02	01/29/2003 10:30	2.72	0.846	116.9	15.82	1.053	6.88
NIMILL02	01/29/2003 10:30	3.12	0.857	110.7	14.82	2.034	7.22
NIMILL02	01/29/2003 10:32	3.69	0.863	100.9	13.3	2.492	7.25
NIMILL02	02/25/2003 10:43	3.22	0.925	78.9	10.53	1.852	9.05
NIMILL02	02/25/2003 10:43	3.18	0.928	77.5	10.35	0.902	9.05
NIMILL02	05/01/2003 10:48	12.87	0.851	111	11.71	0.948	8.56
NIMILL02	05/01/2003 10:49	12.85	0.852	110.1	11.61	1.947	8.56
NIMILL02	05/01/2003 10:50	12.83	0.851	109.3	11.53	2.656	8.56
NIMILL02	05/27/2003 9:01	16.8	0.85	100.8	9.76	1.119	8.92
NIMILL02	05/27/2003 9:02	16.71	0.849	103.8	10.07	2.088	8.93
NIMILL02	05/27/2003 9:03	16.67	0.849	108	10.48	2.75	8.93

Table 29. Historical pH data and averages for Nine Mile Lake, South Red Iron Lake, and North and South Buffalo Lakes, Marshall County, South Dakota.

Nine Mile			N. Buffalo			S. Buffalo			S. Red Iron		
Date	pH	Ref.	Date	pH	Ref.	Date	pH	Ref.	Date	pH	Ref.
8/25/69	8	2	7/30/65	8.5	2	10/21/64	8.3	1	10/21/64	8.6	1
6/25/70	8.3	2	7/30/65	8.6	2	2/12/65	7.4	1	2/12/65	8.2	1
1989	8.96	4	7/30/65	8.6	2	5/21/65	8.3	1	5/21/65	7.6	1
6/28/91	8.8	5	11/26/65	8.7	2	9/10/65	8.7	1	9/10/65	8.7	1
6/28/91	8.85	5	11/26/65	8.7	2	8/25/69	8.5	2	8/25/69	8.7	2
9/10/91	8.08	5	2/11/66	8.2	2	6/25/70	8.6	2	4/29/74	8.5	2
9/10/91	7.83	5	2/11/66	8	2	8/13/79	8.6	3	4/29/74	8.4	2
7/7/93	8.8	5	2/11/66	7.9	2	8/13/79	8.6	3	7/10/74	8.9	2
7/7/93	8.76	5	4/24/66	8.4	2	1989	8.89	4	7/10/74	8.8	2
8/17/93	8.3	5	4/24/66	8.4	2	6/26/91	9.2	5	9/18/74	8.9	2
8/17/93	8.23	5	4/24/66	8.4	2	6/26/91	9.25	5	9/18/74	8.9	2
6/27/00	8.65	5	8/25/69	8.5	2	9/11/91	8.7	5	4/29/74	8.5	2
6/27/00	8.65	5	6/30/98	8.6	5	9/11/91	6.5	5	4/29/74	8.4	2
6/27/00	8.63	5	6/30/98	8.67	5	8/4/92	8.74	5	7/10/74	8.8	2
6/27/00	8.66	5	6/30/98	8.68	5	8/4/92	8.74	5	7/10/74	8.7	2
6/27/00	8.63	5	6/30/98	8.64	5	9/2/92	9.02	5	9/18/74	8.9	2
6/27/00	8.64	5	6/30/98	8.59	5	9/2/92	9.01	5	9/18/74	8.9	2
6/27/00	8.64	5	6/30/98	8.63	5	6/23/99	8.77	5	8/10/79	8.6	3
6/27/00	8.63	5	6/30/98	8.65	5	6/23/99	8.78	5	8/10/79	8.6	3
6/27/00	8.63	5	6/30/98	8.68	5	6/23/99	8.78	5	1989	9.37	4
6/27/00	8.62	5	6/30/98	8.66	5	6/23/99	8.74	5	6/26/91	9.11	5
5/27/03	8.86	5	6/30/98	8.66	5	6/23/99	8.76	5	6/26/91	9.08	5
5/27/03	8.92	5	6/30/98	8.67	5	6/23/99	8.74	5	9/10/91	8.61	5
6/16/04	8.7	5	8/11/98	8.53	5	6/23/99	8.75	5	9/10/91	8.65	5
6/16/04	8.7	5	8/11/98	8.97	5	6/23/99	8.75	5	7/7/93	8.62	5
7/20/04	8.7	5	8/11/98	9.01	5	6/23/99	8.76	5	7/7/93	8.65	5
	8.58		8/11/98	8.99	5	6/23/99	8.76	5	8/17/93	8.14	5
			8/11/98	8.74	5	7/1/03	8.41	5	8/17/93	7.85	5
			8/11/98	8.33	5	7/1/03	8.41	5	6/23/99	8.75	5
			8/11/98	9	5	7/1/03	8.44	5	6/23/99	8.71	5
			8/11/98	9	5	7/1/03	8.45	5	6/23/99	8.76	5
			8/11/98	9	5	7/1/03	8.51	5	6/23/99	8.73	5
			8/11/98	8.37	5	7/1/03	8.51	5	6/23/99	8.64	5
			8/11/98	8.79	5	7/1/03	8.53	5	6/23/99	8.75	5
			8/11/98	8.98	5	7/1/03	8.54	5	6/23/99	8.79	5
			8/11/98	8.99	5	7/1/03	8.68	5	6/23/99	8.79	5
			7/2/02	8.65	5	7/1/03	8.68	5	6/23/99	8.78	5
			7/2/02	8.64	5	7/1/03	8.68	5	6/23/99	8.78	5
			7/2/02	8.63	5	7/1/03	8.63	5	6/23/99	8.78	5
			7/2/02	8.63	5	8/5/03	8.49	5	6/23/99	8.78	5
			7/2/02	8.63	5	8/5/03	8.5	5	6/23/99	8.78	5
			7/2/02	8.62	5	8/5/03	8.49	5	8/4/99	8.65	5
			7/2/02	8.62	5	8/5/03	8.47	5	8/4/99	8.64	5
			7/2/02	8.61	5	8/5/03	8.45	5	8/4/99	8.56	5
			7/2/02	8.63	5	8/5/03	8.47	5	8/4/99	8.66	5
			7/2/02	8.64	5	8/5/03	8.46	5	8/4/99	8.67	5
			7/2/02	8.63	5	8/5/03	8.44	5	8/4/99	8.66	5
			7/2/02	8.62	5	8/5/03	8.57	5	8/4/99	8.62	5
			7/2/02	8.63	5	8/5/03	8.56	5	8/4/99	8.6	5
			8/5/02	8.85	5	8/5/03	8.56	5	8/4/99	8.52	5
			8/5/02	8.86	5	8/5/03	8.53	5	8/4/99	8.61	5
			8/5/02	8.86	5	8/5/03	8.52	5	8/4/99	8.62	5
			8/5/02	8.82	5		**8.57**		8/4/99	8.63	5
			8/5/02	8.82	5				8/4/99	8.6	5
			8/5/02	8.86	5				8/4/99	8.58	5
			8/5/02	8.87	5				8/4/99	8.65	5
			8/5/02	8.86	5				8/4/99	8.65	5
			8/5/02	8.8	5				8/4/99	8.64	5
			8/5/02	8.86	5				8/4/99	8.65	5
			8/5/02	8.87	5				7/1/03	8.43	5
			8/5/02	8.87	5				7/1/03	8.41	5
			8/5/02	8.81	5				7/1/03	8.4	5
				8.68					7/1/03	8.35	5

Table 29. Continued.

Nine Mile			N. Buffalo			S. Buffalo			S. Red Iron		
Date	pH	Ref.	Date	pH	Ref.	Date	pH	Ref.	Date	pH	Ref.
									7/1/03	8.3	5
									7/1/03	8.24	5
									7/1/03	8.22	5
									7/1/03	8.19	5
									7/1/03	8.18	5
									7/1/03	8.16	5
									7/1/03	8.2	5
									7/1/03	8.41	5
									7/1/03	8.37	5
									7/1/03	8.34	5
									7/1/03	8.35	5
									8/5/03	8.46	5
									8/5/03	8.44	5
									8/5/03	8.44	5
									8/5/03	8.42	5
									8/5/03	8.41	5
									8/5/03	8.47	5
									8/5/03	8.47	5
									8/5/03	8.46	5
									8/5/03	8.44	5
									8/5/03	8.5	5
									8/5/03	8.51	5
									8/5/03	8.51	5
									8/5/03	8.49	5
										8.57	

References: 1 – Petri, L.R. and L. R. Larson, no date. 2 – State Lakes Preservation Committee, 1977. 3 – Koth, 1981. 4 – Stueven and Stewart, 1996. 5 – SDDENR, 1991-2003, unpublished data.

APPENDIX B

TMDL Summary for Nine Mile Lake, Marshall County, South Dakota

(HUC 10140101)

MARSHALL COUNTY, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

MARCH, 2007

Nine Mile Lake Total Maximum Daily Load

Waterbody Type:	**Lake (natural)**
State Waterbody ID:	**SD-BS-L-NINE_MILE_01**
303(d) Listing Parameter:	**TSI trend**
Designated Uses:	**Warm water semi-permanent fish life propagation, Immersion recreation, Limited contact recreation, and Fish and Wildlife propagation, recreation and stock watering**
Size of Waterbody:	**282 acres**
Size of Watershed :	**2,722 acres**
Water Quality Standards:	**Narrative and numeric**
Indicators:	**Median growing-season Secchi-chlorophyll *a* TSI, dissolved oxygen, pH, percent macrophyte coverage**
Analytical Approach:	**ANNAGNPS, BATHTUB, FLUX, EDNA**
Location:	**HUC Code: 10140101**
Action:	**Increase dissolved oxygen to 5.0 mg/l, maintain TP loading at 376.2 kg/yr. (1.03 kg/day), and decrease macrophyte coverage by 30%.**
Target:	**Median growing-season Secchi-chlorophyll *a* TSI $\leq$ 63.4 average during the growing season, pH of 9.0, dissolved oxygen of 5.0 mg/l, 376.2 kg/yr (1.03 kg/day) external TP load. 70% macrophyte coverage.**

Objective:

The purpose of this TMDL summary is to clearly document and quantify the causes of beneficial use non-support with Nine Mile Lake. In addition, it documents the concern and support by the public for studying and restoring Nine Mile Lake to full beneficial use status. The TMDL was developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by EPA.

Introduction

Nine Mile Lake is a 282-acre natural lake located in Marshall County, South Dakota (Figure 1). The 1996 - 2002 South Dakota 303(d) Waterbody lists the lake for aquatic nuisance plants (algae), siltation, and nutrients. The 2004 and 2006 South Dakota Integrated Reports identified the lake for TMDL development because of an unsatisfactory trophic state index (TSI).

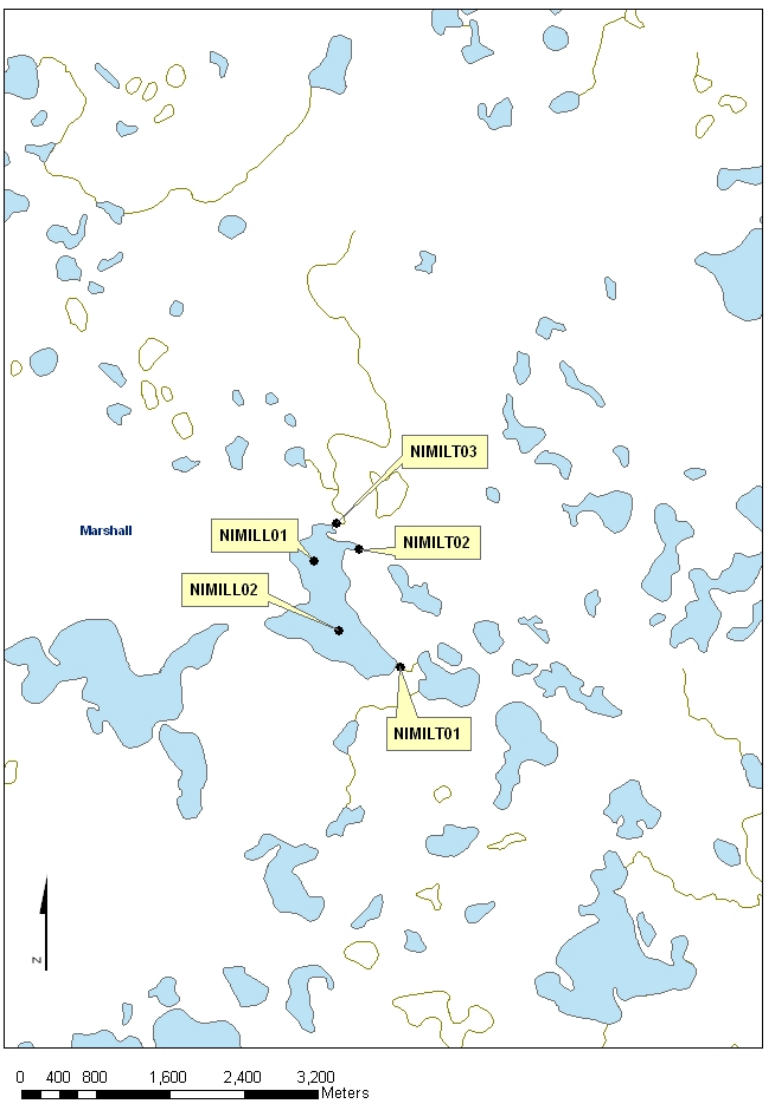

Figure 1. Nine Mile Lake watershed.

The lake has an average depth of 6.6 feet (2 meters), a maximum depth of 10 feet (3 meters). The lake outlet drains into Two Island Lake, a small lake/pond.

Problem Identification

Two tributaries flow into the lake and these drain predominantly grazing lands with some cropland acres. Bacteria decomposing organic matter on the bottom of the lake can cause occasional oxygen depletion, which may ultimately contribute to fish kills. Aquatic macrophytes cover 100% of the lake and are thick enough to impact boating, swimming, and fishing.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

Nine Mile Lake has been assigned the following beneficial uses by the state of South Dakota Surface Water Quality Standards regulations: warm water semi-permanent fish life propagation; immersion recreation; limited contact recreation; and fish and wildlife propagation, recreation and stock watering. 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.

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 entering the lake from external sources is a sign of eutrophication. Nine Mile Lake was identified as not supporting its beneficial uses in the 1996 - 2002 South Dakota 305(b) Water Quality Assessments and the 2004 and 2006 South Dakota Integrated Reports.

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.

The South Dakota Department of Environment and Natural Resources (SD DENR) also uses surrogate measures. SD DENR developed a protocol that established desired TSI levels for lakes based on a fish classification approach. To assess the trophic status of a lake, Lorenzen (2005) used the median growing season Secchi-chlorophyll *a* TSI. This protocol was used to assess impairment and determine a numeric target for Nine Mile Lake. For Nine Mile Lake the targets are median growing season Secchi-chlorophyll *a* TSI values of $\leq$ 63.4 for full support and $\geq$ 63.5 for non-support.

During the assessment Nine Mile Lake had a median growing season (May 15 – September 15) Secchi-chlorophyll *a* TSI of 50.86, which indicated full support of its beneficial uses. To maintain the TSI target level of 63.4, an annual total phosphorus loading of 376.2 kg/yr (1.03 kg/day) is needed.

Pollutant Assessment

Point Sources

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

Nonpoint Sources/ Background Sources

The BATHTUB model predicted a total phosphorus loading rate of 376.2 kg/yr (1.03 kg/day) due to non-point and natural sources. The sediment survey of the lake revealed 43% siltation.

Linkage Analysis

Water quality data were collected from two in-lake sites, two tributary sites and the outlet within the Nine Mile Lake 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 at least 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 in the final report.

The impacts of phosphorus reductions on the condition of Nine Mile Lake were calculated using BATHTUB, an Army Corps of Engineers model. The model predicted a TP load of 376.2 kg/yr (1.03 kg/day) from the tributaries and natural sources and that this load will result in meeting the TSI target of 63.4.

The Annualized Agriculture Nonpoint Pollution Source (ANNAGNPS) model was not used to assess various land use scenarios and their effect of nutrient and sediment loading because the lake was already meeting its target TSI

TMDL and Allocations

ANNUAL

0 kg/yr.	(WLA) point sources
376.2 kg/yr.	(LA) nonpoint sources + natural
Implicit	(MOS)
376.2 kg/yr.	(TMDL) target load

DAILY

0 kg/day	(WLA) point sources
1.03 kg/day	(LA) nonpoint sources + natural
Implicit	(MOS)
1.03 kg/day	(TMDL) target load

Wasteload Allocations (WLAs)

There are no point sources of pollutants of concern in this watershed. Therefore, the "wasteload allocation" for this component is considered zero.

Load Allocations (LAs)

A total maximum annual phosphorus loading rate of 182 kg/yr (1.03 kg/day) is needed to meet the target TSI goal to maintain the lakes beneficial uses. No total phosphorus reductions are currently necessary to attain this target.

In-lake Targets

In-lake targets were established based on state water quality standards and the TSI targets developed by Lorenzen (2005).

Parameter	Target
Dissolved oxygen	5.0 mg/l

pH	9.0
Median growing-season Secchi-chlorophyll *a* TSI	63.4

Dissolved Oxygen

The proposed phosphorus TMDL might indirectly address the dissolved oxygen issue because nutrient loadings are likely the root cause of excess algae and the subsequent loss of dissolved oxygen through decomposition of dead algae and other organic matter. Addressing the phosphorus problem might also prevent or minimize dangerously low dissolved oxygen levels in the lake. Presumably phosphorus control will result in less algae and therefore less organic matter to decompose and less oxygen demand by bacteria. Aeration is recommended as a solution to the low DO levels.

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in precipitation and agricultural practices. Seasonality was determined for the tributaries with the greatest flows (and nutrient and sediment loading) occurring during the spring run-off period. Seasonality in the lake was typical for a lake in south central South Dakota with summer peaks in algae. Thermal stratification did not occur but has been reported in the past. Oxygen depletion throughout the water column occurred once during the summer, probably due to elevated temperatures and decomposition of organic matter.

Margin of Safety

The margin of safety was implicit as conservative estimations were used in the development of the lake restoration strategies. It was recommended that macrophyte control be used to directly improve the beneficial uses impacted by the macrophytes. Best Management Practices are recommended to maintain the nutrient loads at levels that already result in meeting the TSI target and to improve dissolved oxygen concentrations in the lake. The recommended TMDL also provided a margin of safety by predicting in-lake Secchi and chlorophyll *a* TSIs well within the target TSI value.

Critical Conditions

The impairments to Nine Mile Lake are most severe during the summer. This is the result of warm water temperatures, peak macrophyte growth, and resultant decomposition of organic matter on the bottom of the lake.

Follow-Up Monitoring

As part of the implementation effort, in-lake monitoring should be used to measure Secchi transparency, chlorophyll a levels (algae), pH, dissolved oxygen and total phosphorus concentrations, and percent macrophyte coverage. Once the implementation project is completed, the lake will be monitored as part of South Dakota's Statewide Lakes Assessment Project to see if the TMDL and full support of the beneficial uses was achieved.

Public Participation

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

1. Monthly meetings of the Marshall Conservation District.
2. Individual contact with landowners in the watershed.

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

Implementation Plan

The Day County Conservation District has initiated an implementation project for the northeast South Dakota glacial lakes. This project is intended to protect and improve the water quality of lakes in the project area by implementing best management practices. USEPA Section 319 funds are being used to assistance with the lake restoration efforts.

Lake restoration strategies recommended for consideration include: Best Management Practices, animal waste management systems, aeration/circulation, and macrophyte control using various techniques.

SDDENR RESPONSES TO COMMENTS RECEIVED AFTER THE PUBLIC WAS NOTIFIED OF THE FINAL ASSESSMENT REPORT

USEPA COMMENTS:

-----Original Message-----
From: Berry.Vern@epamail.epa.gov [mailto:Berry.Vern@epamail.epa.gov]
Sent: Wednesday, July 25, 2007 5:06 PM
To: Stueven, Gene
Subject: EPA Comments on TMDLs for Geddes, Ninemile, N. Buffalo, S. Buffalo Lakes

Gene,

Thanks for the opportunity to review the Geddes Lake, Ninemile Lake, North Buffalo Lake and South Buffalo Lake Watershed Assessment Reports and TMDLs during the public notice period. The Geddes Lake TMDL, as well as all future TMDLs, need to include some daily expression of load. Please refer to the Anacostia documents attached below for guidance.

North Buffalo Lake
We reviewed the assessment report and "TMDL" for North Buffalo Lake. We do not consider this write up as an approvable TMDL for phosphorus because the waterbody is currently meeting the target TSI value, no reduction in phosphorus loading is needed, and it is currently meeting the applicable narrative WQS. The document also does not contain an approvable TMDL for dissolved oxygen because the linkage analysis (p 33-34) between TP reductions and improvement in DO concentrations is not valid because phosphorus reductions are not needed. If future data collection efforts in this lake conclude that it is impaired for TSI, DO or pH then it should be added to the 303(d) list and TMDLs can be developed at that time.

Nine Mile Lake
We reviewed the assessment report and "TMDL" for Nine Mile Lake. We do not consider this write up as an approvable TMDL for phosphorus because the waterbody is currently meeting the target TSI value, no reduction

in phosphorus loading is needed, and it is currently meeting the applicable narrative WQS. The document also does not contain an approvable TMDL for dissolved oxygen because the linkage analysis (p 37-38) between TP reductions and improvement in DO concentrations is not valid because phosphorus reductions are not needed. If future data collection efforts in this lake conclude that it is impaired for TSI, DO or pH then TMDLs can be developed at that time. Alternately, if DENR is concerned that the current data is not representative of long term trends for the lake (i.e., that it will exceed the TSI target in subsequent sampling events), then historical data could be used to model what the necessary phosphorus load reductions would need to be if the TSI values were to return to that level in the future. Using this approach the a lower phosphorus load (which should be a reduction from the modeled higher
loads) could be written into the TMDL. Another alternative would be to delist Nine Mile Lake in the 2008 IR based on this new assessment data.

South Buffalo Lake
We reviewed the assessment report and "TMDL" for South Buffalo Lake. We do not consider this write up as an approvable TMDL for phosphorus because the waterbody is currently meeting the target TSI value, no reduction in phosphorus loading is needed, and it is currently meeting the applicable narrative WQS. The document also does not contain an approvable TMDL for dissolved oxygen because the linkage analysis (p 36-37) between TP reductions and improvement in DO concentrations is not valid because phosphorus reductions are not needed. If future data collection efforts in this lake conclude that it is impaired for TSI, DO or pH then TMDLs can be developed at that time. Alternately, if DENR is concerned that the current data is not representative of long term trends for the lake (i.e., that it will exceed the TSI target in subsequent sampling events), then historical data could be used to model what the necessary phosphorus load reductions would need to be if the TSI values were to return to that level in the future. Using this approach the a lower phosphorus load (which should be a reduction from the modeled higher loads) could be written into the TMDL. Another alternative would be to delist South Buffalo Lake in the 2008 IR based on this new assessment data.

(See attached file: Geddes Lake PN checklist comments.doc)

Please contact me with any questions.

Vern Berry
Environmental Engineer
US EPA Region 8
Denver, CO

SDDENR RESPONSE:

SDDENR believes that a TMDL can be established for a waterbody regardless of the waterbody's beneficial use status and a TMDL should not be limited to only those waters not fully supporting their beneficial uses. There are times when the median Secchi-chlorophyll *a* TSI target indicates full support of the waterbody's beneficial uses but is so close to the target TSI that prudence dictates establishment of a TMDL. This is especially true when previous and current data show a lake condition that wavers between full and non-support of the beneficial uses.

Such was the case with Nine Mile Lake. Previous data placed the lake on the 1998 – 2000 303(d) lists for partial support, non-support in the 2004 303(d) list, and as a priority in the 2006 303(d) list. But the current, detailed assessment (prompted by the listings) showed a lake meeting its pH and TSI targets. Establishment of a TMDL is critical in developing the proper level of lake/watershed maintenance or restoration.

It is also a more efficient use of funds (in this case, 319 Program funds) to establish a TMDL regardless of beneficial use status because there is no assurance that a detailed assessment will indicate beneficial use non-support. This means that there is a possibility that numerous detailed assessments may have to be done before non-support is shown and a TMDL established. SDDENR feels that doing numerous detailed assessments on a waterbody is not an efficient use of the state's resources. Indeed, this may be counter-productive because there could now be less incentive to run detailed assessments if it is known that the study will have to be re-done if non-support of the beneficial uses is not shown.

In addition, waterbodies such as those behind new or newly repaired dams could use an established TMDL (based on modeling) to direct development or land use in the watershed in a manner that would not exceed the pre-established TMDL. It is unreasonable to wait until these waterbodies are not supporting their beneficial uses before a TMDL can be established.

Finally, the USEPA has already set precedence for allowing TMDL establishment on waterbodies that were meeting their TSI targets and beneficial uses. A TMDL was approved for Lake Alice in Deuel County, South Dakota.

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